THE USE OF HEAT RATES IN PRODUCTION COST MODELING AND MARKET MODELING

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THE USE OF HEAT RATES
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AND MARKET MODELING

I. OVERVIEW

This is a comprehensive description of heat rates as they have been applied to production cost modeling in the past and more importantly how they will apply to market modeling in the future. I define the basic terminology, describe how the data is obtained, and show how it is used in market modeling as opposed to production cost modeling. I also discuss the inherent difficulties and inaccuracies in the use of heat rate data. With the possible exceptions of Sections II and III, this is not intended for someone who is looking for a simplified definition. This report is for someone who requires a comprehensive understanding.

Section II describes the scope of the report and gives an introductory definition of heat rates. Section III defines the basic terminology of heat rates and gives illustrative examples. It defines Input-Output Curves, Average Heat Rates, and Incremental Heat Rates – both Average Incremental and Instantaneous Incremental. It describes how heat rate data is measured and how block heat rate values are calculated from these measurements. Section IV describes heat rates as equations, as opposed to the block heat rates that are most typically used by engineers and utility analysts. Section V illustrates how heat rates are used in production cost modeling. It defines their use in commitment, dispatch and calculating production costs and marginal costs. It also quantifies the errors produced by using block heat rates of modeling instead of the equations that actually define these functions in a real utility. Section VI describes how the use of heat rates will change in the new market, and the modeling of that market. In each Section the concepts are illustrated using both fictitious, illustrative units and real units.

Appendix A provides a summary of the block heat rate data for the slow-start thermal units for each of the three IOUs prior to divestiture: PG&E, SCE and SDG&E. This data is referenced in all sections of this report - and can prove generally useful to engineers and analysts who do work related to heat rates data. The block data is provided for Input-Output Curve values, Average Heat Rates and Incremental Heat Rates – both in table and graphical format. Appendix B provides the detailed calculations for Section IV which describes the development of the heat rate equations that correspond to the block data heat rates of Appendix A. Appendix C provides the details of the calculations for Section V that quantifies the errors caused by using block incremental heat rates in modeling, rather than the equations that more truly characterize the operation of a real utility system. Appendices D, E and F support the work of Section VI. Appendix D quantifies the differences between Incremental Heat Rates and Average Heat Rates, in order to characterize and quantify the differences between the marginal cost of the regulated and market clearing price of the deregulated markets. Appendix E is a simplistic market model, that is similar to Appendix D in its goal, except that it accomplishes the same thing in a more dynamic way that allows for a more descriptive and compete characterization of these differences. Appendix F is a summary of the Energy Commission's 1997 Fuels Report (FR 97) gas prices that were used in Section VI that were used to convert the heat rates differences to dollar cost differences.

II. INTRODUCTION

The fact that you have elected to read this paper suggests that you already have some understanding of heat rates. Most likely, this is an understanding of Average Heat Rates, whereby a heat rate of 10,000 Btu/kWh is representative of a generating unit requiring 10,000 Btu of fuel to generate one kilowatt-hour of electricity. It is probable also that you have an understanding that heat rates are a measure of efficiency whereby a unit that has an Average Heat Rate of 8,000 Btu/kWh is understood to be more efficient than the previously mentioned unit with an Average Heat Rate of 10,000 Btu/kWh -- and more desirable, all other things being equal.

And, it is somewhat likely that you have some understanding of Incremental Heat Rates as being used in the dispatch process of production cost models: the Incremental Heat Rate times the fuel cost equals the cost of that next increment of power.

It is much less likely that you have an understanding of the difference between **Instantaneous** Incremental Heat Rate and **Average** Incremental Heat Rates. This subtlety is not commonly understood but is essential to a comprehensive understanding of heat rates. It is also unlikely -- unless you are a production cost modeler -- that you have an understanding of the Input-Output Curve and how it relates to the Average and Incremental Heat Rates. This paper clarifies all these terms using simple illustrative examples.

This paper describes how heat rates are used in production cost modeling. More significantly, it also describes the relevance of the use of heat rates in the new competitive market where a production cost model is no longer just a production cost model. It now becomes a production cost and market (bidding) model. The bulk of this paper is devoted to explaining and quantifying the differences in production cost and market modeling. An important part of this paper is the supporting analytical data which should prove valuable for future market studies.

III. TERMINOLOGY

An understanding of heat rates starts with an fundamental understanding of the following terms.

- Incremental Costs and Incremental Heat Rates
- Average Costs and Average Heat Rates
- Input-Output Curves

These terms are most simply explained using an illustrative generator designated “Unit X.” This fictitious Unit has a maximum output of three-megawatts (3-MW) and a minimum output of one-megawatt (1-MW). Unit X is a gas-fired thermal unit with three 1-MW blocks of generation. The heat rates and costs are shown in Table 1 on a block-by-block basis. The costs as shown in dollars per megawatt-hour ($/MWh) are based on an assumed natural gas cost of $2.50 per million Btu (MMBtu). To further simplify this explanation, Unit X is assumed to have no variable Operation and Maintenance (O&M) costs.

TABLE 1: INCREMENTAL VERSUS AVERAGE COSTS FOR UNIT X

INCREMENTAL COSTS			AVERAGE COSTS		
BLOCK (MW)	HEAT RATE (Btu/kWh)	COST* ($/MWh)	LEVEL (MW)	HEAT RATE (Btu/kWh)	COST* ($/MWh)
1	20,000	50	1	20,000	50
1	4,000	10	2	12,000	30
1	6,000	15	3	10,000	25

* Using a natural gas price of 2.50 $/MMBtu

Incremental Costs and Heat Rates

Incremental Heat Rates are a measure of the efficiency of a unit for each block (increment) of power that it generates. The Incremental heat rate of Unit X for Block 1 is 20,000 Btu/kWh; that is, Unit X requires 20,000 Btu of fuel to produce the first MW. Similarly, Unit X requires 4,000 Btu for the second MW and 6,000 Btu for the third MW.

The Incremental Cost is, very simply, the cost of each block (increment) of generation. Incremental Costs are derived from Incremental Heat Rates: the Incremental Heat Rate times the fuel cost equals the Incremental Cost. For Unit X, each increment is one megawatt. The cost of the first MW generated (Block 1) is 50 $/MWh: 20,000 Btu/kWh x 2.50 $/MMBtu = 50 $/MWh. The cost of the second MW generated (Block 2) is 10 $/MWh. The cost of the third MW generated (Block 3) is 15 $/MWh.

Average Costs and Heat Rates

The “Average Cost” is subtler than Incremental Cost but is as simple as calculating the average cost of two oranges bought at different prices. If one orange costs $50 and the second costs $10, you easily realize that you paid an average of $30 per orange -- and probably also suspect that you’re paying too much for oranges. Both the Average Heat Rate and the Average Cost are calculated similarly.

For Block 1, the Average Heat Rate (and Average Cost) is the same as the Incremental Heat Rate (and Incremental Cost) as they are the same the increment.

The Average Heat Rate at 2-MW (Level 2) is the average of Block 1 and Block 2 Heat Rates: (20,000+4,000)/2 = 12,000 Btu/kWh. The Average Heat Rate of generating 3-MW is the average of Blocks 1, 2 and 3: (20,000+4,000+ 6,000)/3 = 10,000 Btu/kWh. In this example, only simple averages are used since all block sizes are the same. For a unit with unequal block sizes a weighted average would be used.

The cost of generating at 2-MW is exactly comparable: the average of cost of Block 1 and Block 2 is 30 $/MWh: (50 + 10)/2 = 30 $/MWh – remember the oranges. Similarly, the cost of generating at the level of 3-MW is 25 $/MWh: (50+10+15)/3 = 25 $/MWh.

Input-Output Curve

In the engineering world, the Input-Output Curve is the mechanism that defines the relationship between the Incremental and Average Heat Rates. It is also the data that is actually measured in the field. The Average and Incremental Heat Rates are not measured directly. The Input-Output Curve is measured and the Average and Incremental Heat Rates are constructed from it. Figure 1 illustrates the Input-Output Curve for Unit X.

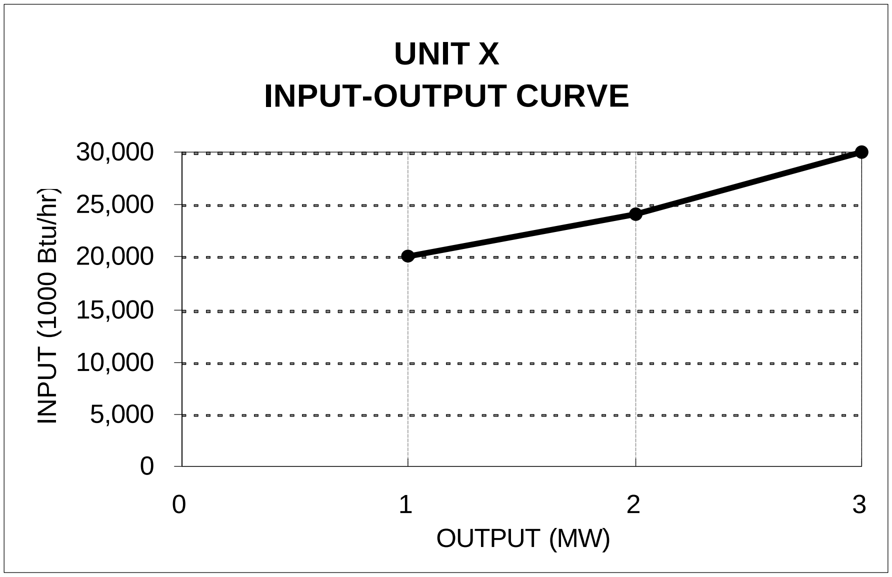


Figure 1

The Input-Output Curve is constructed by measuring the fuel (the input) required to maintain various levels of generation (the output). For Unit X, the engineers would start by measuring the fuel consumed to maintain an output of 1-MW, finding this to be 20,000 Btu/hr. They would then replicate this measurement for 2 and 3 MW, and find that Unit X was consuming 24,000 and 30,000 Btu/hr, respectively. Based on this information, the engineers would construct Figure 1 and could then calculate the Incremental and Average Heat Rates as follows.

The calculation of Average Heat Rate from the Input-Output Curve it is the simplest to explain. The Average Heat Rate at a level of generation is equal to the corresponding input in fuel divided by the power generated. For Unit X at 1-MW this is 20,000,000 Btu/hr divided by the output of 1 MW: 20,000,000 Btu/hr / 1 MW = 20,000 Btu/kWh. The Average Heat Rate at 2-MW is, again, the fuel consumed divided by the output power: 24,000,000 Btu/hr / 2 MW = 12,000 Btu/kWh. The Average Heat Rate at 3-MW is calculated in the same way: 30,000,000 Btu/hr / 3 MW = 10,000 Btu/kWh.

At this point, the reader is better prepared to appreciate that the name “Average Heat Rate” comes from the measuring of the Input-Output curve. When the engineers measure a generating unit to construct the Input-Output curve, they note that there are deviations over time in the number of Btu to maintain the respective output power. They contend with this problem by **averaging** these different measurements to ascertain the **average** Input-Output Curve. Accordingly, they refer to the heat rate that is subsequently derived from this average value as the **Average** Heat Rate.

The Incremental Heat Rate is similar but confined to the “increment” in question, only. The first thing that has to be understood is that our Block 1 Incremental Heat Rate is **not** truly an Incremental Heat Rate. It is an Average Heat Rate in “Incremental Heat Rate clothing.” This can be explained using Unit X. The “so-called” Incremental Heat Rate at Block 1 is shown as 20,000 Btu/kWh -- note that this is equal in value to the Average Incremental Heat Rate of 20,000 Btu/kWh. It is not just equal in value, it is the identical quantity. This format facilitates the calculations of heat rates – for example, Tables 1 and 2. And it is how the data is entered into models. This is all done for convenience but it can not be an Incremental Heat Rate. Incremental Heat Rates, by definition, are used for dispatch decisions. The 20,000 Btu/kWh Incremental Heat Rate it is never used in a dispatch decision and therefore can never be considered a true Incremental Heat Rate. This will become clearer in later discussions.

The first real “increment” is between Blocks 1 and 2. This is shown as a Block 2 value, but represents the Average Incremental Heat Rate from Block 1 to Block 2. Looking at the Input-Output Curve of Unit X, we see that the input fuel requirement changes from 20,000 to 24,000 Btu/hr in moving from Block 1 to Block 2. The incremental change to achieve this additional MW of output is an increase of 4,000 Btu/hr: 24,000 - 20,000 = 4,000 Btu/hr. We define the Incremental Heat Rate as the incremental change in input divided by the incremental change in output: 4,000 Btu/hr / 1 MW = 4,000 Btu/kWh. The calculation for the Incremental Heat Rate for the increment from Block 2 to Block 3 is similar: (30,000 - 24,000) / 1 MW = 6,000 Btu/kWh.

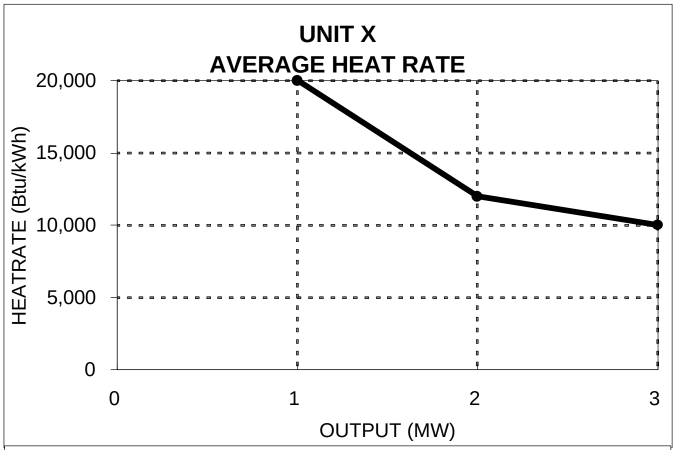
Table 2 summarizes all these results. Figure 2A, on the following page, shows the data of Table 2 combined with the corresponding figures. This is a format to which we will repeatedly return in subsequent sections and you need to be completely comfortable with it. Figure 2B shows the corresponding cost data for reference.

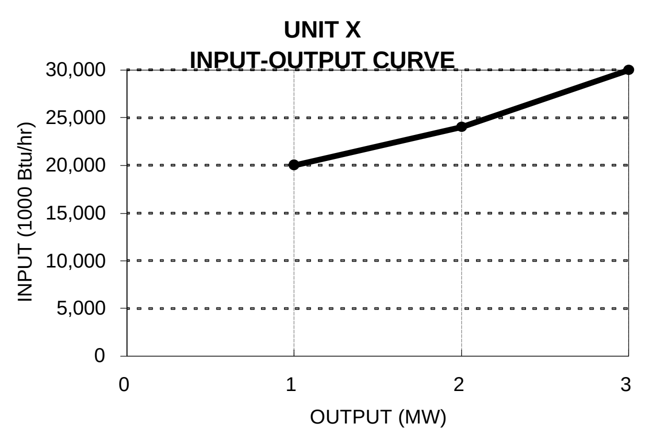
TABLE 2: SUMMARY OF HEAT RATE DATA FOR UNIT X

	CAPACITY (MW)	INPUT-OUTPUT CURVE (1000 Btu/hr)	INCREMENTAL HEAT RATE (Btu/kWh)	AVERAGE HEAT RATE (Btu/kWh)
BLOCK 1	1	20,000	20,000	20,000
BLOCK 2	2	24,000	4,000	12,000
BLOCK 3	3	30,000	6,000	10,000

FIGURE 2A: HEAT RATE PLOTS FOR UNIT X

	Output (MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	1	20,000	20,000	20,000
BLOCK 2	2	24,000	4,000	12,000
BLOCK 3	3	30,000	6,000	10,000





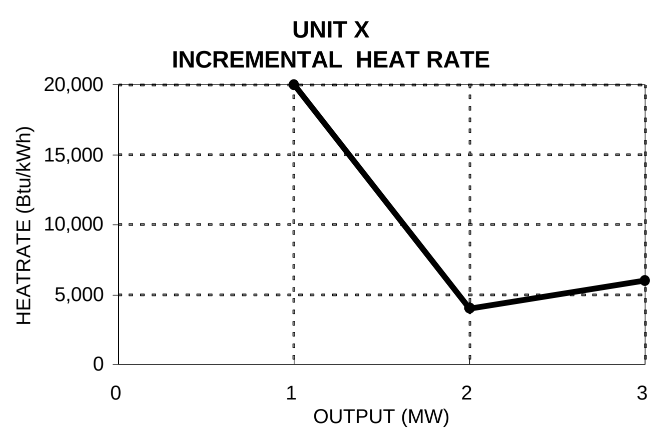
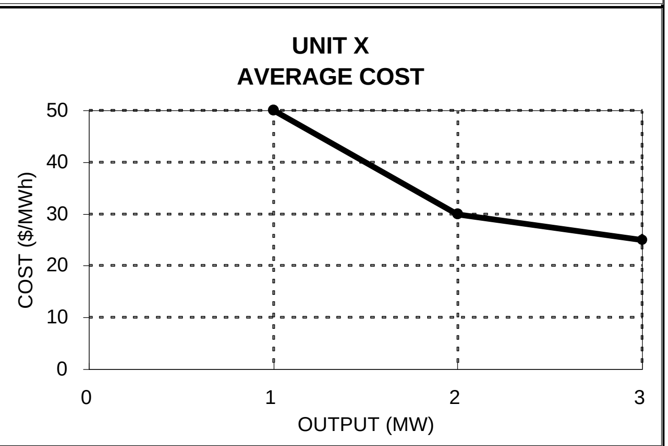
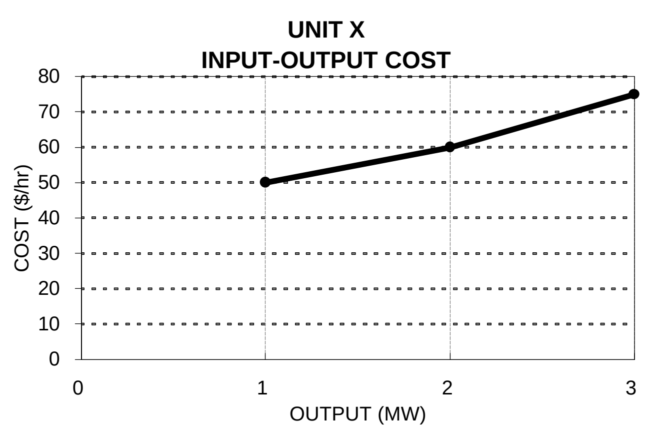
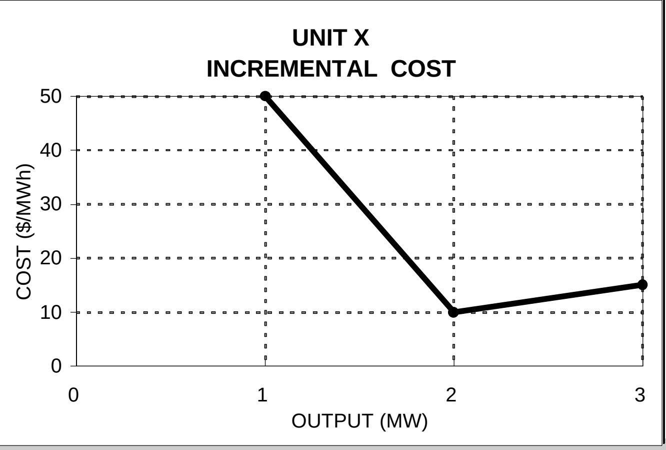


FIGURE 2B: COST PLOTS FOR UNIT X

	Output (MW)	Input-Output Cost ($/hr)	Incremental Cost ($/MWh)	Average Cost ($/MWh)
BLOCK 1	1	50	50	50
BLOCK 2	2	60	10	30
BLOCK 3	3	75	15	25







Thus far, the examples have been limited solely to the fictitious Unit X. It is now time to examine real units in order to get a feel for the real thing. I have selected as examples both the most efficient unit in the PG&E[1] system, Moss Landing 7, and the least efficient unit in the PG&E system, Hunters Point 3. These units are shown below in the same format as Figure 2A.

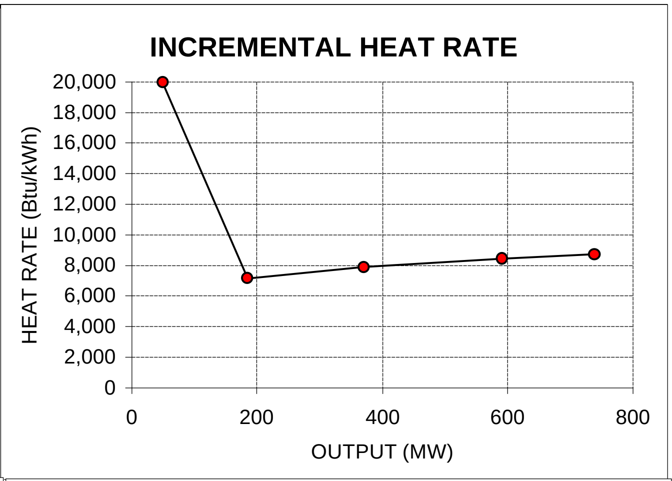
Figure 3 shows Moss Landing 7 with a full load Average Heat Rate of 8,917 Btu/kWh. Remembering that a 100 percent efficient generating unit would require 3,413 Btu/kWh, we can calculate the efficiency of Moss Landing 7 as 38.3 percent: 3,413 / 8,917 = 38.3%.

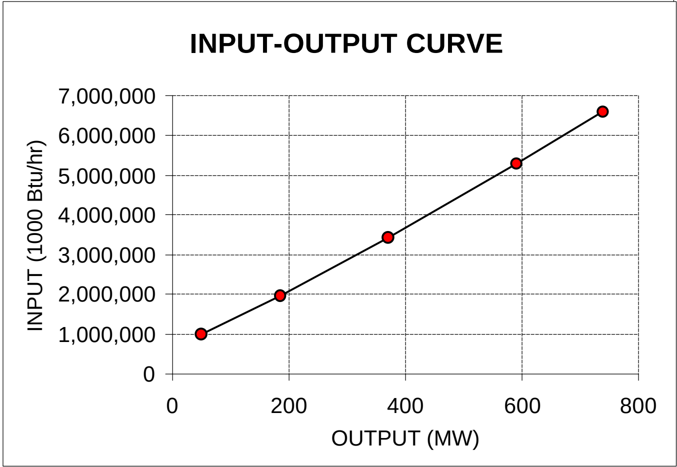
FIGURE 3: MOSS LANDING 7 HEAT RATES

SUMMARY OF HEAT RATE DATA

UNIT: **MOSS LANDING 7**
Duke Energy Nov. 1997

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	7%	50	997,950	19,959	19,959
BLOCK 2	25%	185	1,966,735	7,176	10,631
BLOCK 3	50%	370	3,429,160	7,905	9,268
BLOCK 4	80%	591	5,296,542	8,450	8,962
BLOCK 5	100%	739	6,589,663	8,737	8,917





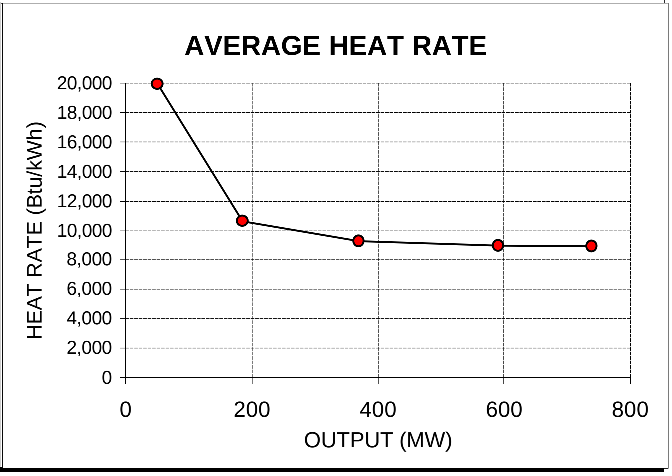


Figure 4 shows Hunter Point 3 with a full load Average Heat Rate of 12,598 Btu/kWh, which corresponds to an efficiency of 27.1 percent: 3,413 / 12,598 = 27.1%. At full load, Hunters Point 3 will consume 41 percent more fuel to produce a gigawatt-hour (GWh) as Moss Landing 7: 12,598 / 8,917 = 1.41.

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[1] This unit was announced on November 7, 1998 as divested to Duke Energy, but for the organizational purposes of this report, it -- and all other IOU divested units -- will be referred to as belonging to the IOU.

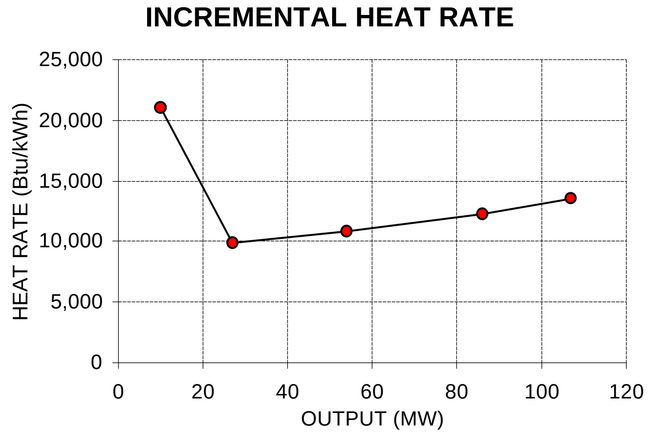
Also, Hunters Point 3 will have a much more expensive incremental cost. Let's compare the second block of each unit. The Hunters Point 3 Incremental Heat Rate for Block 2 is 9,883 Btu/kWh. The corresponding Incremental Heat Rate for Moss Landing 7 is 7,176 Btu/kWh. The relative cost for Hunters Point 3 is therefore 38 percent greater: 9,883 / 7,176 = 1.38.

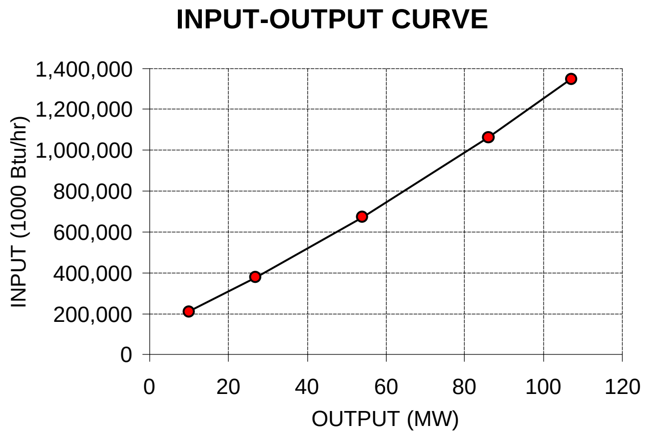
FIGURE 4: HUNTERS POINT 3 HEAT RATES

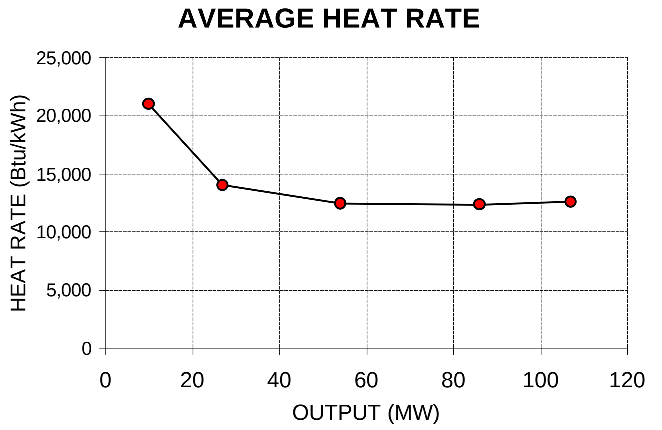
SUMMARY HEAT RATE DATA

UNIT: **HUNTERS POINT 3**

	OUTPUT (%)	OUTPUT (MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	9%	10	210,370	21,037	21,037
BLOCK 2	25%	27	378,378	9,883	14,014
BLOCK 3	50%	54	671,436	10,854	12,434
BLOCK 4	80%	86	1,063,476	12,251	12,366
BLOCK 5	100%	107	1,347,986	13,548	12,598







Appendix A provides a complete set of these summary heat rate data sheets for all of the slow-start thermal units for the three IOUs. These can prove useful for future analytical efforts involving heat rates.

IV. HEAT RATES AS EQUATIONS

The above heat rate definitions are described and illustrated in terms of blocks. Engineers make use of these blocks as “piece-wise linear representations” of the actual heat rate curves that truly characterize the units. In the case of Unit X, these “pieces” were 1-MW each. This was useful for our description and is indeed how the data is typically used by modelers and by engineers in general. This misrepresents the fact, however, that the heat rates are really continuous -- which is equivalent to saying that the blocks are infinitely small. It is these continuous equations that are used to dispatch units in a real system -- not the block data.

Input-Output Curve

The above Input-Output Curve for Unit X is more precisely described by the equation:

$$y = 1000x^2 + 1000x + 18000$$

Where: x = Output in MW
y = Input in 1000 Btu/hr

Setting x equal to the values of 1, 2 and 3 MW, results in y values of 20,000, 24,000 and 30,000 in 1000 Btu/hr. These points correspond exactly to the points in Table 2 and Figure 2, as would be expected.

Incremental Heat Rate Curve

The Incremental Heat Rate (***IHR***) Curve is by definition the amount of energy that must be consumed by the plant in order to achieve an incremental change in output -- in this case, an infinitesimal change in output. This is mathematically defined as the first derivative of the Input-Output Curve:

$$IHR = dy/dx = 2000x + 1000$$

Setting x equal to 1, 2 and 3 MW, results in ***IHRs*** of 3,000, 5,000 and 7,000 Btu/kWh. These points are **Instantaneous** Incremental Heat Rates and do **not** correspond directly to any of the above Figures and Tables that were average values for each block (**Average** Incremental Heat Rates).

For comparison, the Average Incremental Heat Rates can also be calculated using the Input-Output Curve. The calculation consists of dividing the incremental Input-Output value (Btu/hr) by the corresponding increment of output (MW).

$$\begin{aligned}(y_2 - y_1)/ (x_2-x_1) &= [(1000\, x_2^2 + 1000\, x_2 + 18000) - (1000\, x_1^2 + 1000\, x_1 + 18000)] / (x_2-x_1) \\ &= [1000(x_2^2 - x_1^2) + 1000(x_2-x_1)]/ (x_2-x_1) = 1000[(x_2^2 - x_1^2) + (x_2 - x_1)]/ (x_2-x_1) \\ &= 1000[(x_2^2 - x_1^2)/(x_2-x_1) + (x_2 - x_1)/(x_2-x_1)] \\ &= 1000[(x_2+x_1)(x_2-x_1)/(x_2-x_1) + (x_2 - x_1)/(x_2-x_1)] \\ &= 1000(x_2 + x_1 + 1)\end{aligned}$$

Where: x_1 = Minimum Output (MW) of Block
x_2 = Maximum Output (MW) of Block

If values are entered for x_2 and x_1 for Block 2 and 3, then the appropriate values of 4,000 and 6,000 Btu/kWh in Table 2 result.

For Block 2: x_1 = 1MW and x_2 = 2 MW.

$$IHR_{Block\ 2} = 1000(x_2 + x_1 + 1)$$
$$= 1000(2+1+1) = 4{,}000 \text{ Btu/kWh}$$

For Block 3: x_1 = 2 MW and x_2 = 3 MW.

$$IHR_{Block\ 2} = 1000(x_2 + x_1 + 1)$$
$$= 1000(3+2+1) = 6{,}000 \text{ Btu/kWh}$$

Average Heat Rate Curve

The Average Heat Rate (***AHR***) Curve, for Unit X, is defined as the Input-Output Curve divided by the output capacity at that point:

$$AHR = y/x = (1000x^2 + 1000x + 18000) / x = 1000x + 1000 + 18000/x$$

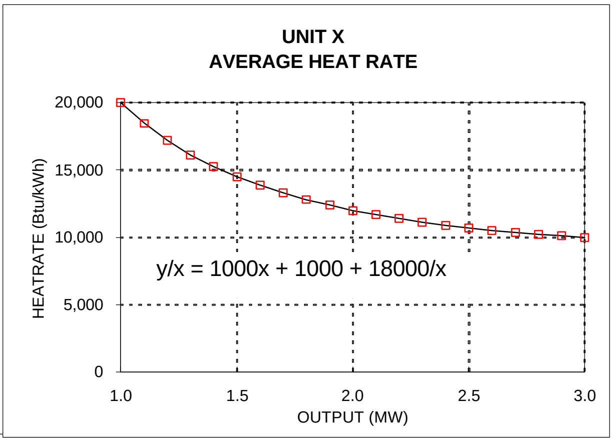
Setting x equal to 1, 2 and then 3 MW, results in ***AHRs*** of 20,000, 12,000 and 10,000 Btu/kWh. These points correspond directly to the above Figures and Tables, as expected.

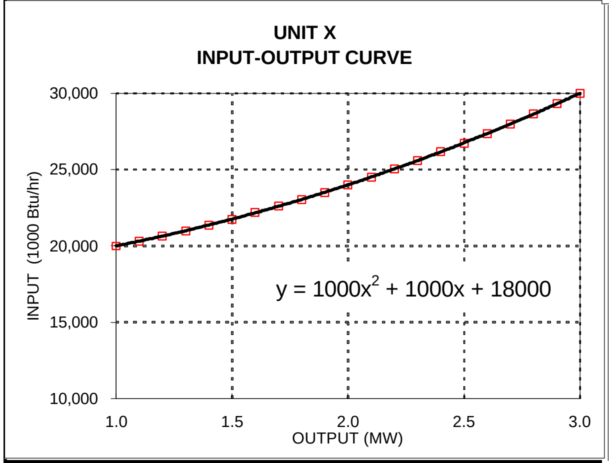
Figure 5 illustrates these equations. This is done at 0.1 MW intervals for convenience, as we can not reasonably illustrate this for an infinite number of points -- or even 200 points (0.01 MW intervals). Though limited in this way, the representation is quite adequate to illustrate that these curves (equations) are much smoother and continuous than the block representation of Figure 2, and therefore more accurately reflect the real data. Note that the equation describing each curve is show on the respective graph.

As before, I have included similar data for real units. Figure 6 shows this heat rate data for Moss Landing 7, the most efficient unit in the PG&E system. Figure 7 shows the same data for Hunters Point 3, the least efficient unit in the PG&E system. Note how differently these curves look from their block counter parts. Again, I have included the equation that was used to develop each graph.

FIGURE 5: UNIT X - AS EQUATIONS
(ILLUSTRATED AT 0.1 MW INCREMENTS)

	CAP (MW)	INPUT-OUTPUT CURVE (1000 btu/hr)	INCREMENTAL HEAT RATE (Btu/kWh)	AVERAGE HEAT RATE (Btu/kWh)
BLOCK 1	1.0	20,000	3,000	20,000
	1.1	20,310	3,200	18,464
	1.2	20,640	3,400	17,200
	1.3	20,990	3,600	16,146
	1.4	21,360	3,800	15,257
	1.5	21,750	4,000	14,500
	1.6	22,160	4,200	13,850
	1.7	22,590	4,400	13,288
	1.8	23,040	4,600	12,800
	1.9	23,510	4,800	12,374
BLOCK 2	2.0	24,000	5,000	12,000
	2.1	24,510	5,200	11,671
	2.2	25,040	5,400	11,382
	2.3	25,590	5,600	11,126
	2.4	26,160	5,800	10,900
	2.5	26,750	6,000	10,700
	2.6	27,360	6,200	10,523
	2.7	27,990	6,400	10,367
	2.8	28,640	6,600	10,229
	2.9	29,310	6,800	10,107
BLOCK 3	3.0	30,000	7,000	10,000





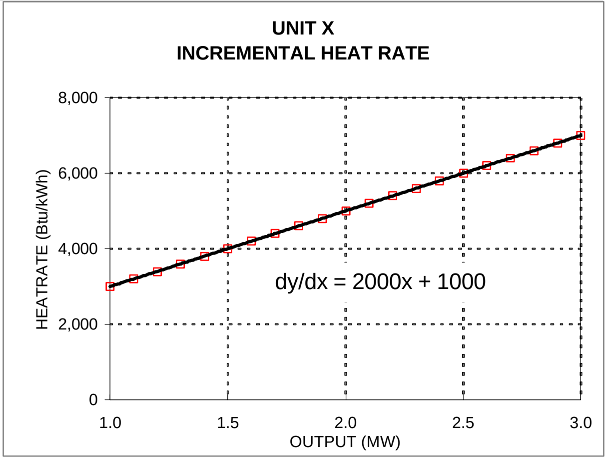
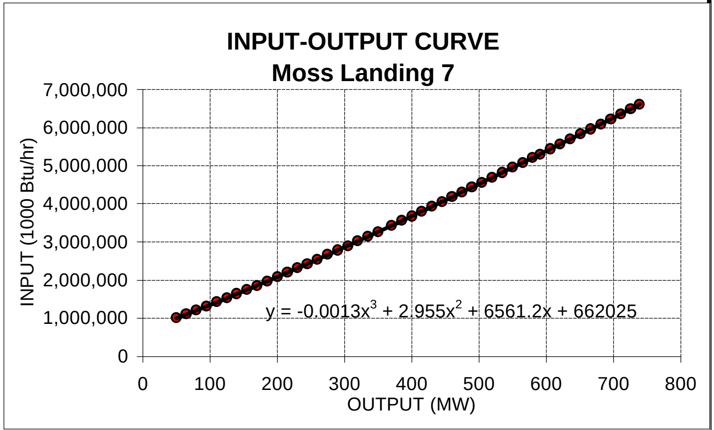
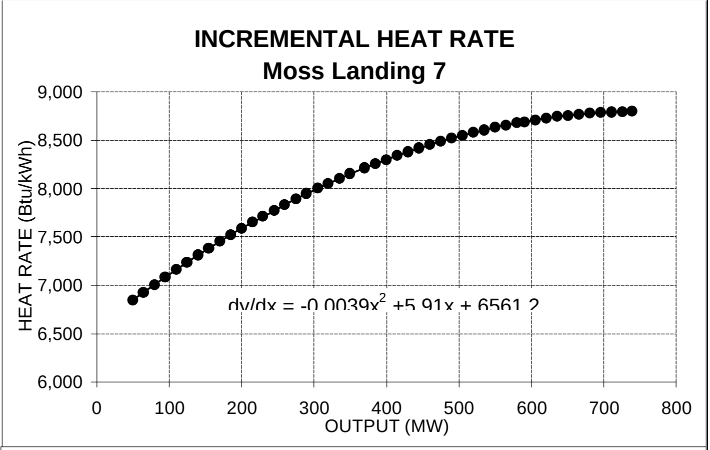


FIGURE 6: MOSS LANDING 7 - AS EQUATIONS

	CAP (MW)	INPUT-OUTPUT CURVE (1000 Btu/hr)	INCREMENTAL HEAT RATES (Btu/kWh)	AVERAGE HEAT RATES (Btu/kWh)
BLOCK 1	50	997,950	6,847	19,959
	65	1,100,631	6,929	16,933
	80	1,205,167	7,009	15,065
	95	1,310,893	7,087	13,799
	110	1,417,782	7,164	12,889
	125	1,525,808	7,239	12,206
	140	1,634,944	7,312	11,678
	155	1,745,164	7,384	11,259
	170	1,856,442	7,453	10,920
BLOCK 2	185	1,968,751	7,521	10,631
	200	2,082,065	7,587	10,410
	215	2,196,358	7,652	10,216
	230	2,311,603	7,714	10,050
	245	2,427,775	7,775	9,909
	260	2,544,846	7,834	9,788
	275	2,662,791	7,892	9,683
	290	2,781,583	7,947	9,592
	305	2,901,195	8,001	9,512
	320	3,021,603	8,053	9,443
	335	3,142,778	8,103	9,381
	350	3,264,695	8,152	9,328
BLOCK 3	370	3,428,360	8,214	9,268
	385	3,551,905	8,258	9,226
	400	3,676,105	8,301	9,190
	415	3,800,932	8,342	9,159
	430	3,926,361	8,381	9,131
	445	4,052,365	8,419	9,106
	460	4,178,918	8,455	9,085
	475	4,305,993	8,489	9,065
	490	4,433,565	8,521	9,048
	505	4,561,606	8,551	9,033
	520	4,690,091	8,580	9,019
	535	4,818,992	8,607	9,007
	550	4,948,285	8,632	8,997
	565	5,077,942	8,655	8,988
	580	5,207,937	8,677	8,979
BLOCK 4	591	5,303,467	8,692	8,962
	606	5,433,986	8,710	8,967
	621	5,564,771	8,727	8,961
	636	5,695,797	8,742	8,956
	651	5,827,035	8,756	8,951
	666	5,958,461	8,767	8,947
	681	6,090,048	8,777	8,943
	696	6,221,770	8,785	8,939
	711	6,353,600	8,792	8,936
	726	6,485,511	8,796	8,933
BLOCK 5	739	6,599,881	8,799	8,971





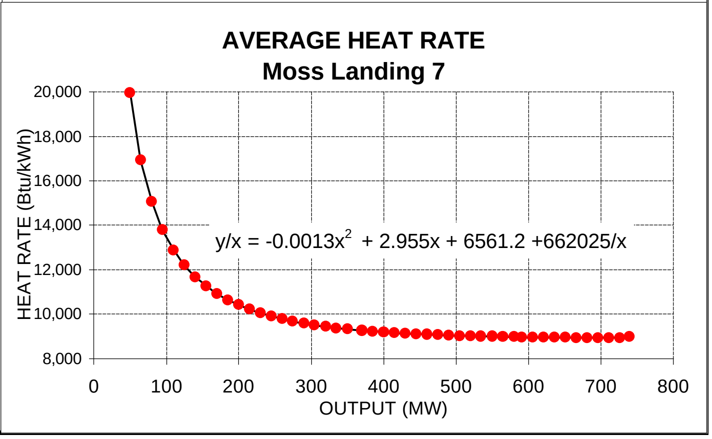
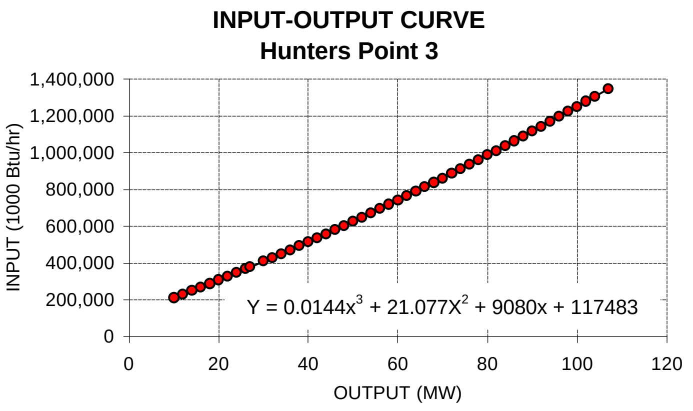
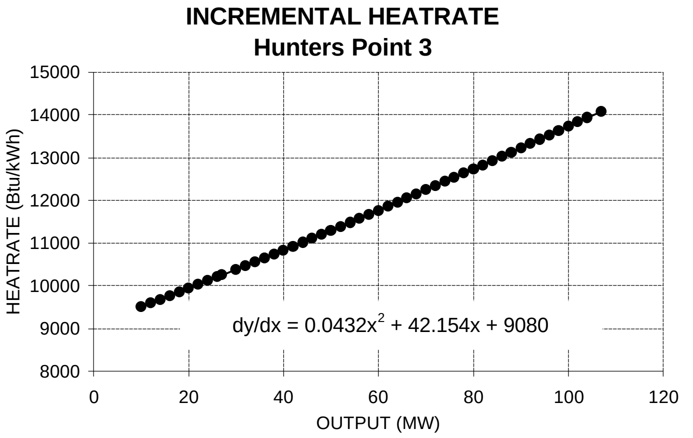
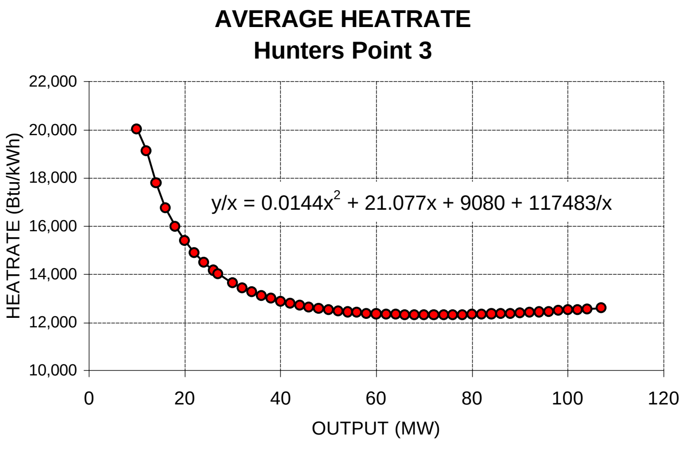


FIGURE 7: HUNTERS POINT 3 - AS EQUATIONS

	CAP (MW)	INPUT-OUTPUT CURVE (1000 Btu/hr)	INCREMENTAL HEAT RATES (Btu/kWh)	AVERAGE HEAT RATES (Btu/kWh)
BLOCK 1	10	210,405	9,506	20,037
	12	229,503	9,592	19,125
	14	248,774	9,679	17,770
	16	268,218	9,766	16,764
	18	287,836	9,853	15,991
	20	307,629	9,940	15,381
	22	327,598	10,028	14,891
	24	347,742	10,117	14,489
	26	368,064	10,205	14,156
BLOCK 2	27	378,292	10,250	14,014
	30	409,241	10,384	13,641
	32	430,098	10,473	13,441
	34	451,134	10,563	13,269
	36	472,351	10,654	13,121
	38	493,748	10,744	12,993
	40	515,328	10,835	12,883
	42	537,090	10,927	12,788
	44	559,035	11,018	12,705
	46	581,164	11,110	12,634
	48	603,477	11,203	12,572
	50	625,976	11,296	12,520
	52	648,660	11,389	12,474
BLOCK 3	54	671,531	11,482	12,434
	56	694,589	11,576	12,403
	58	717,836	11,670	12,376
	60	741,271	11,765	12,355
	62	764,895	11,860	12,337
	64	788,709	11,955	12,324
	66	812,714	12,050	12,314
	68	836,911	12,146	12,308
	70	861,300	12,242	12,304
	72	885,881	12,339	12,304
	74	910,656	12,436	12,306
	76	935,625	12,533	12,311
	78	960,789	12,631	12,318
	80	986,149	12,729	12,327
	82	1,011,704	12,827	12,338
	84	1,037,457	12,926	12,351
BLOCK 4	86	1,063,408	13,025	12,366
	88	1,089,556	13,124	12,381
	90	1,115,904	13,224	12,399
	92	1,142,452	13,324	12,418
	94	1,169,200	13,424	12,438
	96	1,196,149	13,525	12,460
	98	1,223,300	13,626	12,483
	100	1,250,653	13,727	12,507
	102	1,278,210	13,829	12,531
	104	1,305,970	13,931	12,557
BLOCK 5	107	1,347,994	14,085	12,598


INPUT-OUTPUT CURVE
Hunters Point 3


INCREMENTAL HEATRATE
Hunters Point 3


AVERAGE HEATRATE
Hunters Point 3

Appendix B provides a precise description of how to construct the heat rate curves for the real-world units of the three IOUs, but the following is a brief overview of the process:

Input-Output Curve

The Input-Output Curve is defined by the third order equation:

$$y= ax^3 + bx^2+ cx + d$$

Where: x = Output in MW
y = Input in Btu/hr
a-d = The coefficients that define the equation

Incremental Heat Rate Curve

The Instantaneous Incremental Heat Rate (***IHR***) is defined as the first derivative of the Input-Output Curve:

$$IHR = dy/dx = 3ax^2 + 2bx + c$$

As before, the Average Incremental Heat Rates can also be calculated for comparison, using the Input-Output Curve. The calculation consists of dividing the incremental Input-Output value (Btu/hr) by the corresponding increment of output (MW).

$$\begin{aligned}(y_2 - y_1)/ (x_2-x_1) &= [(ax_2^3 + bx_2^2 + cx_2 + d) - (ax_1^3 + bx_1^2 + cx_1 + d)] / (x_2-x_1)\\ &= [a(x_2^3- x_1^3) + b(x_2^2- x_1^2) + c(x_2 - x_1)]/ (x_2 - x_1)\\ &= a(x_2^2 + x_2 x_1 + x_1^2) + b(x_2 + x_1) + c\end{aligned}$$

Where: x_1 = Minimum Output of Block
x_2 = Maximum Output of Block

Average Heat Rate Curve

The Average Heat Rate (***AHR***) is defined as the Input-Output Curve divided by the output (***x***).

$$AHR = y/x = (ax^3 + bx^2 + cx + d) / x = ax^2 + bx + c + d/x$$

Table B-2 in Appendix B delineates the coefficients, ***a - d***, for constructing each of the above heat rate curves for all of the three IOU slow-start units.

V. HEAT RATES IN PRODUCTION COST MODELING

This section discusses heat rates as used in traditional production cost modeling. The next section will discuss the use of heat rates as related to market modeling.

Most typically, heat rates are provided to the modelers as Average Heat Rates in block form and entered in that same format. For the Energy Commission, the block sizes are typically 25, 50, 80 and 100 percent of the maximum capacity, as well as the minimum capacity level. It some instances, however, the data is provided to the modeler or entered into the model in any of the following forms.

- Block Average Heat Rates
- Average Heat Rates as equations
- Block (Average) Incremental Heat Rates
- Input-Output Curves

Most models can take Block Average Heat Rates or Block (Average) Incremental Heat Rates (e.g., UPLAN and Elfin). A few also have the option to make use of the Input-Output Curve (e.g., Elfin). Regardless of the form in which the model receives the heat rate data, it will create whatever additional heat rates it needs to complete its functions.

The heat rate data as provided by the utility is a simplistic representation of the actual measured data. The original data is a collection of measurements, taken over a period of time. This data must be fit to heat rate equations, that can only approximate the original data points. In almost all cases the data is provided as block heat rates which are "piece-wise linear representations" of the heat rate equations. The data provided to the modelers is therefore a simplification of a curve that approximates the actual data. In addition, the data can be distorted due to inaccuracies in transcription or errors in the data manipulation. All data is suspect and should always be inspected for veracity. If the data looks somehow unlikely, try to obtain the data in a form as close to the original data as possible.

Heat Rates are used in the production cost model for four purposes:

- Commitment
- Dispatch
- Marginal Cost
- Production Cost

Regardless of the form in which the heat rate data is entered into the model, it is used to create the necessary Incremental Heat Rates. The Incremental Heat Rates are then used to determine dispatch (which block of which unit is used next) and marginal cost (the cost of the last unit that was used to meet load in that hour). Contrary to your intuition, Average Heat Rates as input to the model are not used to calculate production cost. Incremental Heat Rates are used to construct another set of Average Heat Rates, that are then used for calculating production costs. The Average Heat Rates as input to the model are in some models used for commitment (Elfin uses best Average Heat Rate). But other models do not even use them for this purpose. UPLAN, for example, has a separate entry for this purpose, designated "Long-Run Average Heat Rate" which is the modeler's best estimate as to how the unit will perform over the period being modeled.

Input-Output Curves

As described above, this curve most closely represents the original measured data. It is typically a slightly sloping upward curve, that looks almost like a straight line, and it can therefore be easily and accurately fit to an equation: typically a third-order equation. Figure 8 shows the Input-Output Curve for Unit X in equation form (from Figure 5) superimposed over the block form (from Figure 2). Due to the almost linear nature of this curve, the differences are quite small -- and even difficult to see in the graph. The Modeling representation is two straight lines. The Actual data is an equation.

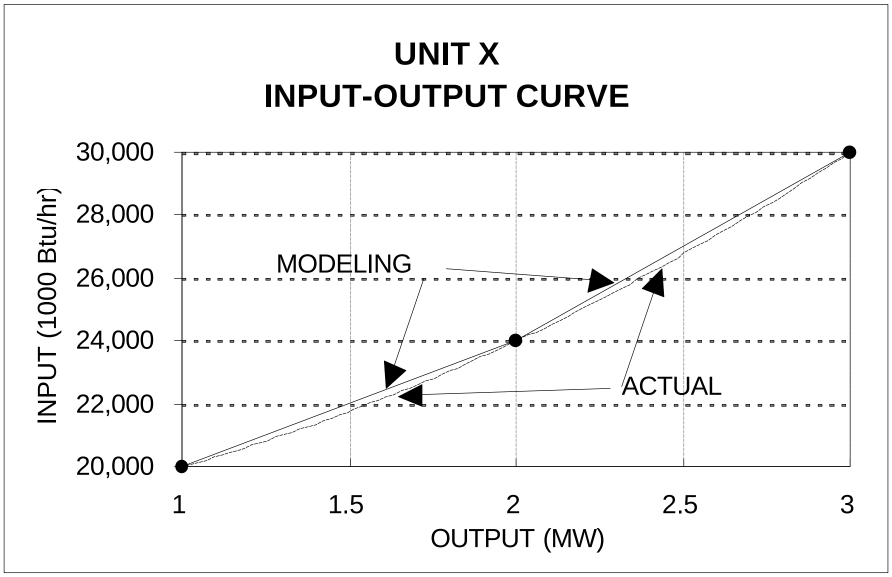


Figure 8

If the Input-Output Curve is used directly in the model, it is entered as a third order equation, as described above. The model will then use this Curve ("Actual" in Figure 8) to create the necessary block Incremental Heat Rates ("Modeling" in Figure 8), which provide the very same results as if the Incremental Heat Rate blocks had been entered directly.

Incremental Heat Rates

In the model, the Incremental Heat Rates are used in block form, designated Average Incremental Heat Rates. The block form is used, rather than the continuous curves of the equations, to make the computational time reasonable. As the number of blocks is increased, the computational time increases. If continuous curves are used, the block size goes to zero, and the number of calculations tends towards infinity.

Average Incremental Heat Rates are generally drawn as shown in Figure 2A, which is reiterated here as Figure 9. But this is not a correct representation of the Average Incremental Heat Rate. They should really be drawn as shown Figure 10. This confusion arises from the fact that modelers are accustomed to using and manipulating data as shown in Tables 1 and 2. The representation of Figure 9 seems like the likely representation of this data -- and it is convenient for most uses -- but it is not precise. Figure 10 in the more accurate representation of Average Incremental Heat Rate.

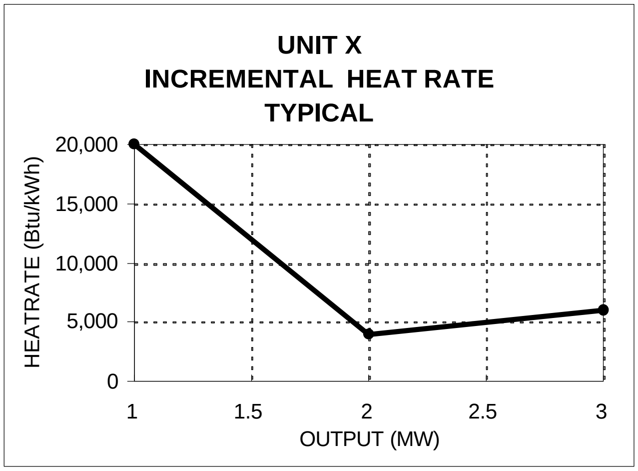


Figure 9

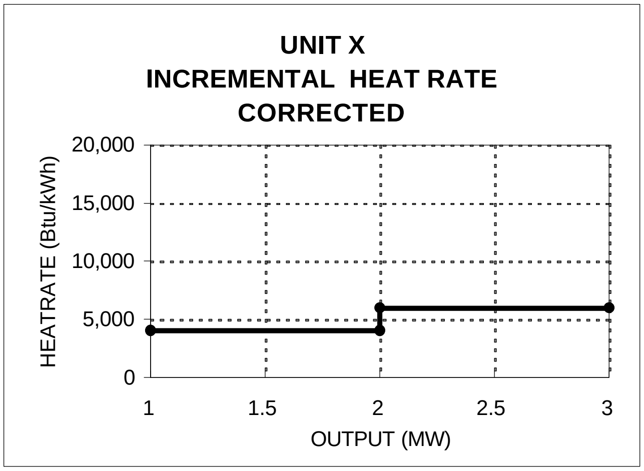


Figure 10

As previously explained, the model does not use the 20,000 Btu/kWh as an Incremental Heat Rate, as it is not used in dispatch decisions. Unit X is committed at its minimum generation level (Block 1 level of 1-MW) and only the values of 4,000 Btu/kWh (from 1 to 2 MW) and 6,000 Btu/kWh (from 2 to 3 MW) are used in the dispatch decisions.

Although Figure 10 is an accurate representation of the Average Incremental Heat Rates as used in models, it is not the true representation of the Incremental Heat Rate used in the dispatch of the units in a real system, as explained in the previous section. The continuous Incremental Heat Rate equations are the true representation that is used in the dispatch of a real system. The block Incremental Heat Rates of Figure 10 used in modeling are known more precisely as **Average** Incremental Heat Rates, as they represent the **average** value over the block. The Incremental Heat Rates of the equations are used in the actual dispatch of real units are known as the **Instantaneous** Incremental Heat Rates. Figure 11 compares the “Modeling” representation (Average Incremental Heat Rate) to the “Actual” heat rates used in dispatch (Instantaneous Incremental Heat Rate).

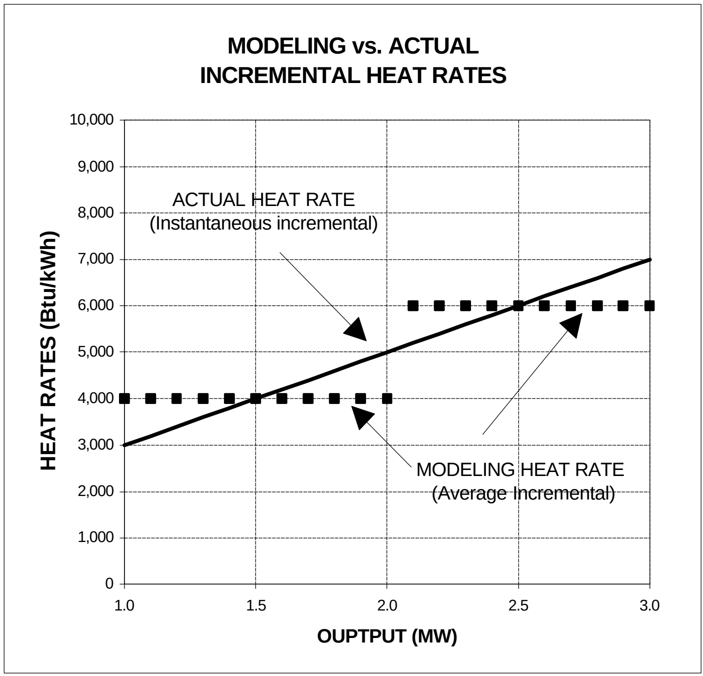
The inherent assumption in using the **modeling** heat rate data is that on average it will emulate the **actual** heat rate data. That is, over time, the modeling approximation will be sometimes low and sometimes high but will average out. Unfortunately, this is not strictly true for Incremental Heat Rates data. There are two areas of concern: (1) the dispatch decision (2) the calculation of marginal cost.

If the blocks are small and are of comparable size, the dispatch error is probably reasonably small. Unfortunately, the block sizes are commonly different since the unit sizes are different. In PG&E, for example, unit sizes vary from 52 MW to 739 MW. A block size that is set at 25 percent, is 13 MW in one case and 185 MW in the second case.

In the case of marginal cost, errors will commonly occur and will be most pronounced at the edges of the blocks. Figure 11 illustrates these errors for our Unit X, comparing the block representation to the continuous representation (which for computational convenience is sampled as 0.1 MW blocks). The applicable errors are 33 % at 1-MW, -20% at 2-MW and -14.3% at 3-MW.

FIGURE 11: UNIT X - COMPARING INCREMENTAL HEAT RATES

		INCREMENTAL HEAT RATES		
	OUTPUT (MW)	ACTUAL (Btu/kWh)	MODELING (Btu/kWh)	ERROR (%)
BLOCK 1	1.0	3,000	4,000	33.3%
	1.1	3,200	4,000	25.0%
	1.2	3,400	4,000	17.6%
	1.3	3,600	4,000	11.1%
	1.4	3,800	4,000	5.3%
	1.5	4,000	4,000	0.0%
	1.6	4,200	4,000	-4.8%
	1.7	4,400	4,000	-9.1%
	1.8	4,600	4,000	-13.0%
	1.9	4,800	4,000	-16.7%
BLOCK 2	2.0	5,000	4,000	-20.0%
	2.1	5,200	6,000	15.4%
	2.2	5,400	6,000	11.1%
	2.3	5,600	6,000	7.1%
	2.4	5,800	6,000	3.4%
	2.5	6,000	6,000	0.0%
	2.6	6,200	6,000	-3.2%
	2.7	6,400	6,000	-6.3%
	2.8	6,600	6,000	-9.1%
	2.9	6,800	6,000	-11.8%
BLOCK 3	3.0	7,000	6,000	-14.3%



Figures 12 and 13 show this same data for our previously identified real illustrative units, Moss Landing 7 and Hunters Point 3. Figure 12 compares the Modeling data of Figure 3 to the Actual equations of Figure 6. Figure 13 compares the Modeling data of Figure 4 to the Actual equations of Figure 7.

Table 3 summarizes these results for Unit X, Moss Landing 7 and Hunters Point 3 along with comparable data for the units in the IOU systems (pre-divestiture). The supporting data and calculations for the IOU system are shown in Appendix C. The Table shows both the most positive and most negative errors for each case. Ignoring the errors for Unit X, which are for illustrative purposes only, the largest errors are still significant. PG&E shows maximum errors of +6.0 and -8.6 percent. SCE shows a maximum errors of +3.4 and -5.4 percent. An examination of the data in Appendix C, however, shows that for the most part the errors are only a few percent.

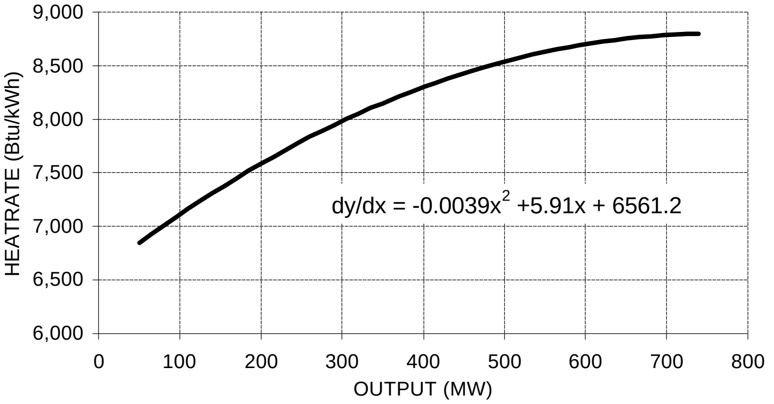
TABLE 3: SUMMARY OF INCREMENTAL HEAT RATE ERRORS

	MAXIMUM ERRORS (%)	
	POSITIVE	NEGATIVE
PG&E	6.0%	-8.6%
SCE	3.4%	-5.4%
SDG&E	0.9%	-5.4%
Moss Landing 7	4.8%	-4.6%
Hunters Point 3	5.8%	-5.9%
UNIT X	33.3%	-20.0%

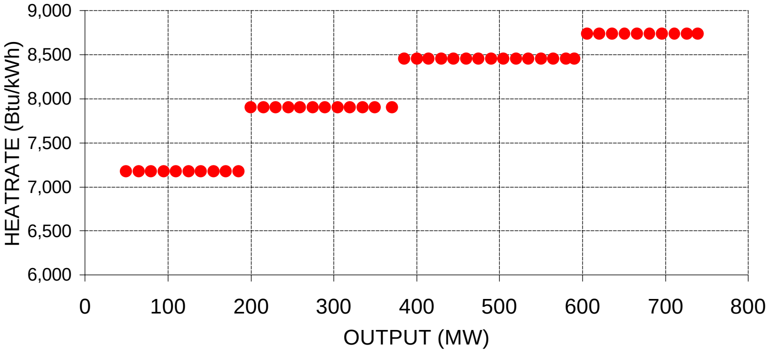
FIGURE12: MOSS LANDING 7 - COMPARING INCREMENTAL HEAT RATES

		INCREMENTAL HEAT RATES		
	CAP (MW)	ACTUAL (Btu/kWh)	MODELING (Btu/kWh)	ERROR (%)
BLOCK 1	50	6,847	7,176	4.8%
	65	6,929	7,176	3.6%
	80	7,009	7,176	2.4%
	95	7,087	7,176	1.2%
	110	7,164	7,176	0.2%
	125	7,239	7,176	-0.9%
	140	7,312	7,176	-1.9%
	155	7,384	7,176	-2.8%
	170	7,453	7,176	-3.7%
BLOCK 2	185	7,521	7,176	-4.6%
	200	7,587	7,905	4.2%
	215	7,652	7,905	3.3%
	230	7,714	7,905	2.5%
	245	7,775	7,905	1.7%
	260	7,834	7,905	0.9%
	275	7,892	7,905	0.2%
	290	7,947	7,905	-0.5%
	305	8,001	7,905	-1.2%
	320	8,053	7,905	-1.8%
	335	8,103	7,905	-2.4%
	350	8,152	7,905	-3.0%
BLOCK 3	370	8,214	7,905	-3.8%
	385	8,258	8,450	2.3%
	400	8,301	8,450	1.8%
	415	8,342	8,450	1.3%
	430	8,381	8,450	0.8%
	445	8,419	8,450	0.4%
	460	8,455	8,450	-0.1%
	475	8,489	8,450	-0.5%
	490	8,521	8,450	-0.8%
	505	8,551	8,450	-1.2%
	520	8,580	8,450	-1.5%
	535	8,607	8,450	-1.8%
	550	8,632	8,450	-2.1%
	565	8,655	8,450	-2.4%
	580	8,677	8,450	-2.6%
BLOCK 4	591	8,692	8,450	-2.8%
	606	8,710	8,737	0.3%
	621	8,727	8,737	0.1%
	636	8,742	8,737	-0.1%
	651	8,756	8,737	-0.2%
	666	8,767	8,737	-0.3%
	681	8,777	8,737	-0.5%
	696	8,785	8,737	-0.6%
	711	8,792	8,737	-0.6%
	726	8,796	8,737	-0.7%
BLOCK 5	739	8,799	8,737	-0.7%

ACTUAL HEAT RATE CURVE
INSTANTANEOUS INCREMENTAL HEATRATE



MODELING HEAT RATE BLOCKS
AVERAGE INCREMENTAL HEATRATE



MODELING vs. ACTUAL
Moss Landing 7

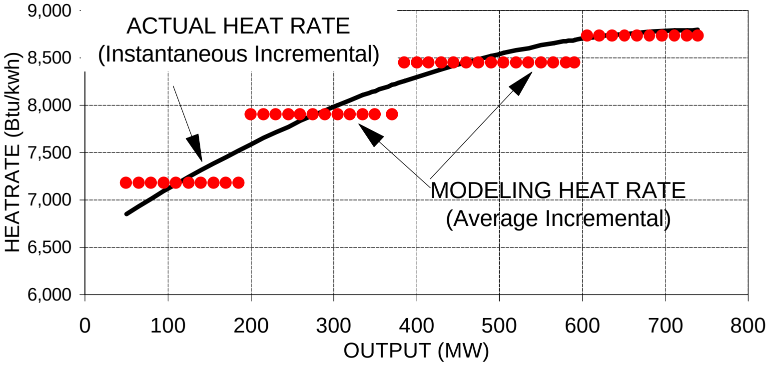
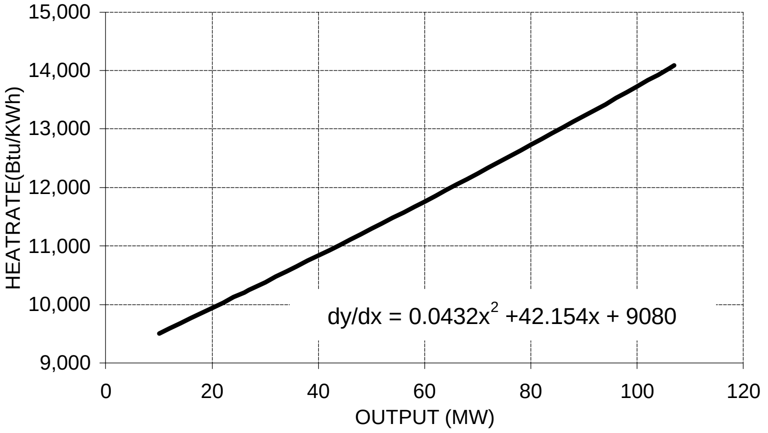


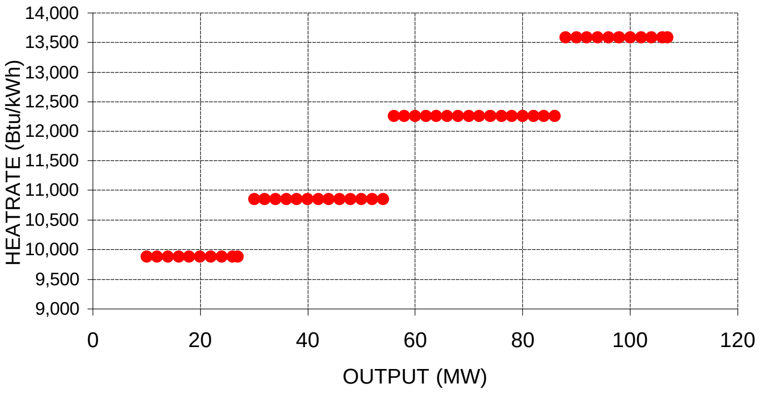
FIGURE13: HUNTERS POINT 3 - COMPARING INCREMENTAL HEAT RATES

	CAP (MW)	INCREMENTAL HEAT RATES ACTUAL (Btu/kWh)	MODELING (Btu/kWh)	ERROR (%)
BLOCK 1	10	9,506	9,883	4.0%
	12	9,592	9,883	3.0%
	14	9,679	9,883	2.1%
	16	9,766	9,883	1.2%
	18	9,853	9,883	0.3%
	20	9,940	9,883	-0.6%
	22	10,028	9,883	-1.4%
	24	10,117	9,883	-2.3%
	26	10,205	9,883	-3.2%
BLOCK 2	27	10,250	9,883	-3.6%
	30	10,384	10,854	4.5%
	32	10,473	10,854	3.6%
	34	10,563	10,854	2.8%
	36	10,654	10,854	1.9%
	38	10,744	10,854	1.0%
	40	10,835	10,854	0.2%
	42	10,927	10,854	-0.7%
	44	11,018	10,854	-1.5%
	46	11,110	10,854	-2.3%
	48	11,203	10,854	-3.1%
	50	11,296	10,854	-3.9%
	52	11,389	10,854	-4.7%
BLOCK 3	54	11,482	10,854	-5.5%
	56	11,576	12,251	5.8%
	58	11,670	12,251	5.0%
	60	11,765	12,251	4.1%
	62	11,860	12,251	3.3%
	64	11,955	12,251	2.5%
	66	12,050	12,251	1.7%
	68	12,146	12,251	0.9%
	70	12,242	12,251	0.1%
	72	12,339	12,251	-0.7%
	74	12,436	12,251	-1.5%
	76	12,533	12,251	-2.3%
	78	12,631	12,251	-3.0%
	80	12,729	12,251	-3.8%
	82	12,827	12,251	-4.5%
	84	12,926	12,251	-5.2%
BLOCK 4	86	13,025	12,251	-5.9%
	88	13,124	13,584	3.5%
	90	13,224	13,584	2.7%
	92	13,324	13,584	2.0%
	94	13,424	13,584	1.2%
	96	13,525	13,584	0.4%
	98	13,626	13,584	-0.3%
	100	13,727	13,584	-1.0%
	102	13,829	13,584	-1.8%
	104	13,931	13,584	-2.5%
	106	14,034	13,584	-3.2%
BLOCK 5	107	14,085	13,584	-3.6%

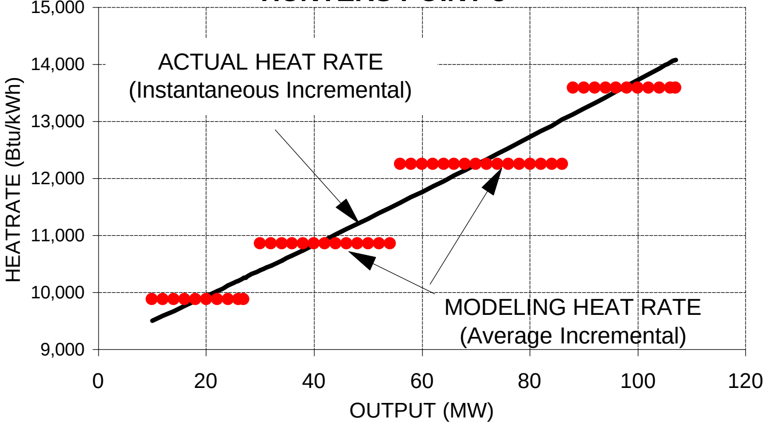
ACTUAL HEAT RATE CURVE
INSTANTANEOUS INCREMENTAL HEAT RATE



MODELING HEAT RATE BLOCKS
AVERAGE INCREMENTAL HEAT RATE



MODELING vs. ACTUAL
HUNTERS POINT 3



Average Heat Rate

Figure 14 shows the typical representation of the block Average Heat Rate for Unit X, repeated from Figure 2A. As with the Input-Output and the Incremental Heat Rate Curves, this is not strictly correct. As previously explained, Figure 14 is really a piece-wise linear representation of the actual Average Heat Rate curve, which is shown in Figure 15.

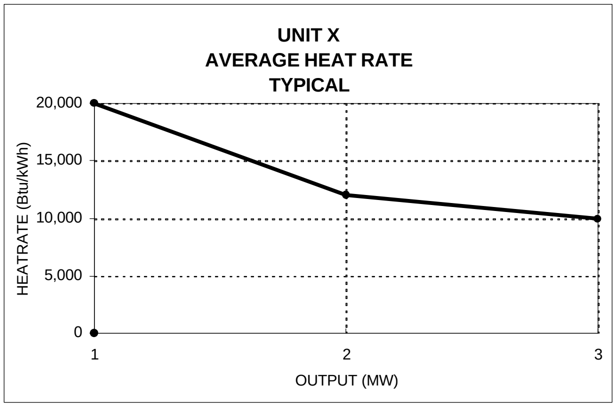


Figure 14

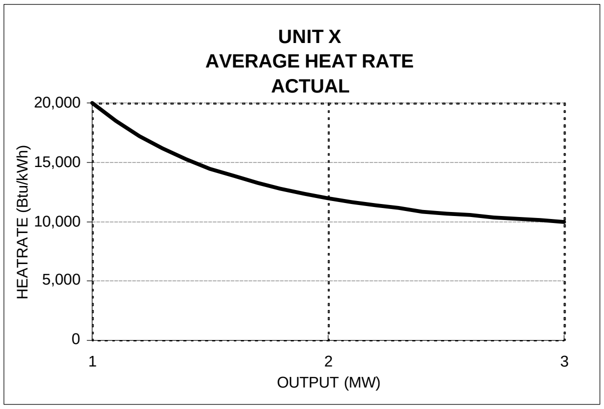


Figure 15

This error is of no particular importance, however. As explained above, the Average Heat Rate block data plays a very small role in modeling. Other than its possible use for commitment, it has no direct function. The Average Heat Rate data is entered into the model primarily to be used in the development of the Incremental Heat Rate block data -- and the model is only using the block point so that the linear nature of the data does not compromise the modeling. It is the Incremental Heat Rate block data that is used to calculate the Average Heat Rates and the corresponding production costs. This may seem somewhat “round-about” but this will become clearer as we continue.

As demand increases, the model looks at the various blocks of power available to it and decides which block is the least expensive. In the case of Unit X, its offering would be 10 $/MWh (4,000 Btu/kWh) for Block 2 and 15 $/MWh (6,000 Btu/kWh) for Block 3. Unit X’s production cost turns out to be the very same as if it were based on its Average Heat Rate, 30 $/MWh at 2 MW and 25 $/MWh as 3 MW. Based on this description, it would appear that the model would actually be using the above Average Heat Rate Curve as previously defined. Actually, this is only a coincidence and only seems to work because I used cases where the output was precisely 1, 2 or 3 MW.

Take the subtler case where the output is 1.5 MW. The model calculates the production cost using block Incremental Heat Rates as follows. It notes that the heat rate of block 1 as 20,000 Btu/kWh and calculates the corresponding cost of the one MWh as $50. It then notes that Unit X has provided 1/2 MW from Block 2 at 4,000 Btu/kWh and calculates the cost of that as one-half of a MWh as $5: 4,000 Btu/kWh x 2.5 $/MMBtu x 1/2 MWh = $5. The production cost for this hour is simply the sum of the two costs: $50 + $5 = $55. The average cost of generation is equal to the total production cost ($55) divided by the total generation (1.5 MWh): 36.67 $/MWh.

The Average Heat Rate can be calculated as 14,667 Btu/kWh: 36.67 $/MWh / 2.5 $/MMBtu = 14,667 Btu/kWh. The actual Average Heat Rate predicted by the Average Heat Rate equation is 14,500 Btu/kWh. We see that the error is 1.1 percent: 14,667/14,500 - 1 = 1.1%.

Figure 16 compares the Average Heat Rate as would be calculated in the model against the actual data at 0.1 MW intervals. It is clear that even in this simplistic Unit X case, the effect of this error is small: of the order of 1 percent or less.

FIGURE 16: UNIT X
CALCULATED vs. ACTUAL AVERAGE HEAT RATES

	OUTPUT (MW)	INCREMENTAL HEAT RATE (Btu/kWh)	AVERAGE HEAT RATES		ERROR (%)
			CALCULATED (Btu/kWh)	ACTUAL (Btu/kWh)	
BLOCK 1	1.0	4,000	20,000	20,000	0.0%
	1.1	4,000	18,545	18,464	0.4%
	1.2	4,000	17,333	17,200	0.8%
	1.3	4,000	16,308	16,146	1.0%
	1.4	4,000	15,429	15,257	1.1%
	1.5	4,000	14,667	14,500	1.1%
	1.6	4,000	14,000	13,850	1.1%
	1.7	4,000	13,412	13,288	0.9%
	1.8	4,000	12,889	12,800	0.7%
	1.9	4,000	12,421	12,374	0.4%
BLOCK 2	2.0	4,000	12,000	12,000	0.0%
	2.1	6,000	11,714	11,671	0.4%
	2.2	6,000	11,455	11,382	0.6%
	2.3	6,000	11,217	11,126	0.8%
	2.4	6,000	11,000	10,900	0.9%
	2.5	6,000	10,800	10,700	0.9%
	2.6	6,000	10,615	10,523	0.9%
	2.7	6,000	10,444	10,367	0.8%
	2.8	6,000	10,286	10,229	0.6%
	2.9	6,000	10,138	10,107	0.3%
BLOCK 3	3.0	6,000	10,000	10,000	0.0%

Figure 17 shows the comparable calculations for our two real units: Moss Landing 7 and Hunters Point 3. The error is even smaller: in all cases less than one percent. I have not provided the corresponding graphs as the lines would track so closely together that it would make this representation meaningless.

I find the error to be surprisingly small given the apparent grossness of the block Incremental Heat Rate representation. It is clear that this is not something to bother ourselves about. But it is important to know this for a fact.

FIGURE 17: COMPARING INCREMENTAL HEAT RATES

MOSS LANDING 7

	CAP (MW)	INCR. HR MODELING (Btu/kWh)	AVERAGE HEAT RATES		
			CALCULATED (Btu/kWh)	ACTUAL (Btu/kWh)	ERROR (%)
BLOCK 1	50	7,176	19,959	19,959	0.0%
	65	7,176	17,009	16,933	0.5%
	80	7,176	15,165	15,065	0.7%
	95	7,176	13,904	13,799	0.8%
	110	7,176	12,986	12,889	0.8%
	125	7,176	12,289	12,206	0.7%
	140	7,176	11,741	11,678	0.5%
	155	7,176	11,300	11,259	0.4%
	170	7,176	10,936	10,920	0.1%
BLOCK 2	185	7,176	10,631	10,642	-0.1%
	200	7,905	10,426	10,410	0.2%
	215	7,905	10,251	10,216	0.3%
	230	7,905	10,098	10,050	0.5%
	245	7,905	9,963	9,909	0.5%
	260	7,905	9,845	9,788	0.6%
	275	7,905	9,739	9,683	0.6%
	290	7,905	9,644	9,592	0.5%
	305	7,905	9,558	9,512	0.5%
	320	7,905	9,481	9,443	0.4%
	335	7,905	9,410	9,381	0.3%
	350	7,905	9,346	9,328	0.2%
	365	7,905	9,268	9,266	0.0%
BLOCK 3	370	7,905	9,214	9,239	-0.3%
	380	8,450	9,246	9,239	0.1%
	395	8,450	9,216	9,202	0.2%
	410	8,450	9,188	9,169	0.2%
	425	8,450	9,162	9,140	0.2%
	440	8,450	9,138	9,114	0.3%
	455	8,450	9,115	9,092	0.3%
	470	8,450	9,094	9,071	0.2%
	485	8,450	9,074	9,054	0.2%
	500	8,450	9,055	9,038	0.2%
	515	8,450	9,038	9,024	0.2%
	530	8,450	9,021	9,011	0.1%
	545	8,450	9,005	9,000	0.1%
	560	8,450	8,990	8,991	0.0%
	575	8,450	8,976	8,982	-0.1%
	590	8,450	8,963	8,974	-0.1%
BLOCK 4	591	8,450	8,962	8,974	-0.1%
	605	8,737	8,957	8,967	-0.1%
	620	8,737	8,952	8,961	-0.1%
	635	8,737	8,946	8,956	-0.1%
	650	8,737	8,942	8,951	-0.1%
	665	8,737	8,937	8,947	-0.1%
	680	8,737	8,933	8,943	-0.1%
	695	8,737	8,928	8,940	-0.1%
	710	8,737	8,924	8,936	-0.1%
	725	8,737	8,920	8,933	-0.1%
BLOCK 5	739	8,737	8,917	8,931	-0.2%

HUNTERS POINT 3

	CAP (MW)	INCR. HR MODELING (Btu/kWh)	AVERAGE HEAT RATES		
			CALCULATED (Btu/kWh)	ACTUAL (Btu/kWh)	ERROR (%)
BLOCK 1	10	9,883	21,037	21,037	0.0%
	12	9,883	19,178	19,125	0.3%
	14	9,883	17,850	17,770	0.5%
	16	9,883	16,854	16,764	0.5%
	18	9,883	16,080	15,991	0.6%
	20	9,883	15,460	15,381	0.5%
	22	9,883	14,953	14,891	0.4%
	24	9,883	14,531	14,489	0.3%
	26	9,883	14,173	14,156	0.1%
BLOCK 2	27	9,883	14,014	14,011	0.0%
	30	10,854	13,698	13,641	0.4%
	32	10,854	13,520	13,441	0.6%
	34	10,854	13,364	13,269	0.7%
	36	10,854	13,224	13,121	0.8%
	38	10,854	13,099	12,993	0.8%
	40	10,854	12,987	12,883	0.8%
	42	10,854	12,886	12,788	0.8%
	44	10,854	12,793	12,705	0.7%
	46	10,854	12,709	12,634	0.6%
	48	10,854	12,632	12,572	0.5%
	50	10,854	12,560	12,520	0.3%
	52	10,854	12,495	12,474	0.2%
BLOCK 3	54	10,854	12,434	12,436	0.0%
	56	12,251	12,428	12,403	0.2%
	58	12,251	12,421	12,376	0.4%
	60	12,251	12,416	12,355	0.5%
	62	12,251	12,410	12,337	0.6%
	64	12,251	12,405	12,324	0.7%
	66	12,251	12,401	12,314	0.7%
	68	12,251	12,396	12,308	0.7%
	70	12,251	12,392	12,304	0.7%
	72	12,251	12,388	12,304	0.7%
	74	12,251	12,385	12,306	0.6%
	76	12,251	12,381	12,311	0.6%
	78	12,251	12,378	12,318	0.5%
	80	12,251	12,375	12,327	0.4%
	82	12,251	12,372	12,338	0.3%
	84	12,251	12,369	12,351	0.1%
BLOCK 4	86	12,251	12,366	12,365	0.0%
	88	13,584	12,394	12,381	0.1%
	90	13,584	12,420	12,399	0.2%
	92	13,584	12,445	12,418	0.2%
	94	13,584	12,470	12,438	0.3%
	96	13,584	12,493	12,460	0.3%
	98	13,584	12,515	12,483	0.3%
	100	13,584	12,536	12,507	0.2%
	102	13,584	12,557	12,531	0.2%
	104	13,584	12,577	12,557	0.2%
BLOCK 5	107	13,584	12,605	12,598	0.1%

VI. HEAT RATES IN MARKET MODELING

The previous section described the use of heat rates in production cost modeling. In this section, I describe their role in the competitive market -- which is a much more complex role.

In the market model, it is the bids that determine the dispatch of the units -- not their costs of operation. Bidding data is entered into market models in one of two ways, and most models allow for both of these. One way requires that the bid is determined outside of the model and entered into the model as a unit cost ($/MWh), in which case heat rates play no direct role in setting the Market Clearing Price (MCP). It is not to be forgotten, however, that the heat rates in the model must continue to play the role of emulating operating costs -- operating costs by definition depend on heat rates.

The other way of developing bids is to let the model estimate the bid -- generally as some function of operating costs. One method is to assume that the bid is based on variable costs -- the economists' favorite. That is, the bid is based on the fuel cost associated with Average Heat Rate (plus O&M and start-up costs). Unfortunately, most models have not been able to make this transition, and model designers are allowing their models to dispatch as they always have, based on incremental cost (Incremental Heat Rate) -- also known as marginal or nodal cost. This proxy for the real mechanism inevitably leads to questionable results. The models then find some way to emulate the actual MCP by adding on some additional amount to the incremental cost so that the overall revenue will be adequate to ensure a viable market.

The comprehensive solution to this problem requires that the model do both methods of dispatch. Members of the market will bid based on Average Cost because they must rely on the market for all of their revenue. If they bid their incremental cost and set the market clearing price (MCP), they would lose the difference between their Average and Incremental Costs -- otherwise known as no-load cost (described below). Participants who are not members can bid their Incremental Cost because their other costs (no-load costs) are captured through other sales.

The Relationship Between Average and Incremental Heat Rates

What now becomes apparent is that we have those who can bid based on Incremental Heat Rates competing against those who must by necessity bid based on Average Heat Rates -- a strange paradigm by anyone's standards. In this same vein, we have an IOU who is used to dispatching based on Incremental Costs (Incremental Heat Rates) constructing bids based on Average Costs (Average Heat Rates). For markets that require one-part bidding, this is further complicated by the need for monotonically increasing bids: each subsequent capacity block is bid at a price higher than the last. The market members find themselves with the laborious task of trying to construct monotonically **increasing** bids from **decreasing** Average Costs (Average Heat Rates) -- a formidable task.

It should now become clear why it is important to understand and quantify the differences between Average and Incremental Costs. I have attempted to quantify these differences as ratios of Average Heat Rate (***AHR***) to Incremental Heat Rate (***IHR***).

Figure 18 shows the ratio of the ***AHR*** to the ***IHR*** for Moss Landing 7, the most efficient unit in the PG&E system (pre-divestiture). At maximum output, the difference between ***AHR*** and ***IHR*** is insignificant. But at minimum output, ***AHR***/***IHR*** is 2.9. The average over all generation levels is 1.26.

FIGURE 18

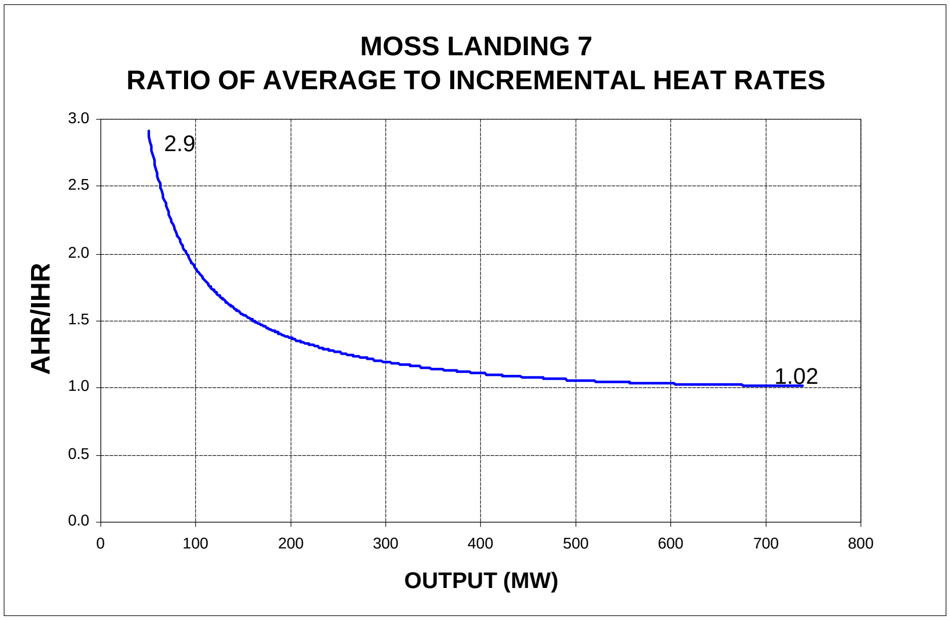


Figure 19 shows the corresponding ratio for Hunters Point 2, the least efficient unit in the PG&E system. At full output ***AHR***/***IHR*** is 0.9. At minimum output it is 2.2. The average value is 1.16.

FIGURE 19

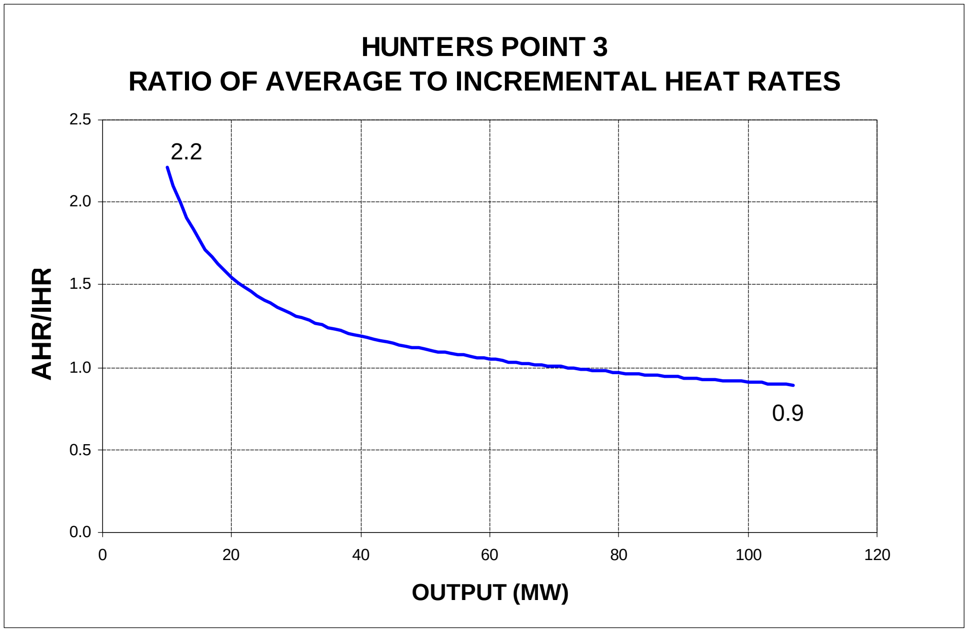


Table 5 shows these same values for all of the subject IOU units. $R(x_1)$ is the value of ***AHR/IHR*** at minimum power output. $R(x_2)$ is the corresponding value at maximum power output. R_{AVE} is the average value for the entire range of output. The supporting data and calculations are provided in Appendix D, but the procedure is briefly described below.

TABLE 5: AVERAGE TO INCREMENTAL HEAT RATE RATIOS (R)

	OUTPUT (MW)		AVERAGE/INCREMENTAL		
	X1	**X2**	**R(X1)**	**R(X2)**	**Rave**
PG&E UNITS					
Contra Costa 6	46	340	1.46	0.92	1.13
Contra Costa 7	46	340	1.58	0.94	1.14
Humboldt 1&2	10	105	1.95	0.84	1.18
Hunters Point 2	10	107	2.13	0.96	1.19
Hunters Point 3	10	107	2.21	0.89	1.16
Hunters Point 4	62	326	1.37	1.00	1.10
Morro Bay 1&2	62	326	1.35	1.00	1.11
Morro Bay 3	46	338	1.46	1.05	1.14
Morro Bay 4	46	338	1.48	1.01	1.12
Moss Landing 6	50	739	2.87	1.05	1.25
Moss Landing 7	50	739	2.91	1.02	1.26
Pittsburg 1&2	62	326	1.54	0.95	1.17
Pittsburg 3&4	62	326	1.43	0.86	1.13
Pittsburg 5	46	325	1.54	1.03	1.14
Pittsburg 6	46	325	1.67	0.97	1.16
Pittsburg 7	120	720	1.62	0.97	1.20
Potrero 3	47	207	1.20	0.89	1.05
Averages			**1.68**	**0.98**	**1.17**
SCE UNITS					
Alamitos 1&2	20	350	3.19	1.04	1.34
Alamitos 3&4	40	640	3.02	1.04	1.33
Alamitos 5&6	260	960	1.42	1.00	1.12
Cool Water 1	17	65	1.30	1.01	1.10
Cool Water 2	19	81	1.31	1.02	1.11
Cool Water 3&4	140	512	2.02	1.10	1.43
El Segundo 1&2	20	350	3.04	1.05	1.32
El Segundo 3&4	40	670	2.96	1.03	1.31
Etiwanda 1&2	20	264	2.72	1.00	1.30
Etiwanda 3&4	40	640	2.75	1.02	1.28
Highgrove 1&2	8	66	5.87	1.58	2.41
Highgrove 3&4	10	89	8.51	1.73	2.99
Huntington Beach 1&2	40	430	1.96	1.01	1.20
Long Beach 8&9	70	560	1.31	1.02	1.08
Mandalay 1&2	40	430	1.90	0.95	1.16
Ormond Beach 1	250	750	1.35	1.00	1.13
Ormond Beach 2	50	750	2.46	0.99	1.23
Redondo Beach 5&6	20	350	3.54	1.09	1.41
Redondo Beach 7&8	260	960	1.32	1.02	1.12
San Bernardino 1&2	14	126	3.24	1.15	1.54
Averages			**1.83**	**1.03**	**1.27**
SDG&E UNITS					
Encina 1	20	107	1.47	0.91	1.10
Encina 2	20	104	1.34	0.94	1.08
Encina 3	20	110	1.32	0.98	1.09
Encina 4	20	300	1.87	0.97	1.13
Encina 5	20	330	2.07	0.95	1.15
South Bay 1	30	143	1.43	0.93	1.10
South Bay 2	30	150	1.33	0.99	1.10
South Bay 3	30	175	1.40	0.96	1.10
South Bay 4	45	150	1.30	1.01	1.12
Averages			**1.47**	**0.96**	**1.12**

The minimum and maximum Ratios, $R(x_1)$ and $R(x_2)$, were calculated using the equations for the Average Heat Rate (***AHR***) and Incremental Heat Rate (***IHR***), for each unit, as follows:

The Input-Output Curve is typically defined by the third order equation:

$$y = ax^3 + bx^2 + cx + d$$

Where: x = Output in MW
y = Input in Btu/hr
a-d = The coefficients that define the equation

The Average Heat Rate (***AHR***) is defined as the Input-Output Curve (y) divided by the output (x):

$$AHR = y/x = (ax^3 + bx^2 + cx + d) / x$$

The Incremental Heat Rate (***IHR***) is defined as the first derivative of the Input-Output Curve:

$$IHR = dy/dx = 3ax^2 + 2bx + c$$

The Ratio of Average Heat Rate to Incremental Heat Rate (R) is therefore:

$$R = AHR/IHR = (y/x) / dy/dx = [(ax^3+bx^2+cx+d)/x] / (3ax^2+2bx+c)$$

The minimum output ratio, $R(x_1)$, and maximum output ratio, $R(x_2)$, are then developed by setting x equal to the minimum output (x_1) and maximum output (x_2) values, respectively.

$$R(x_1) = [(a\, x_1^3+b\, x_1^2+c\, x_1+d)/ x_1] / (3a\, x_1^2+2b\, x_1+c)$$

$$R(x_2) = [(a\, x_2^3+b\, x_2^2+c\, x_2+d)/ x_2] / (3a\, x_2^2+2b\, x_2+c)$$

The average value, R_{AVE}, is found by integrating R from the minimum output (x_1) to the maximum output (x_2), and then dividing this result by the difference between the minimum and maximum outputs ($x_2 - x_1$):

$$R_{AVE} = [\int R\, dx \text{ \{from } x_1 \text{ to } x_2\text{\}}] / (x_2 - x_1)$$

$$= [\int AHR/IHR\, dx \text{ \{from } x_1 \text{ to } x_2\text{\}}] / (x_2 - x_1)$$

Where: x_1 = ***Minimum Operating Level(MW)***
x_2 = ***Maximum Operating Level (MW)***

The integration of R, ($\int R\, dx$), is:

$$\int R\, dx =[(x/3) +(d\cdot Ln(x)/c) +(bG/18a) - (dG/2c) + (2cE/3F) - (bdE/cF) - (Eb^2/9aF)]$$

Where: $E = ATan((3ax+b)/F)$
$F = (3ab-x^2)^{1/2}$
$G = Ln(3ax^2+2bx+c)$
Ln = ***Natural Log***
$ATan$ = ***Arc Tangent***

Substituting the coefficients of Table B-2 in Appendix B into the above equations gives the results shown in Table 5. Using the now familiar Moss Landing 7 unit to illustrate this gives:

$a = -0.0013$
$b = 2.955$
$c = 6561.2$
$d = 662025$

$x_1 =$ 50 MW
$x_2 =$ 739 MW

- The ***AHR/IHR*** at minimum generation: $R(x_1)$

$R(x_1) = AHR/IHR = (ax^3+bx^2+cx+d)/x] / (3ax^2+2bx+c)$: $x_1 =$ 50 MW

$$R(50) = AHR/IHR = [(-0.0013\cdot 50^3+2.955\cdot 50^2+6561.2\cdot 50+662025)/50] \\ / (3\cdot -0.0013\cdot 50^2+2\cdot 2.955\cdot 50+662025)$$

$R(50) = AHR/IHR =$ <u>2.91</u>

- The ***AHR/IHR*** at maximum generation: $R(x_2)$

$R(x_2)= AHR/IHR = (y/x)/y' = [(ax^3+bx^2+cx+d)/x] / (3ax^2+2bx+c)$: $x_2 =$ 739 MW

$$R(739) = AHR/IHR = [(-0.0013\cdot 739^3+2.955\cdot 739^2+6561.2\cdot 739+662025)/739] \\ / (3\cdot -0.0013\cdot 739^2+2\cdot 2.955\cdot 739+662025)$$

$R(739) = AHR/IHR =$ <u>1.02</u>

- The average ***AHR/IHR***: R_{AVE}

$R_{AVE} = [\int R\, dx \{\text{from } x_1 \text{ to } x_2\}] / (x_2 - x_1)$

$$\int R\, dx =[(x/3) +(d\cdot Ln(x)/c) +(bG/18a) - (dG/2c) + (2cE/3F) - (bdE/cF) - (Eb^2/9aF)]$$

Where: $E = ATan((3ax+b)/F)$
$F = (3ab-x^2)^{1/2}$
$G = Ln(3ax^2+2bx+c)$

$$R(739) = (739/3)+(662025\ln(739)/6561.2)+(2.955G/18/-0.0013)-(662025G/2/6561.2) \\ +(2\cdot 6561.2E/3F) -(2.955\cdot 662025E/6561.2F)-(2.955^2E/9\cdot -0.0013F)$$

Where: $E = \text{ATan}((3\cdot -0.0013\cdot 739+2.955)/F)$
$F = (3\cdot -0.0013\cdot 2.955-739^2)^{1/2}$
$G = \text{Ln}(3\cdot -0.0013\cdot 739^2+2\cdot 2.955\cdot 739+6561.2)$

$$\boldsymbol{R}(50) = (50/3)+(662025\ln(50)/6561.2)+(2.955\boldsymbol{G}/18/-0.0013)-(662025\boldsymbol{G}/2/6561.2)$$
$$+(2\cdot 6561.2\boldsymbol{E}/3\boldsymbol{F}) -(2.955\cdot 662025\boldsymbol{E}/6561.2\boldsymbol{F})-(2.955^{2}\boldsymbol{E}/9\cdot -0.0013\boldsymbol{F})$$

Where: $\boldsymbol{E} = \mathrm{ATan}((3\cdot -0.0013\cdot 50+2.955)/\boldsymbol{F})$

$\boldsymbol{F} = (3\cdot -0.0013\cdot 2.955-50^{2})^{1/2}$

$\boldsymbol{G} = \mathrm{Ln}(3\cdot -0.0013\cdot 50^{2}+2\cdot 2.955\cdot 50+6561.2)$

$$\boldsymbol{R}_{AVE} = [R(739) - R(50)] / (739 - 50) = \underline{1.2596.}$$

At the bottom of each set of IOU values in Table 5 is an average value that is calculated as the weighted average using the relevant capacity for each ***R(x)*** value:

Average $\boldsymbol{R(x) = [\sum R(x) \cdot x] / \sum x}$ for all x in an IOU

- System average $\boldsymbol{R(x_1)}$ is weighted by $\boldsymbol{x_1}$.
- System average $\boldsymbol{R(x_2)}$ is weighted by $\boldsymbol{x_2}$.
- System average $\boldsymbol{R_{AVE}}$ is weighted by $\boldsymbol{x_2 - x_1}$.

Table 5 can be better visualized in graphical form. Figures 20A, B and C present the data of Table 5 in graphical form, except this time system ratios of ***AHR/HR*** are arranged in terms of increasing values of $\boldsymbol{R(x_1)}$**.**

FIGURE 20A

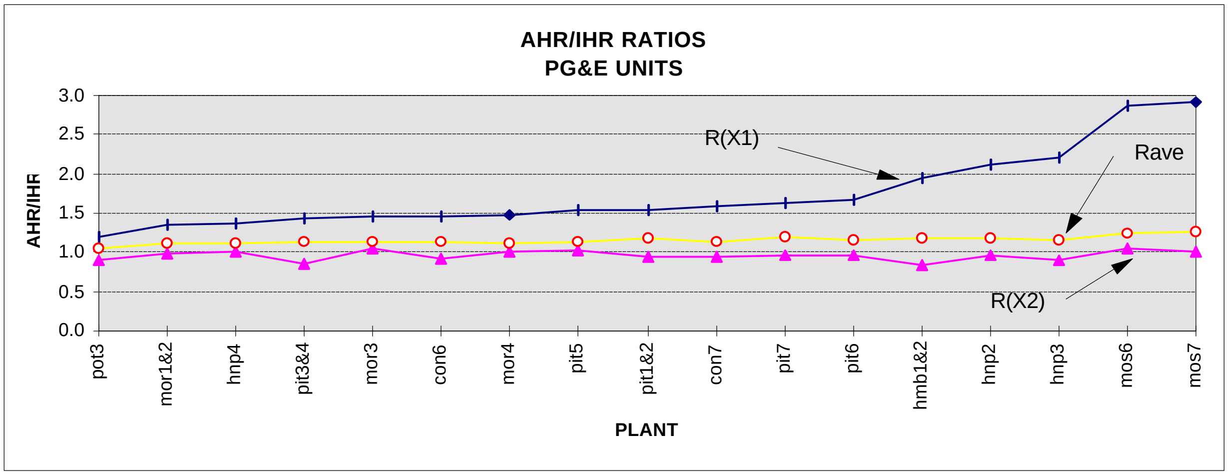


FIGURE 20B

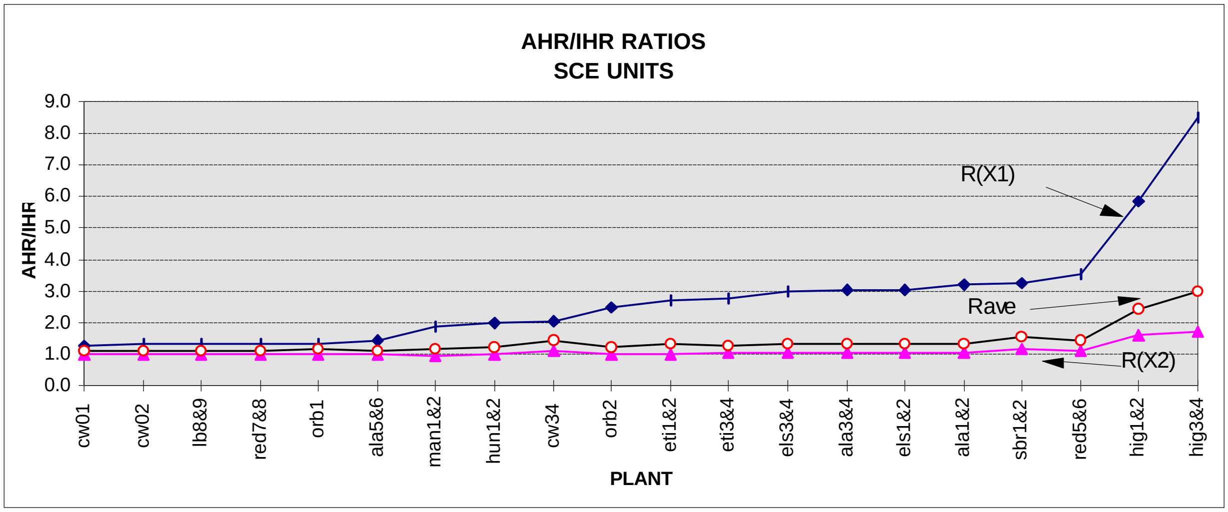


FIGURE 20C

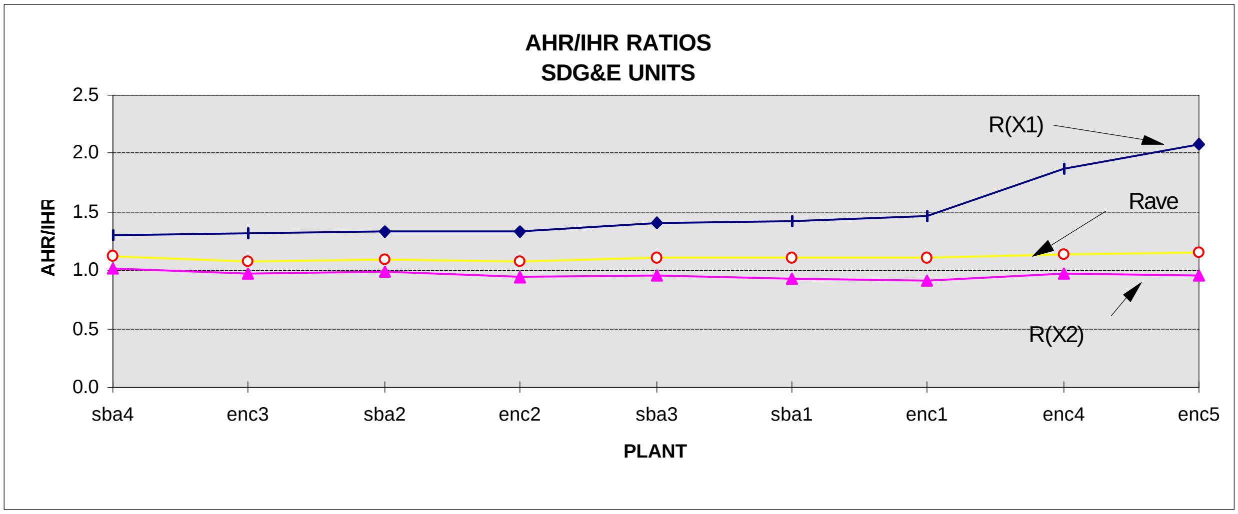


Table 6 summarizes the ranges of the **unit** data found in the Table 5 (and Figures 20A, B & C). Table 7 summarizes the **system average** values for each IOU (pre-divestiture).

TABLE 6: UNIT RATIOS OF AHR/IHR

UTILITY	RATIOS OF ***AHR***/***IHR***		
	$R(x_1)$	$R(x_2)$	R_{AVE}
PG&E	1.20 - 2.91	0.84 - 1.05	1.05 - 1.26
SCE	1.30 - 8.51	0.95 - 1.73	1.08 - 2.99
SDG&E	1.30 - 2.07	0.91 - 1.01	1.08 - 1.15

It is apparent from Table 6 that the minimum output values, $R(x_1)$, vary dramatically and are typically large. But the maximum outputs, $R(x_2)$, vary slightly and are typically small in magnitude. The average values, R_{AVE}, which would be the most representative of the operation of the units over time, do not vary as dramatically or are as large as the $R(x_1)$ values but are nonetheless significantly large in range and magnitude -- suggesting the potential for large differences between the incremental cost and the average cost.

The system average ratios of Table 7 are probably more useful than the ranges of Table 6, in that it is a more average representation of the effect on market clearing price (MCP). Considering that the PG&E and SCE units will set the MCP much more often than SDG&E, it appears that on average the Average Heat Rate, R_{AVE}, will tend to be in the range of 17 to 27 percent higher than the Incremental Heat Rate (***IHR***) -- during those hours that the IOU units set the MCP.

TABLE 7: SYSTEM RATIOS OF AHR/IHR

UTILITY	RATIOS OF ***AHR***/***IHR***		
	$R(x_1)$	$R(x_2)$	R_{AVE}
PG&E	1.68	0.98	1.17
SCE	1.83	1.03	1.27
SDG&E	1.47	0.96	1.12

The 17 to 27 percent values are meaningful if one is willing to accept the simplifying assumption that over the long run all units will be used equally and each unit will experience all levels of generation an equal number of hours. This is of course simplistic, but useful for this simplistic characterization.

In actual practice, the more efficient units will be used more than the less efficient units and all units will tend to generate more at their lower levels than their higher levels. In general, both of these realities will increase the ratio (***R***) of Average Heat Rate (***AHR***) to Incremental Heat Rate (***IHR***). This is very difficult to quantify, but nevertheless I attempt to so in the next section, A Simplistic Market Model.

A Simplistic Market Model

This section presents a Simplistic Market Model that is a more comprehensive emulation of the ratio (***R***) of Average Heat Rate (***AHR***) to Incremental Heat Rate (***IHR***). This model uses the above heat rate data but combines the data into an emulation of the competitive market, which allows us to look at the system ***R*** values throughout various levels of generation, rather than the system average (R_{AVE}) values described above. The calculations and methodology are provided in Appendix E for those who would like to replicate this process in detail, but the following adequately describes the method and results.

Traditional production cost modeling consists of commitment and dispatch. The commitment process consists of identifying the most economic set of plants necessary to meet the daily peak. The dispatch of these plants is based on the incremental cost of each plant's capacity blocks. The Incremental Cost is determined by the fuel cost (the ***IHR*** times dispatch gas price) plus variable O&M, on a $/MWh basis. The available capacity block with the least Incremental Cost at the moment of increased load is dispatched to meet that load.

In the California market, the PX and the ISO disavow responsibility for commitment and assign that responsibility to the bidder. The PX and the ISO rely solely on dispatch. They dispatch the system based on the lowest bid offered, indifferent to the actual cost of dispatch.

For the case of non-members, who have other means of capturing revenue and are just offering increments of surplus power to the market, their bids will probably continue to be based on their Incremental Costs. But for the members of the market (IOUs and those who will depend on the market for all their revenue), their bids must reflect all costs, not just Incremental Costs. Their variable O&M costs will not change, but their fuel related bid must now reflect their average cost (***AHR*** times total gas price) as well as their start-up costs.

The Simplistic Market Model ignores the effects of variable O&M and start-up costs -- as well as the effects of commitment. It concentrates solely on the differences in heat rates between the ***AHR***, which is representative of MCP, and ***IHR***, which is representative of traditional dispatch (that is, MC). Figures 21A, B & C compare ***AHR*** to ***IHR*** on a graphical basis. These heat rate curves are for the IOU slow-start gas-fired units (steam units and combined cycle units), ignoring the fast-start units (CTs), as CTs do not in general set the MCP.[2] Units other than the IOU units are ignored under the simplifying assumption that the IOU units will set the market clearing price most of the time -- although this is only approximately true.[3] The heat rate curves are shown separately for each IOU in order to make the presentation more legible. In actual practice, the three curves would be combined -- and would include all units and not just the slow-start gas-fired units.

The process for deriving the ***AHR*** and ***IHR*** curves of the Figure 21 series is burdensome but conceptually quite simple. To facilitate this understanding, you should imagine that this data is simply the sorting of the block heat rate data provided in Appendix A. Then realize that this data can not be used directly as ***AHR*** and ***IHR*** are not directly comparable.

Each Incremental Heat Rate (***IHR***) value is an <u>average for its block</u>. Each Average Heat Rate (***AHR***) value is the point values at the <u>end of the block</u>. To make these values comparable requires that ***AHR*** values also be characterized as an average for the same block. This is done using the equations of Appendix B. This new value is delineated as $\boldsymbol{AHR_{AVE}}$ to differentiate it from the traditional ***AHR*** value. ***IHR*** is then recalculated using the corresponding equation, so that ***AHR*** and ***IHR*** will be completely comparable. As with all previous analyses, in cases where two units have the same size capacity blocks, they are combined into one equivalent unit in order to make the computation and representation simpler.

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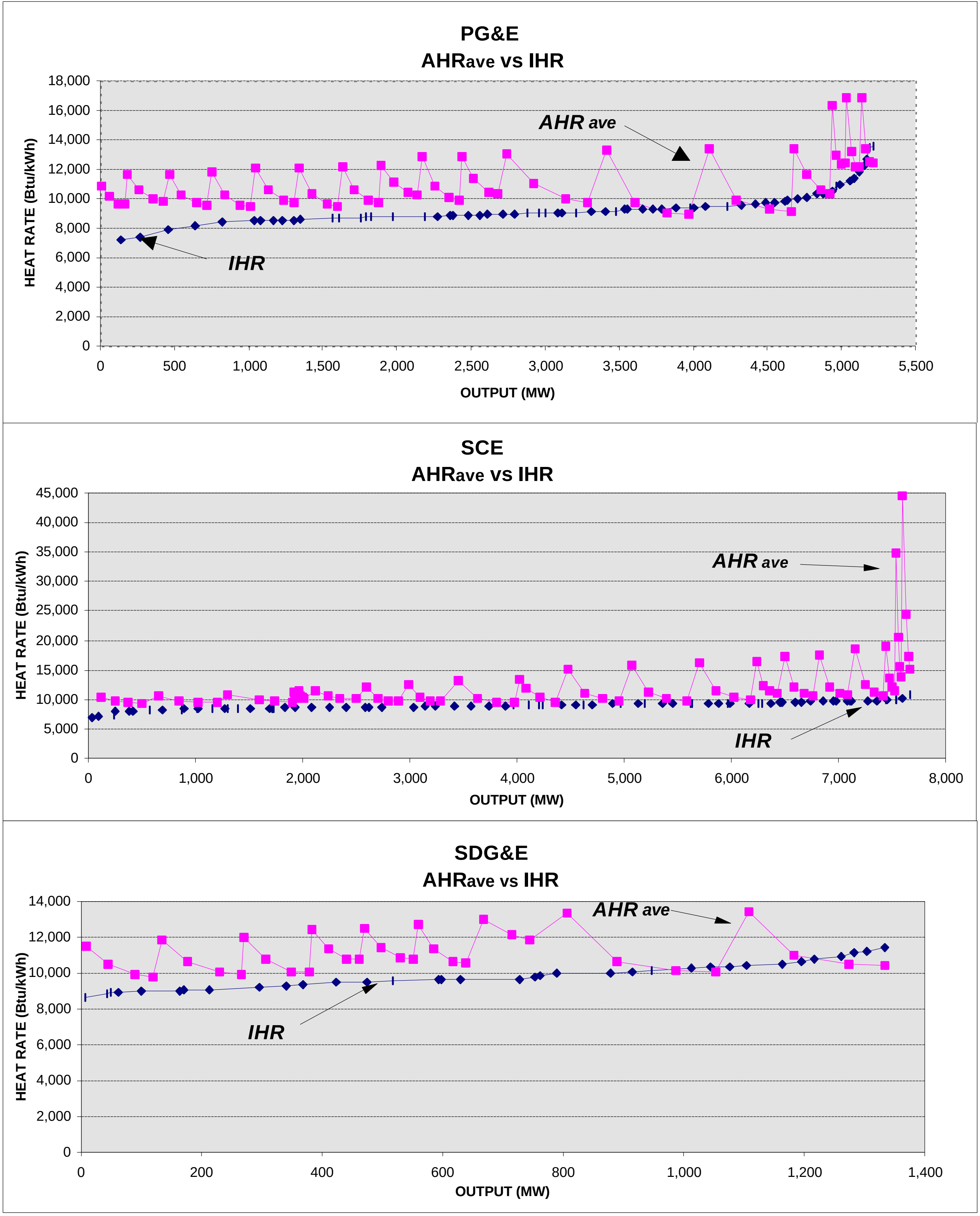
[2] Although CTs can bid into the PX market and set the MCP, it is expected that in general CTs will bid into the non-spin market and will not set the MCP.

[3] Various simulations suggest that the slow-start gas-fired IOU units will only set the market clearing price approximately 50 to 70 percent of the time, depending on the particular set of assumptions.

FIGURE 21A,B&C



The ***IHR*** curves of the Figure 21 series are constructed to emulate the dispatch of the regulated system. Each slow-start gas-fired unit is represented by four ***IHR*** blocks.[4] These heat rate blocks are then sorted by increasing ***IHRs.***

The **AHR_{AVE}** curves of Figure 21 are constructed to emulate the dispatch of the competitive market. These values are sorted similar to those of ***IHR*** except the **AHR_{AVE}** blocks can not simply be ordered by increasing **AHR_{AVE}** value, as was done with the ***IHR*** values. This would lead to the physical impossibility of less expensive upper blocks being dispatched before more expensive lower blocks. To represent this physical limitation, the units are first sorted based on their first block heat rates (Block 2). When the first unit with the lowest expensive first block **AHR_{AVE}** is identified, it is logical that all of its upper blocks will then be dispatched before going on to the first block (Block 2) of any other unit; as at that point, no other unit's first block can compete with this unit's upper blocks. Thus, we see the saw-tooth nature of the **AHR_{AVE}** curves in the Figure 21 series. The downward sloping arc of each "tooth" represents the **AHR_{AVE}** curve of that unit, starting at the highest heat rate block (first block) and ending at the minimum point (last block).

The two curves of Figure 21 series clearly illustrate the fact that the **AHR_{AVE}** dispatch is inherently more costly than the ***IHR*** dispatch -- without even accounting for the difference between the dispatch price of gas and the total price of gas. We can also see from these same figures that the **AHR_{AVE}** curve is not flat, as is the ***IHR*** curve. This suggests that the typical statements about there not being much variance in the MCP bids between units is perhaps too simplistic.

At the same time, these **AHR_{AVE}** curves can not be truly representative of the California market, as the market requires 1-Part monotonic bidding, such that each unit's bid price series must increase with each block of power. That is, the **AHR_{AVE}** must look similar to the ***IHR*** curve. The knowledge of this paradox allows us to understand the dilemma of the plant owner in bidding a unit's costs into the market -- or the modeler in modeling the market. Each unit has declining (downward sloping) costs that must be converted to monotonically increasing (upward sloping) costs. These curves can be equal at one point, only. This means that if the plant owner wants to bid its unit's costs in any one hour, the owner must know the exact generation level -- that one point where the curves are equal. Herein lies the difficulty for the plant owner -- and the modeler. If the exact capacity level (block heat rate) can be determined, the correct unit is dispatched. Otherwise, the incorrect unit is selected resulting in inefficient dispatch and the concomitant shift in revenues to an alternative bidder.

We can not hope to emulate the actual dispatch of the system with this simplistic model. Nevertheless, we can develop a crude proxy for the system by rearranging the ***IHR*** and **AHR_{AVE}** data into weighted averages. The Figure 22 series uses the same data of the Figure 21 series except that it is a running weighted average -- as each unit is added, a weighted system average is calculated based on the cumulative capacity (MW) of the blocks. This is done for both the ***IHR*** and the **AHR_{AVE}** data. The respective curves are system values of ***IHR*** and the **AHR_{AVE}**, and are designated ***SIHR*** and the **$SAHR_{AVE}$**, respectively.

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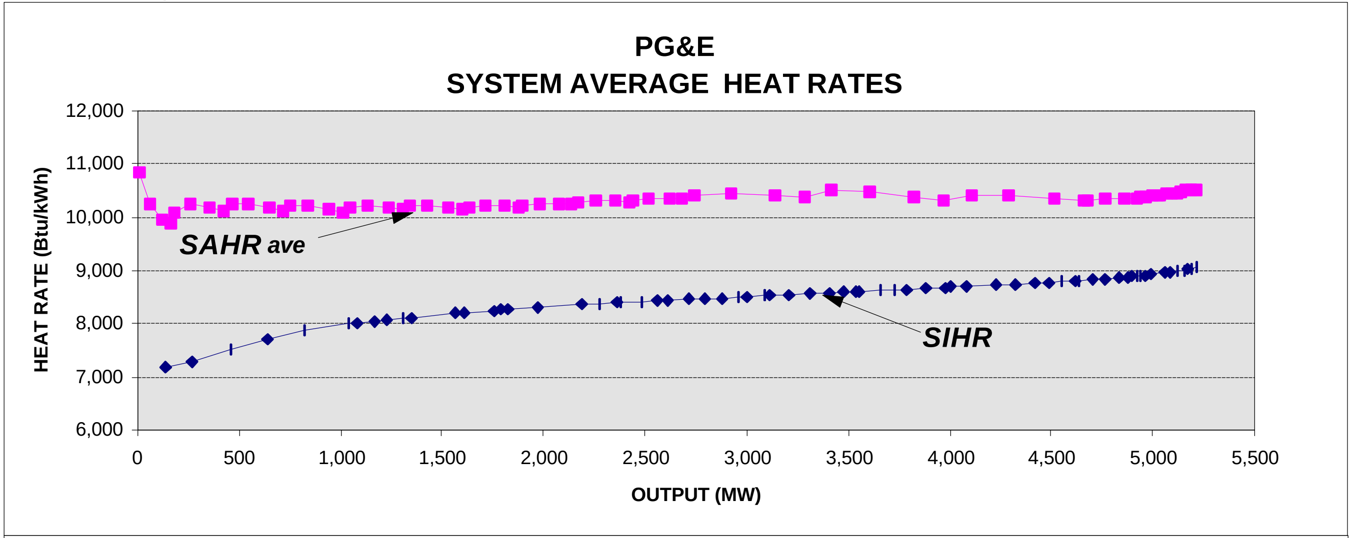
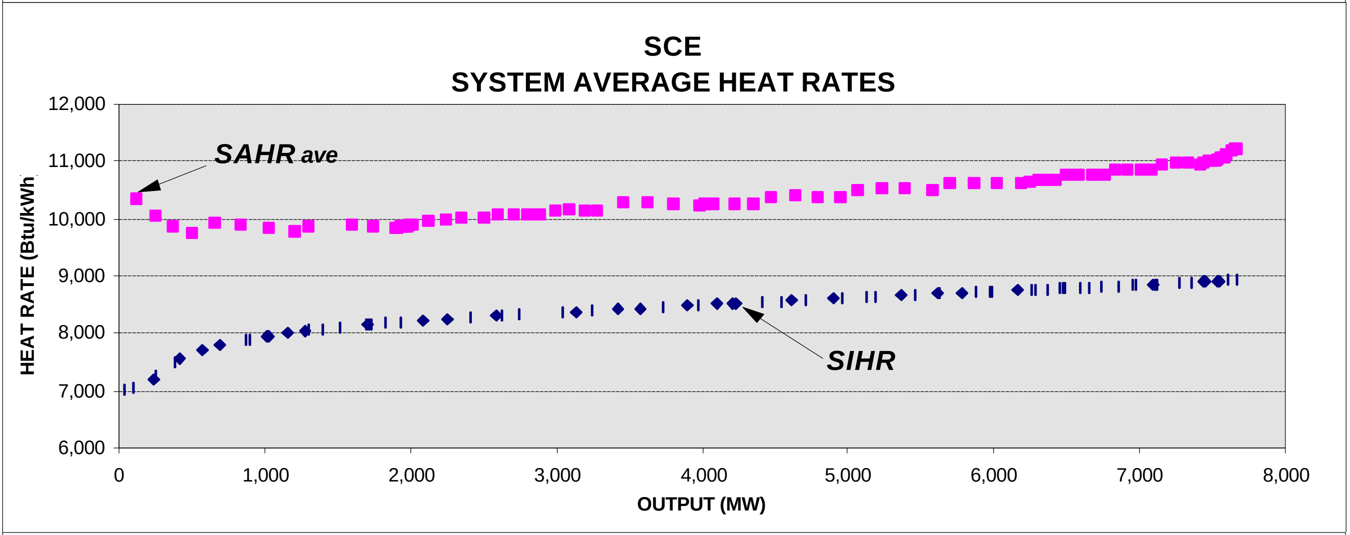
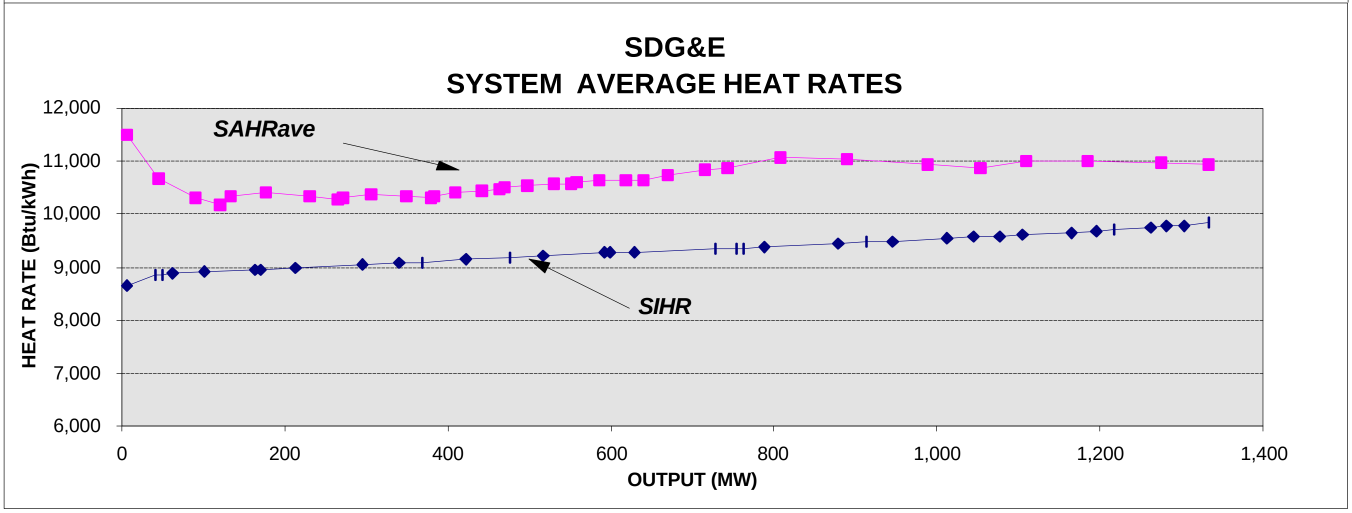
[4] Appendix A provides five blocks of average heat rate data but the first block does not qualify as an incremental heat rate. It is an average heat rate.

FIGURE 22A,B&C


PG&E
SYSTEM AVERAGE HEAT RATES


SCE
SYSTEM AVERAGE HEAT RATES


SDG&E
SYSTEM AVERAGE HEAT RATES

The weighted average data shown in the Figure 22 series can be considered as representative of an average value that could be expected over time at various levels of generation -- looking at individual IOUs, one at a time. These Figures show that the ratio of $SAHR_{AVE}$ to $SIHR$ does increase at lower generation levels, but not as dramatically as we might have thought -- assuming that we're looking at reasonably to be expected values of output.

These results can be made to conform to our results in the previous section by taking the end point in each curve. Table 8 summarizes the heat rate data for the last point in each curve and calculates the $SAHR_{AVE}$ / $SIHR$ values for each utility. These $SAHR_{AVE}$ / $SIHR$ values are very close to the Table 7 values but do not match exactly. This is to be expected since mathematically they are not exactly equivalent.

TABLE 8: SUMMARY OF SYSTEM HEAT RATES

	PG&E	SCE	SDG&E
$SIHR$ HEAT RATE (Btu/kWh)	9,057	8,943	9,830
$SAHR_{AVE}$ HEAT RATE (Btu/kWh)	10,522	11,217	10,944
$SAHR_{AVE}$ / $SIHR$	1.16	1.25	1.11

This same data also suggests that units will have a different competitive status under the restructured market than they do now. For example, under regulation and traditional dispatch (IHR), the SCE units would seem to have the most favorable position -- absent consideration of gas prices -- since SCE has the lowest $SHIR$ (8,943 Btu/kWh). But based on the market dispatch (AHR_{AVE}), PG&E would appear to have the most favorable position -- since PG&E has the lowest $SAHR_{AVE}$ (10,522 Btu/kWh).

My heat rate analysis up to this point has ignored costs, which is clearly a short coming which will now be corrected. Table 9 presents estimated 1998 gas prices, which were taken from the Energy Commission's 1997 Fuels Forecast (FR 97) approved on March 18, 1998.

TABLE 9: SUMMARY OF 1998 GAS PRICES (FR 97)

FORECAST YEAR = 1998	DISPATCH ($/MMBtu)	TOTAL ($/MMBtu)
PG&E	2.31	2.51
Cool Water	2.24	2.34
SCE OTHER	2.43	2.61
SDG&E	2.34	2.91

Figures 23A, B & C provide the comparable cost data for each IOU based on the above 1998 gas prices. Figure 24 combines the Figure 23 series into one graph, and for the first time we have a representation of the total system -- IOUs only. In Figure 24, $SAHR_{AVE}$ times the total price of gas can be considered a proxy for MCP and $SHIR$ times the dispatch price of gas can be considered a proxy for MC. The distances between these two curves allow us to appreciate the difference between MCP and MC that is due to the combination of heat rate and gas price differences.

FIGURE 23A,B&C

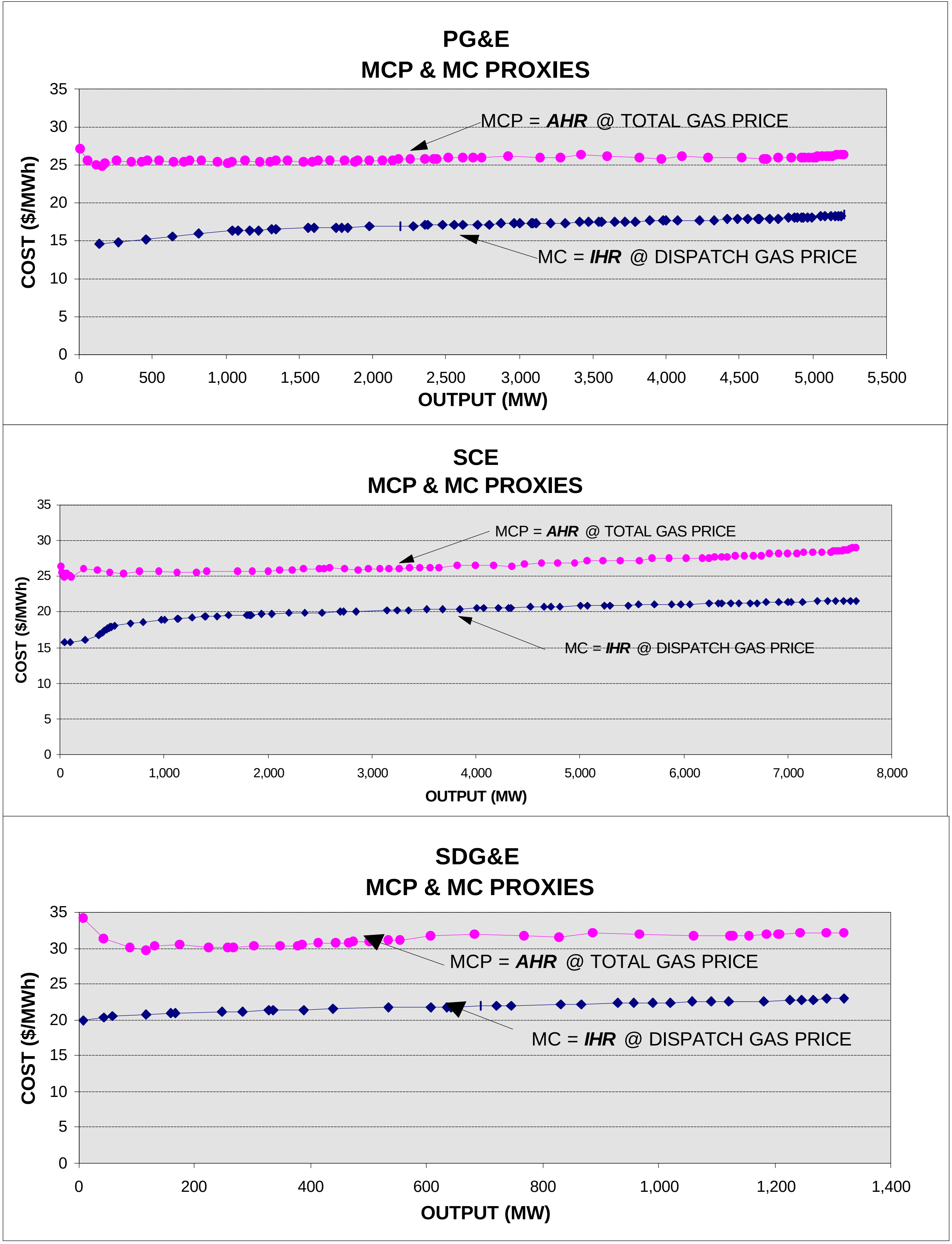


FIGURE 24

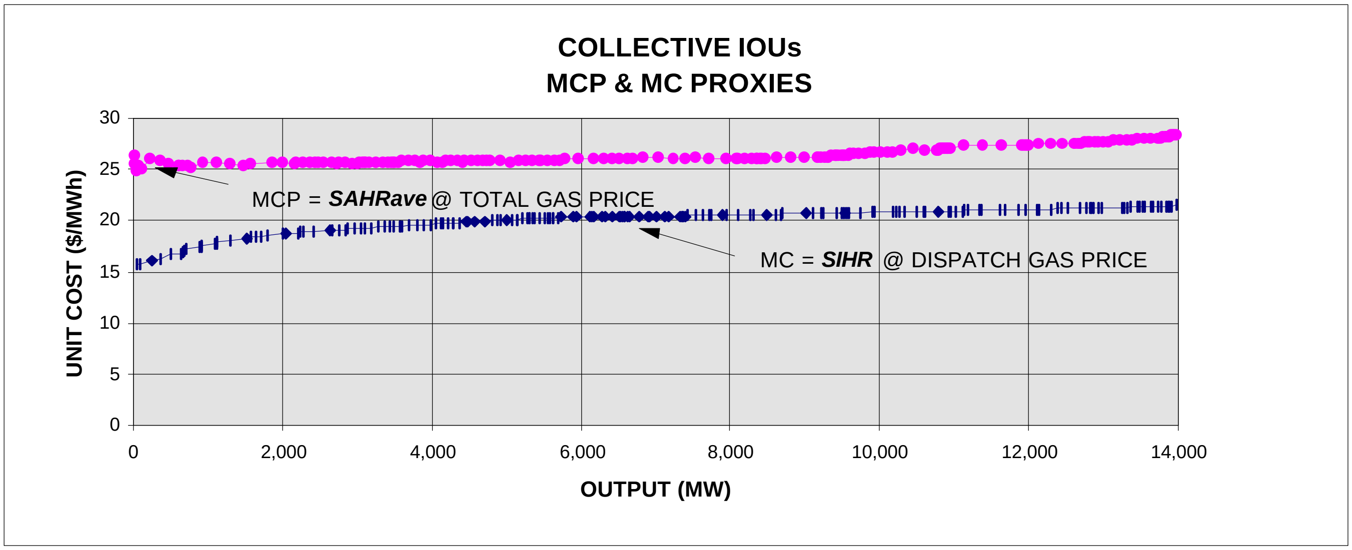
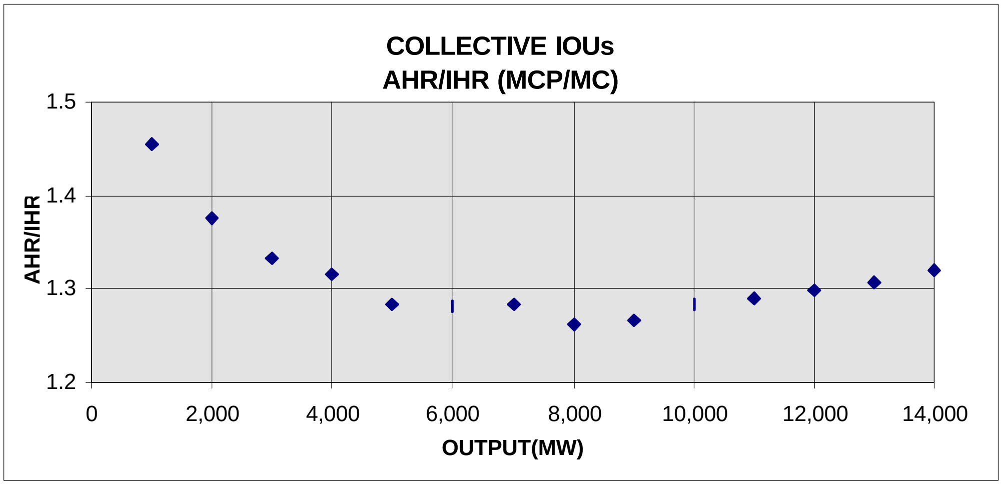


Figure 25 is a curve that is the ratio of the two curves in Figure 24. It is the ratio of the MCP proxy to the MC proxy for selected points: at 1000 MW intervals. The curve shows values in the range of 1.26 to 1.45 depending on the output level. These are very significant differences to be sure, but perhaps not as large as we might have expected given that in any one hour the difference can be much higher than this – as high as 8.5:1 as we have already shown.

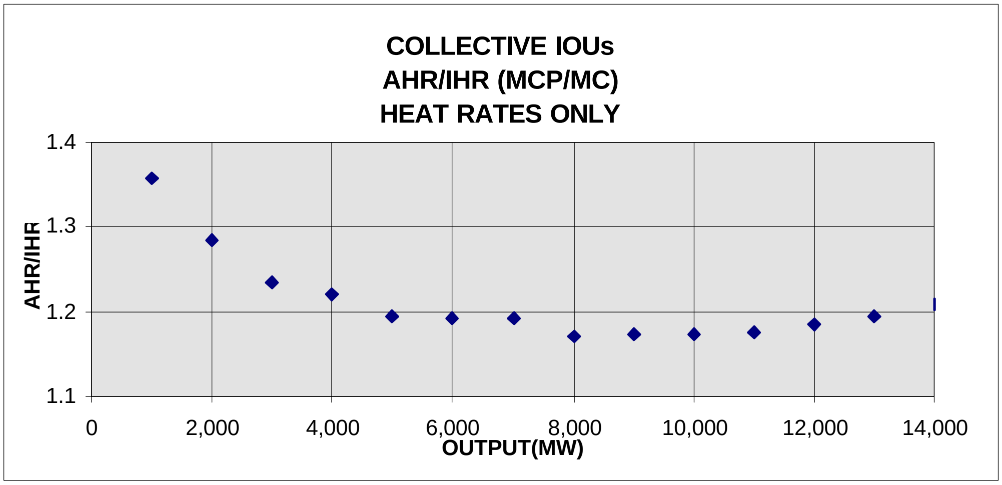
FIGURE 25



The Figure 25 curve implies that given an extended period of time where each unit is allowed to experience all of its various levels, the average will be as shown. Remembering our earlier conclusion that this is probably simplistic because units will tend to operate more at their lower levels, we have to conclude that the 1.26 to 1.45 range is probably low. At the same time, we must recognize that the lowest and highest portions of the curve will tend to be used the least. The least that we can say here is that this ratio will undoubtedly be 1.26 -- or higher. **That is, the MCP should exceed traditional MC by something greater than 26 percent.**

Figure 26 is the same as Figure 25 except that the difference due to the gas price differential has been removed. This Figure represents the difference between Average and Incremental Heat Rates, only. The range is now 1.17 to 1.36, as opposed to the 1.26 to 1.45 of Figure 25. The effect of using Average instead of Incremental Heat Rates is in the range is something greater than 17 percent. The effect of the gas prices is therefore about 9 percentage points. Compared to earlier Natural Gas Price Forecasts, this differential is small. For example, there were years in earlier forecasts where PG&E had dispatch gas prices that were 25 percent lower than the total gas price. At the same time, Energy Commission Staff expects that the 9 percentage points probably overstate the differential in the future as there are indications that the fixed cost component of contract gas prices will become smaller and smaller. It is also expected that utilities and others will probably bid their total price of gas in order to receive reasonable remuneration from the competitive market. Figure 26 is therefore probably the more accurate estimate.

FIGURE 26



It is important to keep in mind that these representations are exceedingly simplistic. First, they are based on IOU (pre-divestiture) slow-start gas-fired units, only. Second, the ***IHR*** and the $\boldsymbol{AHR_{AVE}}$ values are based on a simplistic averaging system. Third, all system generation and transmission constraints are ignored. Finally, these calculations are for one year, only. There is no reason to believe that these representations are anything but illustrative.

No-Load Heat Rates

No-Load Heat Rates relate to the concept of No-Load Costs which were conceived at a time when the California competitive market was proposed to be based on three-part bidding. Although this concept is no longer relevant in the California market, it continues to be a subject of discussion. In addition, the No-Load Cost concept may still prove viable in other competitive markets. For these reasons, it is included within this paper.

The three components to 3-parts bidding are:

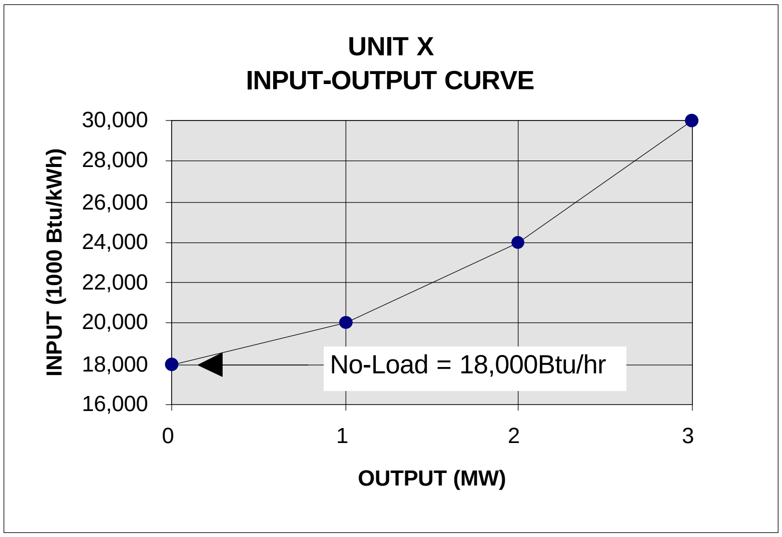
- No-Load Bid
- Monotonic Energy Bid
- Start-Up Costs

Only the first two items are germane to our present discussion -- the Start-Up costs will be ignored in this paper. As already explained, the market participants need to bid their Average Costs; but bidding

Average Costs, which are declining costs, does not allow for bidding monotonic bids. Before the decision was made to go to one-part bidding, the market designers decided to solve this problem using the No-Load Cost component. When this No-Load Cost is subtracted from the Average Cost, Monotonic Energy Bids remain.

The No-Load Heat Rate is defined as the extrapolation of the Input-Output Curve back to the vertical axis (Input). This can most easily be illustrated by returning to our Unit X. The Unit X Input-Output Curve is shown in Figure 27, using the equation developed for Figure 5: $y = 1000x^2 + 1000x + 18000$, where x = Output in MW and y = Input in 1000 Btu/hr. Extrapolating back to the Input axis creates an intercept point of 18,000,000 Btu/hr which defines the No-Load quantity. Note that this same value can be obtained by setting $x = 0$ in the Input-Output equation.

FIGURE 27



Multiplying this 18,000,000 Btu/hr by our fuel cost of 2.5 $/MMBtu provides the hourly bid quantity of $45 per hour. This is by definition a fixed cost in each hour that is independent of the output. At the same time, its effect on the calculation of the Monotonic Energy Bid is not a constant amount. This is illustrated in Table 10.

TABLE 10: CALCULATION OF MONOTONIC ENERGY BIDS FOR UNIT X

UNIT X	BLOCK 1 (HEAT RATE)	BLOCK 2 (HEAT RATE)	BLOCK 3 (HEAT RATE)
MONOTONIC ENERGY BID	5 $/MWh (2,000 Btu/kWh)	7.5 $/MWh (3,000 Btu/kWh)	10 $/MWh (4,000 Btu/kWh)
NO-LOAD BID	45 $/MWh (18,000 Btu/kWh)	22.5 $/MWh (9,000 Btu/kWh)	15 $/MWh (6,000 Btu/kWh)
TOTAL ENERGY BID	50 $/MWh (20,000 Btu/kWh)	30 $/MWh (12,000 Btu/kWh)	25 $/MWh (10,000 Btu/kWh)

The Monotonic Energy Bids are calculated as the difference between the Total Energy Bid and the No-Load Bid. For Block 1, the total cost is 50 $/MWh (20,000 Btu/kWh) and the No-Load is 45 $/MWh (18,000 Btu/kWh). The monotonic bid is therefore 5 $/MWh (2,000 Btu/kWh): 50 $/MWh (20,000 Btu/kWh) - 45 $/MWh (18,000 Btu/kWh). For Block 2 the No-Load Cost has to be spread across twice as many MW so its cost (and heat rate) is divided by two and the Monotonic Energy Bid is 30 $/MWh -

22.5 $/MWh = 7.5 $/MWh. Similarly for the Block 3 the No-Load Cost is spread across three times as many MW and is divided by 3 and the Monotonic Energy Bid is calculated as 10 $/MWh.

This can be illustrated with graphs. Figure 28 shows the hourly costs for Unit X, which show No-Load as being constant at $45 per hour. It is the monotonic energy bid that varies from $5 at 1-MW to $10 at 3-MW.

FIGURE 28

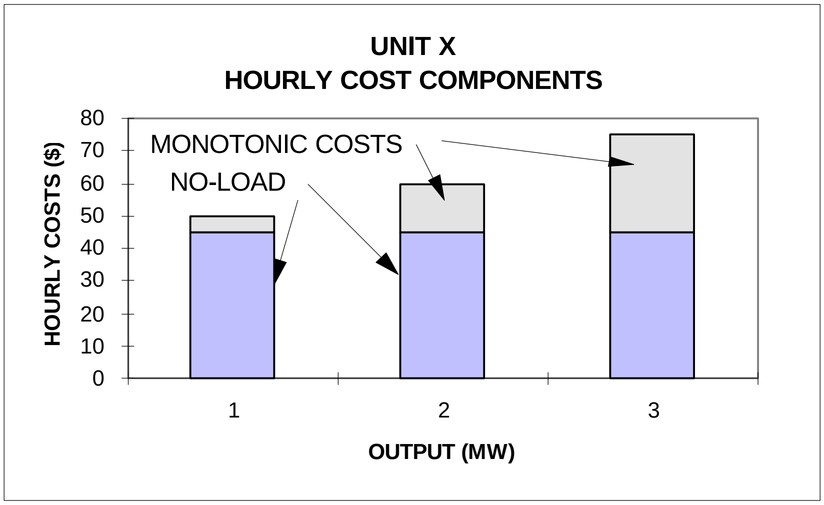
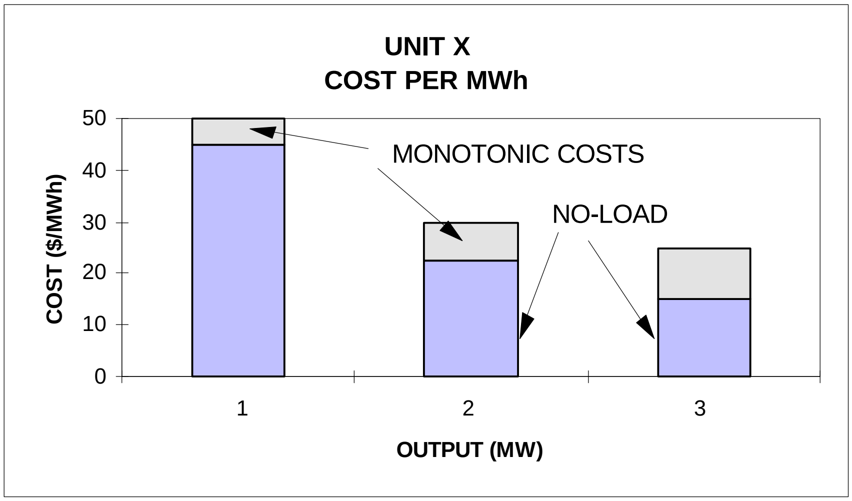


Figure 29 shows the costs per unit energy varying as illustrated in Table 10. It shows the No-Load Costs decreasing as they are spread over more MWh, and the monotonic costs increasing as required by 3-part bidding. The total of these two costs represent the Average Cost, corresponding to the Average Heat Rate.

FIGURE 29



As with past efforts I provide a real unit to illustrate No-Load Costs for real units: Moss Landing 7. Figure 30 shows No-Load calculation using the Input-Output Curve. As before, the no-load value can be found as the ***d*** coefficient of the Input-Output Curve (Table B-2 in Appendix B.)

FIGURE 30

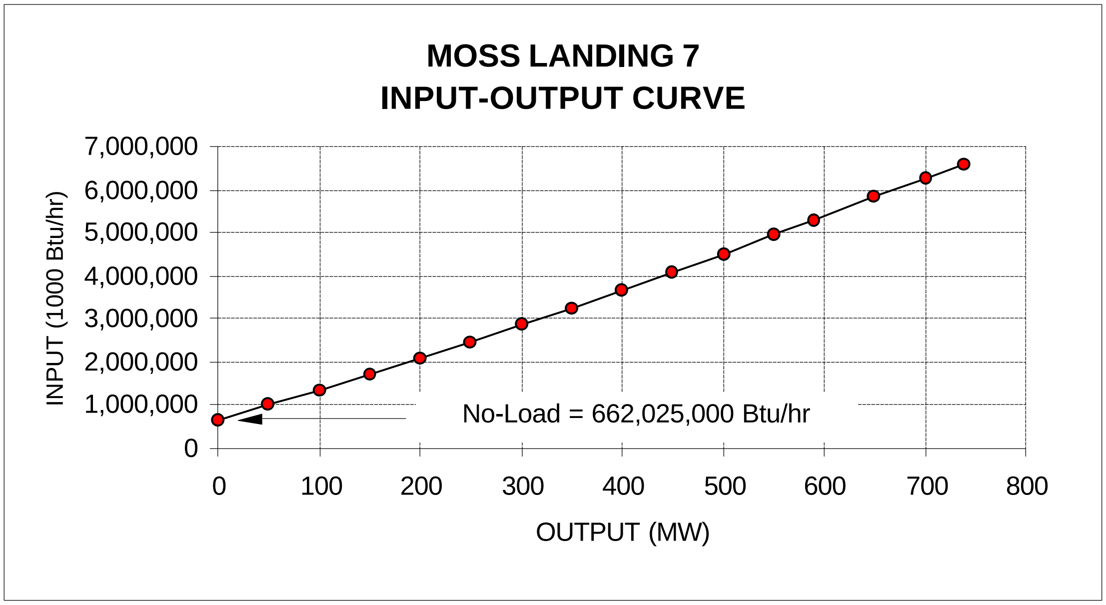


Figure 31 shows the No-Load Costs for Moss Landing 7 on an hourly basis. Figure 32 shows these same costs on $/MWh basis.

FIGURE 31

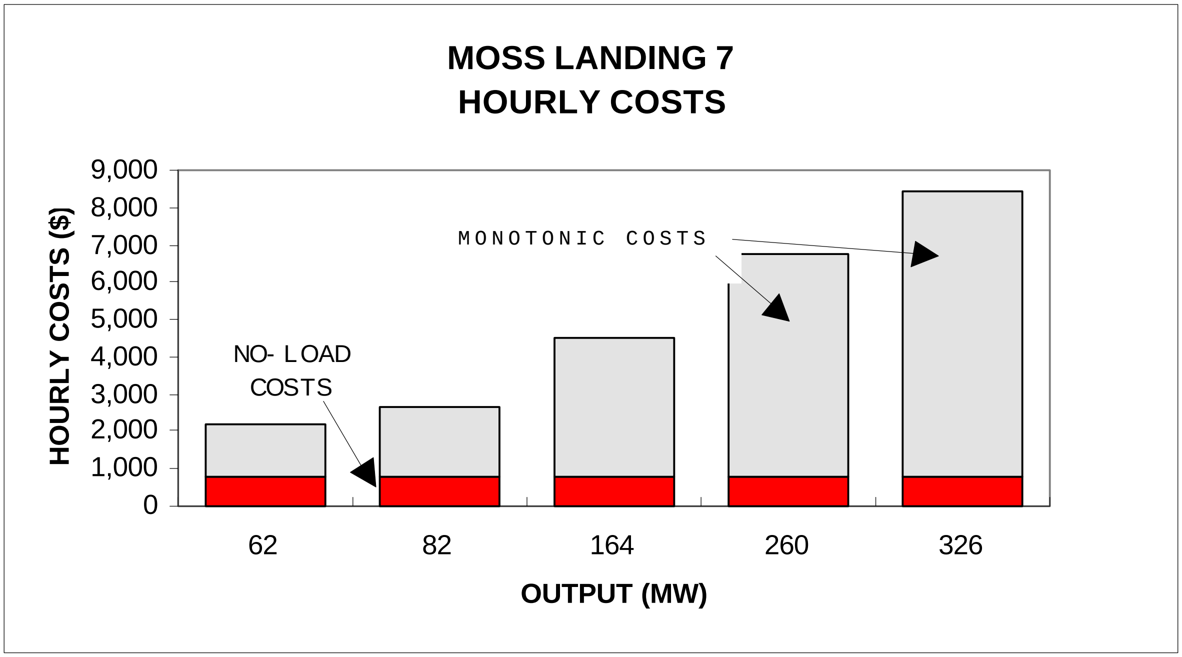
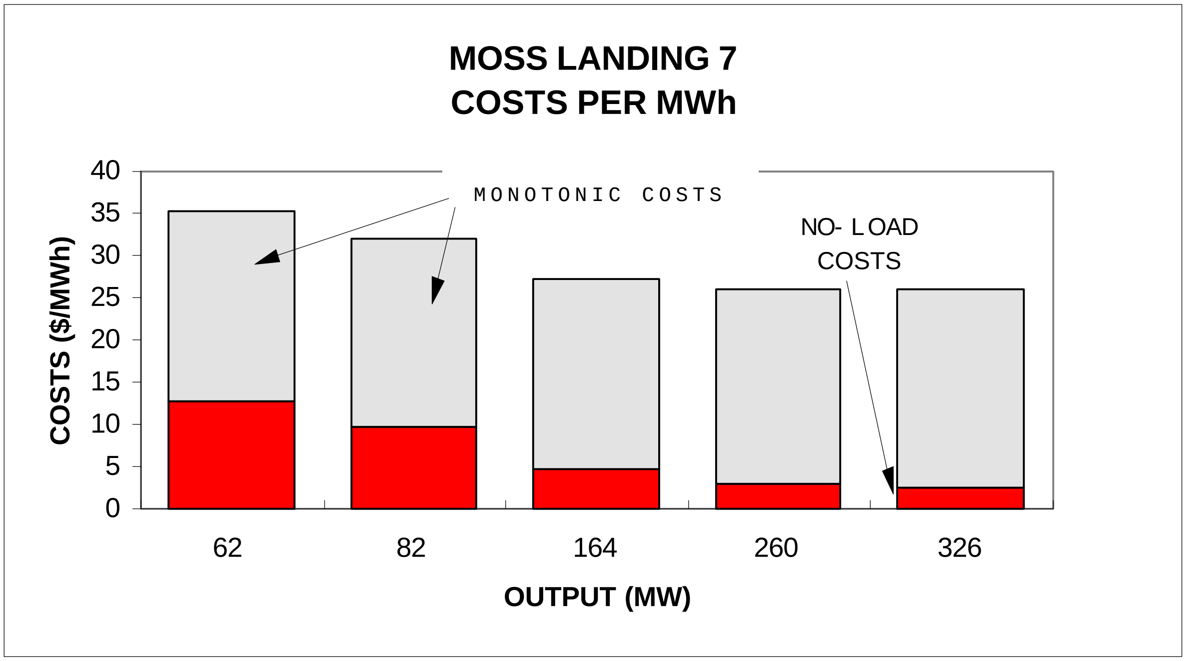


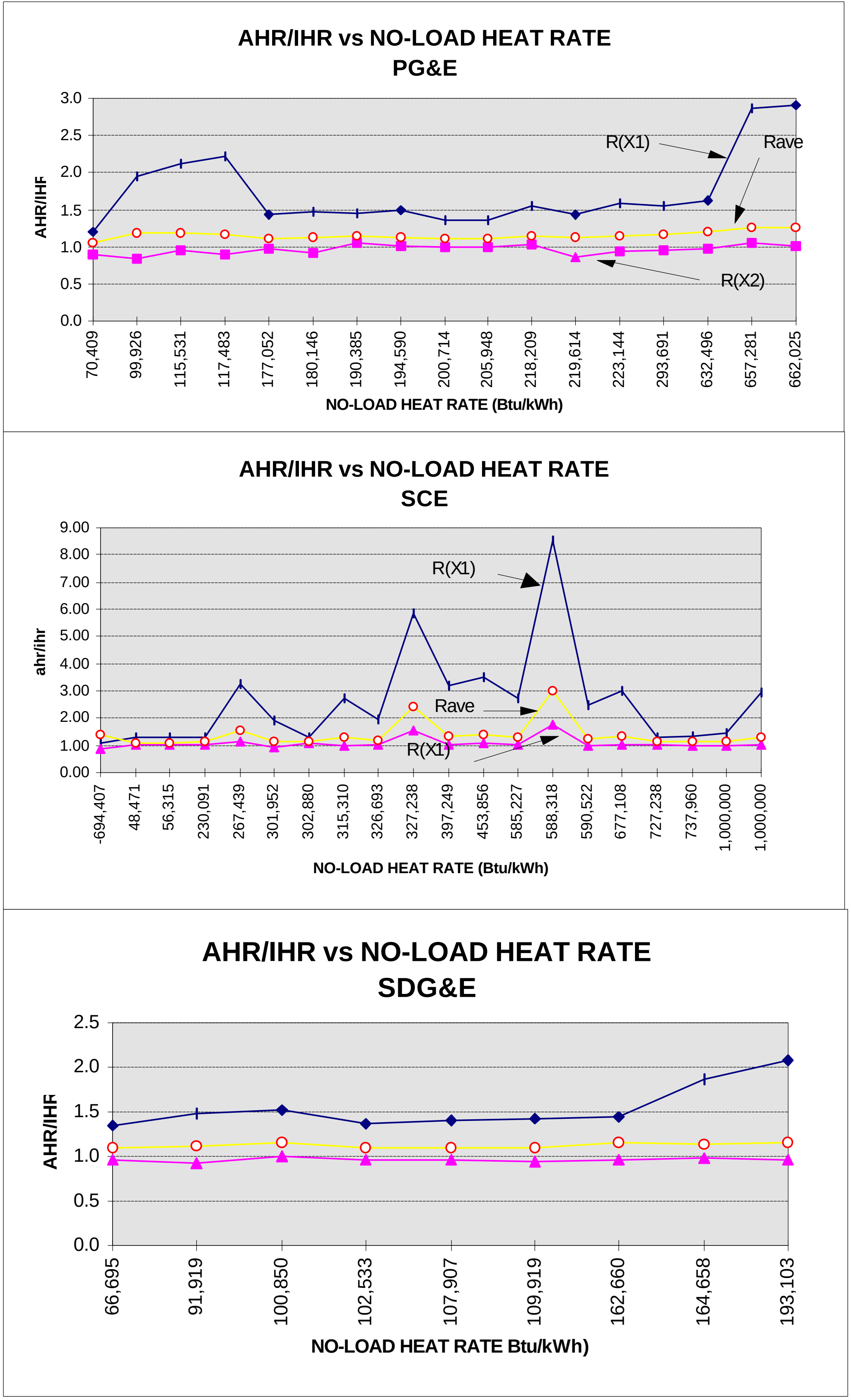
FIGURE 32



I have calculated and summarized the No-Load Heat Rates for all the IOU units, using the "***d***" coefficient of the heat rate equations as the No-Load Heat Rate. The supporting data is provided in Appendix D. Using this data, I made what I consider to be an important correlation. Figures 33A, B and C show ***AHR/IHR*** ratios as a function of these No-Load Heat Rates. I expected to find a very high correlation between the ***AHR/IHR*** ratios and No-Load Heat Rates, since they both reflect the difference between ***AHR*** and ***IHR***. But in fact, they do not seem to correlate at all.

This correlation is bad enough that I have to wonder about the viability of the proposed concept for market bidding. In Figures 33 the situation becomes ludicrous in that there is a negative value for No-Load Heat Rate. It is possible, however, that if the equations were completely reworked, going back to the original Input-Output field measurements, that much of the heat rate data would change and perhaps change the nature of the correlation so that the No-Load Heat Rates would make sense.

FIGURE 33A,B&C



APPENDICES A - E

FOR

THE USE OF HEAT RATES IN PRODUCTION COST MODELING AND MARKET MODELING

APPENDIX A
SUMMARY OF BLOCK HEAT RATE DATA

This appendix provides a summary of all the known heat rate data for the slow-start thermal units owned by the IOUs -- prior to divestiture. For those units that have been divested, they are still grouped by the IOU that formerly owned them but the new owner is noted. Each summary includes the Input-Output Curve, the (Average) Incremental Heat Rates and the Average Heat Rates, as well as the corresponding plots of that data.

The sources of this data is as follows:

- PG&E: ER 96 CFM Filing dated April 1996 except for Moss Landing 6 & 7 which are taken from 1994 CPUC Rate Case
- SCE: ER 94 CFM Filing dated June 1993
- SDG&E: April 28, 1997 FAX from Pat Harner of SDG&E

During the review of this data I noticed a number of anomalies. In some cases I changed the data in order to make it appear more reasonable. In the remainder of the cases, I elected to use the data as it was provided by the IOU but noted my concerns.

In attempting to use the ER 96 CFM heat rate data for PG&E, I noticed that there were four instances when some of a unit's heat rate blocks were changed from the previously used data (1994 Rate Case) but not others -- which is physically impossible. Figures A-1 through A-4 summarize these instances. Morro Bay 4 shows a revised Block 2 heat rate but none of its other heat rate blocks were revised. Moss Landing 6 shows only Blocks 1 and 2 being revised from ER 94 numbers. Moss Landing 7 shows Blocks 1, 2 and 5 being revised but not Blocks 3 and 4. Pittsburg 7 showed only Block 5 being revised. For Morro Bay 4 and Pittsburg 7, I elected to use the ER 96 CFM data as is because the effects on the heat rate characteristics appeared to be insignificant. For Moss Landing 6 and 7, I reverted to the 1994 Rate Case data as the ER 96 data was producing serious anomalies in the Instantaneous Incremental Heat Rate curves; Figure A-5 illustrates this for Moss Landing 7 -- the curve should not be turning down on the end. This decision was based on a conversation with Mark Meldgin of PG&E and Jim Hoffsis of the Northern California Unit.

FIGURE A-1

UNIT:	**MORRO BAY 4 - PG&E 1994 RATE CASE**					UNIT:	**MORRO BAY 4 - ER 96 CFM**				
			Input-Outp	Incrementa	Average				Input-Outp	Incrementa	Average
	OUTPUT		Curve	Heat Rate	Heat Rate		OUTPUT		Curve	Heat Rate	Heat Rate
	(%)	(MW)	(1000 Btu/hr	(Btu/kWh)	(Btu/kWh)		(%)	(MW)	(1000 Btu/hr	(Btu/kWh)	(Btu/kWh)
BLOCK 1	14%	46	590,364	12,834	12,834	BLOCK 1	14%	46	590,364	12,834	12,834
BLOCK 2	25%	85	930,495	8,721	10,947	BLOCK 2	25%	85	921,995	8,503	10,847
BLOCK 3	50%	169	1,672,931	8,839	9,899	BLOCK 3	50%	169	1,672,931	8,940	9,899
BLOCK 4	80%	270	2,591,190	9,092	9,597	BLOCK 4	80%	270	2,591,190	9,092	9,597
BLOCK 5	100%	338	3,224,520	9,314	9,540	BLOCK 5	100%	338	3,224,520	9,314	9,540

FIGURE A-2

UNIT: **MOSS LANDING 6 - PG&E 1994 RATE CASE**
Duke Energy Nov. 1997

	OUTPUT (%)	(MW)	Input-Outp Curve (1000 Btu/hr	Incrementa Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	7%	50	997,950	19,959	19,959
BLOCK 2	25%	185	1,985,975	7,319	10,735
BLOCK 3	50%	370	3,503,900	8,205	9,470
BLOCK 4	80%	591	5,409,423	8,622	9,153
BLOCK 5	100%	739	6,704,208	8,749	9,072

UNIT: **MOSS LANDING 6 - ER 96 CFM**
Duke Energy Nov. 1997

	OUTPUT (%)	(MW)	Input-Outp Curve (1000 Btu/hr	Incrementa Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	7%	50	990,900	19,818	19,818
BLOCK 2	25%	185	1,933,435	6,982	10,451
BLOCK 3	50%	370	3,503,900	8,489	9,470
BLOCK 4	80%	591	5,409,423	8,622	9,153
BLOCK 5	100%	739	6,704,208	8,749	9,072

FIGURE A-3

UNIT: **MOSS LANDING 7 - PG&E 1994 RATE CASE**
Duke Energy Nov. 1997

	OUTPUT (%)	(MW)	Input-Outp Curve (1000 Btu/hr	Incrementa Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	7%	50	997,950	19,959	19,959
BLOCK 2	25%	185	1,966,735	7,176	10,631
BLOCK 3	50%	370	3,429,160	7,905	9,268
BLOCK 4	80%	591	5,296,542	8,450	8,962
BLOCK 5	100%	739	6,589,663	8,737	8,917

UNIT: **MOSS LANDING 7 - ER 96 CFM**
Duke Energy Nov. 1997

	OUTPUT (%)	(MW)	Input-Outp Curve (1000 Btu/hr	Incrementa Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	7%	50	990,900	19,818	19,818
BLOCK 2	25%	185	1,924,185	6,913	10,401
BLOCK 3	50%	370	3,429,160	8,135	9,268
BLOCK 4	80%	591	5,296,542	8,450	8,962
BLOCK 5	100%	739	6,561,581	8,548	8,879

FIGURE A-4

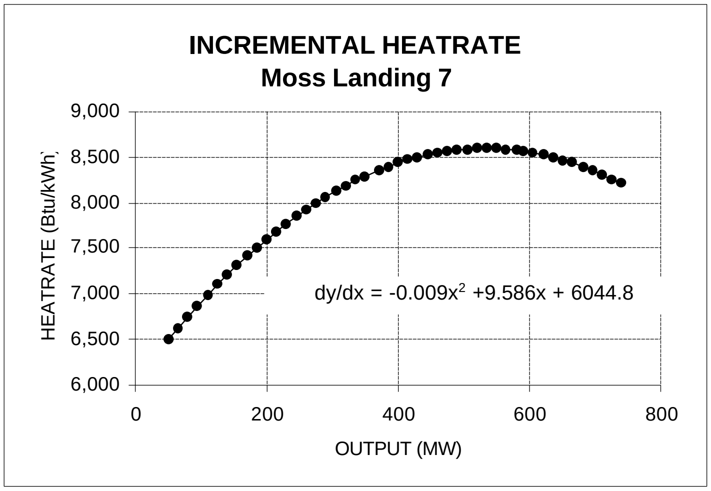
UNIT: **PITTSBURG 7 - PG&E 1994 RATE CASE**

	OUTPUT (%)	(MW)	Input-Outp Curve (1000 Btu/hr	Incrementa Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	17%	120	1,686,000	14,050	14,050
BLOCK 2	25%	180	2,194,020	8,467	12,189
BLOCK 3	50%	360	3,725,640	8,509	10,349
BLOCK 4	80%	576	5,615,424	8,749	9,749
BLOCK 5	100%	720	6,981,840	9,489	9,697

UNIT: **PITTSBURG 7 - ER 96 CFM**

	OUTPUT (%)	(MW)	Input-Outp Curve (1000 Btu/hr	Incrementa Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	17%	120	1,686,000	14,050	14,050
BLOCK 2	25%	180	2,194,020	8,467	12,189
BLOCK 3	50%	360	3,725,640	8,509	10,349
BLOCK 4	80%	576	5,615,424	8,749	9,749
BLOCK 5	100%	720	6,993,360	9,569	9,713

FIGURE A-5



The SCE data was taken from ER 94 CFM filings, as SCE did not file CFM data for ER 96. The only exception is the data for Cool Water 3&4, which I considered to be questionable. Figure A-6 shows the heat rate summary data for this unit as provided for ER 94 CFM filing. Note the irregular shape of the heat rate data, particularly the highly unlikely shape of the Incremental Heat Rate data.

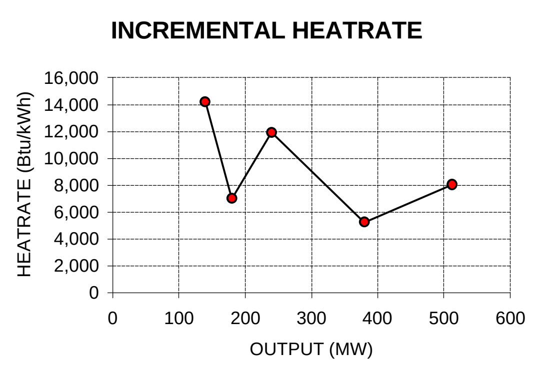
I felt that something was probably wrong with this data and took the liberty to changing it. Looking at the Input-Output data, it appears that Block 3 is an erroneous point. I fixed this data by ignoring this unlikely value, fitting an equation to the remaining 4 points of the Input-Output Curve and reconstructing the heat rate values as shown in Figure A-7.

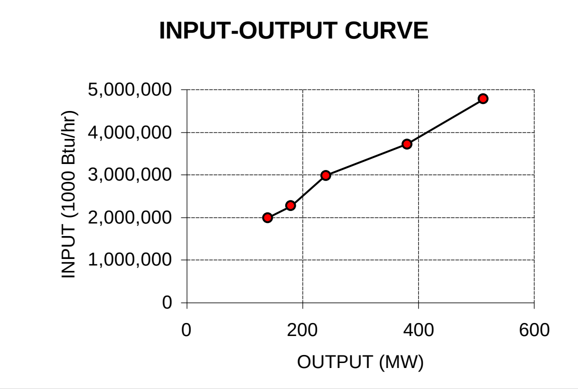
FIGURE A-6

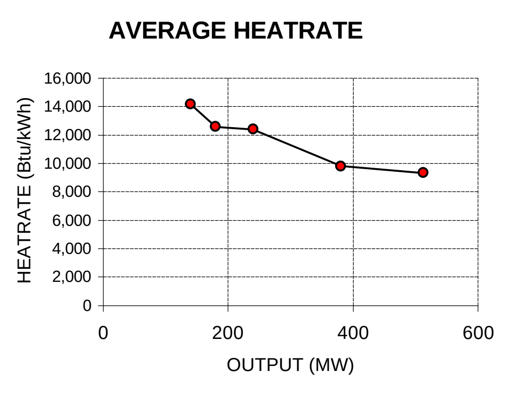
SUMMARY HEAT RATE DATA

UNIT: **COOL WATER 3&4**

	OUTPUT (%)	OUTPUT (MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	27%	140	1,983,800	14,170	14,170
BLOCK 2	35%	180	2,264,400	7,015	12,580
BLOCK 3	47%	240	2,980,560	11,936	12,419
BLOCK 4	74%	380	3,716,400	5,256	9,780
BLOCK 5	100%	512	4,776,960	8,035	9,330







My decision on this is arguable as a combined cycle unit is a combination of a steam unit and a CT. One would expect therefore some irregularity in the heat rate curves. Nevertheless, I have elected to stay with my proposed revision until the Cool Water 3 and 4 heat rate data can be verified.

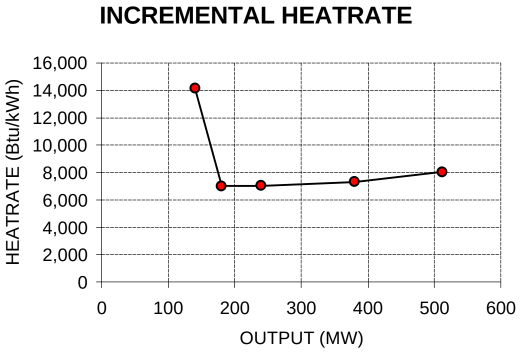
The SDG&E data was taken from a 4/28/97 FAX from Pat Harner. SDG&E did not file ER 96 CFM heat rate data and there ER 94 data appeared to be unreasonable in some cases.

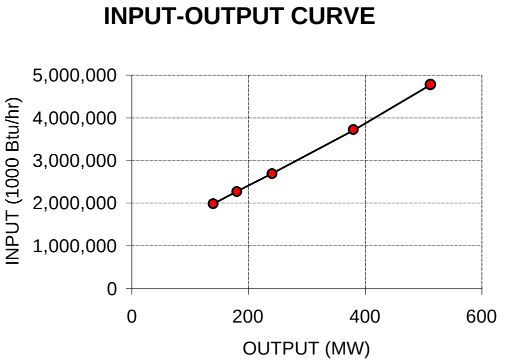
FIGURE A-7

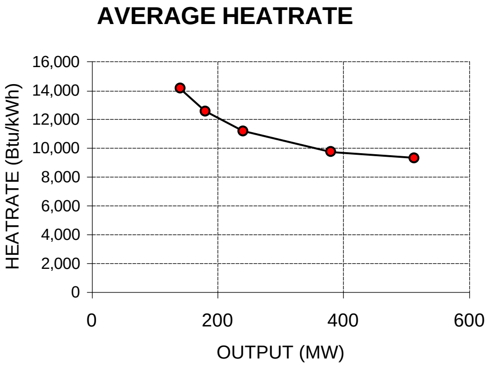
SUMMARY HEAT RATE DATA

UNIT: **COOL WATER 3&4**

	OUTPUT (%)	OUTPUT (MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	27%	140	1,983,721	14,169	14,169
BLOCK 2	35%	180	2,264,236	7,013	12,579
BLOCK 3	47%	240	2,688,080	7,064	11,200
BLOCK 4	74%	380	3,714,898	7,334	9,776
BLOCK 5	100%	512	4,773,296	8,018	9,323







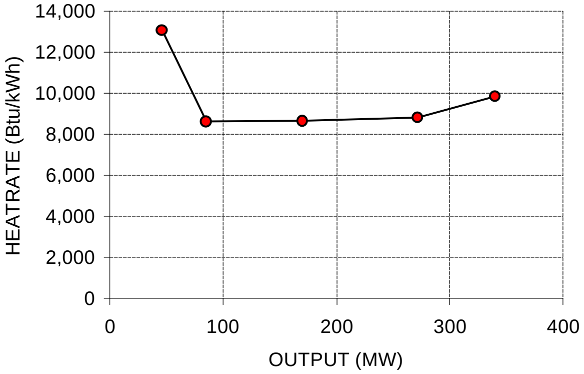
PG&E
SUMMARY HEAT RATE DATA
(SOURCE: ER 96 CFM FILING)

SUMMARY HEAT RATE DATA

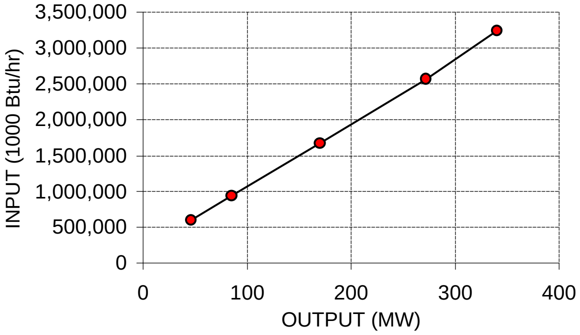
UNIT: **CONTRA COSTA 6**

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	14%	46	600,944	13,064	13,064
BLOCK 2	25%	85	936,870	8,613	11,022
BLOCK 3	50%	170	1,670,930	8,636	9,829
BLOCK 4	80%	272	2,570,944	8,824	9,452
BLOCK 5	100%	340	3,240,540	9,847	9,531

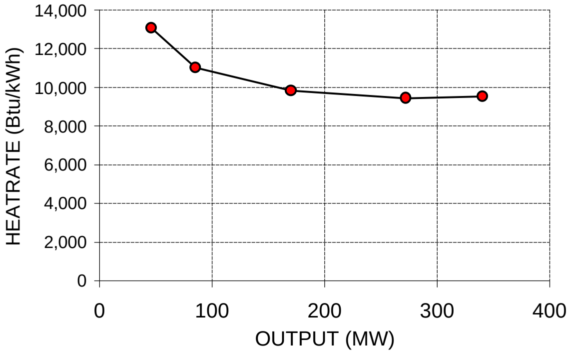
INCREMENTAL HEATRATE



INPUT-OUTPUT CURVE



AVERAGE HEATRATE

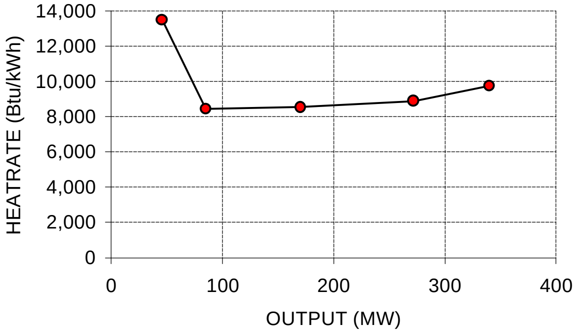


SUMMARY HEAT RATE DATA

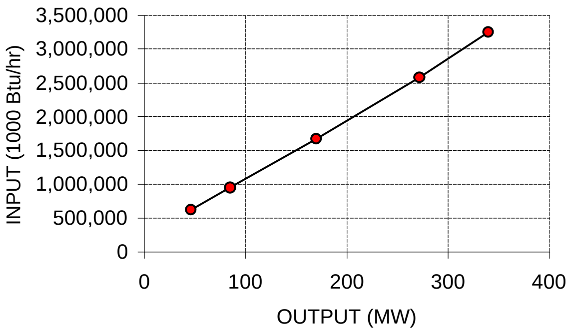
UNIT: **CONTRA COSTA 7**

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	14%	46	621,046	13,501	13,501
BLOCK 2	25%	85	950,045	8,436	11,177
BLOCK 3	50%	170	1,675,690	8,537	9,857
BLOCK 4	80%	272	2,584,544	8,910	9,502
BLOCK 5	100%	340	3,248,700	9,767	9,555

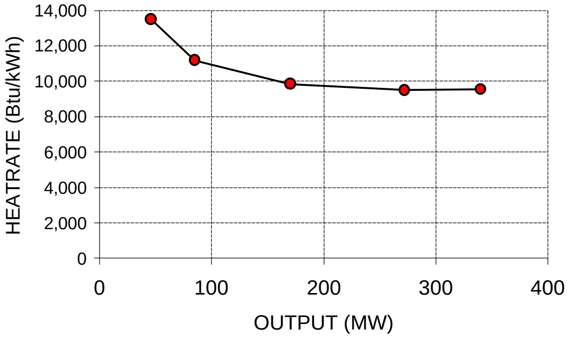
INCREMENTAL HEATRATE



INPUT-OUTPUT CURVE



AVERAGE HEATRATE

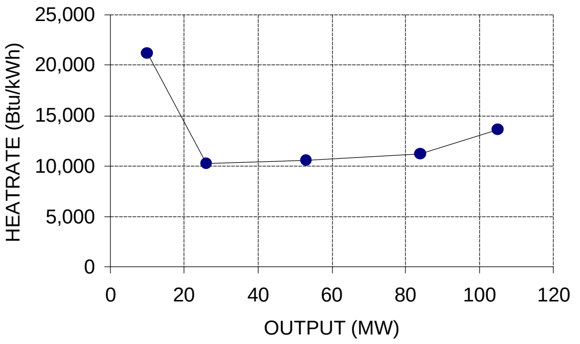


SUMMARY HEAT RATE DATA

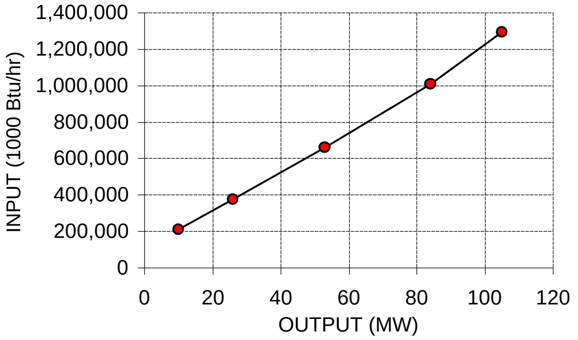
UNIT: **HUMBOLDT 1&2**

	OUTPUT (%)	OUTPUT (MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	10%	10	211,645	21,165	21,165
BLOCK 2	25%	26	376,350	10,294	14,475
BLOCK 3	50%	53	662,050	10,581	12,492
BLOCK 4	80%	84	1,010,184	11,230	12,026
BLOCK 5	100%	105	1,296,803	13,649	12,351

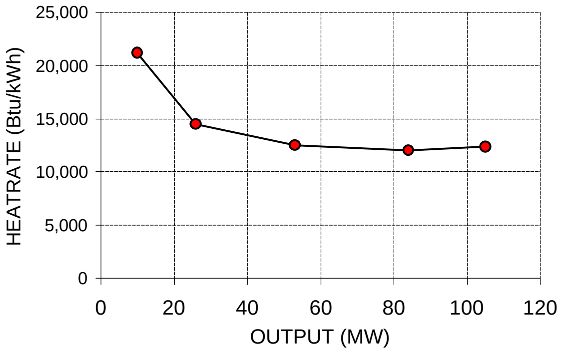
INCREMENTAL HEATRATE



INPUT-OUTPUT CURVE



AVERAGE HEATRATE

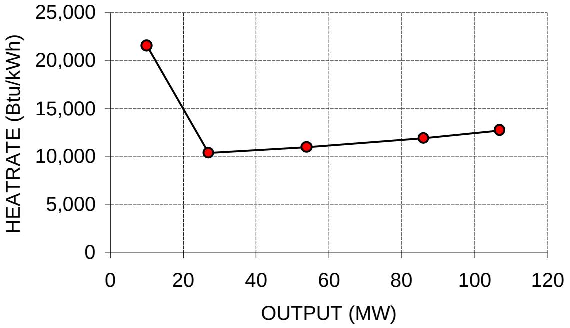


SUMMARY HEAT RATE DATA

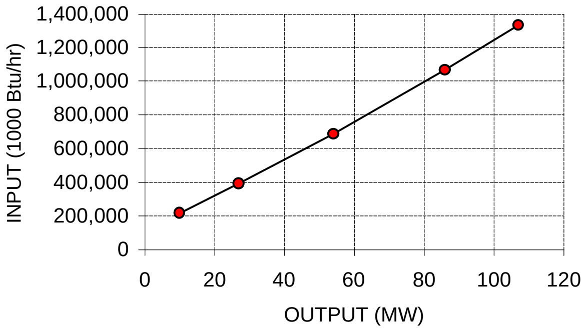
UNIT: **HUNTERS POINT 2**

	OUTPUT (%)	OUTPUT (MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	9%	10	215,510	21,551	21,551
BLOCK 2	25%	27	391,824	10,371	14,512
BLOCK 3	50%	54	688,122	10,974	12,743
BLOCK 4	80%	86	1,067,862	11,867	12,417
BLOCK 5	100%	107	1,334,504	12,697	12,472

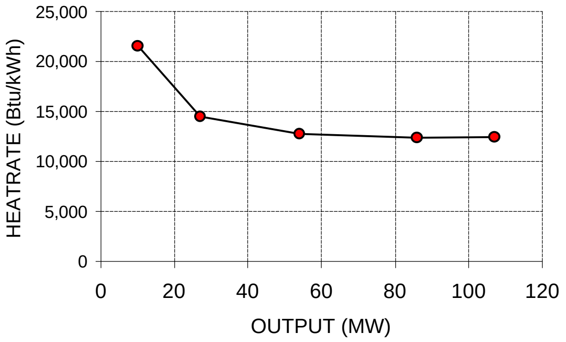
INCREMENTAL HEATRATE



INPUT-OUTPUT CURVE



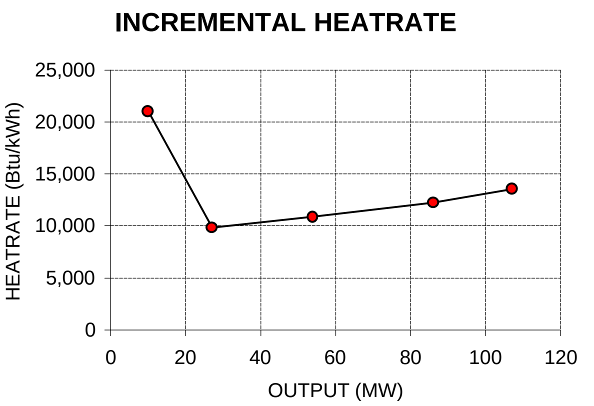
AVERAGE HEATRATE

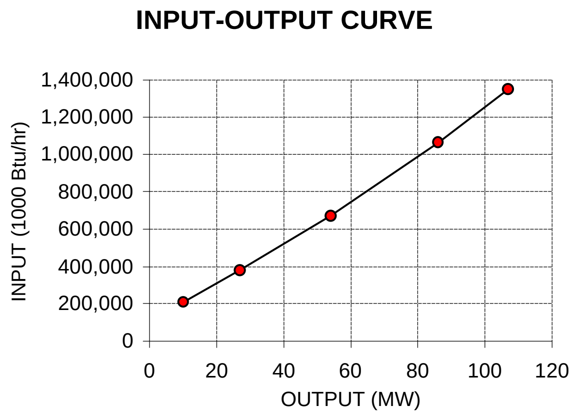


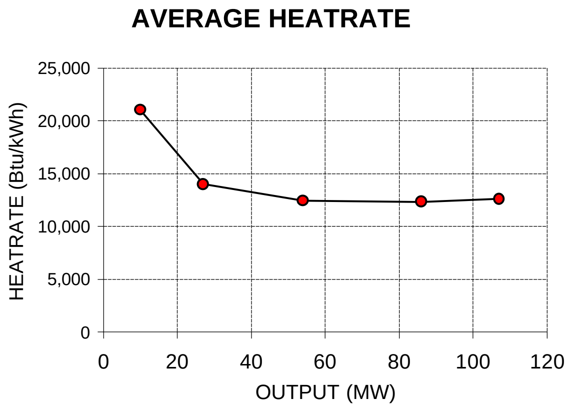
SUMMARY HEAT RATE DATA

UNIT: **HUNTERS POINT 3**

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	9%	10	210,370	21,037	21,037
BLOCK 2	25%	27	378,378	9,883	14,014
BLOCK 3	50%	54	671,436	10,854	12,434
BLOCK 4	80%	86	1,063,476	12,251	12,366
BLOCK 5	100%	107	1,347,986	13,548	12,598



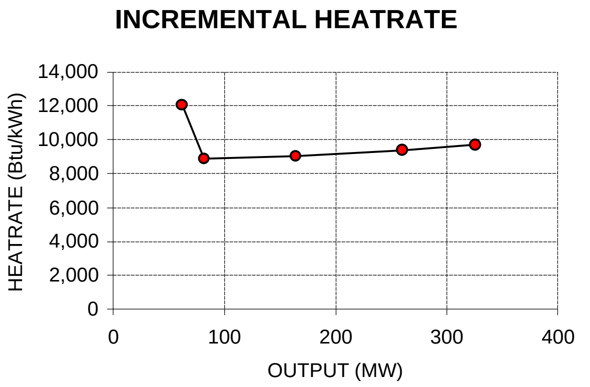


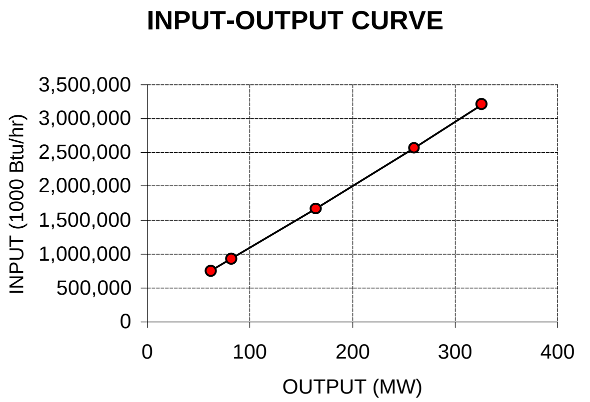


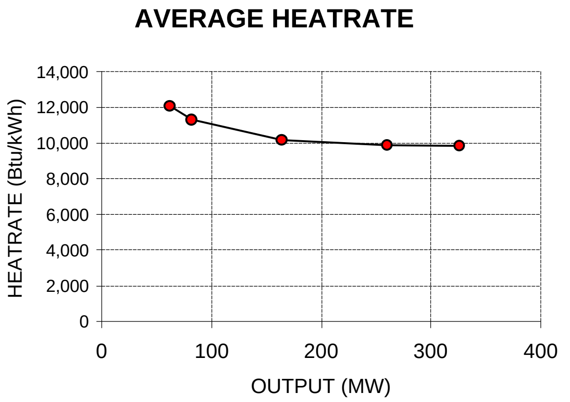
SUMMARY HEAT RATE DATA

UNIT: **HUNTERS POINT 4**

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	19%	62	748,092	12,066	12,066
BLOCK 2	25%	82	926,108	8,901	11,294
BLOCK 3	50%	164	1,667,060	9,036	10,165
BLOCK 4	80%	260	2,567,240	9,377	9,874
BLOCK 5	100%	326	3,208,166	9,711	9,841





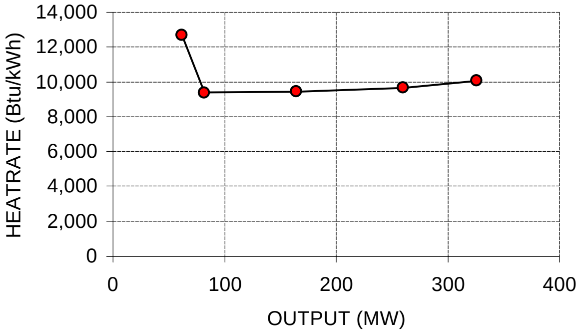


SUMMARY HEAT RATE DATA

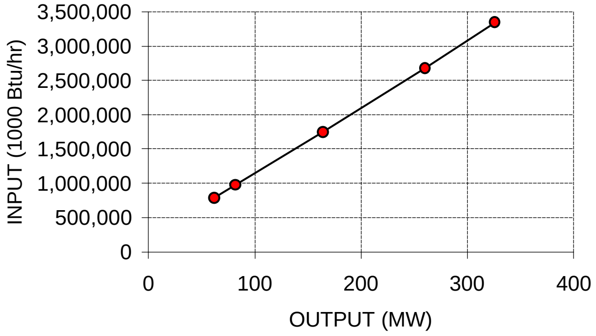
UNIT: **MORRO BAY 1&2**

	OUTPUT (%)	OUTPUT (MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	19%	62	786,408	12,684	12,684
BLOCK 2	25%	82	974,201	9,390	11,881
BLOCK 3	50%	164	1,748,568	9,444	10,662
BLOCK 4	80%	260	2,676,700	9,668	10,295
BLOCK 5	100%	326	3,341,500	10,073	10,250

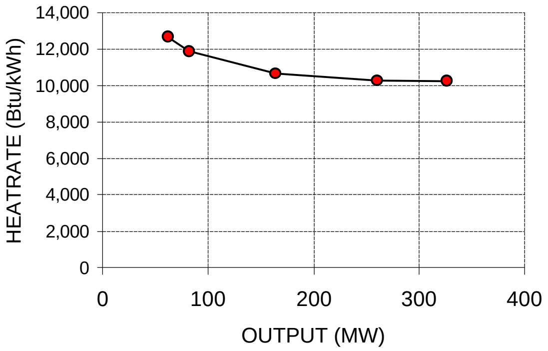
INCREMENTAL HEATRATE



INPUT-OUTPUT CURVE



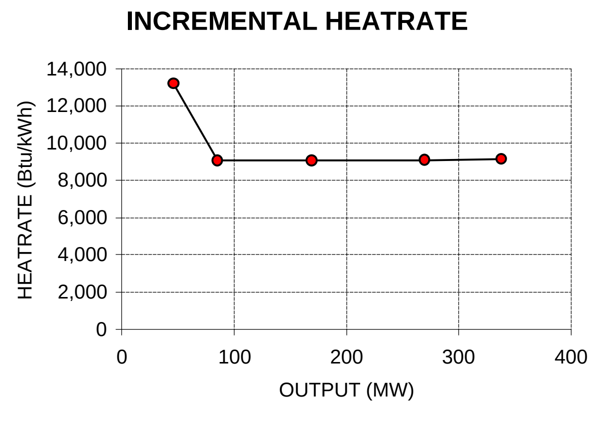
AVERAGE HEATRATE

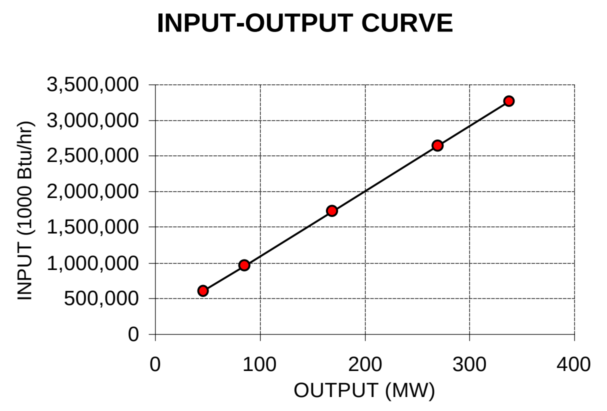


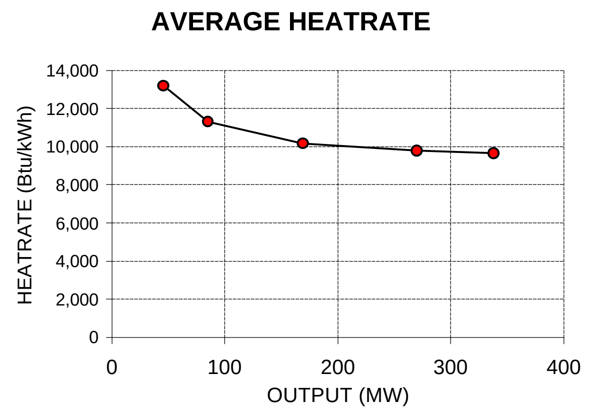
SUMMARY HEAT RATE DATA

UNIT: **MORRO BAY 3**

	OUTPUT		Input-Output Curve	Incremental Heat Rate	Average Heat Rate
	(%)	(MW)	(1000 Btu/hr)	(Btu/kWh)	(Btu/kWh)
BLOCK 1	14%	46	606,924	13,194	13,194
BLOCK 2	25%	85	960,670	9,070	11,302
BLOCK 3	50%	169	1,721,096	9,053	10,184
BLOCK 4	80%	270	2,640,060	9,099	9,778
BLOCK 5	100%	338	3,261,700	9,142	9,650



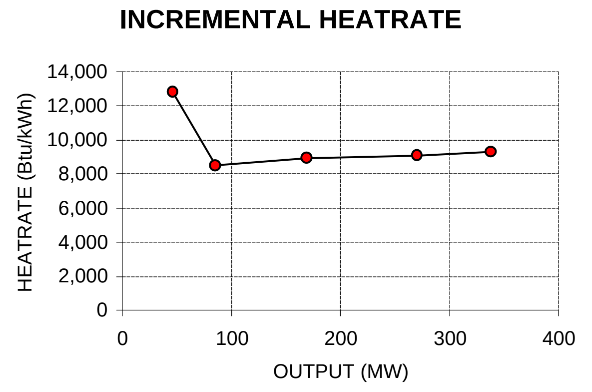


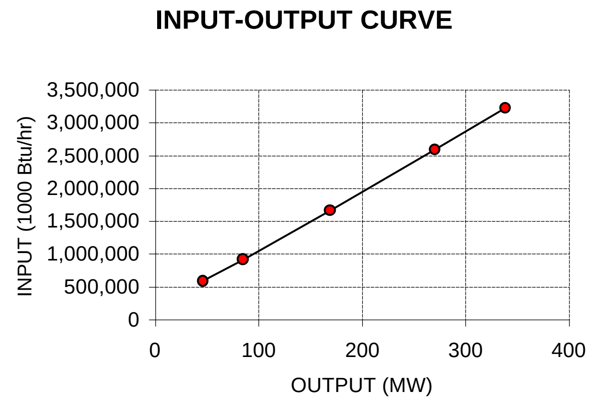


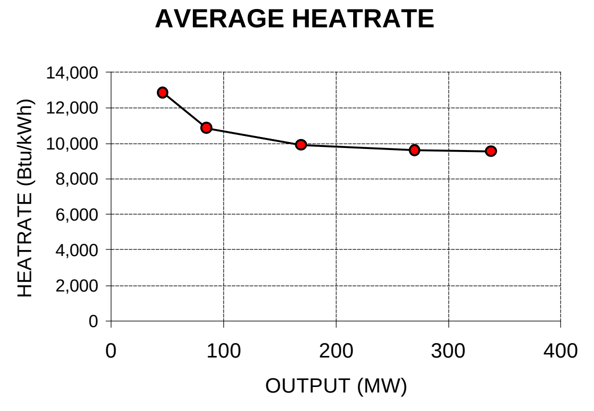
SUMMARY HEAT RATE DATA

UNIT: **MORRO BAY 4**

	OUTPUT		Input-Output Curve	Incremental Heat Rate	Average Heat Rate
	(%)	(MW)	(1000 Btu/hr)	(Btu/kWh)	(Btu/kWh)
BLOCK 1	14%	46	590,364	12,834	12,834
BLOCK 2	25%	85	921,995	8,503	10,847
BLOCK 3	50%	169	1,672,931	8,940	9,899
BLOCK 4	80%	270	2,591,190	9,092	9,597
BLOCK 5	100%	338	3,224,520	9,314	9,540



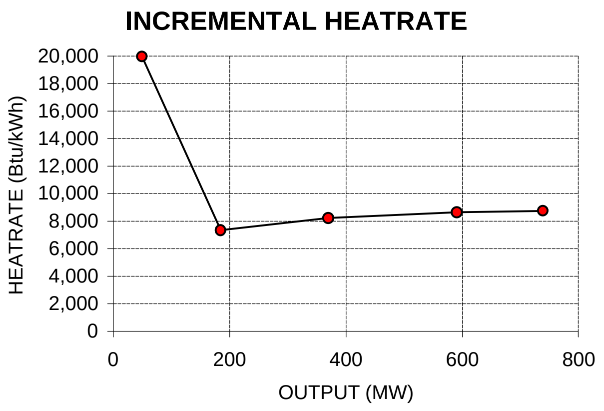


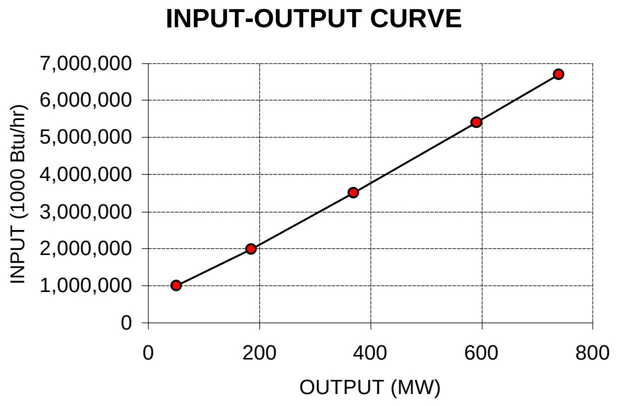


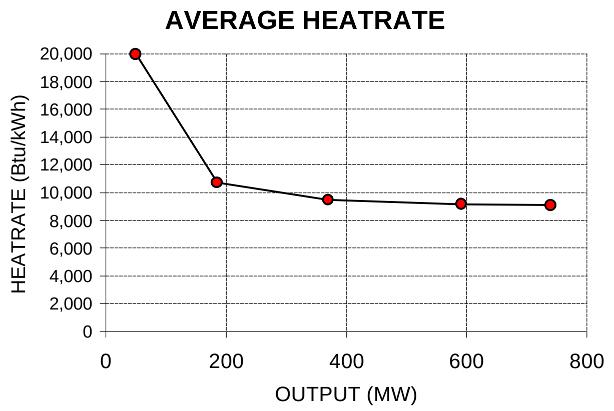
SUMMARY HEAT RATE DATA

UNIT: **MOSS LANDING 6**
Duke Energy Nov. 1997

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	7%	50	997,950	19,959	19,959
BLOCK 2	25%	185	1,985,975	7,319	10,735
BLOCK 3	50%	370	3,503,900	8,205	9,470
BLOCK 4	80%	591	5,409,423	8,622	9,153
BLOCK 5	100%	739	6,704,208	8,749	9,072



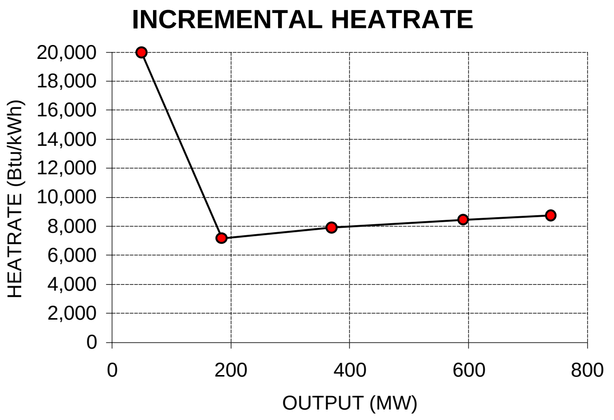


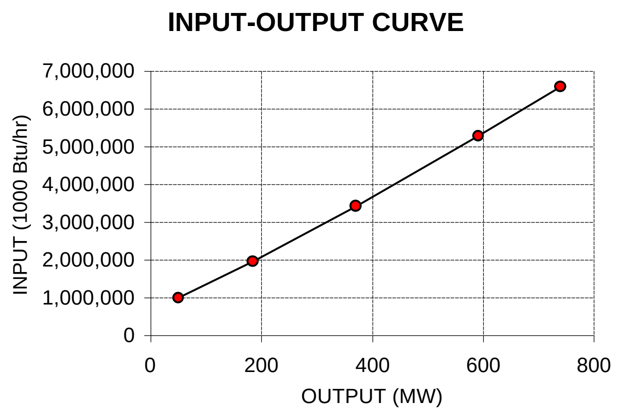


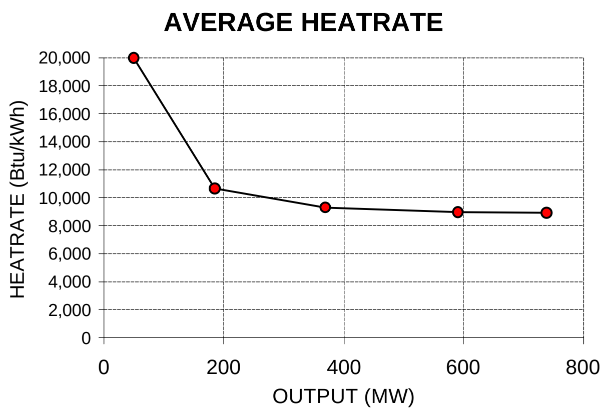
SUMMARY OF HEAT RATE DATA

UNIT: **MOSS LANDING 7**
Duke Energy Nov. 1997

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	7%	50	997,950	19,959	19,959
BLOCK 2	25%	185	1,966,735	7,176	10,631
BLOCK 3	50%	370	3,429,160	7,905	9,268
BLOCK 4	80%	591	5,296,542	8,450	8,962
BLOCK 5	100%	739	6,589,663	8,737	8,917



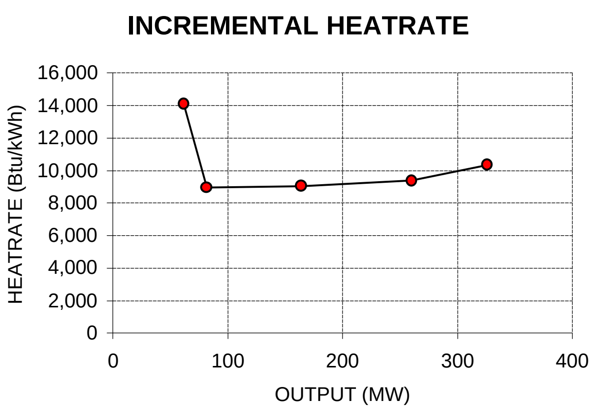


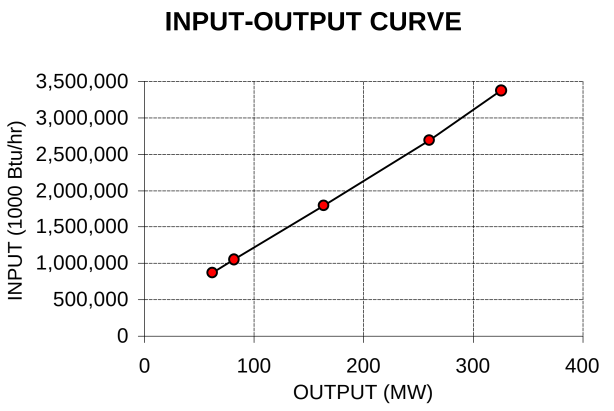


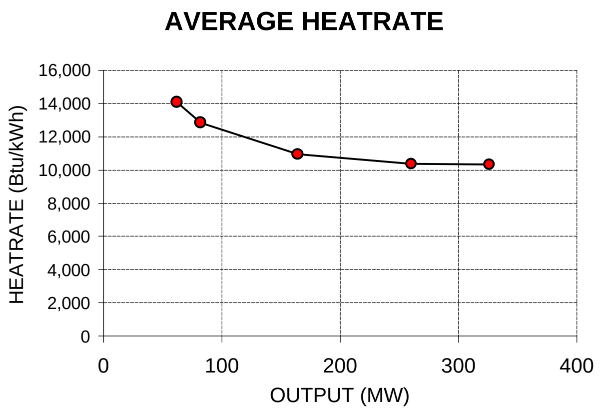
SUMMARY HEAT RATE DATA

UNIT: **PITTSBURG 1&2**

	OUTPUT (%)	OUTPUT (MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	19%	62	873,642	14,091	14,091
BLOCK 2	25%	82	1,052,798	8,958	12,839
BLOCK 3	50%	164	1,793,094	9,028	10,934
BLOCK 4	80%	260	2,692,950	9,374	10,358
BLOCK 5	100%	326	3,374,752	10,330	10,352


INCREMENTAL HEATRATE

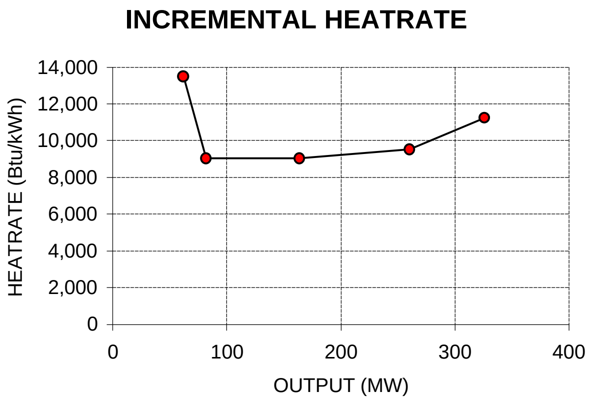

INPUT-OUTPUT CURVE


AVERAGE HEATRATE

SUMMARY HEAT RATE DATA

UNIT: **PITTSBURG 3&4**

	OUTPUT (%)	OUTPUT (MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	19%	62	836,256	13,488	13,488
BLOCK 2	25%	82	1,017,005	9,037	12,403
BLOCK 3	50%	164	1,757,998	9,037	10,720
BLOCK 4	80%	260	2,670,200	9,502	10,270
BLOCK 5	100%	326	3,411,264	11,228	10,464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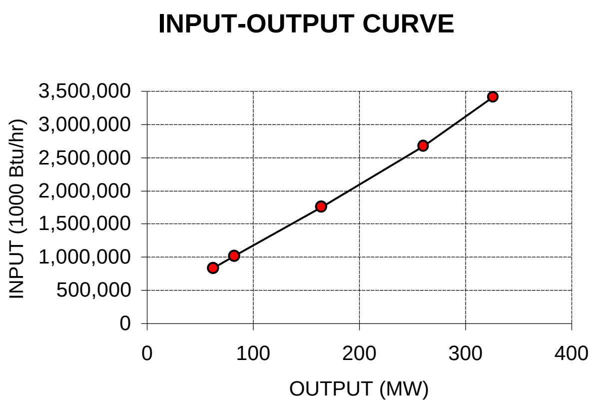
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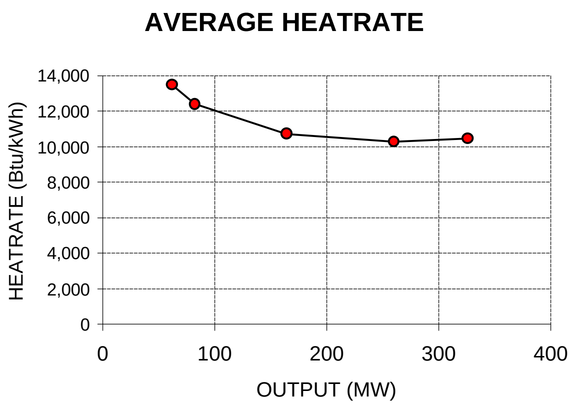
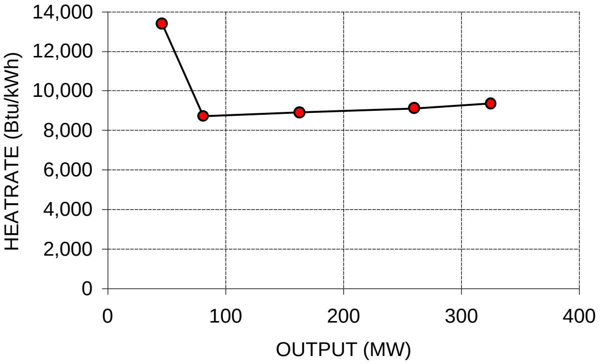

AVERAGE HEATRATE

SUMMARY HEAT RATE DATA

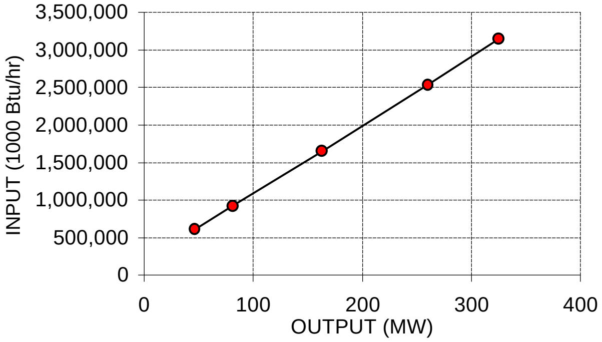
UNIT: **PITTSBURG 5**

	OUTPUT (%)	OUTPUT (MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	14%	46	615,664	13,384	13,384
BLOCK 2	25%	81	920,970	8,723	11,370
BLOCK 3	50%	163	1,651,679	8,911	10,133
BLOCK 4	80%	260	2,537,080	9,128	9,758
BLOCK 5	100%	325	3,144,700	9,348	9,676

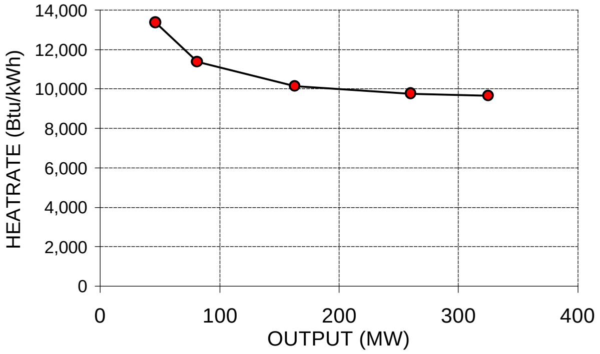
INCREMENTAL HEATRATE



INPUT-OUTPUT CURVE



AVERAGE HEATRATE

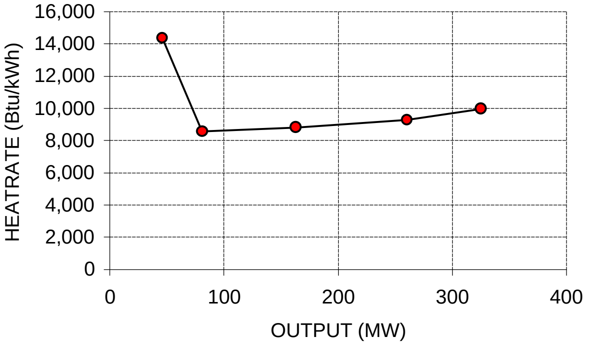


SUMMARY HEAT RATE DATA

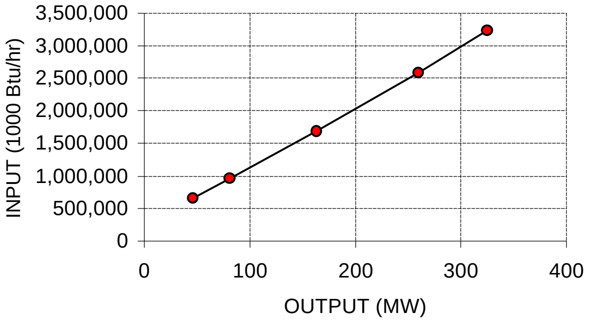
UNIT: **PITTSBURG 6**

	OUTPUT (%)	OUTPUT (MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	14%	46	660,284	14,354	14,354
BLOCK 2	25%	81	960,174	8,568	11,854
BLOCK 3	50%	163	1,683,464	8,821	10,328
BLOCK 4	80%	260	2,583,620	9,280	9,937
BLOCK 5	100%	325	3,232,125	9,977	9,945

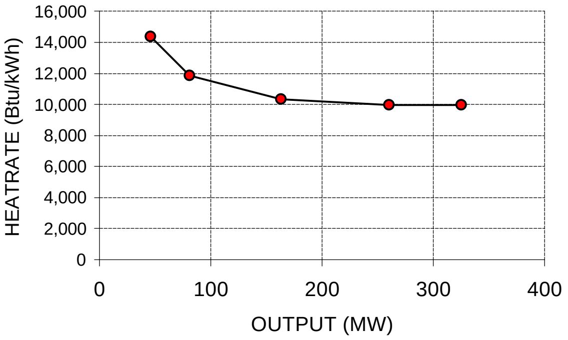
INCREMENTAL HEATRATE



INPUT-OUTPUT CURVE



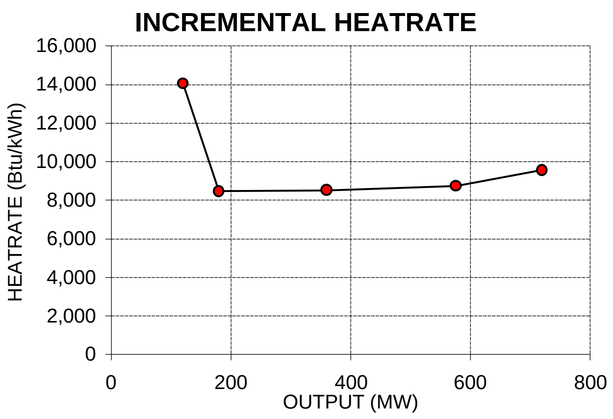
AVERAGE HEATRATE

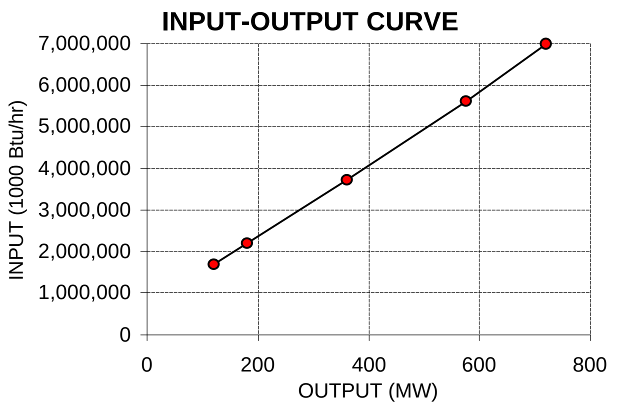


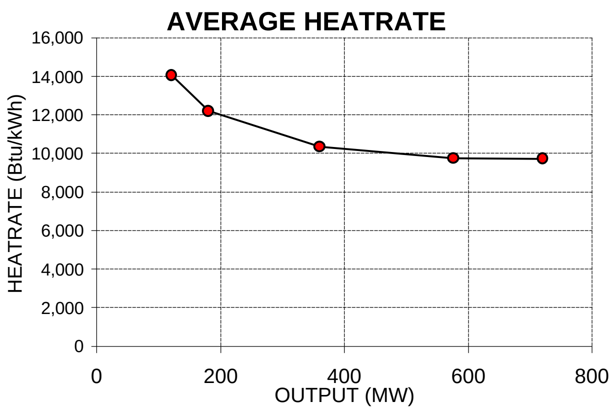
SUMMARY HEAT RATE DATA

UNIT: **PITTSBURG 7**

	OUTPUT		Input-Output Curve	Incremental Heat Rate	Average Heat Rate
	(%)	(MW)	(1000 Btu/hr)	(Btu/kWh)	(Btu/kWh)
BLOCK 1	17%	120	1,686,000	14,050	14,050
BLOCK 2	25%	180	2,194,020	8,467	12,189
BLOCK 3	50%	360	3,725,640	8,509	10,349
BLOCK 4	80%	576	5,615,424	8,749	9,749
BLOCK 5	100%	720	6,993,360	9,569	9,713


INCREMENTAL HEATRATE

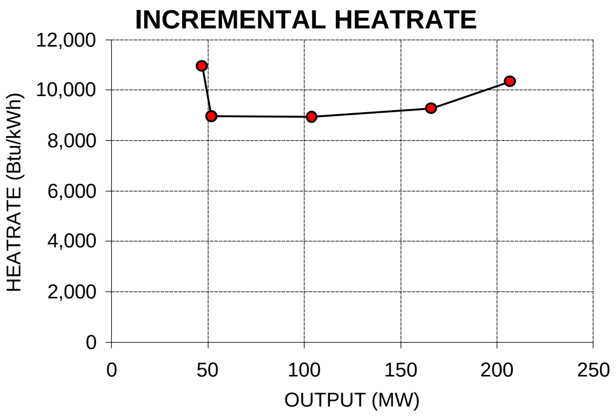

INPUT-OUTPUT CURVE


AVERAGE HEATRATE

SUMMARY HEAT RATE DATA

UNIT: **POTRERO 3**

	OUTPUT		Input-Output Curve	Incremental Heat Rate	Average Heat Rate
	(%)	(MW)	(1000 Btu/hr)	(Btu/kWh)	(Btu/kWh)
BLOCK 1	23%	47	514,697	10,951	10,951
BLOCK 2	25%	52	559,520	8,965	10,760
BLOCK 3	50%	104	1,023,880	8,930	9,845
BLOCK 4	80%	166	1,598,746	9,272	9,631
BLOCK 5	100%	207	2,022,597	10,338	9,771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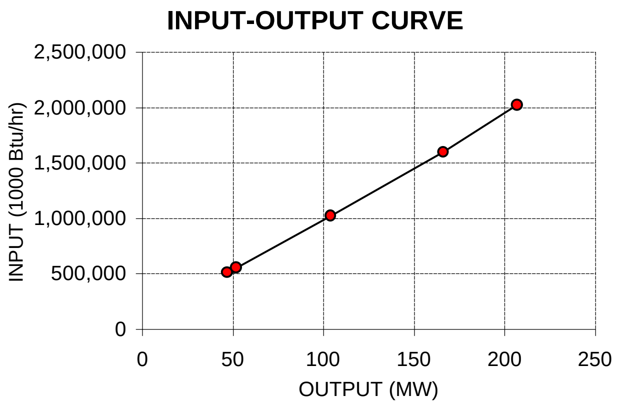
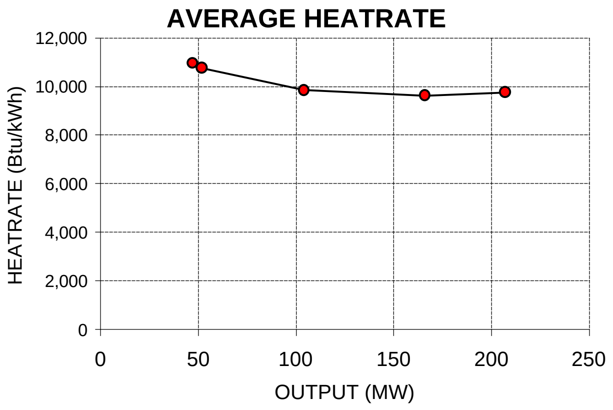

INPUT-OUTPUT CURVE

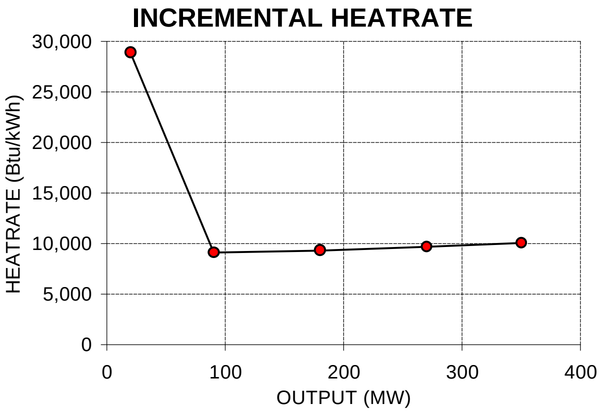

AVERAGE HEATRATE

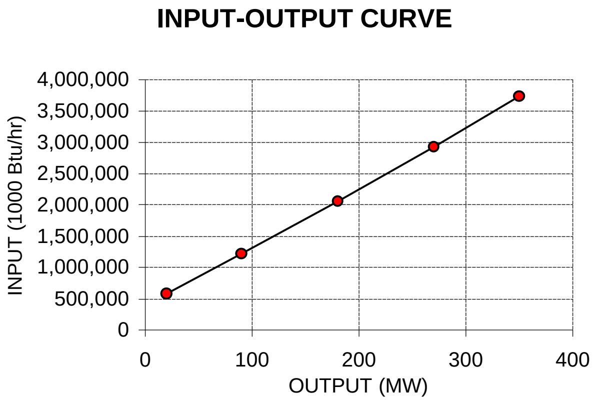
SCE
SUMMARY HEAT RATE DATA
(SOURCE: ER 94 CFM FILING)

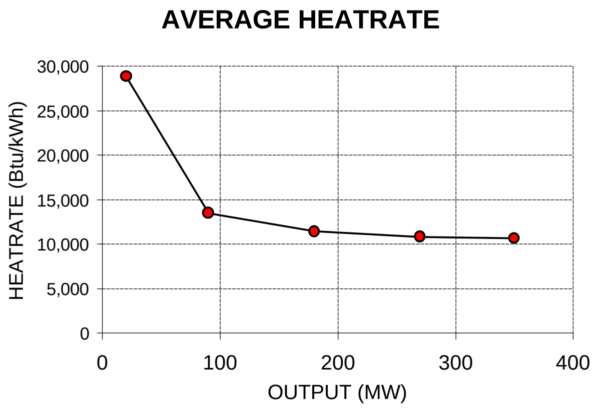
SUMMARY HEAT RATE DATA

UNIT: **ALAMITOS 1&2**

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	6%	20	577,980	28,899	28,899
BLOCK 2	26%	90	1,216,755	9,125	13,520
BLOCK 3	51%	180	2,057,760	9,345	11,432
BLOCK 4	77%	270	2,927,610	9,665	10,843
BLOCK 5	100%	350	3,732,050	10,056	10,663



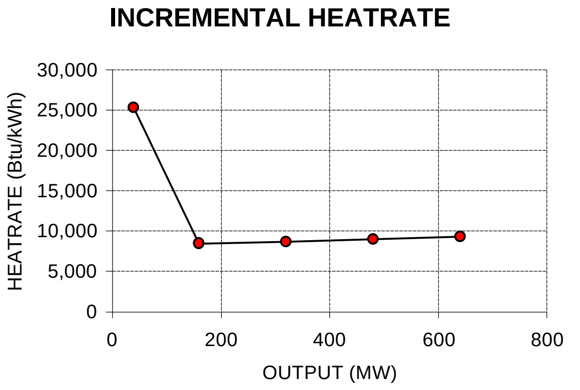


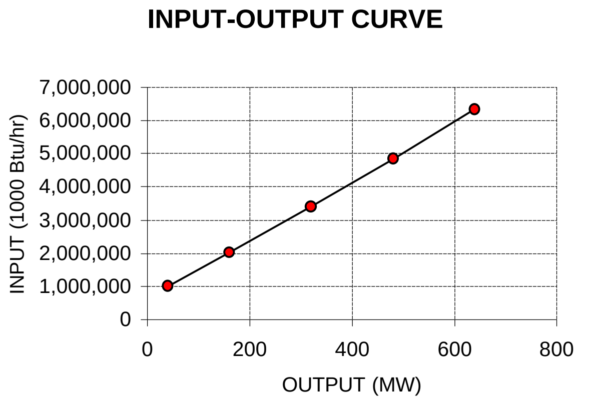


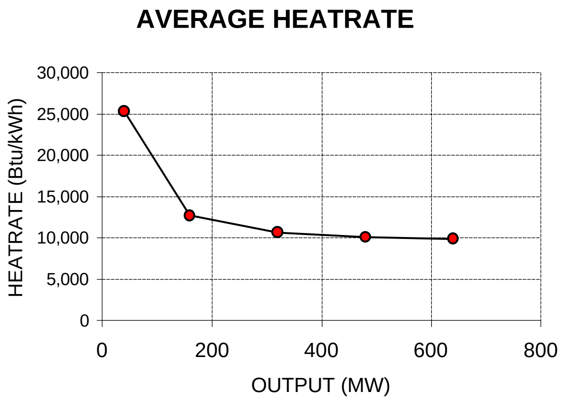
SUMMARY HEAT RATE DATA

UNIT: **ALAMITOS 3&4**

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	6%	40	1,011,300	25,283	25,283
BLOCK 2	25%	160	2,024,880	8,447	12,656
BLOCK 3	50%	320	3,407,680	8,643	10,649
BLOCK 4	75%	480	4,840,320	8,954	10,084
BLOCK 5	100%	640	6,334,400	9,338	9,898



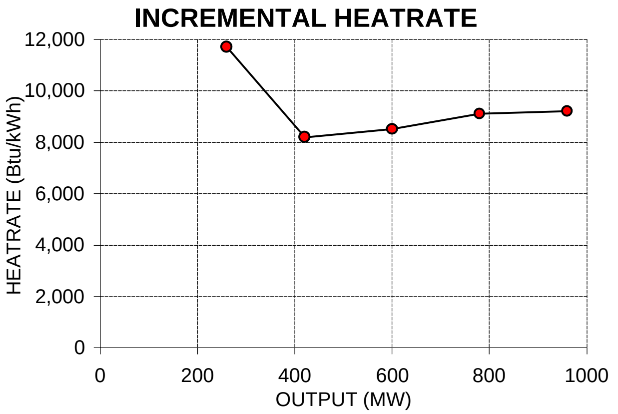


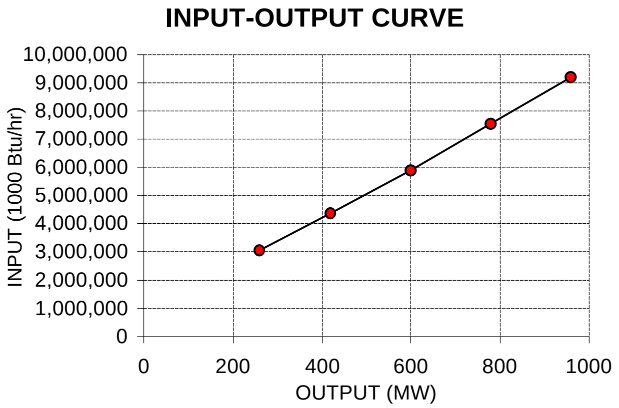


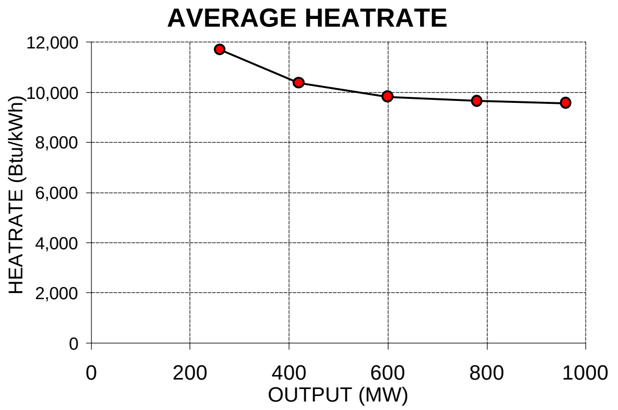
SUMMARY HEAT RATE DATA

UNIT: **ALAMITOS 5&6**
AES 1/1/98

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	27%	260	3,045,380	11,713	11,713
BLOCK 2	44%	420	4,357,920	8,203	10,376
BLOCK 3	63%	600	5,890,500	8,514	9,818
BLOCK 4	81%	780	7,530,900	9,113	9,655
BLOCK 5	100%	960	9,191,040	9,223	9,574



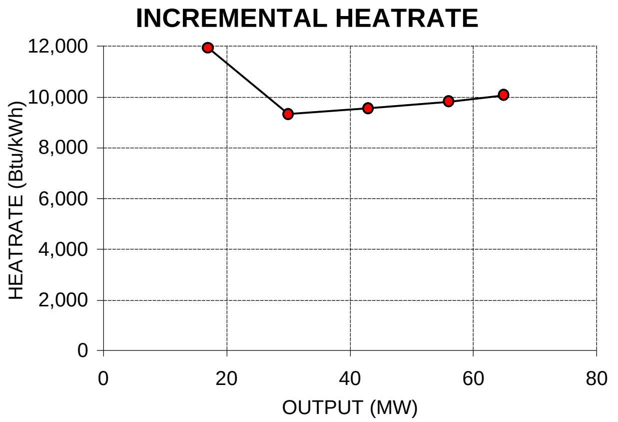


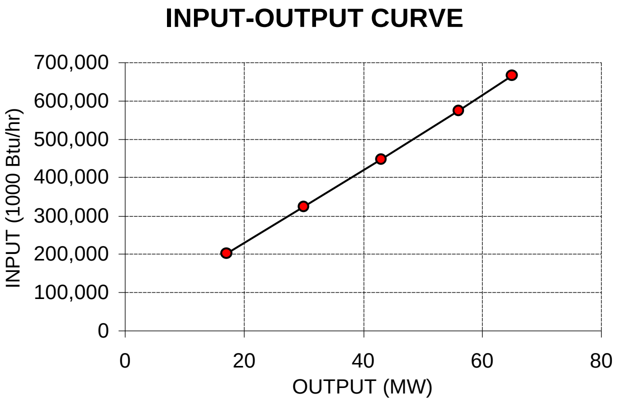


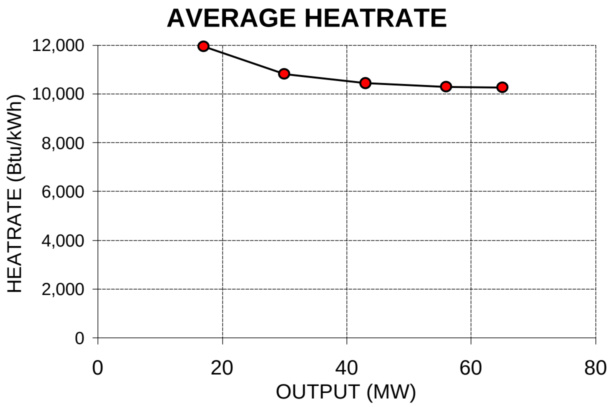
SUMMARY HEAT RATE DATA

UNIT: **COOL WATER 1**
Houston Industries Inc. 1/1/98

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	26%	17	203,048	11,944	11,944
BLOCK 2	46%	30	324,240	9,322	10,808
BLOCK 3	66%	43	448,318	9,544	10,426
BLOCK 4	86%	56	575,904	9,814	10,284
BLOCK 5	100%	65	666,575	10,075	10,255



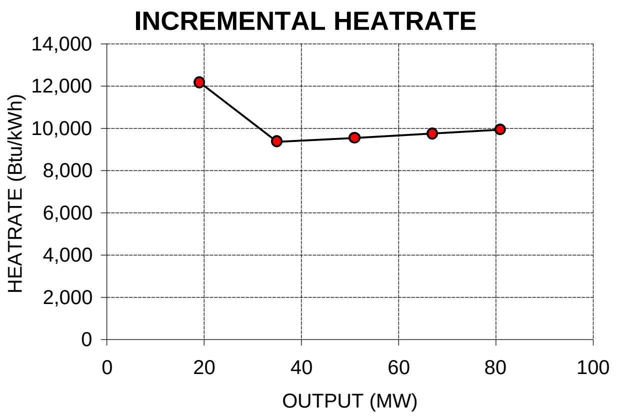


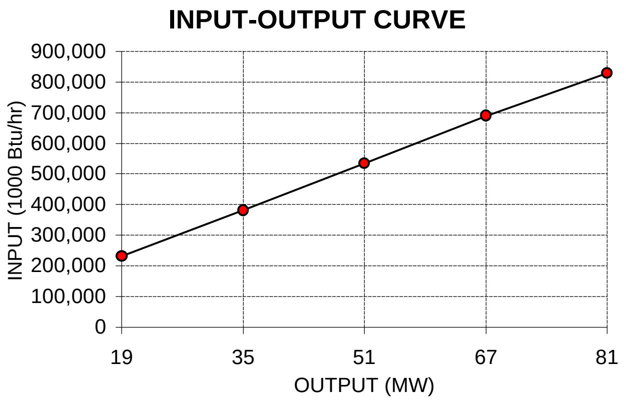


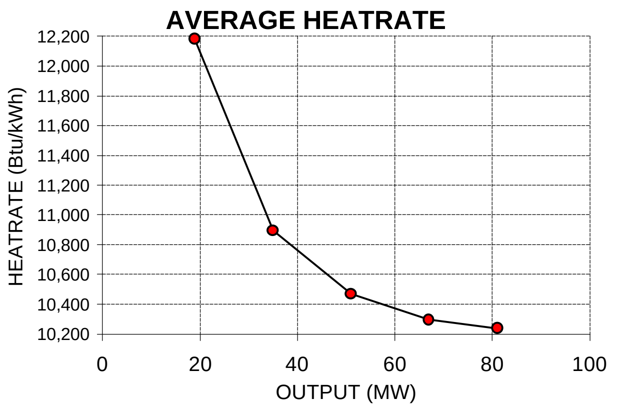
SUMMARY HEAT RATE DATA

UNIT: **COOL WATER 2**
Houston Industries Inc. 1/1/98

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	23%	19	231,439	12,181	12,181
BLOCK 2	43%	35	381,325	9,368	10,895
BLOCK 3	63%	51	533,970	9,540	10,470
BLOCK 4	83%	67	689,832	9,741	10,296
BLOCK 5	100%	81	829,278	9,960	10,238



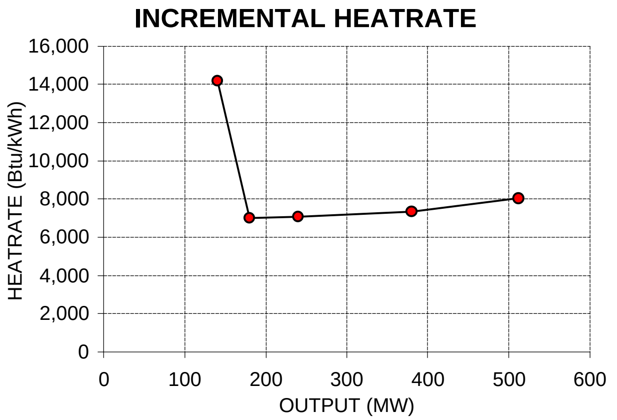


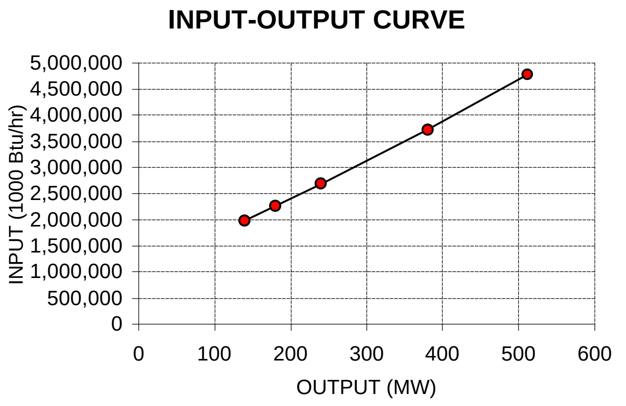


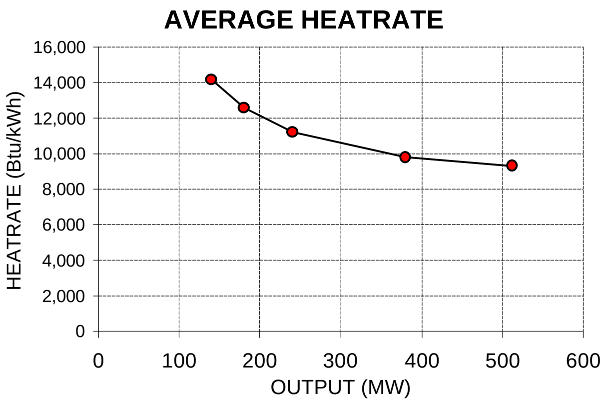
SUMMARY HEAT RATE DATA

UNIT: **COOL WATER 3&4**
Houston Industries Inc. 1/1/98

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	27%	140	1,983,660	14,169	14,169
BLOCK 2	35%	180	2,264,220	7,014	12,579
BLOCK 3	47%	240	2,688,000	7,063	11,200
BLOCK 4	74%	380	3,714,880	7,335	9,776
BLOCK 5	100%	512	4,773,376	8,019	9,323
Summer Rate		482			



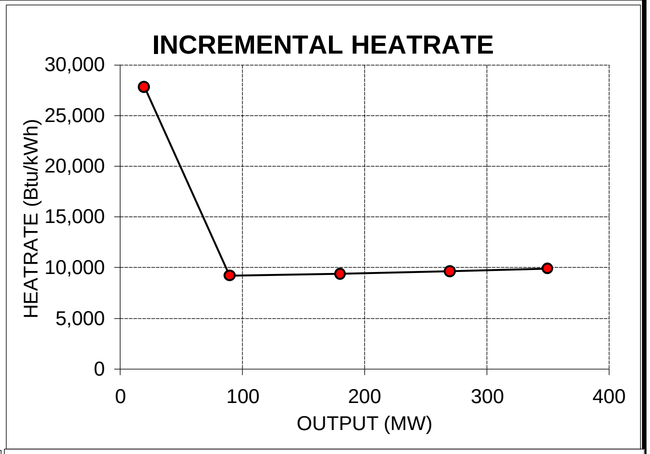


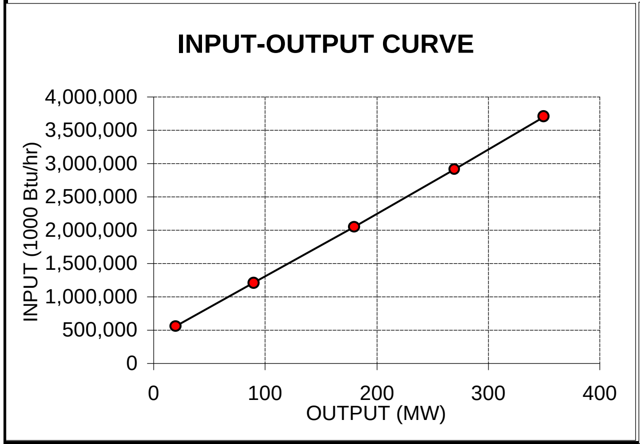


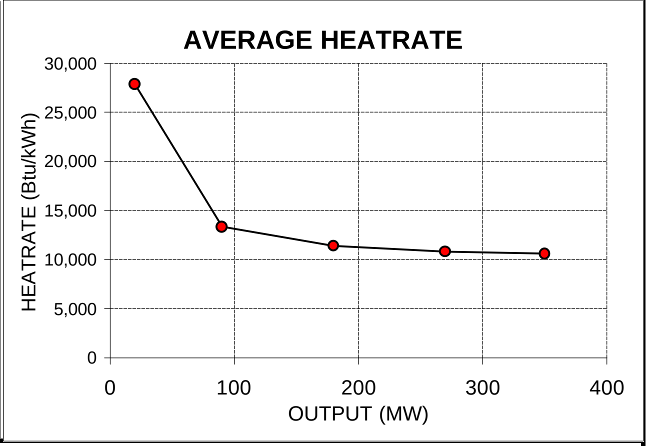
SUMMARY HEAT RATE DATA

UNIT: **EL SEGUNDO 1&2**
NRG/ Destec Consortium

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	6%	20	556,760	27,838	27,838
BLOCK 2	26%	90	1,202,400	9,223	13,360
BLOCK 3	51%	180	2,048,040	9,396	11,378
BLOCK 4	77%	270	2,914,785	9,631	10,796
BLOCK 5	100%	350	3,706,850	9,901	10,591


INCREMENTAL HEATRATE

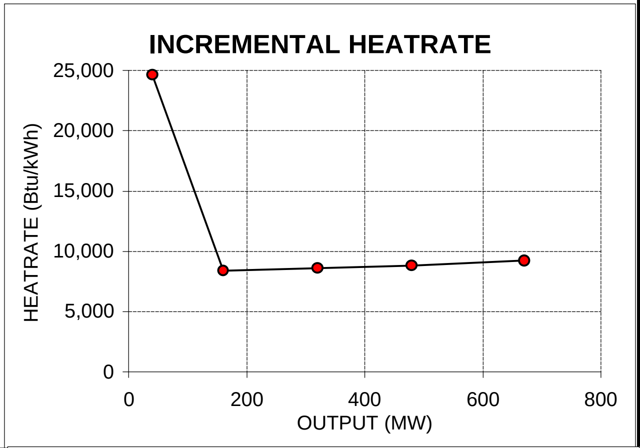

INPUT-OUTPUT CURVE


AVERAGE HEATRATE

SUMMARY HEAT RATE DATA

UNIT: **EL SEGUNDO 3&4**
NRG/ Destec Consortium

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	6%	40	985,120	24,628	24,628
BLOCK 2	24%	160	1,991,920	8,390	12,450
BLOCK 3	48%	320	3,364,160	8,577	10,513
BLOCK 4	72%	480	4,777,920	8,836	9,954
BLOCK 5	100%	670	6,526,135	9,201	9,741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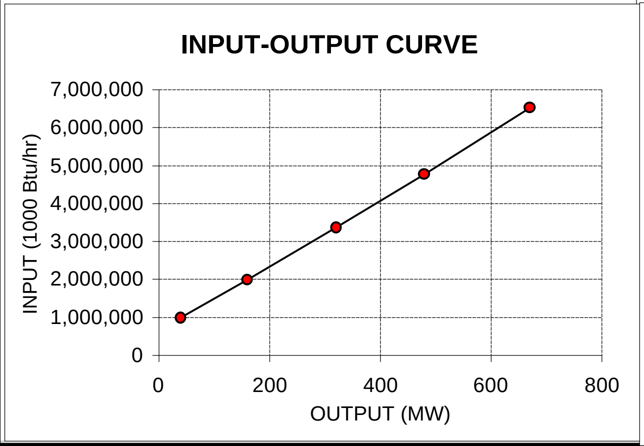
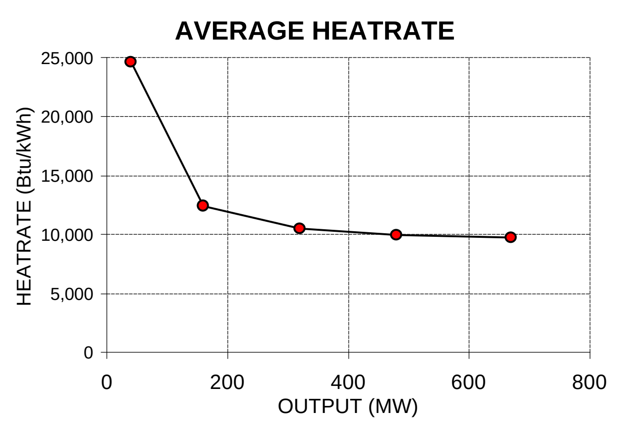
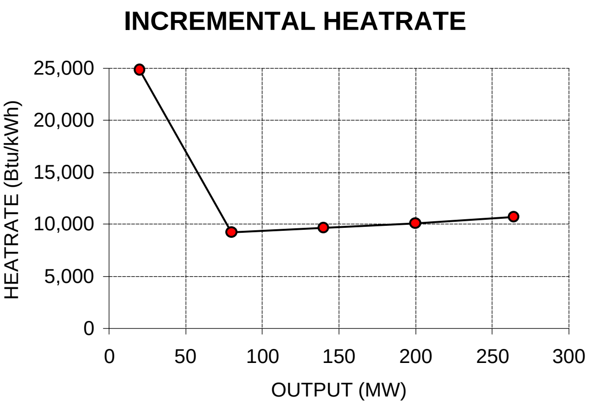

INPUT-OUTPUT CURVE

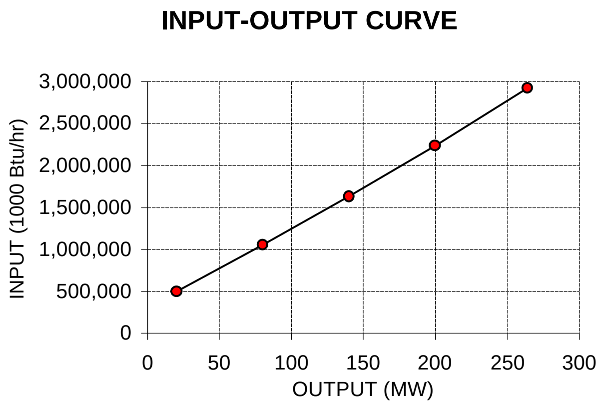

AVERAGE HEATRATE

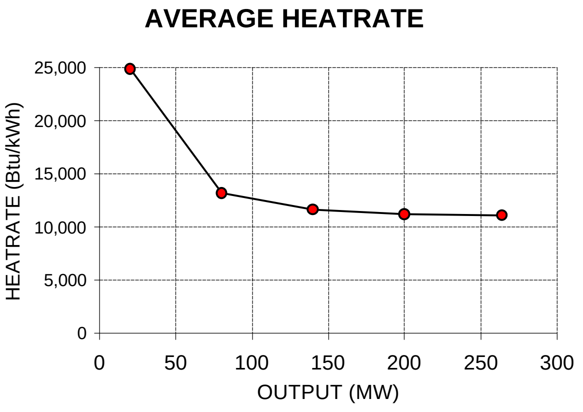
SUMMARY HEAT RATE DATA

UNIT: **ETIWANDA 1&2**

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	8%	20	496,960	24,848	24,848
BLOCK 2	30%	80	1,052,680	9,262	13,159
BLOCK 3	53%	140	1,630,580	9,632	11,647
BLOCK 4	76%	200	2,236,700	10,102	11,184
BLOCK 5	100%	264	2,923,008	10,724	11,072



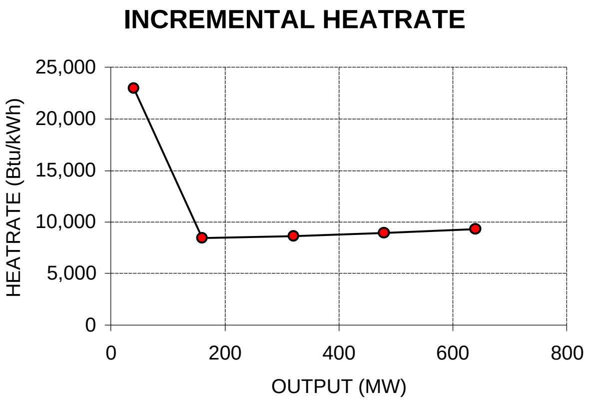


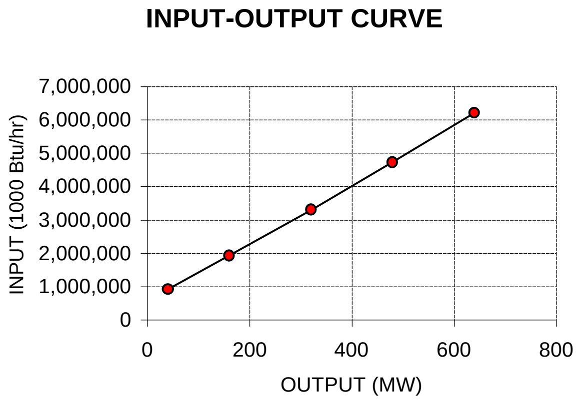


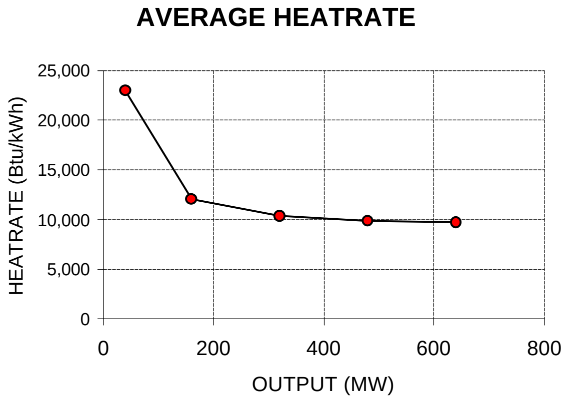
SUMMARY HEAT RATE DATA

UNIT: **ETIWANDA 3&4**

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	6%	40	919,180	22,980	22,980
BLOCK 2	25%	160	1,931,360	8,435	12,071
BLOCK 3	50%	320	3,313,280	8,637	10,354
BLOCK 4	75%	480	4,741,200	8,925	9,878
BLOCK 5	100%	640	6,227,840	9,292	9,731





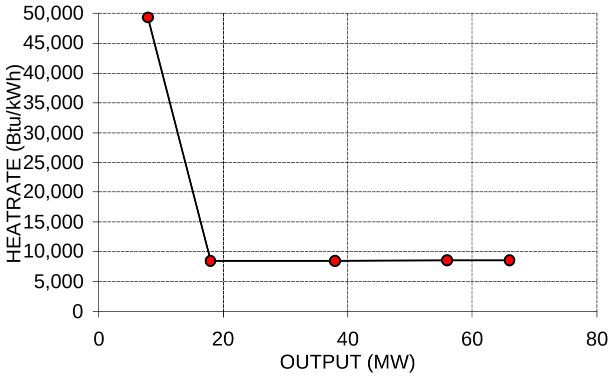


SUMMARY HEAT RATE DATA

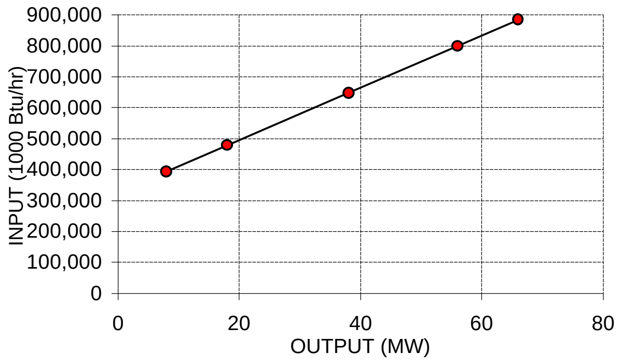
UNIT: **HIGHGROVE 1&2**
Thermo Ecotek 1/1/98

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	12%	8	394,428	49,304	49,304
BLOCK 2	27%	18	478,563	8,414	26,587
BLOCK 3	58%	38	647,333	8,439	17,035
BLOCK 4	85%	56	799,811	8,471	14,282
BLOCK 5	100%	66	884,766	8,496	13,406

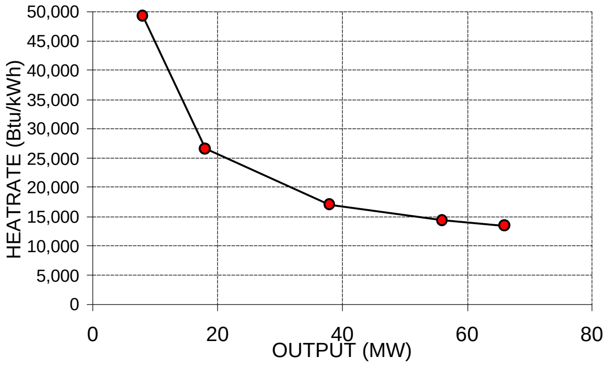
INCREMENTAL HEAT RATE



INPUT-OUTPUT CURVE



AVERAGE HEAT RATE

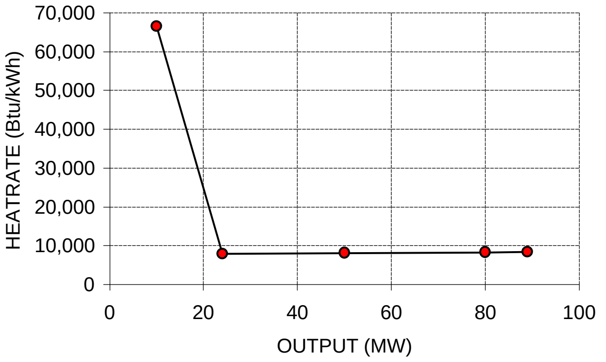


SUMMARY OF HEAT RATE DATA

UNIT: **HIGHROVE 3&4**
Thermo Ecotek 1/1/98

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	11%	10	666,030	66,603	66,603
BLOCK 2	27%	24	776,602	7,898	32,358
BLOCK 3	56%	50	987,124	8,097	19,742
BLOCK 4	90%	80	1,237,224	8,337	15,465
BLOCK 5	100%	89	1,313,607	8,487	14,760

INCREMENTAL HEAT RATE



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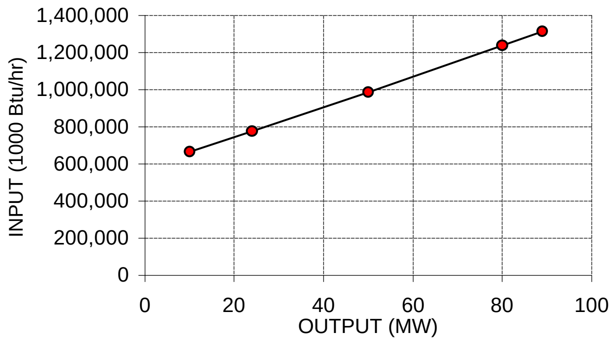
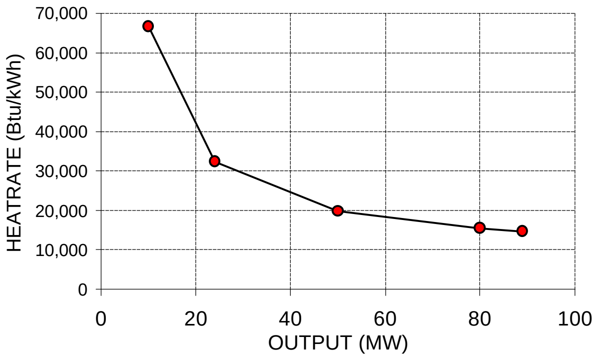


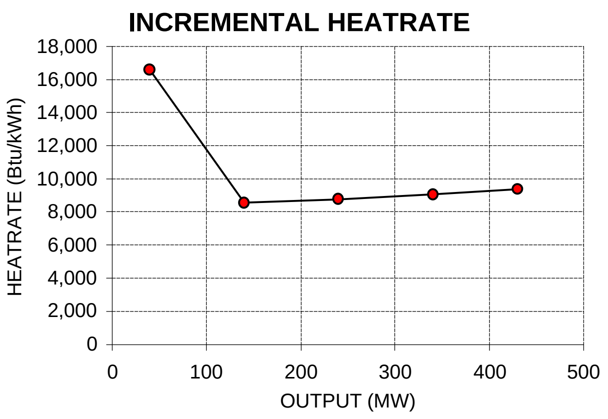
AVERAGE HEAT RATE

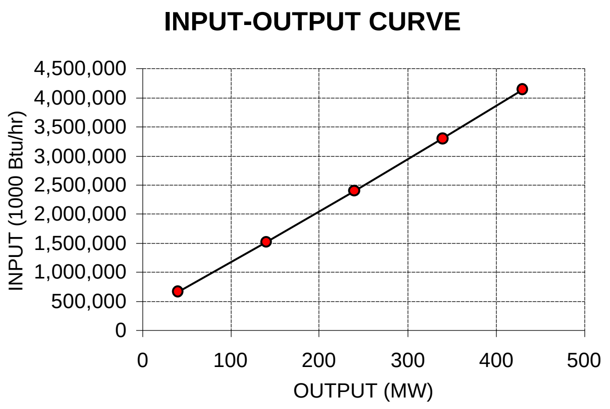


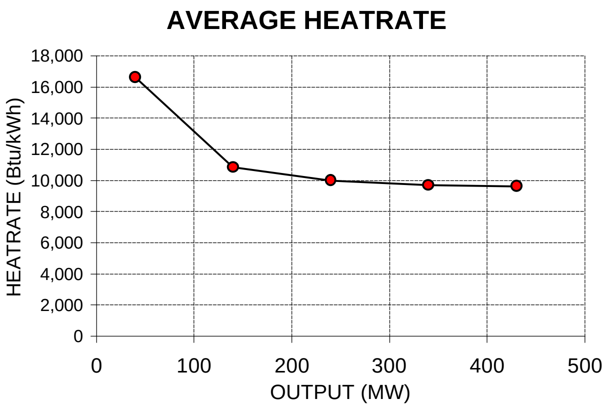
SUMMARY HEAT RATE DATA

UNIT: **HUNTINGTON BEACH 1&2**
AES Corp. 1/1/98

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	9%	40	664,240	16,606	16,606
BLOCK 2	33%	140	1,519,420	8,552	10,853
BLOCK 3	56%	240	2,396,520	8,771	9,986
BLOCK 4	79%	340	3,301,570	9,051	9,711
BLOCK 5	100%	430	4,146,060	9,383	9,642


INCREMENTAL HEATRATE

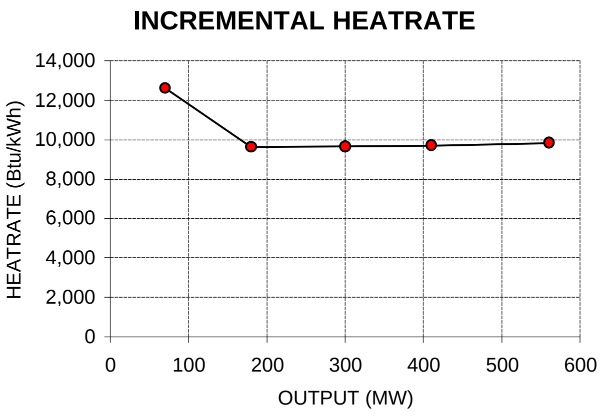

INPUT-OUTPUT CURVE

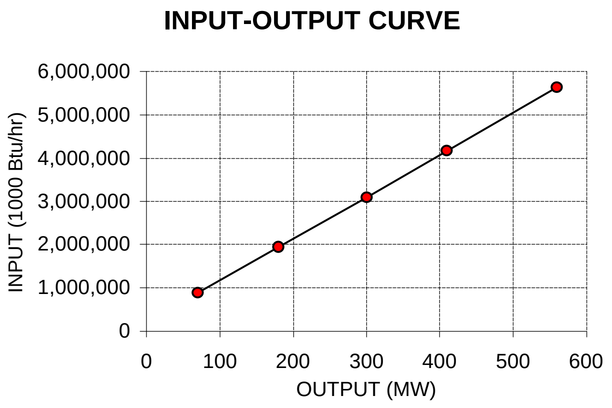

AVERAGE HEATRATE

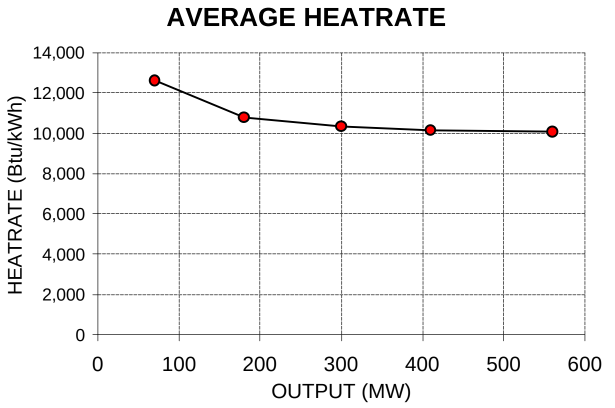
SUMMARY HEAT RATE DATA

UNIT: **LONG BEACH 8&9**

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	13%	70	882,000	12,600	12,600
BLOCK 2	32%	180	1,938,600	9,605	10,770
BLOCK 3	54%	300	3,096,000	9,645	10,320
BLOCK 4	73%	410	4,163,550	9,705	10,155
BLOCK 5	100%	560	5,636,400	9,819	10,065


INCREMENTAL HEATRATE

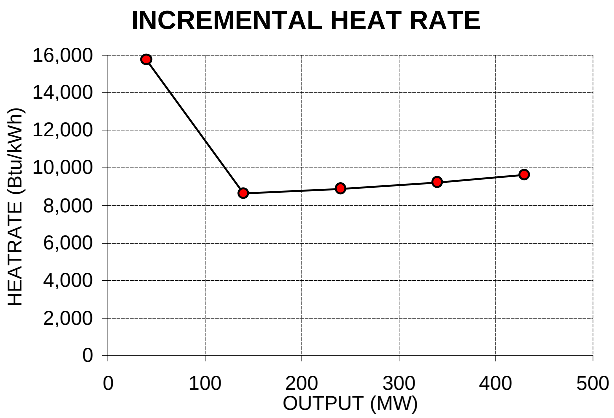

INPUT-OUTPUT CURVE

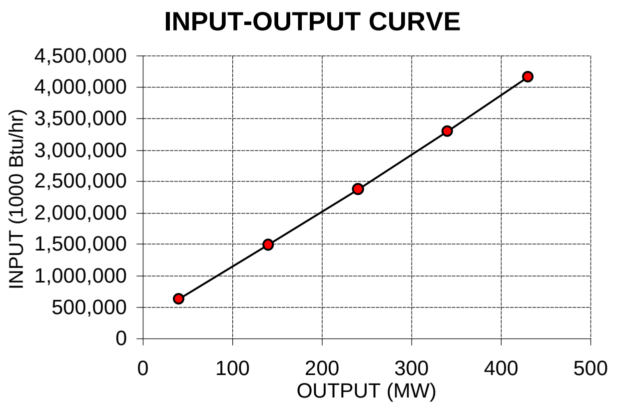

AVERAGE HEATRATE

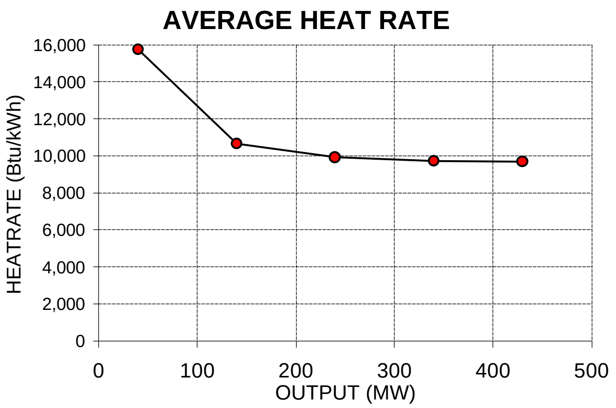
SUMMARY HEAT RATE DATA

UNIT: **MANDALAY 1&2**
Houston Industries Inc. 1/1/98

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	9%	40	629,380	15,735	15,735
BLOCK 2	33%	140	1,491,280	8,619	10,652
BLOCK 3	56%	240	2,379,000	8,877	9,913
BLOCK 4	79%	340	3,300,380	9,214	9,707
BLOCK 5	100%	430	4,166,055	9,619	9,689



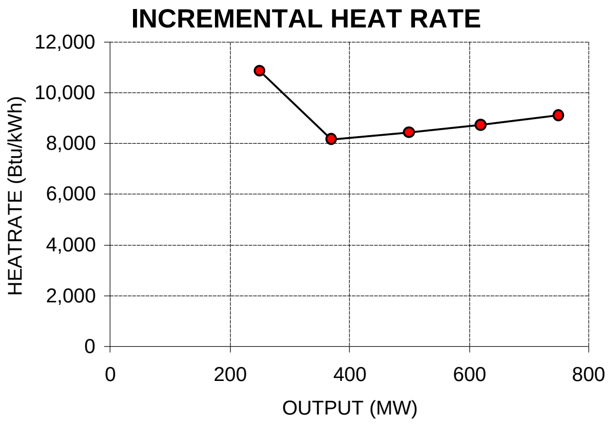


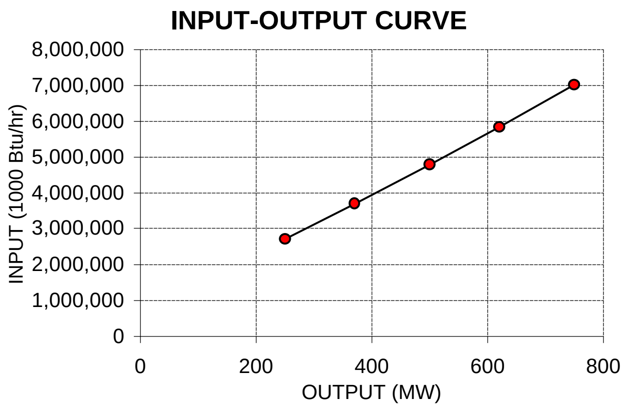


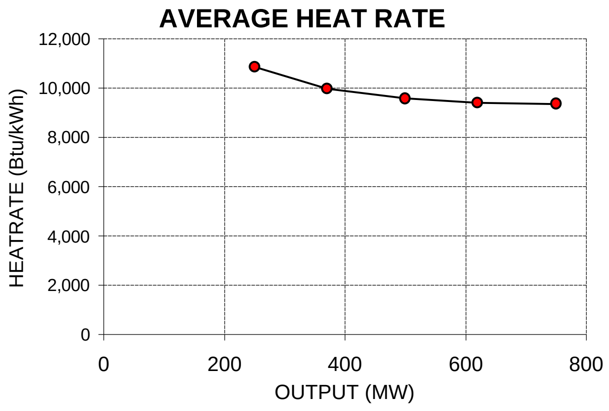
SUMMARY HEAT RATE DATA

UNIT: **ORMOND BEACH 1**

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	33%	250	2,713,000	10,852	10,852
BLOCK 2	49%	370	3,692,970	8,166	9,981
BLOCK 3	67%	500	4,788,500	8,427	9,577
BLOCK 4	83%	620	5,836,060	8,730	9,413
BLOCK 5	100%	750	7,019,250	9,101	9,359



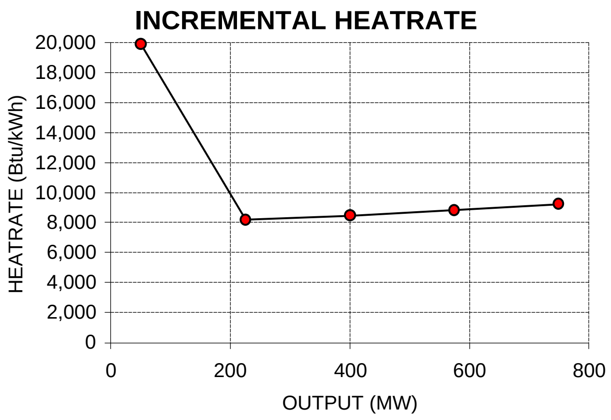


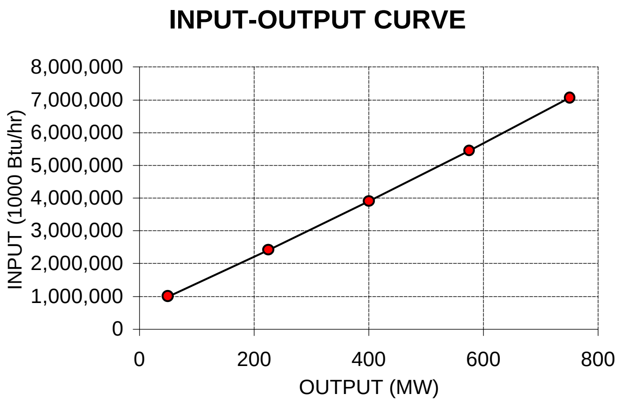


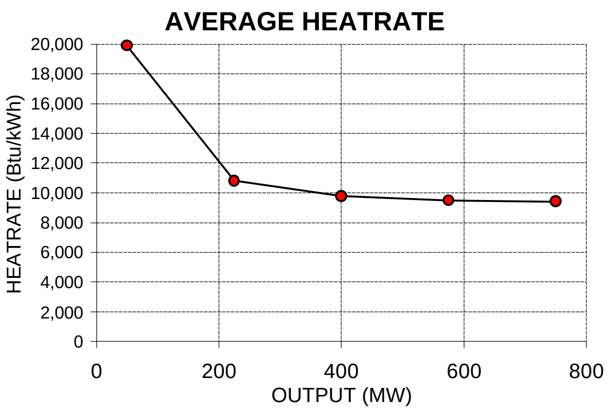
SUMMARY HEAT RATE DATA

UNIT: **ORMOND BEACH 2**

	OUTPUT (%)	OUTPUT (MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	7%	50	993,850	19,877	19,877
BLOCK 2	30%	225	2,427,075	8,190	10,787
BLOCK 3	53%	400	3,907,200	8,458	9,768
BLOCK 4	77%	575	5,448,125	8,805	9,475
BLOCK 5	100%	750	7,067,250	9,252	9,423



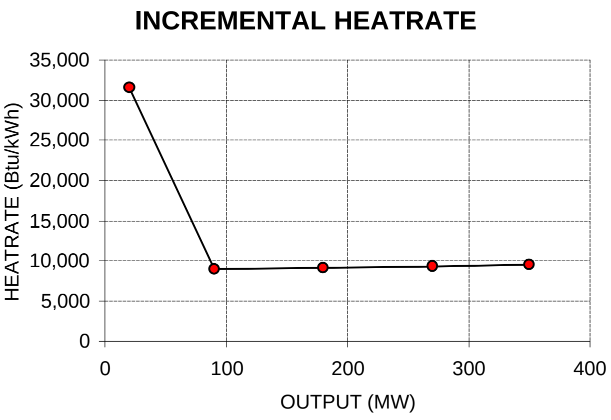


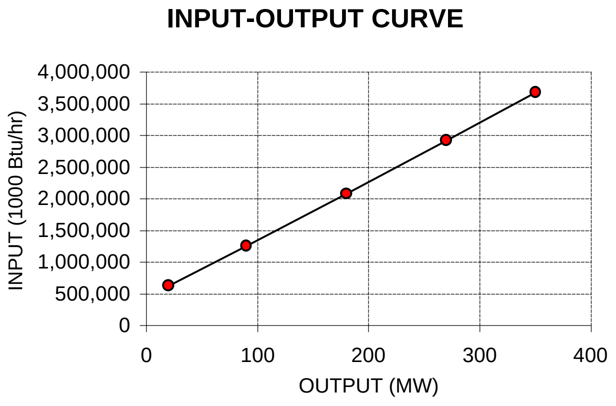


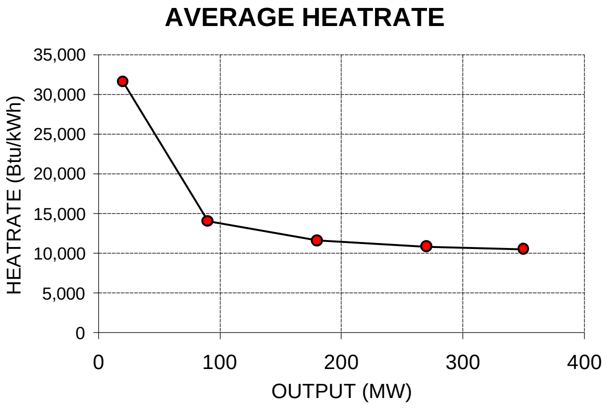
SUMMARY HEAT RATE DATA

UNIT: **REDONDO BEACH 5&6**
AES Corp. 1/1/98

	OUTPUT (%)	OUTPUT (MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	6%	20	632,340	31,617	31,617
BLOCK 2	26%	90	1,261,755	8,992	14,020
BLOCK 3	51%	180	2,083,770	9,134	11,577
BLOCK 4	77%	270	2,922,750	9,322	10,825
BLOCK 5	100%	350	3,685,325	9,532	10,530





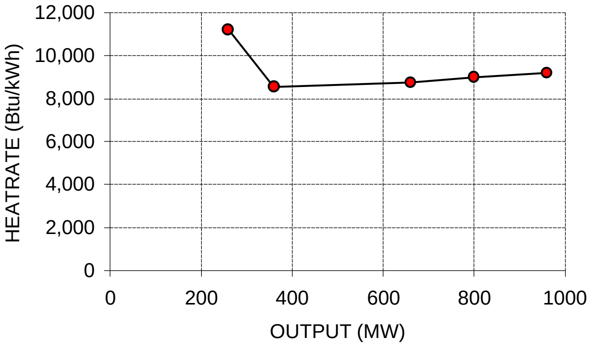


SUMMARY HEAT RATE DATA

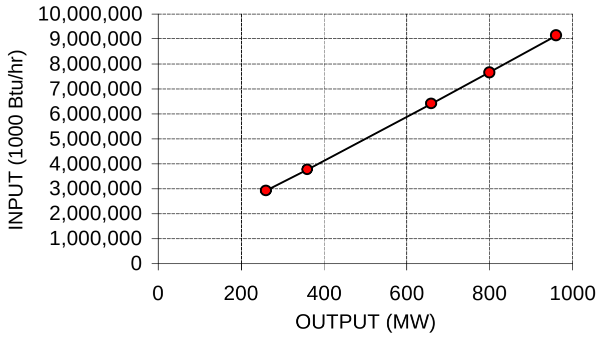
UNIT: **REDONDO BEACH 7&8**
AES Corp. 1/1/98

	OUTPUT (%)	OUTPUT (MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	27%	260	2,917,070	11,220	11,220
BLOCK 2	38%	360	3,772,260	8,552	10,479
BLOCK 3	69%	660	6,395,730	8,745	9,691
BLOCK 4	83%	800	7,655,600	8,999	9,570
BLOCK 5	100%	960	9,128,640	9,207	9,509

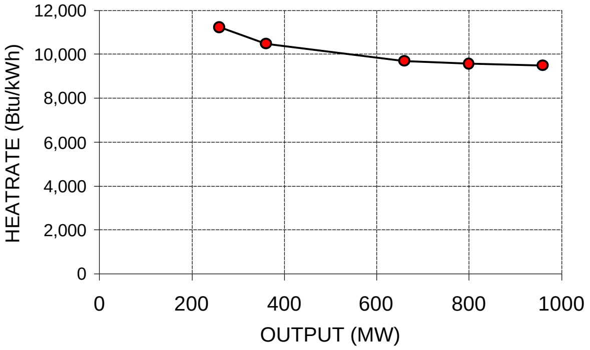
INCREMENTAL HEATRATE



INPUT-OUTPUT CURVE



AVERAGE HEATRATE

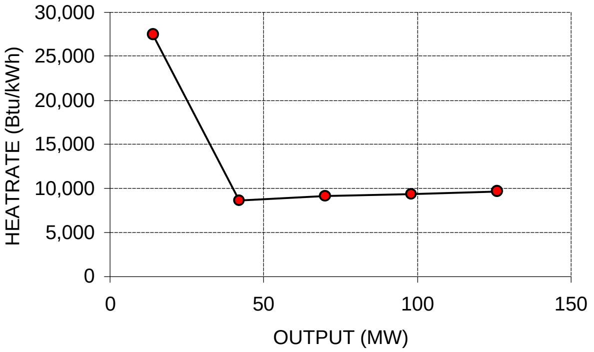


SUMMARY HEAT RATE DATA

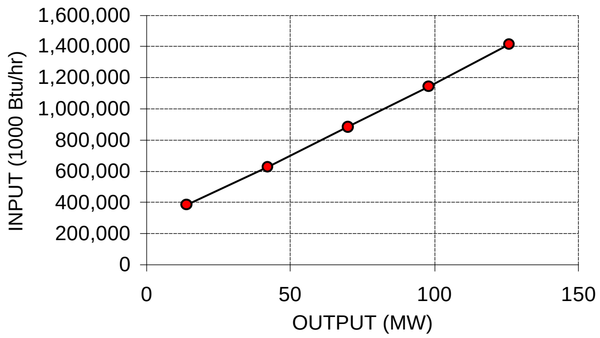
UNIT: **SAN BERNARDINO 1&2**
Thermo Ecotek 1/1/98

	OUTPUT (%)	OUTPUT (MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	11%	14	384,727	27,481	27,481
BLOCK 2	33%	42	627,249	8,662	14,935
BLOCK 3	56%	70	881,895	9,095	12,599
BLOCK 4	78%	98	1,143,611	9,347	11,670
BLOCK 5	100%	126	1,414,854	9,687	11,229

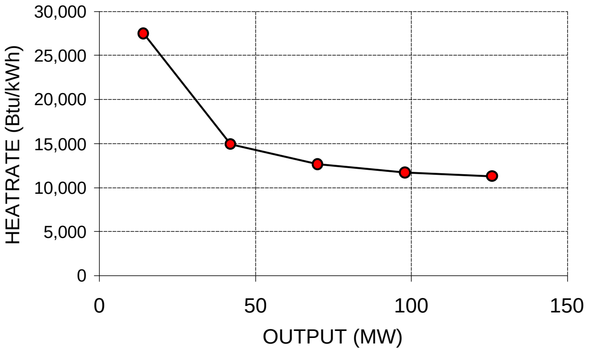
INCREMENTAL HEATRATE



INPUT-OUTPUT CURVE



AVERAGE HEATRATE

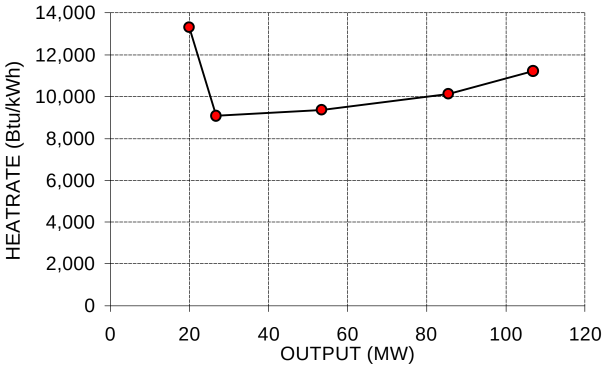


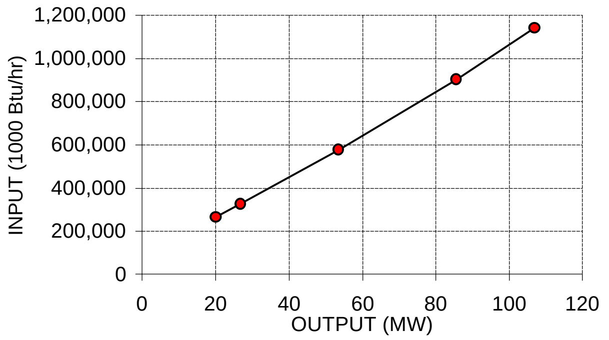
SDG&E
SUMMARY HEAT RATE DATA
(SOURCE: April 28, 1997 FAX)

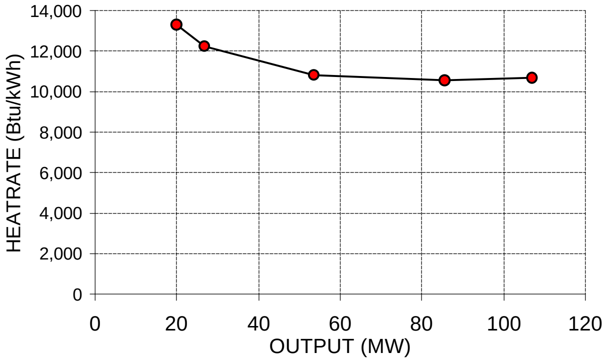
SUMMARY HEAT RATE DATA

UNIT: **ENCINA 1**

	OUTPUT (%)	 (MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	19%	20	266,060	13,303	13,303
BLOCK 2	25%	27	327,367	9,082	12,238
BLOCK 3	50%	54	577,533	9,352	10,795
BLOCK 4	80%	86	903,080	10,142	10,550
BLOCK 5	100%	107	1,142,760	11,200	10,680


INCREMENTAL HEATRATE

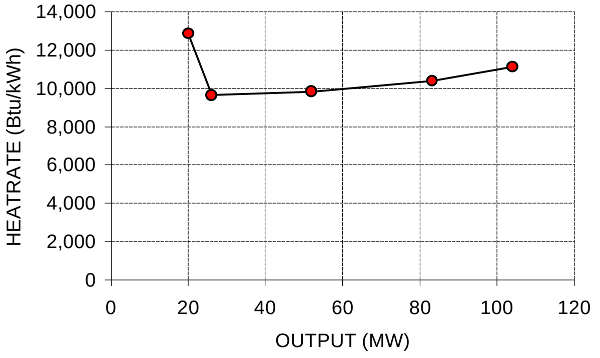

INPUT-OUTPUT CURVE

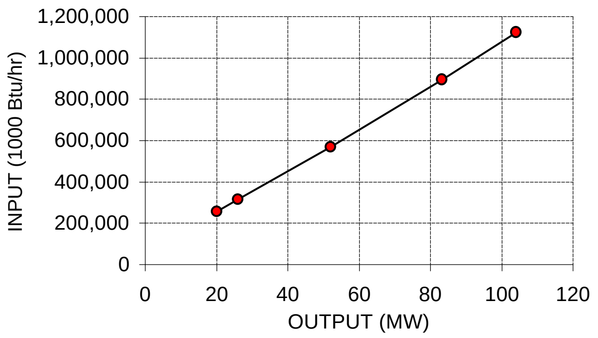

AVERAGE HEATRATE

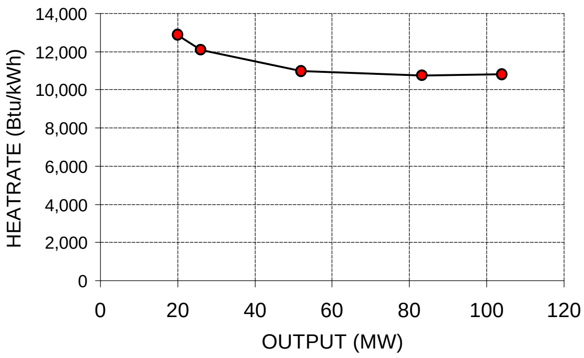
SUMMARY HEAT RATE DATA

UNIT: **ENCINA 2**

	OUTPUT (%)	 (MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	19%	20	257,200	12,860	12,860
BLOCK 2	25%	26	314,990	9,632	12,115
BLOCK 3	50%	52	570,232	9,817	10,966
BLOCK 4	80%	83	893,734	10,369	10,742
BLOCK 5	100%	104	1,124,864	11,112	10,816


INCREMENTAL HEATRATE

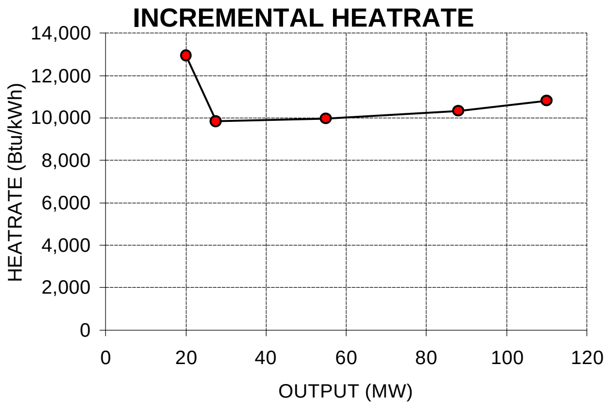

INPUT-OUTPUT CURVE

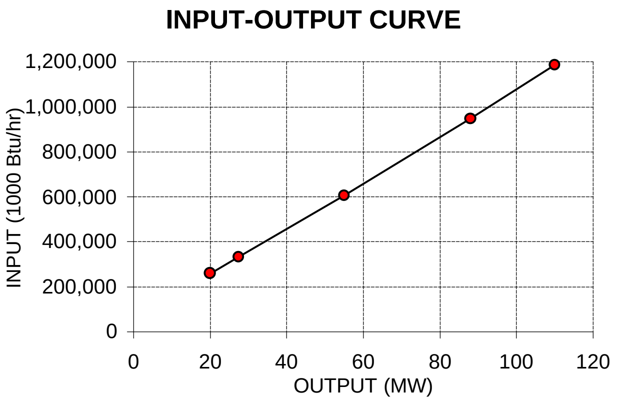

AVERAGE HEATRATE

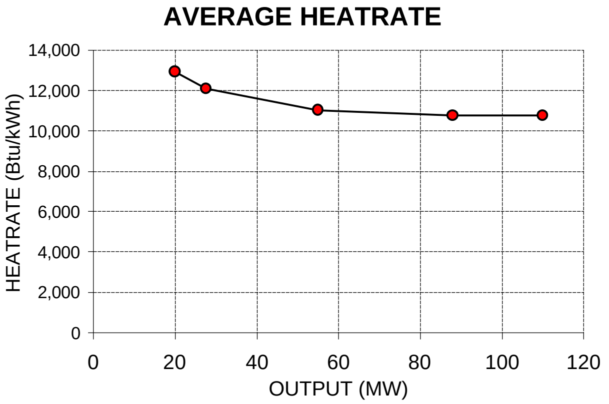
SUMMARY HEAT RATE DATA

UNIT: **ENCINA 3**

	OUTPUT (%)	OUTPUT (MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	18%	20	258,720	12,936	12,936
BLOCK 2	25%	28	332,530	9,841	12,092
BLOCK 3	50%	55	606,540	9,964	11,028
BLOCK 4	80%	88	947,232	10,324	10,764
BLOCK 5	100%	110	1,185,030	10,809	10,773



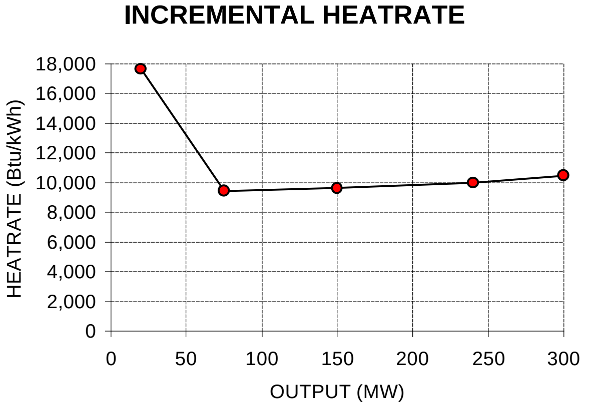


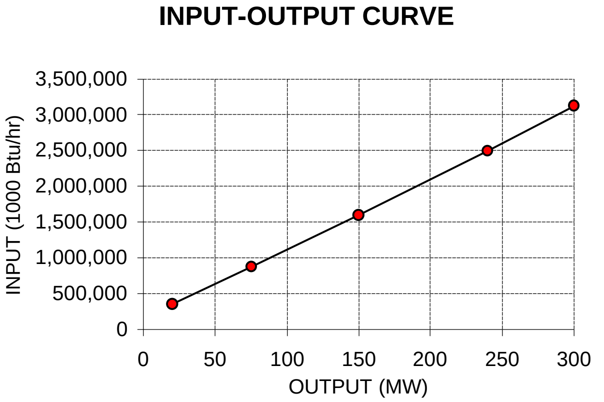


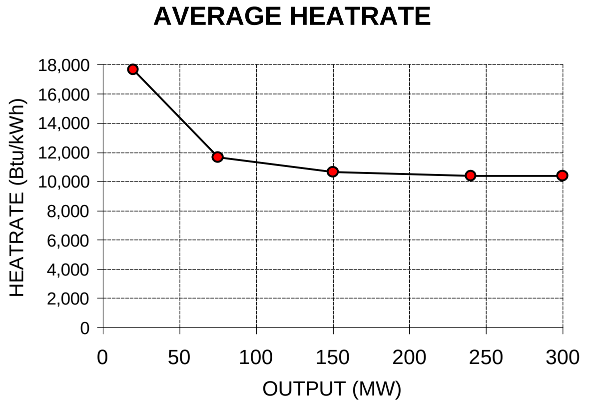
SUMMARY HEAT RATE DATA

UNIT: **ENCINA 4**

	OUTPUT (%)	OUTPUT (MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	7%	20	353,480	17,674	17,674
BLOCK 2	25%	75	874,500	9,473	11,660
BLOCK 3	50%	150	1,596,300	9,624	10,642
BLOCK 4	80%	240	2,495,520	9,991	10,398
BLOCK 5	100%	300	3,124,500	10,483	10,415



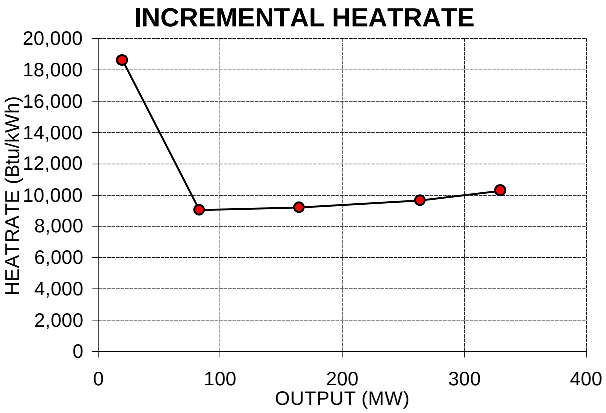


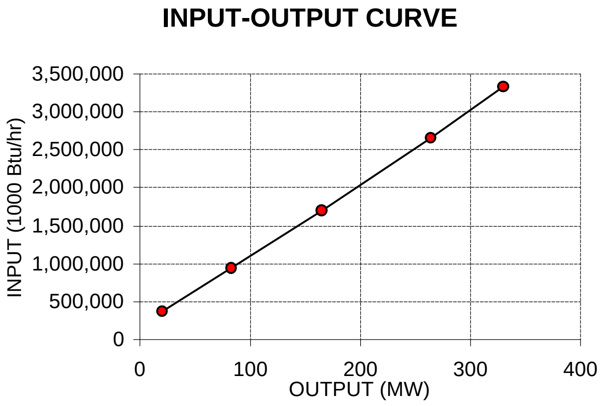


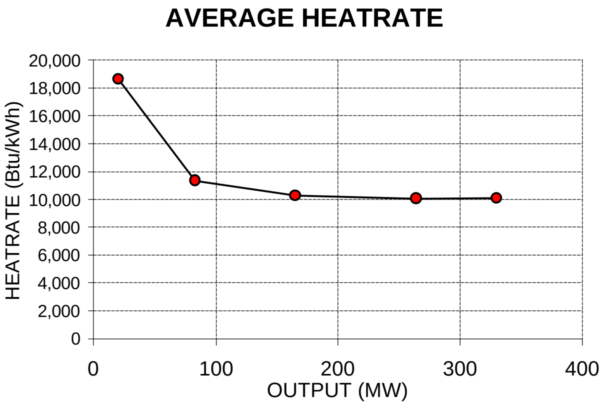
SUMMARY HEAT RATE DATA

UNIT: **ENCINA 5**

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	6%	20	372,640	18,632	18,632
BLOCK 2	25%	83	941,967	9,037	11,349
BLOCK 3	50%	165	1,695,870	9,194	10,278
BLOCK 4	80%	264	2,652,144	9,659	10,046
BLOCK 5	100%	330	3,330,030	10,271	10,091





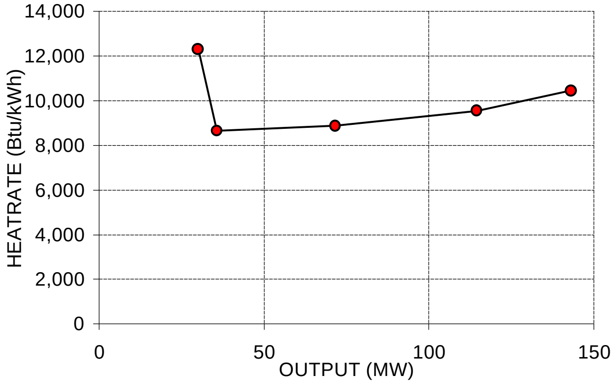


SUMMARY HEAT RATE DATA

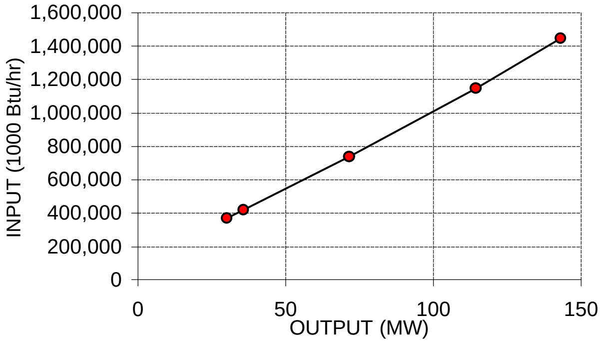
UNIT: **SOUTH BAY 1**

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	21%	30	369,180	12,306	12,306
BLOCK 2	25%	36	418,954	8,656	11,719
BLOCK 3	50%	72	736,236	8,875	10,297
BLOCK 4	80%	114	1,145,830	9,548	10,016
BLOCK 5	100%	143	1,444,872	10,456	10,104

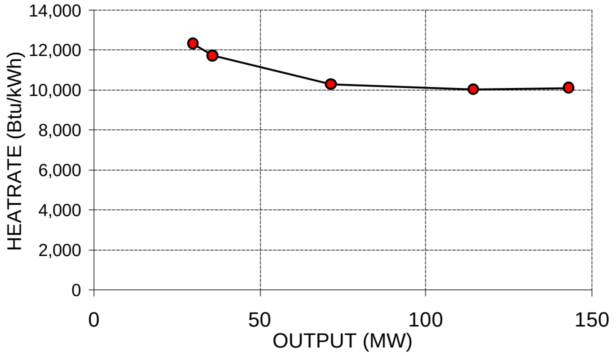
INCREMENTAL HEATRATE



INPUT-OUTPUT CURVE



AVERAGE HEATRATE

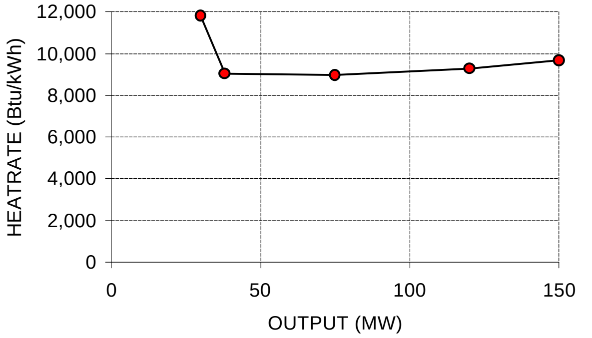


SUMMARY HEAT RATE DATA

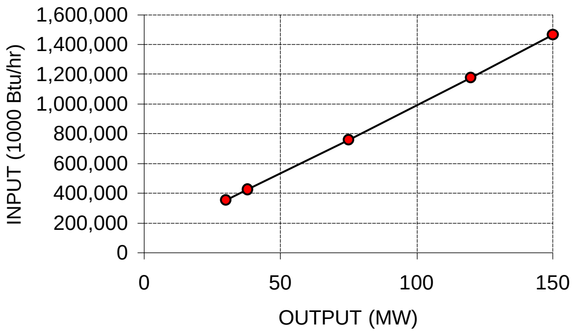
UNIT: **SOUTH BAY 2**

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	20%	30	353,970	11,799	11,799
BLOCK 2	25%	38	426,322	9,044	11,219
BLOCK 3	50%	75	758,025	8,965	10,107
BLOCK 4	80%	120	1,175,520	9,278	9,796
BLOCK 5	100%	150	1,465,200	9,656	9,768

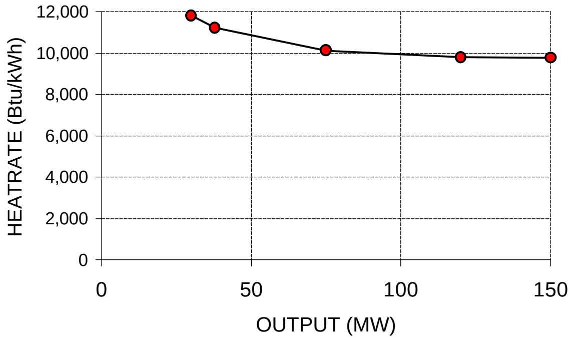
INCREMENTAL HEATRATE



INPUT-OUTPUT CURVE



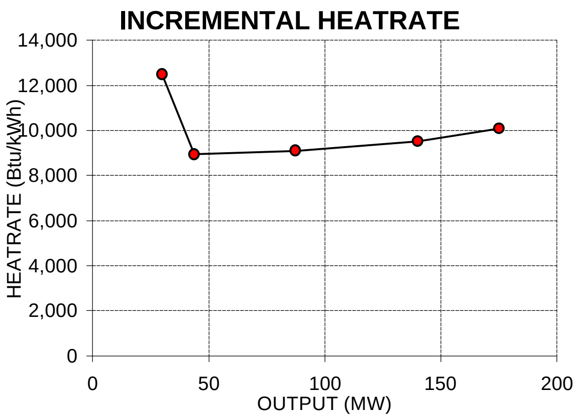
AVERAGE HEATRATE

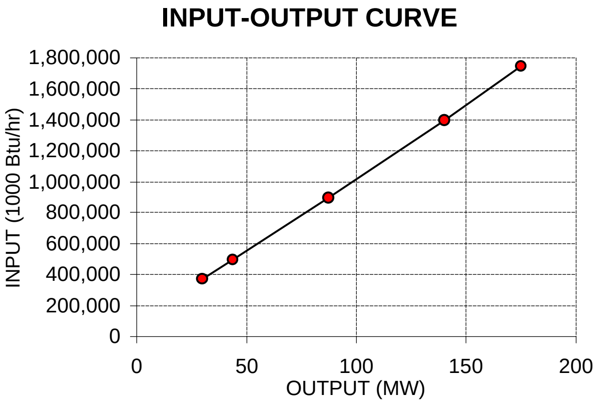


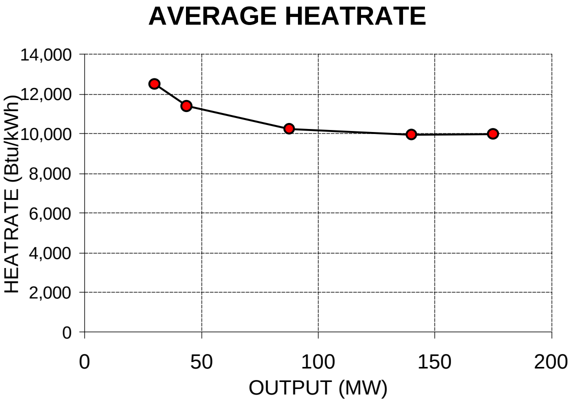
SUMMARY HEAT RATE DATA

UNIT: **SOUTH BAY 3**

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	17%	30	374,430	12,481	12,481
BLOCK 2	25%	44	497,350	8,940	11,368
BLOCK 3	50%	88	895,038	9,090	10,229
BLOCK 4	80%	140	1,394,400	9,512	9,960
BLOCK 5	100%	175	1,747,200	10,080	9,984


INCREMENTAL HEATRATE


INPUT-OUTPUT CURVE

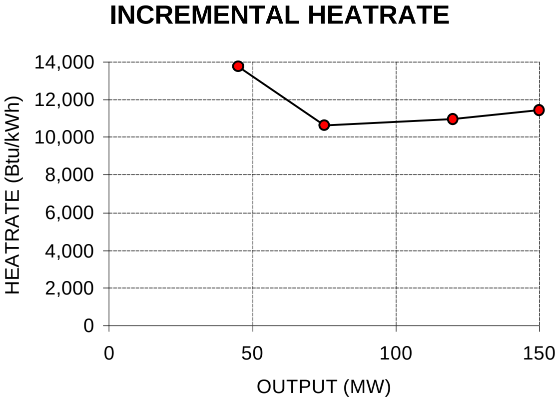

AVERAGE HEATRATE

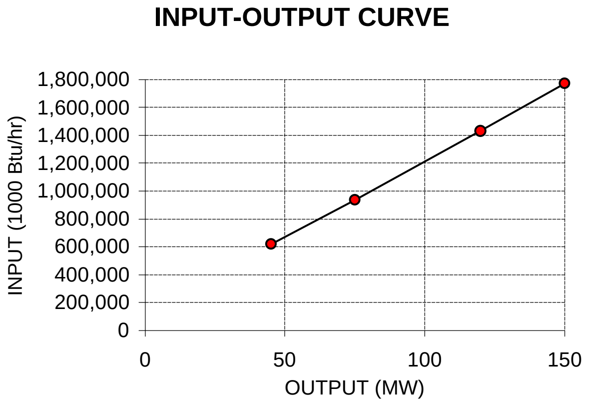
SUMMARY HEAT RATE DATA

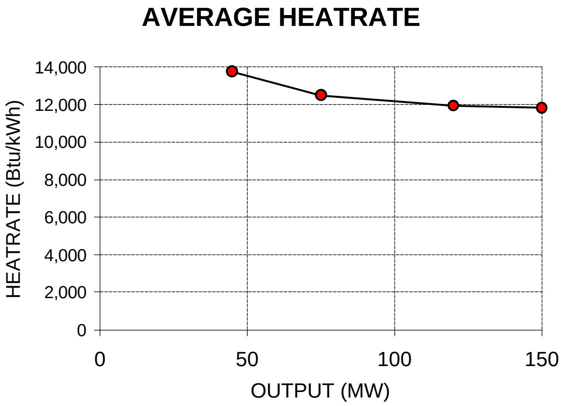
UNIT: **SOUTH BAY 4**

	OUTPUT (%)	(MW)	Input-Output Curve (1000 Btu/hr)	Incremental Heat Rate (Btu/kWh)	Average Heat Rate (Btu/kWh)
BLOCK 1	30%	45	618,615	13,747	13,747
BLOCK 2	50%	75	937,500	10,630	12,500
BLOCK 3	80%	120	1,430,520	10,956	11,921
BLOCK 4	100%	150	1,773,300	11,426	11,822

Note: Only 4 blocks because minimum block > 25% block.


INCREMENTAL HEATRATE


INPUT-OUTPUT CURVE


AVERAGE HEATRATE

APPENDIX B
DATA FOR HEAT RATE EQUATIONS

This Appendix describes my method for developing the heat rate equations, as well as providing the parameters that define these equations. The heat rate curves are:

- Input-Output Curve
- Incremental Heat Rate Curve
- Average Heat Rate Curve

Input-Output Curve

The Input-Output Curve is typically defined by the third order equation:

$$y = ax^3 + bx^2 + cx + d$$

Where: x = Output in MW
y = Input in Btu/hr
a-d = coefficients that define the equation

Incremental Heat Rate Curve

The Incremental Heat Rate (***IHR***) is defined as the first derivative of the Input-Output Curve:

$$IHR = dy/dx = 3ax^2 + 2bx + c$$

Average Heat Rate Curve

The Average Heat Rate (***AHR***) is defined as the Input-Output Curve divided by the output (x).

$$AHR = y/x = (ax^3 + bx^2 + cx + d) / x$$

The complete step-by-step process of constructing these heat rate curves is as follows. Enter the **block** heat rate data of Appendix A into an Excel spreadsheet, as is shown in Table B-1 for the illustrative case of Moss Landing 7. “I/O Curve” is the input-output block data. “***IHR***” is the Incremental Heat Rate block data. “***AHR***” is the Average Heat Rate block data. Actually, only the I/O curve data is necessary for this process -- the rest of the data is provided herein for completeness.

TABLE B-1: ELFIN HEAT RATE DATA FOR MOSS LANDING 7.

	OUTPUT		I/O CURVE	***IHR***	***AHR***
	(%)	(MW)	(Btu/hr)	(Btu/kWh)	(Btu/kWh)
1	6.8%	50	997,950	19,959	19,959
2	25.0%	185	1,966,735	7,176	10,631
3	50.1%	370	3,429,160	7,905	9,268
4	80.0%	591	5,296,542	8,450	8,962
5	100.0%	739	6,589,663	8,737	8,917

Using the I/O Curve (Btu/hr) and Output (MW) data of Table B-1, prepare an Excel graph as shown in Figure B-1.

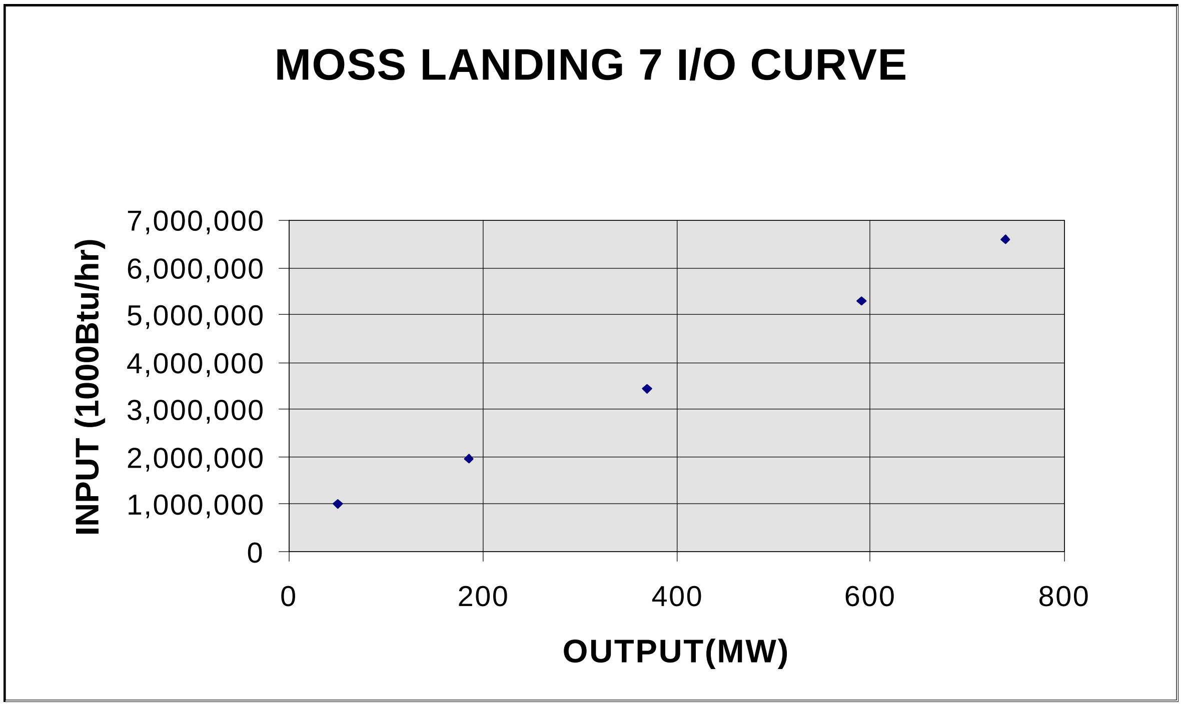


Figure B-1

Next, use the Excel feature of “insert trendline” to identify a third order equation to fit the data points -- and select the option that prints the equation on the graph, as shown in Figure B-2.

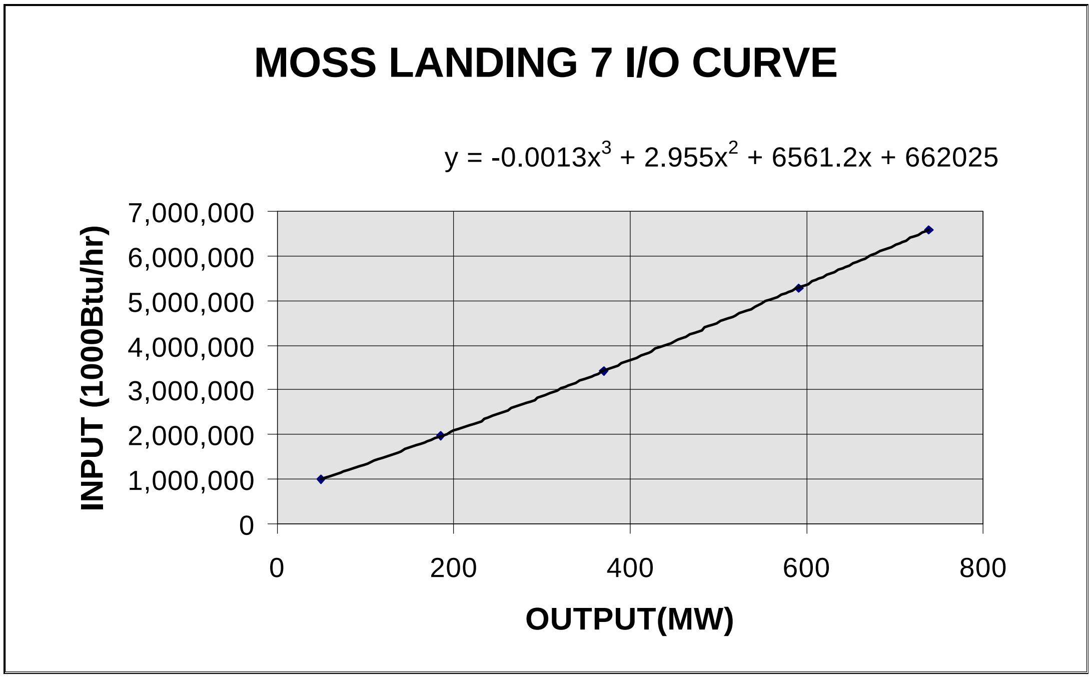


Figure B-2

Copy the coefficients, ***a* - *d***, into the above equations. These equations along with the values of X_1 and X_2 define the curves. For Moss Landing 7:

$a = -0.0013$ $x_1 = 50$ MW
$b = 2.955$ $x_2 = 739$ MW
$c = 6561.2$
$d = 662{,}025$

Using these coefficients, the Input-Output (***I/O***), Incremental Heat Rate (***IHR***) and Average Heat Rate (***AHR***) Curves can be developed, as follows:

$$I/O = y = ax^3 + bx^2 + cx + d = -0.0013x^3 + 2.955x^2 + 6561.2x + 662025$$

$$IHR = dy/dx = 3ax^2 + 2bx + c = -0.0039x^3 + 5.91x^2 + 6561.2$$

$$AHR = y/x = (ax^3 + bx^2 + cx + d) / x = (-0.0013x^3 + 2.955x^2 + 6561.2x + 662025) /x$$

Table B-2 summarizes the coefficients (***a* - *d***) and the minimum (x_1) and maximum (x_2) output values for each of the IOU units. Note that these curves can never fit the I/O data of Appendix A exactly, so that the I/O equation points – as well as the other heat rate equation points – will never match the original data exactly. But they will be close enough for all practical purposes.

TABLE B-2: SUMMARY HEAT RATE DATA

	COEFICIENTS				OUTPUT (MW)	
	a	b	c	d	MIN	MAX
PG&E UNITS						
Contra Costa 6	0.0148	-6.0775	9356.2	180,146	46	340
Contra Costa 7	0.0099	-2.9176	8746.7	223,144	46	340
Humboldt 1&2	0.2946	-30.3370	11330.0	99,926	10	105
Hunters Point 2	0.0116	12.9790	9870.6	115,531	10	107
Hunters Point 3	0.0144	21.0770	9080.0	117,483	10	107
Hunters Point 4	0.0010	1.3752	8659.0	205,948	62	326
Morro Bay 1&2	0.0049	-1.1685	9498.3	200,714	62	326
Morro Bay 3	0.0006	-0.1178	9063.6	190,385	46	338
Morro Bay 4	0.0004	1.0588	8559.2	194,590	46	338
Moss Landing 6	-0.0021	3.6945	6598.2	657,281	50	739
Moss Landing 7	-0.0013	2.9550	6561.2	662,025	50	739
Pittsburg 1&2	0.0148	-5.3036	9610.6	293,691	62	326
Pittsburg 3&4	0.0300	-12.1140	10551.0	219,614	62	326
Pittsburg 5	-0.0001	1.3632	8752.4	218,209	46	325
Pittsburg 6	0.0056	-0.0515	8550.1	266,012	46	325
Pittsburg 7	0.0023	-1.8450	8951.1	632,496	120	720
Potrero 3	0.0468	-11.9850	9908.0	70,409	47	207
SCE UNITS						
Alamitos 1&2	0.0018	0.8174	9018.2	397,249	20	350
Alamitos 3&4	0.0005	0.4401	8338.1	677,108	40	640
Alamitos 5&6	-0.0006	2.2408	6843.4	1,000,000	260	960
Cool Water 1	0.0293	6.1850	8979.5	48,471	17	65
Cool Water 2	0.0203	3.2256	9148.4	56,315	19	81
Cool Water 3&4	0.0035	-1.4482	7206.1	993,648	140	512
El Segundo 1&2	0.0010	0.7726	9129.0	373,847	20	360
El Segundo 3&4	0.0004	0.4377	8294.0	652,689	40	670
Etiwanda 1&2	0.0053	1.7528	9044.1	315,310	20	264
Etiwanda 3&4	0.0005	0.4642	8328.1	585,227	40	640
Highgrove 1&2	0.0004	0.8061	8392.3	327,238	8	66
Highgrove 3&4	-0.0086	5.6470	7715.1	588,318	10	89
Huntington 1&2	0.0011	0.6180	8411.7	326,693	40	430
Long Beach 8&9	0.0004	-0.0512	9600.9	210,025	70	560
Mandaly 1&2	0.0022	0.8052	8238.8	301,952	40	430
Ormond Beach 1	0.0006	0.3588	7773.3	737,960	250	750
Ormond Beach 2	0.0005	0.4250	8043.1	590,522	50	750
Redondo 5&6	0.0007	0.6815	8910.0	453,856	20	350
Redondo 7&8	0.0002	0.2479	8345.6	727,238	260	960
San Bernardino 1&2	-0.0099	7.9479	8260.7	267,439	14	126
SDG&E UNITS						
Encina 1	0.0806	-0.0003	8949.0	86,430	20	107
Encina 2	0.0597	0.0023	9535.0	66,030	20	104
Encina 3	0.0349	0.0034	9780.0	62,840	20	110
Encina 4	0.0048	0.0010	9437.0	164,700	20	300
Encina 5	0.0049	0.0010	8975.0	193,100	20	330
South Bay 1	0.0386	0.0094	8528.0	112,300	30	143
South Bay 2	0.0147	-0.0041	8850.0	88,070	30	150
South Bay 3	0.0162	0.0004	8873.0	107,800	30	175
South Bay 4	0.0182	-0.0052	10430.0	147,600	45	150

APPENDIX C
INCREMENTAL HEAT RATE ERRORS

This Appendix shows the method used to quantify the magnitude of the errors caused by using the **Average** Incremental Heat Rate block data of modeling in place of the **Incremental** Heat Rate data used in the actual dispatch of the generation system.

I evaluated only the block data end points assuming that the maximum errors would occur at these points. The Actual heat rates (Instantaneous Incremental Heat Rates) were developed using the heat rate curve data from Appendix B. It might appear that the Block heat rates (Average Incremental Heat Rates) could be taken directly from Appendix A. But since equations had to be developed for the Instantaneous Heat Rate values, I used those same equations to develop the Block heat rates in order to make the two quantities more comparable. The differences are small but it does make the data appear more reasonable.

INSTANTANEOUS INCREMENTAL HEAT RATES - ACTUAL DATA

The Instantaneous Incremental Heat Rates are developed from the basic Input-Output Curve, which is typically defined by the third order equation:

$$y = ax^3 + bx^2 + cx + d$$

Where: x = Output in MW
y = Input in Btu/hr
$a\text{-}d$ = The coefficients that define the equation

The Instantaneous Incremental Heat Rate (***IIHR***) is defined as the first derivative of the Input-Output Curve:

$$IIHR = dy/dx = 3ax^2 + 2bx + c$$

AVERAGE INCREMENTAL HEAT RATE - BLOCK DATA

The Average Incremental Heat Rates (***AIHR***) can also be calculated using the Input-Output Curve. The calculation consists of dividing the incremental Input-Output value (Btu/hr) by the corresponding increment of output (MW).

$$\begin{aligned} AIHR &= (y_2 - y_1)/ (x_2 - x_1) \\ &= [(ax_2^3 + bx_2^2 + cx_2 + d) - (ax_1^3 + bx_1^2 + cx_1 + d)] / (x_2 - x_1) \\ &= [a(x_2^3 - x_1^3) + b(x_2^2 - x_1^2) + c(x_2 - x_1)]/ (x_2 - x_1) \\ &= a(x_2^2 + x_2 x_1 + x_1^2) + b(x_2 + x_1) + c \end{aligned}$$

Where: $\boldsymbol{x_1}$ **=** Minimum Output of Block
$\boldsymbol{x_2}$ **=** Maximum Output of Block

ILLUSTRATIVE EXAMPLE

The complete step-by-step process of constructing this heat rate data is done using the first block of Moss Landing 7. The coefficients (***a-d***) and the $\boldsymbol{x_1}$ and $\boldsymbol{x_2}$ values for Moss Landing 7 are taken from Table B-2 in Appendix B:

a = -0.0013	x_1 = 50 MW
b = 2.955	x_2 =185 MW
c = 6561.2	
d = 662025	

Instantaneous Incremental Heat Rates

$$IIHR = 3a\,x_1^2 + 2bx_1 + c$$

$$IIHR(50) = 3(-0.0013)50^2 + 2(2.955)50 + 6561.2 = 6847.95 = \underline{6847}$$

$$IIHR(185) = 3(-0.0013)185^2 + 2(2.955)185 + 6561.2 = 6847.95 = \underline{7521}$$

Average Incremental Heat Rates

$$AIHR = a(x_2^2 + x_2\,x_1 + x_1^2) + b(x_2 + x_1) + c$$

$$= -0.0013(185^2 + 185\text{x}50 + 50^2) + 2.955(185 + 50) + 6561.2 = 7195.86 = \underline{7196}$$

Errors

$$Error = (AIHR - IIHR) / IIHR$$

$$Error\ (50) = (7196 - 6847) / 6847 = 5.1\%$$

$$Error\ (185) = (7196 - 7521) / 7521 = -4.3\%$$

Using ***AIHR*** for estimating ***IIHR*** causes results in a values that is 5.1 percent too high at 50 MW and -4.3 percent too low at 185 MW.

The corresponding errors between ***IIHR*** and ***AIHR*** are calculated for the 50 and 185 MW points. Table C-1 shows the results of similar calculations for PG&E. Tables C-2 and C-3 show the resulting values for SCE and SDG&E, respectively. The columns delineated as "ACTUAL" are the Instantaneous Heat Rate (***IIHR***) values, and the columns delineated as "BLOCKS" are the Average Incremental Heat Rate (***AIHR***) values. The "ERROR" column is calculated as the percent difference between these two values relative to the "ACTUAL" value. Table C-4 summarizes the percent errors of Tables C-1 through C-3 and sorts them from high to low. This is the data that provides the maximum error numbers in Table 3 of the main report. The errors range from 6.9 to -8.6 percent but most are a few percent or less.

TABLE C-1: INCREMENTAL HEAT RATE ERRORS

PG&E UNITS

					INCREMENTAL HEAT RATES		
PLT	Blk	CAPACITY		COEFICIENTS	ACTUAL	BLOCKS	ERROR
Name	#	(%)	(MW)		(Btu/kWh)	(Btu/kWh)	(%)
				a = 0.0148			
con6	1	14%	46	b = -6.0775	8,891	8,756	-1.5%
con6	2	25%	85	c = 9356.2	8,644	8,756	1.3%
con6	3	50%	170	d = 180146	8,573	8,555	-0.2%
con6	4	80%	272	X1 = 46	9,335	8,877	-4.9%
con6	5	100%	340	X2 = 340	10,356	9,811	-5.3%
				a = 0.0099			
con7	1	14%	46	b = -2.9176	8,541	8,496	-0.5%
con7	2	25%	85	c = 8746.7	8,465	8,496	0.4%
con7	3	50%	170	d = 223144	8,613	8,503	-1.3%
con7	4	80%	272	X1 = 46	9,357	8,933	-4.5%
con7	5	100%	340	X2 = 340	10,196	9,754	-4.3%
				a = 0.2946			
hmb1&2	1	10%	10	b = -30.337	10,812	10,543	-2.5%
hmb1&2	2	25%	26	c = 11330	10,350	10,543	1.9%
hmb1&2	3	50%	53	d = 99926	10,597	10,366	-2.2%
hmb1&2	4	80%	84	X1 = 10	12,469	11,392	-8.6%
hmb1&2	5	100%	105	X2 = 105	14,703	13,521	-8.0%
				a = 0.0116			
hnp2	1	9%	10	b = 12.979	10,134	10,364	2.3%
hnp2	2	25%	27	c = 9870.6	10,597	10,364	-2.2%
hnp2	3	50%	54	d = 115531	11,374	10,981	-3.5%
hnp2	4	80%	86	X1 = 10	12,360	11,861	-4.0%
hnp2	5	100%	107	X2 = 107	13,047	12,701	-2.6%
				a = 0.0144			
hnp3	1	9%	10	b = 21.077	9,506	9,876	3.9%
hnp3	2	25%	27	c = 9080	10,250	9,876	-3.6%
hnp3	3	50%	54	d = 117483	11,482	10,861	-5.4%
hnp3	4	80%	86	X1 = 10	13,025	12,246	-6.0%
hnp3	5	100%	107	X2 = 107	14,085	13,552	-3.8%
				a = 0.001			
hnp4	1	19%	62	b = 1.3752	8,841	8,873	0.4%
hnp4	2	25%	82	c = 8659	8,905	8,873	-0.4%
hnp4	3	50%	164	d = 205948	9,191	9,044	-1.6%
hnp4	4	80%	260	X1 = 62	9,577	9,379	-2.1%
hnp4	5	100%	326	X2 = 326	9,874	9,724	-1.5%
				a = 0.0049			
mor1&2	1	19%	62	b = -1.1685	9,410	9,407	0.0%
mor1&2	2	25%	82	c = 9498.3	9,406	9,407	0.0%
mor1&2	3	50%	164	d = 200714	9,510	9,441	-0.7%
mor1&2	4	80%	260	X1 = 62	9,884	9,675	-2.1%
mor1&2	5	100%	326	X2 = 326	10,299	10,081	-2.1%
				a = 0.0006			
mor3	1	14%	46	b = -0.1178	9,057	9,056	0.0%
mor3	2	25%	85	c = 9063.6	9,057	9,056	0.0%
mor3	3	50%	169	d = 190385	9,075	9,064	-0.1%
mor3	4	80%	270	X1 = 46	9,131	9,100	-0.3%
mor3	5	100%	338	X2 = 338	9,190	9,159	-0.3%
				a = 0.0004			
mor4	1	14%	46	b = 1.0588	8,659	8,703	0.5%
mor4	2	25%	85	c = 8559.2	8,748	8,703	-0.5%
mor4	3	50%	169	d = 194590	8,951	8,848	-1.2%
mor4	4	80%	270	X1 = 46	9,218	9,083	-1.5%
mor4	5	100%	338	X2 = 338	9,412	9,314	-1.0%

					INCREMENTAL HEAT RATES		
PLT	Blk	CAPACITY		COEFICIENTS	ACTUAL	BLOCKS	ERROR
Name	#	(%)	(MW)		(Btu/kWh)	(Btu/kWh)	(%)
				a = -0.0021			
mos6	1	7%	50	b = 3.6945	6,952	7,370	6.0%
mos6	2	25%	185	c = 6598.2	7,750	7,370	-4.9%
mos6	3	50%	370	d = 657281	8,470	8,146	-3.8%
mos6	4	80%	591	X1 = 50	8,765	8,668	-1.1%
mos6	5	100%	739	X2 = 739	8,618	8,714	1.1%
				a = -0.0013			
mos7	1	7%	50	b = 2.955	6,847	7,196	5.1%
mos7	2	25%	185	c = 6561.2	7,521	7,196	-4.3%
mos7	3	50%	370	d = 662025	8,214	7,890	-3.9%
mos7	4	80%	591	X1 = 50	8,692	8,485	-2.4%
mos7	5	100%	739	X2 = 739	8,799	8,760	-0.4%
				a = 0.0148			
pit1&2	1	19%	62	b = -5.3036	9,124	9,079	-0.5%
pit1&2	2	25%	82	c = 9610.6	9,039	9,079	0.4%
pit1&2	3	50%	164	d = 293691	9,065	9,003	-0.7%
pit1&2	4	80%	260	X1 = 62	9,854	9,391	-4.7%
pit1&2	5	100%	326	X2 = 326	10,871	10,331	-5.0%
				a = 0.03			
pit3&4	1	19%	62	b = -12.114	9,395	9,276	-1.3%
pit3&4	2	25%	82	c = 10551	9,169	9,276	1.2%
pit3&4	3	50%	164	d = 219614	8,998	8,983	-0.2%
pit3&4	4	80%	260	X1 = 62	10,336	9,529	-7.8%
pit3&4	5	100%	326	X2 = 326	12,218	11,211	-8.2%
				a = -0.0001			
pit5	1	14%	46	b = 1.3632	8,697	8,744	0.5%
pit5	2	25%	81	c = 8572.4	8,791	8,744	-0.5%
pit5	3	50%	163	d = 218209	9,009	8,900	-1.2%
pit5	4	80%	260	X1 = 46	9,261	9,135	-1.4%
pit5	5	100%	325	X2 = 325	9,427	9,344	-0.9%
				a = 0.0056			
pit6	1	14%	46	b = -0.0515	8,581	8,613	-0.1%
pit6	2	25%	81	c = 8550.1	8,652	8,613	-1.0%
pit6	3	50%	163	d = 266012	8,980	8,797	-1.8%
pit6	4	80%	260	X1 = 46	9,659	9,293	-3.9%
pit6	5	100%	325	X2 = 325	10,291	9,963	-3.1%
				a = 0.0023			
pit7	1	17%	120	b = -1.845	8,608	8,555	-0.6%
pit7	2	25%	180	c = 8951.1	8,510	8,555	0.5%
pit7	3	50%	360	d = 632496	8,517	8,476	-0.5%
pit7	4	80%	576	X1 = 120	9,115	8,762	-3.9%
pit7	5	100%	720	X2 = 720	9,871	9,469	-4.1%
				a = 0.0468			
pot3	1	23%	47	b = -11.985	9,092	9,066	-0.3%
pot3	2	25%	52	c = 9908	9,041	9,066	0.3%
pot3	3	50%	104	d = 70409	8,934	8,924	-0.1%
pot3	4	80%	166	X1 = 47	9,798	9,276	-5.3%
pot3	5	100%	207	X2 = 207	10,962	10,341	-5.7%

TABLE C-2: INCREMENTAL HEAT RATES ERRORS

SCE UNITS

					INCREMENTAL HEAT RATES								INCREMENTAL HEAT RATES		
PLT Name	Blk #	CAPACITY (%)	(MW)	COEFICIENTS	ACTUAL (Btu/kWh)	BLOCKS (Btu/kWh)	ERROR (%)	PLT Name	Blk #	CAPACITY (%)	(MW)	COEFICIENTS	ACTUAL (Btu/kWh)	BLOCKS (Btu/kWh)	ERROR (%)
				a = 0.0018								a = 0.0004			
ala1&2	1	6%	20	b = 0.8174	9,053	9,127	0.8%	hig1&2	1	12%	8	b = 0.8061	8,405	8,413	0.1%
ala1&2	2	26%	90	c = 9018.2	9,209	9,127	-0.9%	hig1&2	2	27%	18	c = 8392.3	8,422	8,413	-0.1%
ala1&2	3	51%	180	d = 397249	9,487	9,341	-1.5%	hig1&2	3	58%	38	d = 327238	8,455	8,438	-0.2%
ala1&2	4	77%	270	X1 = 20	9,853	9,663	-1.9%	hig1&2	4	85%	56	X1 = 8	8,486	8,471	-0.2%
ala1&2	5	100%	350	X2 = 350	10,252	10,047	-2.0%	hig1&2	5	100%	66	X2 = 66	8,504	8,495	-0.1%
				a = 0.0005								a = -0.0086			
ala3&4	1	6%	40	b = 0.4401	8,376	8,443	0.8%	hig3&4	1	11%	10	b = 5.647	7,825	7,899	0.9%
ala3&4	2	25%	160	c = 8338.1	8,517	8,443	-0.9%	hig3&4	2	27%	24	c = 7715.1	7,971	7,899	-0.9%
ala3&4	3	50%	320	d = 677108	8,773	8,639	-1.5%	hig3&4	3	56%	50	d = 588318	8,215	8,096	-1.4%
ala3&4	4	75%	480	X1 = 40	9,106	8,933	-1.9%	hig3&4	4	90%	80	X1 = 10	8,454	8,338	-1.4%
ala3&4	5	100%	640	X2 = 640	9,516	9,305	-2.2%	hig3&4	5	100%	89	X2 = 89	8,516	8,485	-0.4%
				a = -0.0006								a= 0.0011			
ala5&6	1	27%	260	b = 2.2408	7,887	8,155	3.4%	hun1&2	1	9%	40	b = 0.618	8,466	8,552	1.0%
ala5&6	2	44%	420	c = 6843.4	8,408	8,155	-3.0%	hun1&2	2	33%	140	c = 8411.7	8,649	8,552	-1.1%
ala5&6	3	63%	600	d = 1.00E+06	8,884	8,656	-2.6%	hun1&2	3	56%	240	d = 326693	8,898	8,768	-1.5%
ala5&6	4	81%	780	X1 = 260	9,244	9,074	-1.8%	hun1&2	4	79%	340	X1 = 40	9,213	9,050	-1.8%
ala5&6	5	100%	960	X2 = 960	9,487	9,375	-1.2%	hun1&2	5	100%	430	X2 = 430	9,553	9,379	-1.8%
				a = 0.0293								a= 0.0004			
cw01	1	26%	17	b = 6.185	9,215	9,320	1.1%	lbc8&9	1	11%	70	b = -0.0512	9,600	9,608	0.1%
cw01	2	46%	30	c = 8979.5	9,430	9,320	-1.2%	lbc8&9	2	33%	180	c = 9600.9	9,621	9,608	-0.1%
cw01	3	66%	43	d = 48471	9,674	9,549	-1.3%	lbc8&9	3	56%	300	d = 210025	9,678	9,647	-0.3%
cw01	4	86%	56	X1 = 17	9,948	9,808	-1.4%	lbc8&9	4	78%	410	X1 = 70	9,761	9,717	-0.4%
cw01	5	100%	65	X2 = 65	10,155	10,050	-1.0%	lbc8&9	5	100%	560	X2 = 560	9,920	9,836	-0.8%
				a = 0.0203								a = 0.0022			
cw02	1	23%	19	b = 3.2256	9,293	9,368	0.8%	man1&2	1	9%	40	b = 0.8052	8,314	8,443	1.6%
cw02	2	43%	35	c = 9148.4	9,449	9,368	-0.9%	man1&2	2	33%	140	c = 8238.8	8,594	8,443	-1.8%
cw02	3	63%	51	d = 56315	9,636	9,540	-1.0%	man1&2	3	56%	245	d = 301952	9,030	8,799	-2.5%
cw02	4	83%	67	X1 = 19	9,854	9,742	-1.1%	man1&2	4	79%	340	X1 = 40	9,549	9,279	-2.8%
cw02	5	100%	81	X2 = 81	10,071	9,960	-1.1%	man1&2	5	100%	430	X2 = 430	10,152	9,842	-3.1%
				a = 0.0035								a = 0.0006			
cw34	1	27%	140	b = -1.4482	7,006	7,013	0.1%	orb1	1	33%	250	b = 0.3588	8,065	8,171	1.3%
cw34	2	35%	180	c = 7206.1	7,025	7,013	-0.2%	orb1	2	49%	370	c = 7773.3	8,285	8,171	-1.4%
cw34	3	47%	240	d = 993648	7,116	7,064	-0.7%	orb1	3	67%	500	d = 737960	8,582	8,429	-1.8%
cw34	4	74%	380	X1 = 140	7,622	7,334	-3.8%	orb1	4	83%	620	X1 = 250	8,910	8,742	-1.9%
cw34	5	100%	512	X2 = 512	8,476	8,018	-5.4%	orb1	5	100%	750	X2 = 750	9,324	9,112	-2.3%
				a = 0.0010								a = 0.0005			
els1&2	1	6%	20	b = 0.7726	9,161	9,224	0.7%	orb2	1	7%	50	b = 0.4250	8,089	8,192	1.3%
els1&2	2	26%	90	c = 9129.0	9,292	9,224	-0.7%	orb2	2	30%	225	c = 8043.1	8,310	8,192	-1.4%
els1&2	3	51%	180	d = 373847	9,504	9,394	-1.2%	orb2	3	53%	400	d = 590522	8,623	8,459	-1.9%
els1&2	4	77%	270	X1 = 20	9,765	9,631	-1.4%	orb2	4	77%	575	X1 = 50	9,028	8,818	-2.3%
els1&2	5	100%	350	X2 = 360	10,037	9,898	-1.4%	orb2	5	100%	750	X2 = 750	9,524	9,268	-2.7%
				a = 0.0004								a = 0.0007			
els3&4	1	6%	40	b = 0.4377	8,331	8,395	0.8%	red5&6	1	6%	20	b = 0.6815	8,938	8,992	0.6%
els3&4	2	24%	160	c = 8294.0	8,465	8,395	-0.8%	red5&6	2	26%	90	c = 8910	9,050	8,992	-0.6%
els3&4	3	48%	320	d = 652689	8,697	8,576	-1.4%	red5&6	3	51%	180	d = 453856	9,223	9,134	-1.0%
els3&4	4	72%	480	X1 = 40	8,991	8,839	-1.7%	red5&6	4	77%	270	X1 = 20	9,431	9,324	-1.1%
els3&4	5	100%	670	X2 = 670	9,419	9,198	-2.4%	red5&6	5	100%	350	X2 = 350	9,644	9,535	-1.1%
				a = 0.0053								a = 0.0002			
eti1&2	1	8%	20	b = 1.7528	9,121	9,264	1.6%	red7&8	1	27%	260	b = 0.2479	8,515	8,557	0.5%
eti1&2	2	30%	80	c = 9044.1	9,426	9,264	-1.7%	red7&8	2	38%	360	c = 8345.6	8,602	8,557	-0.5%
eti1&2	3	53%	140	d = 315310	9,847	9,627	-2.2%	red7&8	3	69%	660	d = 727238	8,934	8,759	-2.0%
eti1&2	4	76%	200	X1 = 20	10,381	10,104	-2.7%	red7&8	4	83%	800	X1 = 260	9,126	9,028	-1.1%
eti1&2	5	100%	264	X2 = 264	11,078	10,719	-3.2%	red7&8	5	100%	960	X2 = 960	9,375	9,248	-1.4%
				a = 0.0005								a = -0.0099			
eti3&4	1	6%	40	b = 0.4642	8,368	8,438	0.8%	sbr1&2	1	11%	14	b = 7.9479	8,477	8,681	2.4%
eti3&4	2	25%	160	c = 8328.1	8,515	8,438	-0.9%	sbr1&2	2	33%	42	c = 8260.7	8,876	8,681	-2.2%
eti3&4	3	50%	320	d = 585227	8,779	8,641	-1.6%	sbr1&2	3	56%	70	d = 267439	9,228	9,056	-1.9%
eti3&4	4	75%	480	X1 = 40	9,119	8,943	-1.9%	sbr1&2	4	78%	98	X1 = 14	9,533	9,384	-1.6%
eti3&4	5	100%	640	X2 = 640	9,537	9,322	-2.3%	sbr1&2	5	100%	126	X2 = 126	9,792	9,667	-1.3%

TABLE C-3: INCREMENTAL HEAT RATE ERRORS

SDG&E UNITS

PLT	Blk	CAPACITY		COEFICIENTS	INCREMENTAL HEAT RATES		
					ACTUAL	BLOCKS	ERROR
Name	#	(%)	(MW)		(Btu/kWh)	(Btu/kWh)	(%)
				a = 0.0806			
enc1	1	18.7%	20	b = -0.0003	9,046	9,082	0.40%
enc1	2	25.0%	27	c = 8949.0	9,122	9,082	-0.44%
enc1	3	50.0%	54	d = 86,430	9,641	9,353	-2.99%
enc1	4	80.0%	86	X1 = 20	10,722	10,140	-5.42%
enc1	5	100.0%	107	X2 = 107	11,719	11,202	-4.41%
				a = 0.0597			
enc2	1	19.2%	20	b = 0.0023	9,607	9,630	0.25%
enc2	2	25.0%	26	c = 9535.0	9,656	9,630	-0.27%
enc2	3	50.0%	52	d = 66,030	10,020	9,818	-2.01%
enc2	4	80.0%	83	X1 = 20	10,775	10,368	-3.78%
enc2	5	100.0%	104	X2 = 104	11,473	11,111	-3.15%
				a = 0.0349			
enc3	1	18.2%	20	b = 0.0034	9,822	9,840	0.18%
enc3	2	25.0%	28	c = 9780.0	9,859	9,840	-0.20%
enc3	3	50.0%	55	d = 62,840	10,097	9,965	-1.31%
enc3	4	80.0%	88	X1 = 20	10,590	10,325	-2.51%
enc3	5	100.0%	110	X2 = 110	11,046	10,810	-2.14%
				a = 0.0048			
enc4	1	6.7%	20	b = 0.0010	9,443	9,473	0.32%
enc4	2	25.0%	75	c = 9437.0	9,518	9,473	-0.47%
enc4	3	50.0%	150	d = 164,700	9,759	9,625	-1.37%
enc4	4	80.0%	240	X1 = 20	10,261	9,991	-2.63%
enc4	5	100.0%	300	X2 = 300	10,724	10,484	-2.24%
				a = 0.0049			
enc5	1	6.1%	20	b = 0.0010	8,981	9,018	0.42%
enc5	2	25.0%	83	c = 8975.0	9,075	9,018	-0.62%
enc5	3	50.0%	165	d = 193,100	9,373	9,207	-1.77%
enc5	4	80.0%	264	X1 = 20	9,994	9,660	-3.34%
enc5	5	100.0%	330	X2 = 330	10,567	10,270	-2.81%
				a = 0.0386			
sba1	1	21.0%	30	b = 0.0094	8,633	8,654	0.25%
sba1	2	25.0%	36	c = 8528.0	8,677	8,654	-0.26%
sba1	3	50.0%	72	d = 112,300	9,121	8,874	-2.71%
sba1	4	80.0%	114	X1 = 30	10,046	9,548	-4.95%
sba1	5	100.0%	143	X2 = 143	10,899	10,456	-4.06%
				a = 0.0147			
sba2	1	20.0%	30	b = -0.0041	8,890	8,900	0.12%
sba2	2	25.0%	38	c = 8850.0	8,912	8,900	-0.13%
sba2	3	50.0%	75	d = 88,070	9,098	8,995	-1.14%
sba2	4	80.0%	120	X1 = 30	9,485	9,277	-2.20%
sba2	5	100.0%	150	X2 = 150	9,843	9,658	-1.88%
				a = 0.0162			
sba3	1	17.1%	30	b = 0.0004	8,917	8,940	0.26%
sba3	2	25.0%	44	c = 8873.0	8,966	8,940	-0.29%
sba3	3	50.3%	88	d = 107,800	9,244	9,089	-1.67%
sba3	4	80.1%	140	X1 = 30	9,823	9,511	-3.17%
sba3	5	100.0%	175	X2 = 175	10,357	10,080	-2.67%
				a = 0.0182			
sba4	1	30.0%	45	b = -0.0052	10,540	10,630	0.85%
sba4	2	50.0%	75	c = 10430.0	10,736	10,630	-0.99%
sba4	3	80.0%	120	d = 147,600	11,214	10,957	-2.30%
sba4	5	100.0%	150	X1 = 45	11,656	11,427	-1.96%
				X2 = 150		10,838	

TABLE C-4: SUMMARY OF INCREMENTAL HEAT RATE ERRORS

----- CONTINUED -----

PG&E UNITS		**SCE UNITS**		**SDG&E UNITS**		**PG&E UNITS**		**SCE UNITS**	
UNIT	ERROR	UNIT	ERROR	UNIT	ERROR	UNIT	ERROR	UNIT	ERROR
mos6	6.0%	ala5&6	3.4%	sba4	0.9%	pit6	-1.8%	cw01	-1.2%
mos7	5.1%	sbr1&2	2.4%	enc5	0.4%	hnp4	-2.1%	ala5&6	-1.2%
hnp3	3.9%	eti1&2	1.6%	enc1	0.4%	mor1&2	-2.1%	sbr1&2	-1.3%
hnp2	2.3%	man1&2	1.6%	enc4	0.3%	mor1&2	-2.1%	cw01	-1.3%
hmb1&2	1.9%	orb1	1.3%	sba3	0.3%	hmb1&2	-2.2%	red7&8	-1.4%
con6	1.3%	orb2	1.3%	sba1	0.2%	hnp2	-2.2%	hig3&4	-1.4%
pit3&4	1.2%	cw01	1.1%	enc2	0.2%	mos7	-2.4%	els1&2	-1.4%
mos6	1.1%	hun1&2	1.0%	enc3	0.2%	hmb1&2	-2.5%	orb1	-1.4%
pit5	0.5%	hig3&4	0.9%	sba2	0.1%	hnp2	-2.6%	els1&2	-1.4%
pit7	0.5%	eti3&4	0.8%	sba2	-0.1%	pit6	-3.1%	els3&4	-1.4%
mor4	0.5%	ala1&2	0.8%	enc3	-0.2%	hnp2	-3.5%	cw01	-1.4%
pit1&2	0.4%	cw02	0.8%	sba1	-0.3%	hnp3	-3.6%	orb2	-1.4%
con7	0.4%	ala3&4	0.8%	enc2	-0.3%	hnp3	-3.8%	hig3&4	-1.4%
hnp4	0.4%	els3&4	0.8%	sba3	-0.3%	mos6	-3.8%	hun1&2	-1.5%
pot3	0.3%	els1&2	0.7%	enc1	-0.4%	pit7	-3.9%	ala3&4	-1.5%
mor1&2	0.0%	red5&6	0.6%	enc4	-0.5%	pit6	-3.9%	ala1&2	-1.5%
mor3	0.0%	red7&8	0.5%	enc5	-0.6%	mos7	-3.9%	sbr1&2	-1.6%
mor3	0.0%	hig1&2	0.1%	sba4	-1.0%	hnp2	-4.0%	eti3&4	-1.6%
mor1&2	0.0%	cw34	0.1%	sba2	-1.1%	pit7	-4.1%	els3&4	-1.7%
pot3	-0.1%	lbc8&9	0.1%	enc3	-1.3%	mos7	-4.3%	eti1&2	-1.7%
mor3	-0.1%	hig1&2	-0.1%	enc4	-1.4%	con7	-4.3%	man1&2	-1.8%
pit6	-0.1%	hig1&2	-0.1%	sba3	-1.7%	con7	-4.5%	hun1&2	-1.8%
pit3&4	-0.2%	lbc8&9	-0.1%	enc5	-1.8%	pit1&2	-4.7%	orb1	-1.8%
con6	-0.2%	cw34	-0.2%	sba2	-1.9%	mos6	-4.9%	hun1&2	-1.8%
pot3	-0.3%	hig1&2	-0.2%	sba4	-2.0%	con6	-4.9%	ala5&6	-1.8%
mor3	-0.3%	hig1&2	-0.2%	enc2	-2.0%	pit1&2	-5.0%	sbr1&2	-1.9%
mor3	-0.3%	lbc8&9	-0.3%	enc3	-2.1%	con6	-5.3%	orb1	-1.9%
hnp4	-0.4%	hig3&4	-0.4%	sba2	-2.2%	pot3	-5.3%	ala3&4	-1.9%
mos7	-0.4%	lbc8&9	-0.4%	enc4	-2.2%	hnp3	-5.4%	orb2	-1.9%
pit7	-0.5%	red7&8	-0.5%	sba4	-2.3%	pot3	-5.7%	ala1&2	-1.9%
pit1&2	-0.5%	red5&6	-0.6%	enc3	-2.5%	hnp3	-6.0%	eti3&4	-1.9%
mor4	-0.5%	cw34	-0.7%	enc4	-2.6%	pit3&4	-7.8%	red7&8	-2.0%
con7	-0.5%	els1&2	-0.7%	sba3	-2.7%	hmb1&2	-8.0%	ala1&2	-2.0%
pit5	-0.5%	els3&4	-0.8%	sba1	-2.7%	pit3&4	-8.2%	sbr1&2	-2.2%
pit7	-0.6%	lbc8&9	-0.8%	enc5	-2.8%	hmb1&2	-8.6%	ala3&4	-2.2%
pit1&2	-0.7%	cw02	-0.9%	enc1	-3.0%			eti1&2	-2.2%
mor1&2	-0.7%	ala3&4	-0.9%	enc2	-3.2%			eti3&4	-2.3%
pit5	-0.9%	ala1&2	-0.9%	sba3	-3.2%			orb1	-2.3%
pit6	-1.0%	hig3&4	-0.9%	enc5	-3.3%			orb2	-2.3%
mor4	-1.0%	eti3&4	-0.9%	enc2	-3.8%			els3&4	-2.4%
mos6	-1.1%	red5&6	-1.0%	sba1	-4.1%			man1&2	-2.5%
mor4	-1.2%	cw02	-1.0%	enc1	-4.4%			ala5&6	-2.6%
pit5	-1.2%	cw01	-1.0%	sba1	-5.0%			eti1&2	-2.7%
pit3&4	-1.3%	red7&8	-1.1%	enc1	-5.4%			orb2	-2.7%
con7	-1.3%	cw02	-1.1%					man1&2	-2.8%
pit5	-1.4%	hun1&2	-1.1%					ala5&6	-3.0%
mor4	-1.5%	red5&6	-1.1%					man1&2	-3.1%
con6	-1.5%	red5&6	-1.1%					eti1&2	-3.2%
hnp4	-1.5%	cw02	-1.1%					cw34	-3.8%
hnp4	-1.6%	els1&2	-1.2%					cw34	-5.4%

APPENDIX D
AVERAGE TO INCREMENTAL HEAT RATE RATIOS

This Appendix provides the detailed description for the calculation of Average Heat Rate (***AHR***) to Incremental Heat Rate (***IHR***) presented in Section VI of the main body of this report. These Ratios, **$R(x)$**, are calculated using the equations described in Appendix B and are done for three cases:

- The ***AHR/IHR*** at minimum generation: **$R(x_1)$**
- The ***AHR/IHR*** at maximum generation: **$R(x_2)$**
- The average ***AHR/IHR***: **R_{AVE}**

The minimum generation ratio, **$R(x_1)$**, and maximum generation ratio, **$R(x_2)$**, are calculated using the equations for the Average Heat Rate (***AHR***) and Incremental Heat Rate (***IHR***) curves for each unit, as follows.

The Input-Output Curve is defined by the third order equation:

$$y = ax^3 + bx^2 + cx + d$$

Where: **x** = Output in MW
y = Input in Btu/hr
a-d = The coefficients that define the equation

The Average Heat Rate (***AHR***) is defined as the Input-Output Curve (y) divided by the output (***x***):

$$AHR = y/x = (ax^3 + bx^2 + cx + d) / x$$

The Incremental Heat Rate (***IHR***) is defined as the first derivative of the Input-Output Curve:

$$IHR = dy/dx = 3ax2^2 + 2bx + c$$

The Ratio ***(R)*** of Average Heat Rate ***(AHR)*** to Incremental Heat Rate ***(IHR)*** is therefore:

$$R = AHR/IHR = (y/x) / dy/dx = [(ax^3+bx^2+cx+d)/x] / (3ax^2+2bx+c)$$

The minimum and maximum generation values of the ***R*** are then developed by setting ***x*** equal to the minimum (x_1) and maximum (x_2) output capacities of the units.

The average value, R_{AVE}, is found by integrating R from the minimum capacity (x_1) to the maximum capacity (x_2), and then dividing this result by the difference between the minimum and maximum outputs ($x_2 - x_1$):

$$R_{AVE} = [\int R\,dx \;\{\text{from } x_1 \text{ to } x_2\}] \;/\; (x_2 - x_1)$$

$$= [\int AHR/IHR\,dx \;\{\text{from } x_1 \text{ to } x_2\}] \;/\; (x_2 - x_1)$$

Where: x_1 = ***Minimum Operating Level(MW)***
x_2 = ***Maximum Operating Level (MW)***

The integration of R, ($\int R\,dx$), is:

$$\int R\,dx = [(x/3) + (d \cdot Ln(x)/c) + (bG/18a) - (dG/2c) + (2cE/3F) - (bdE/cF) - (Eb^2/9aF)]$$

Where: $E = ATan((3ax+b)/F)$
$F = (3ab-x^2)^{1/2}$
$G = Ln(3ax^2+2bx+c)$
Ln = ***Natural Log***
$ATan$ = ***Arc Tangent***

Moss Landing 7, once again, provides the necessary step-by-step illustration. The above equations can be evaluated using the values in Table B-2, of Appendix B: the coefficients (***a-d***) and the x_1 and x_2 values.

a = -0.0013	x_1 = 50 MW
b = 2.955	x_2 = 739 MW
c = 6561.2	
d = 662025	

The $R(x)$ values are now calculated as follows:

- The ***AHR/IHR*** at minimum generation: $R(x_1)$

$R(x_1) = AHR/IHR = (ax^3+bx^2+cx+d)/x] / (3ax^2+2bx+c)$: for x_1 = 50 MW

$R(50) = AHR/IHR =$ (-0.0013*50^3+2.955*50^2+6561.2*50+662025)/50]
/ (3* -0.0013*50^2+2*2.955*50+662025) = <u>2.91</u>

- The ***AHR/IHR*** at maximum generation: $R(x_2)$

$R(x_2) = AHR/IHR = (y/x)/y' = [(ax^3+bx^2+cx+d)/x] / (3ax^2+2bx+c)$: x_2 = 739 MW

$R(739) = AHR/IHR =$ (-0.0013*739^3+2.955*739^2+6561.2*739+662025)/739]
/ (3* -0.0013*739^2+2*2.955*739+662025) = <u>1.02</u>

- The average ***AHR/IHR***: $\boldsymbol{R_{AVE}}$

$$R_{AVE} = [\int R\,dx\ \{\text{from } x_1 \text{ to } x_2\}] / (x_2 - x_1)$$

The integration of $\boldsymbol{R}$, ($\int R\,dx$), is:

$$\int R\,dx = [(x/3) + (d \cdot Ln(x)/c) + (bG/18a) - (dG/2c) + (2cE/3F) - (bdE/cF) - (Eb^2/9aF)]$$

Where: $E = ATan((3ax+b)/F)$
$F = (3ab-x^2)^{1/2}$
$G = Ln(3ax^2+2bx+c)$
Ln = Natural Log
$ATan$ = Arc Tangent

$$R(739) = (739/3)+(662025\ln(739)/6561.2)+(2.955\boldsymbol{G}/18/-0.0013)-(662025\boldsymbol{G}/2/6561.2)$$
$$+(2\cdot 6561.2\boldsymbol{E}/3\boldsymbol{F}) -(2.955\cdot 662025\boldsymbol{E}/6561.2\boldsymbol{F})-(2.955^2\boldsymbol{E}/9\cdot -0.0013\boldsymbol{F})$$

Where: $\boldsymbol{E} = \text{ATan}((3\cdot -0.0013\cdot 739+2.955)/F)$
$\boldsymbol{F} = (3\cdot -0.0013\cdot 2.955-739^2)^{1/2}$
$\boldsymbol{G} = \text{Ln}(3\cdot -0.0013\cdot 739^2+2\cdot 2.955\cdot 739+6561.2)$

$$R(50) = (50/3)+(662025\ln(50)/6561.2)+(2.955\boldsymbol{G}/18/-0.0013)-(662025\boldsymbol{G}/2/6561.2)$$
$$+(2\cdot 6561.2\boldsymbol{E}/3\boldsymbol{F}) -(2.955\cdot 662025\boldsymbol{E}/6561.2\boldsymbol{F})-(2.955^2\boldsymbol{E}/9\cdot -0.0013\boldsymbol{F})$$

Where: $\boldsymbol{E} = \text{ATan}((3\cdot -0.0013\cdot 50+2.955)/\boldsymbol{F})$
$\boldsymbol{F} = (3\cdot -0.0013\cdot 2.955-50^2)^{1/2}$
$\boldsymbol{G} = \text{Ln}(3\cdot -0.0013\cdot 50^2+2\cdot 2.955\cdot 50+6561.2)$

$$R_{AVE} = [R(739) - R(50)] / (739 - 50) = \underline{1.26}$$

This is prohibitive to do as a hand calculation and an attempt to use an Excel spreadsheet failed due to imaginary numbers being part of the solution. This required that Math Lab be used directly.

Table D-2 shows the results of calculating the $\boldsymbol{R(x)}$ values for the IOU units. Table D-2CALCS shows the calculation of the system average values for each of the $\boldsymbol{R(x)}$ values:

- System average $\boldsymbol{R(x_1)}$ is weighted by $\boldsymbol{x_1}$.
- System average $\boldsymbol{R(x_2)}$ is weighted by $\boldsymbol{x_2}$.
- System average $\boldsymbol{R_{AVE}}$ is weighted by $\boldsymbol{x_1 - x_2}$.

Table D-3 is the same as Table D-2 except that the data has been sorted by $\boldsymbol{R(x_1)}$.The Figure D-1 series shows this same data graphically.

TABLE D-2: SUMMARY OF *R(X)* VALUES

	OUTPUT (MW)		AVERAGE/INCREMENTAL		
	X1	**X2**	**R(X1)**	**R(X2)**	**Rave**
PG&E UNITS					
Contra Costa 6	46	340	1.46	0.92	1.13
Contra Costa 7	46	340	1.58	0.94	1.14
Humboldt 1&2	10	105	1.95	0.84	1.18
Hunters Point 2	10	107	2.13	0.96	1.19
Hunters Point 3	10	107	2.21	0.89	1.16
Hunters Point 4	62	326	1.37	1.00	1.10
Morro Bay 1&2	62	326	1.35	1.00	1.11
Morro Bay 3	46	338	1.46	1.05	1.14
Morro Bay 4	46	338	1.48	1.01	1.12
Moss Landing 6	50	739	2.87	1.05	1.25
Moss Landing 7	50	739	2.91	1.02	1.26
Pittsburg 1&2	62	326	1.54	0.95	1.17
Pittsburg 3&4	62	326	1.43	0.86	1.13
Pittsburg 5	46	325	1.54	1.03	1.14
Pittsburg 6	46	325	1.67	0.97	1.16
Pittsburg 7	120	720	1.62	0.97	1.20
Potrero 3	47	207	1.20	0.89	1.05
Averages			**1.68**	**0.98**	**1.17**
SCE UNITS					
Alamitos 1&2	20	350	3.19	1.04	1.34
Alamitos 3&4	40	640	3.02	1.04	1.33
Alamitos 5&6	260	960	1.42	1.00	1.12
Cool Water 1	17	65	1.30	1.01	1.10
Cool Water 2	19	81	1.31	1.02	1.11
Cool Water 3&4	140	512	2.02	1.10	1.43
El Segundo 1&2	20	350	3.04	1.05	1.32
El Segundo 3&4	40	670	2.96	1.03	1.31
Etiwanda 1&2	20	264	2.72	1.00	1.30
Etiwanda 3&4	40	640	2.75	1.02	1.28
Highgrove 1&2	8	66	5.87	1.58	2.41
Highgrove 3&4	10	89	8.51	1.73	2.99
Huntington Beach 1&2	40	430	1.96	1.01	1.20
Long Beach 8&9	70	560	1.31	1.02	1.08
Mandalay 1&2	40	430	1.90	0.95	1.16
Ormond Beach 1	250	750	1.35	1.00	1.13
Ormond Beach 2	50	750	2.46	0.99	1.23
Redondo Beach 5&6	20	350	3.54	1.09	1.41
Redondo Beach 7&8	260	960	1.32	1.02	1.12
San Bernardino 1&2	14	126	3.24	1.15	1.54
Averages			**1.83**	**1.03**	**1.27**
SDG&E UNITS					
Encina 1	20	107	1.47	0.91	1.10
Encina 2	20	104	1.34	0.94	1.08
Encina 3	20	110	1.32	0.98	1.09
Encina 4	20	300	1.87	0.97	1.13
Encina 5	20	330	2.07	0.95	1.15
South Bay 1	30	143	1.43	0.93	1.10
South Bay 2	30	150	1.33	0.99	1.10
South Bay 3	30	175	1.40	0.96	1.10
South Bay 4	45	150	1.30	1.01	1.12
Averages			**1.47**	**0.96**	**1.12**

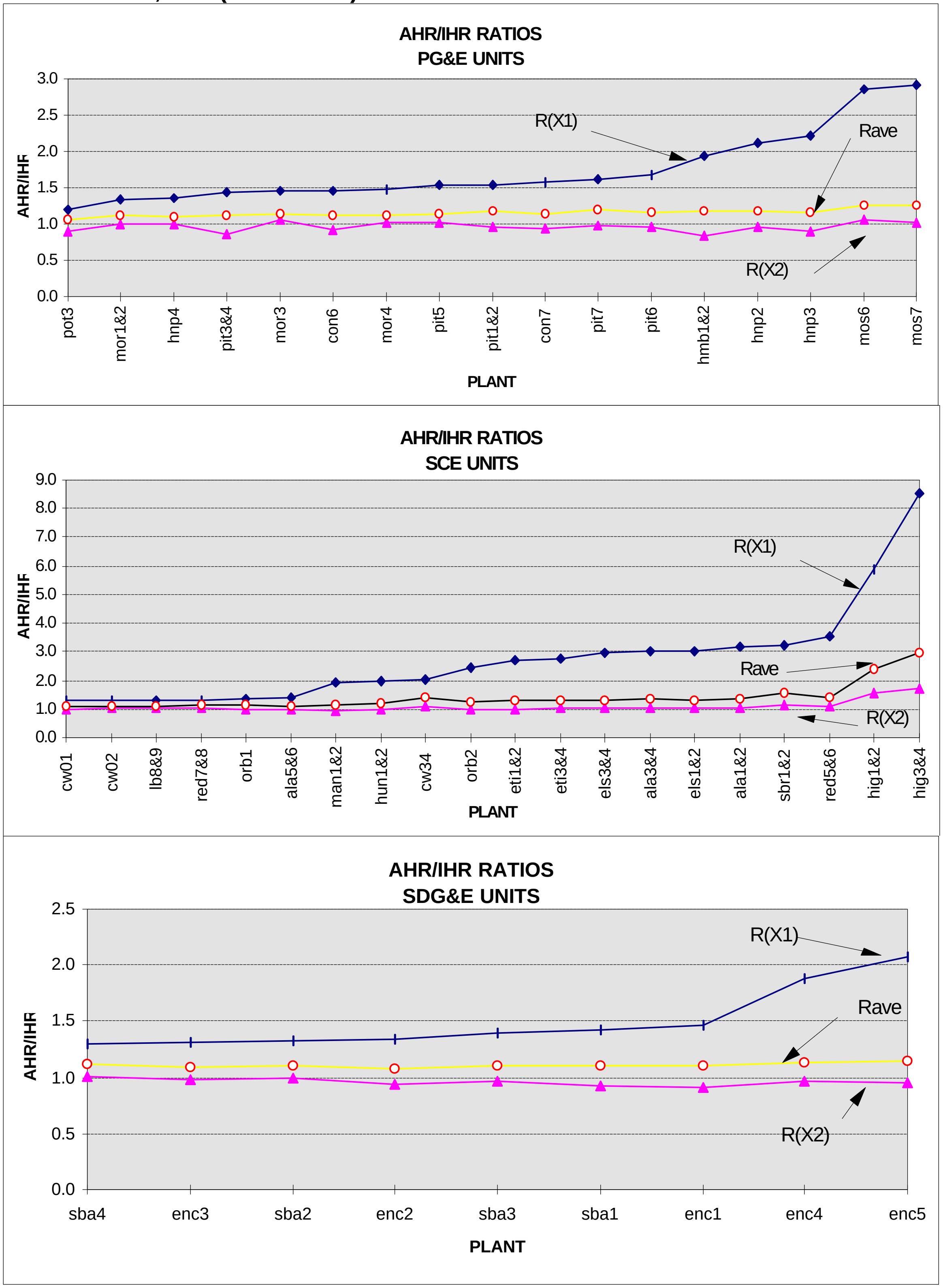
TABLE D-2CALCS: CALCULATIONS OF *R(X)* VALUES

	OUTPUT (MW)			AVERAGE/INCREMENTAL			WEIGHTED		
	X1	**X2**	**X2-X1**	**R(X1)**	**R(X2)**	**Rave**	X1*R(X1)	X2*R(X2)	(X2-X1)*Rave
PG&E UNITS									
Contra Costa 6	46	340	294	1.46	0.92	1.13	67.38	312.90	331.05
Contra Costa 7	46	340	294	1.58	0.94	1.14	72.62	318.64	335.53
Humboldt 1&2	10	105	95	1.95	0.84	1.18	19.47	88.15	112.12
Hunters Point 2	10	107	97	2.13	0.96	1.19	21.27	102.29	115.01
Hunters Point 3	10	107	97	2.21	0.89	1.16	22.13	95.70	112.14
Hunters Point 4	62	326	264	1.37	1.00	1.10	84.64	325.04	291.36
Morro Bay 1&2	62	326	264	1.35	1.00	1.11	83.56	324.58	293.52
Morro Bay 3	46	338	292	1.46	1.05	1.14	67.04	355.14	332.86
Morro Bay 4	46	338	292	1.48	1.01	1.12	68.20	342.54	327.98
Moss Landing 6	50	739	689	2.87	1.05	1.25	143.29	777.84	863.32
Moss Landing 7	50	739	689	2.91	1.02	1.26	145.66	750.09	867.86
Pittsburg 1&2	62	326	264	1.54	0.95	1.17	95.65	310.53	310.16
Pittsburg 3&4	62	326	264	1.43	0.86	1.13	88.81	279.21	297.84
Pittsburg 5	46	325	279	1.54	1.03	1.14	70.76	333.60	318.42
Pittsburg 6	46	325	279	1.67	0.97	1.16	76.89	314.02	323.98
Pittsburg 7	120	720	600	1.62	0.97	1.20	194.87	701.06	719.37
Potrero 3	47	207	160	1.20	0.89	1.05	56.59	184.54	168.72
Totals/Averages	821	6,034	5,213	**1.68**	**0.98**	**1.17**	1,378.84	5,915.85	6,121.23
SCE UNITS									
Alamitos 1&2	20	350	330	3.19	1.04	1.34	63.84	363.93	441.73
Alamitos 3&4	40	640	600	3.02	1.04	1.33	120.75	664.66	798.01
Alamitos 5&6	260	960	700	1.42	1.00	1.12	370.26	959.64	782.81
Cool Water 1	17	65	48	1.30	1.01	1.10	22.03	65.62	53.02
Cool Water 2	19	81	62	1.31	1.02	1.11	24.90	82.35	68.80
Cool Water 3&4	140	512	372	2.02	1.10	1.43	283.13	563.18	531.03
El Segundo 1&2	20	350	330	3.04	1.05	1.32	60.78	369.00	436.30
El Segundo 3&4	40	670	630	2.96	1.03	1.31	118.27	693.30	824.97
Etiwanda 1&2	20	264	244	2.72	1.00	1.30	54.49	263.83	316.85
Etiwanda 3&4	40	640	600	2.75	1.02	1.28	109.84	653.94	767.97
Highgrove 1&2	8	66	58	5.87	1.58	2.41	46.93	104.04	139.63
Highgrove 3&4	10	89	79	8.51	1.73	2.99	85.11	154.26	236.14
Huntington Beach 1&2	40	430	390	1.96	1.01	1.20	78.45	433.93	466.24
Long Beach 8&9	70	560	490	1.31	1.02	1.08	91.88	568.63	531.22
Mandalay 1&2	40	430	390	1.90	0.95	1.16	76.13	410.62	451.86
Ormond Beach 1	250	750	500	1.35	1.00	1.13	336.39	753.21	566.67
Ormond Beach 2	50	750	700	2.46	0.99	1.23	122.85	742.61	861.31
Redondo Beach 5&6	20	350	330	3.54	1.09	1.41	70.75	382.18	466.05
Redondo Beach 7&8	260	960	700	1.32	1.02	1.12	342.61	975.45	783.35
San Bernardino 1&2	14	126	112	3.24	1.15	1.54	45.37	144.47	172.40
Totals/Averages	1,378	9,043	7,665	**1.83**	**1.03**	**1.27**	2,524.77	9,348.82	9,696.34
SDG&E UNITS									
Encina 1	20	107	87	1.47	0.91	1.10	29.41	97.52	95.76
Encina 2	20	104	84	1.34	0.94	1.08	26.77	98.04	90.64
Encina 3	20	110	90	1.32	0.98	1.09	26.34	107.28	97.66
Encina 4	20	300	280	1.87	0.97	1.13	37.43	291.36	317.74
Encina 5	20	330	310	2.07	0.95	1.15	41.49	315.13	356.79
South Bay 1	30	143	113	1.43	0.93	1.10	42.77	132.57	124.51
South Bay 2	30	150	120	1.33	0.99	1.10	39.82	148.86	132.03
South Bay 3	30	175	145	1.40	0.96	1.10	41.99	168.69	159.63
South Bay 4	45	150	105	1.30	1.01	1.12	58.69	152.15	117.77
Totals/Averages			1.47	**1.47**	**0.96**	**1.12**			

TABLE D-3: SORTED BY $R(X_1)$ VALUES

		OUTPUT (MW)		AVERAGE/INCREMENTAL		
		X1	**X2**	**R(X1)**	**R(X2)**	**Rave**
PG&E UNITS	ABREV,					
Potrero 3	pot3	47	207	1.20	0.89	1.05
Morro Bay 1&2	mor1&2	62	326	1.35	1.00	1.11
Hunters Point 4	hnp4	62	326	1.37	1.00	1.10
Pittsburg 3&4	pit3&4	62	326	1.43	0.86	1.13
Morro Bay 3	mor3	46	338	1.46	1.05	1.14
Contra Costa 6	con6	46	340	1.46	0.92	1.13
Morro Bay 4	mor4	46	338	1.48	1.01	1.12
Pittsburg 5	pit5	46	325	1.54	1.03	1.14
Pittsburg 1&2	pit1&2	62	326	1.54	0.95	1.17
Contra Costa 7	con7	46	340	1.58	0.94	1.14
Pittsburg 7	pit7	120	720	1.62	0.97	1.20
Pittsburg 6	pit6	46	325	1.67	0.97	1.16
Humboldt 1&2	hmb1&2	10	105	1.95	0.84	1.18
Hunters Point 2	hnp2	10	107	2.13	0.96	1.19
Hunters Point 3	hnp3	10	107	2.21	0.89	1.16
Moss Landing 6	mos6	50	739	2.87	1.05	1.25
Moss Landing 7	mos7	50	739	2.91	1.02	1.26
Averages				**1.68**	**0.98**	**1.17**
SCE UNITS						
Cool Water 1	cw01	17	65	1.30	1.01	1.10
Cool Water 2	cw02	19	81	1.31	1.02	1.11
Long Beach 8&9	lb8&9	70	560	1.31	1.02	1.08
Redondo Beach 7&8	red7&8	260	960	1.32	1.02	1.12
Ormond Beach 1	orb1	250	750	1.35	1.00	1.13
Alamitos 5&6	ala5&6	260	960	1.42	1.00	1.12
Mandalay 1&2	man1&2	40	430	1.90	0.95	1.16
Huntington Beach 1&2	hun1&2	40	430	1.96	1.01	1.20
Cool Water 3&4	cw34	140	512	2.02	1.10	1.43
Ormond Beach 2	orb2	50	750	2.46	0.99	1.23
Etiwanda 1&2	eti1&2	20	264	2.72	1.00	1.30
Etiwanda 3&4	eti3&4	40	640	2.75	1.02	1.28
El Segundo 3&4	els3&4	40	670	2.96	1.03	1.31
Alamitos 3&4	ala3&4	40	640	3.02	1.04	1.33
El Segundo 1&2	els1&2	20	350	3.04	1.05	1.32
Alamitos 1&2	ala1&2	20	350	3.19	1.04	1.34
San Bernardino 1&2	sbr1&2	14	126	3.24	1.15	1.54
Redondo Beach 5&6	red5&6	20	350	3.54	1.09	1.41
Highgrove 1&2	hig1&2	8	66	5.87	1.58	2.41
Highgrove 3&4	hig3&4	10	89	8.51	1.73	2.99
Averages				**1.83**	**1.03**	**1.27**
SDG&E UNITS						
South Bay 4	sba4	45	150	1.30	1.01	1.12
Encina 3	enc3	20	110	1.32	0.98	1.09
South Bay 2	sba2	30	150	1.33	0.99	1.10
Encina 2	enc2	20	104	1.34	0.94	1.08
South Bay 3	sba3	30	175	1.40	0.96	1.10
South Bay 1	sba1	30	143	1.43	0.93	1.10
Encina 1	enc1	20	107	1.47	0.91	1.10
Encina 4	enc4	20	300	1.87	0.97	1.13
Encina 5	enc5	20	330	2.07	0.95	1.15
Averages				**1.47**	**0.96**	**1.12**

FIGURE D-1A,B&C (TABLE D-3)



Since ***AHR/IHR*** is simply a function of ***AHR*** and ***IHR***, it is of interest to see what their relative roles are in this regard. Looking at **$R(x_1)$,** for example, we see some very large values, which obviously must be driven by large ***AHR***, small ***IHR*** or both. Figures D-2A, B and C show the ***R*** values as a function of

AHR(x_1). Although not entirely consistent, the ***AHR*** appears to be a significant driver in setting the high values of ***R(x_1)*** -- but not particularly for ***R_{AVE}*** or ***R(x_2)***, with the possible exception of SCE**.** The data for Figures D-2 is tabulated in Table D-4.

FIGURE D-2A,B&C (TABLE D-4)

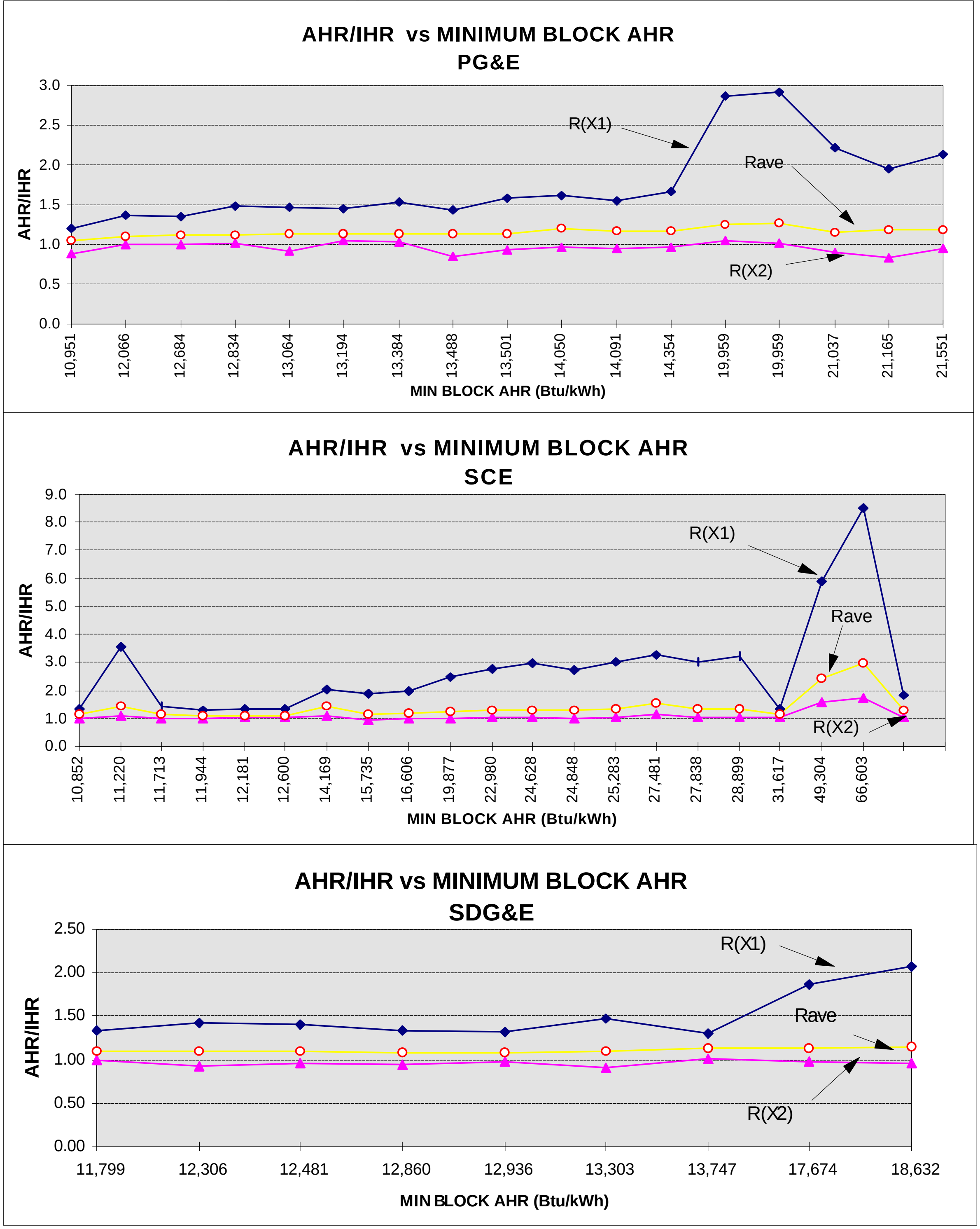


TABLE D-4: SORTED BY *AHR*(X_1)

		OUTPUT (MW)		AHR	AVERAGE/INCREMENTAL		
		X1	**X2**	**X1**	**R(X1)**	**R(X2)**	**Rave**
PG&E UNITS	ABREV,						
Potrero 3	pot3	47	207	10,951	1.20	0.89	1.05
Hunters Point 4	hnp4	62	326	12,066	1.37	1.00	1.10
Morro Bay 1&2	mor1&2	62	326	12,684	1.35	1.00	1.11
Morro Bay 4	mor4	46	338	12,834	1.48	1.01	1.12
Contra Costa 6	con6	46	340	13,064	1.46	0.92	1.13
Morro Bay 3	mor3	46	338	13,194	1.46	1.05	1.14
Pittsburg 5	pit5	46	325	13,384	1.54	1.03	1.14
Pittsburg 3&4	pit3&4	62	326	13,488	1.43	0.86	1.13
Contra Costa 7	con7	46	340	13,501	1.58	0.94	1.14
Pittsburg 7	pit7	120	720	14,050	1.62	0.97	1.20
Pittsburg 1&2	pit1&2	62	326	14,091	1.54	0.95	1.17
Pittsburg 6	pit6	46	325	14,354	1.67	0.97	1.16
Moss Landing 6	mos6	50	739	19,959	2.87	1.05	1.25
Moss Landing 7	mos7	50	739	19,959	2.91	1.02	1.26
Hunters Point 3	hnp3	10	107	21,037	2.21	0.89	1.16
Humboldt 1&2	hmb1&2	10	105	21,165	1.95	0.84	1.18
Hunters Point 2	hnp2	10	107	21,551	2.13	0.96	1.19
Averages					**1.68**	**0.98**	**1.17**
SCE UNITS							
Ormond Beach 1	orb1	250	750	10,852	1.35	1.00	1.13
Redondo Beach 5&6	red5&6	20	350	11,220	3.54	1.09	1.41
Alamitos 5&6	ala5&6	260	960	11,713	1.42	1.00	1.12
Cool Water 1	cw01	17	65	11,944	1.30	1.01	1.10
Cool Water 2	cw02	19	81	12,181	1.31	1.02	1.11
Long Beach 8&9	lb8&9	70	560	12,600	1.31	1.02	1.08
Cool Water 3&4	cw34	140	512	14,169	2.02	1.10	1.43
Mandalay 1&2	man1&2	40	430	15,735	1.90	0.95	1.16
Huntington Beach 1&2	hun1&2	40	430	16,606	1.96	1.01	1.20
Ormond Beach 2	orb2	50	750	19,877	2.46	0.99	1.23
Etiwanda 3&4	eti3&4	40	640	22,980	2.75	1.02	1.28
El Segundo 3&4	els3&4	40	670	24,628	2.96	1.03	1.31
Etiwanda 1&2	eti1&2	20	264	24,848	2.72	1.00	1.30
Alamitos 3&4	ala3&4	40	640	25,283	3.02	1.04	1.33
San Bernardino 1&2	sbr1&2	14	126	27,481	3.24	1.15	1.54
El Segundo 1&2	els1&2	20	350	27,838	3.04	1.05	1.32
Alamitos 1&2	ala1&2	20	350	28,899	3.19	1.04	1.34
Redondo Beach 7&8	red7&8	260	960	31,617	1.32	1.02	1.12
Highgrove 1&2	hig1&2	8	66	49,304	5.87	1.58	2.41
Highgrove 3&4	hig3&4	10	89	66,603	8.51	1.73	2.99
Averages					**1.83**	**1.03**	**1.27**
SDG&E UNITS							
South Bay 2	sba2	30	150	11,799	1.33	0.99	1.10
South Bay 1	sba1	30	143	12,306	1.43	0.93	1.10
South Bay 3	sba3	30	175	12,481	1.40	0.96	1.10
Encina 2	enc2	20	104	12,860	1.34	0.94	1.08
Encina 3	enc3	20	110	12,936	1.32	0.98	1.09
Encina 1	enc1	20	107	13,303	1.47	0.91	1.10
South Bay 4	sba4	45	150	13,747	1.30	1.01	1.12
Encina 4	enc4	20	300	17,674	1.87	0.97	1.13
Encina 5	enc5	20	330	18,632	2.07	0.95	1.15
Averages					**1.47**	**0.96**	**1.12**

Figures D-3A, B and C are similar to Figures D-2A, B, and C except that we are looking at the correlation with ***IHR***, rather than the ***AHR***. In this case the results are much more ambiguous. A low or a high ***IHR*** seems to go with a high ***AHR/IHR*** ratio equally well. It appears that only ***AHR*** shows any correlation. The tabulated numbers for Figures D-3A, B and C are provided in Table D-5.

FIGURE D-3A,B&C (TABLE D-5)

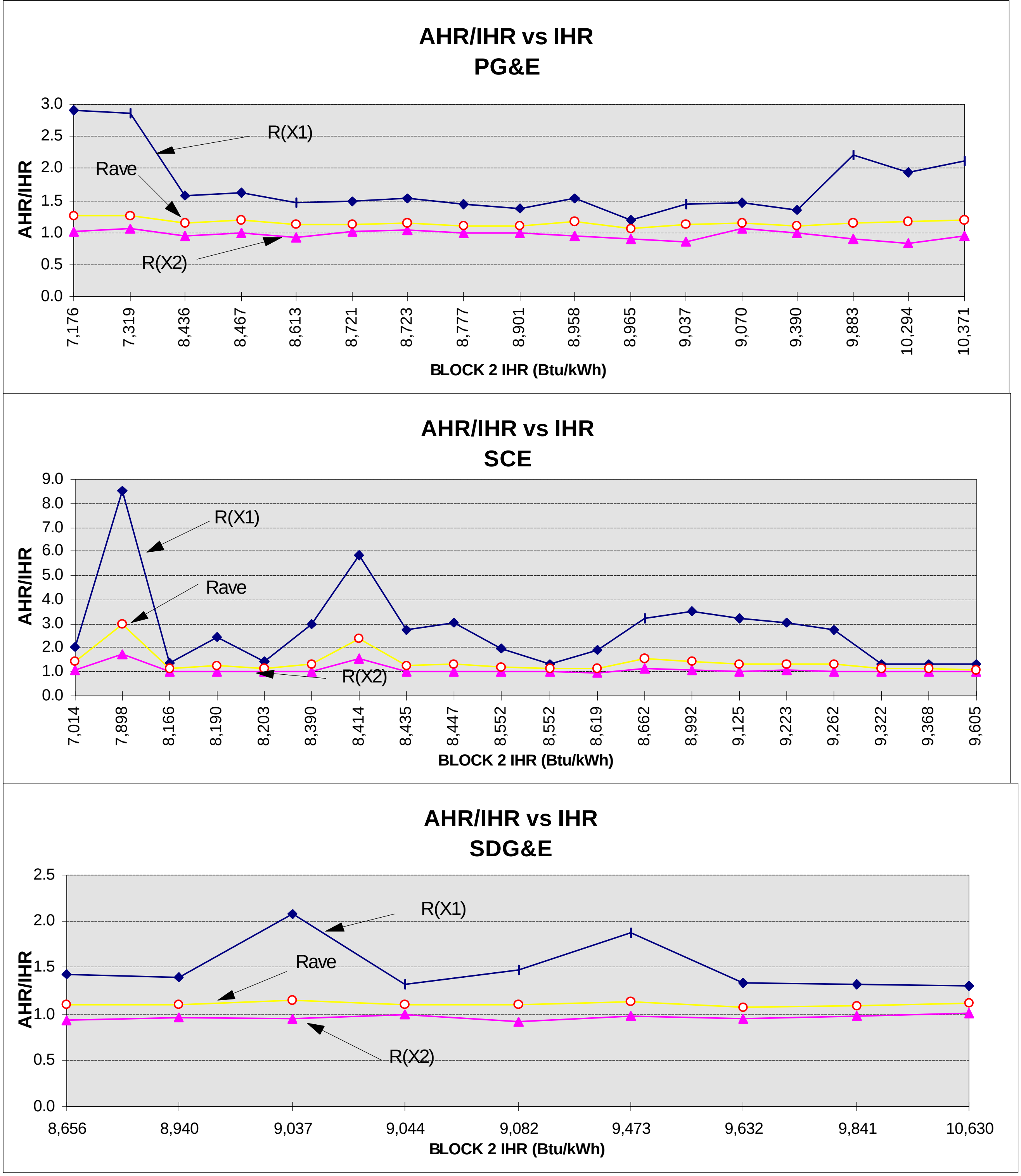


TABLE D-5: SORTED BY *$IHR(X_1)$*

		OUTPUT (MW)		***IHR***	AVERAGE/INCREMENTAL		
		X1	**X2**	**X1**	***R(X1)***	***R(X2)***	***Rave***
PG&E UNITS	ABREV,						
Moss Landing 7	mos7	50	739	7,176	2.91	1.02	1.26
Moss Landing 6	mos6	50	739	7,319	2.87	1.05	1.25
Contra Costa 7	con7	46	340	8,436	1.58	0.94	1.14
Pittsburg 7	pit7	120	720	8,467	1.63	0.98	1.20
Contra Costa 6	con6	46	340	8,613	1.46	0.92	1.13
Morro Bay 4	mor4	46	338	8,721	1.48	1.01	1.12
Pittsburg 5	pit5	46	325	8,723	1.54	1.03	1.14
Pittsburg 6	pit6	46	325	8,777	1.44	0.98	1.12
Hunters Point 4	hnp4	62	326	8,901	1.37	1.00	1.10
Pittsburg 1&2	pit1&2	62	326	8,958	1.54	0.95	1.17
Potrero 3	pot3	47	207	8,965	1.20	0.89	1.05
Pittsburg 3&4	pit3&4	62	326	9,037	1.43	0.86	1.13
Morro Bay 3	mor3	46	338	9,070	1.46	1.05	1.14
Morro Bay 1&2	mor1&2	62	326	9,390	1.35	1.00	1.11
Hunters Point 3	hnp3	10	107	9,883	2.21	0.89	1.16
Humboldt 1&2	hmb1&2	10	105	10,294	1.95	0.84	1.18
Hunters Point 2	hnp2	10	107	10,371	2.13	0.96	1.19
Averages					**1.67**	**0.98**	**1.17**
SCE UNITS							
Cool Water 3&4	cw34	140	512	7,014	2.02	1.10	1.43
Highgrove 3&4	hig3&4	10	89	7,898	8.51	1.73	2.99
Ormond Beach 1	orb1	250	750	8,166	1.35	1.00	1.13
Ormond Beach 2	orb2	50	750	8,190	2.46	0.99	1.23
Alamitos 5&6	ala5&6	260	960	8,203	1.42	1.00	1.12
El Segundo 3&4	els3&4	40	670	8,390	2.96	1.03	1.31
Highgrove 1&2	hig1&2	8	66	8,414	5.87	1.58	2.41
Etiwanda 3&4	eti3&4	40	640	8,435	2.75	1.02	1.28
Alamitos 3&4	ala3&4	40	640	8,447	3.02	1.04	1.33
Huntington Beach 1&	hun1&2	40	430	8,552	1.96	1.01	1.20
Redondo Beach 7&8	red7&8	260	960	8,552	1.32	1.02	1.12
Mandalay 1&2	man1&2	40	430	8,619	1.90	0.95	1.16
San Bernardino 1&2	sbr1&2	14	126	8,662	3.24	1.15	1.54
Redondo Beach 5&6	red5&6	20	350	8,992	3.54	1.09	1.41
Alamitos 1&2	ala1&2	20	350	9,125	3.19	1.04	1.34
El Segundo 1&2	els1&2	20	350	9,223	3.04	1.05	1.32
Etiwanda 1&2	eti1&2	20	264	9,262	2.72	1.00	1.30
Cool Water 1	cw01	17	65	9,322	1.30	1.01	1.10
Cool Water 2	cw02	19	81	9,368	1.31	1.02	1.11
Long Beach 8&9	lb8&9	70	560	9,605	1.31	1.02	1.08
Averages					**1.83**	**1.03**	**1.27**
SDG&E UNITS							
South Bay 1	sba1	30	143	8,656	1.43	0.93	1.10
South Bay 3	sba3	30	175	8,940	1.40	0.96	1.10
Encina 5	enc5	20	330	9,037	2.07	0.95	1.15
South Bay 2	sba2	30	150	9,044	1.33	0.99	1.10
Encina 1	enc1	20	107	9,082	1.47	0.91	1.10
Encina 4	enc4	20	300	9,473	1.87	0.97	1.13
Encina 2	enc2	20	104	9,632	1.34	0.94	1.08
Encina 3	enc3	20	110	9,841	1.32	0.98	1.09
South Bay 4	sba4	45	150	10,630	1.30	1.01	1.12
Averages					**1.47**	**0.96**	**1.12**

APPENDIX E
A SIMPLISTIC MARKET MODEL

This Appendix describes the development of the Simplistic Market Model described in Section VI, of the main body of this report. This model is a very simplified characterization of the market that does not pretend to have the accuracy of a model such as UPLAN but is, at the same time, more useful in visualizing the competitive market as it compares to the existing regulated market. It does this by making a pseudo comparison of the Marginal Cost (MC) of the regulated market to the Market Clearing Price (MCP) of the competitive market. It does this using the heat rate and fuel cost data of the IOU slow-start gas-fired units for the three IOUs: PG&E, SCE and SDG&E -- all at pre-divestiture ownership.

Block Incremental Heat Rates (***IHR***) are used for characterizing the MC, and block Average Heat Rates (***AHR***) are used for characterizing MCP. This would be simply a matter of comparing the ***IHR*** and ***AHR*** block values from Appendix A except for the fact that they are no directly comparable to one another, as will be explained below. It therefore becomes necessary to characterize the ***IHR*** and ***AHR*** values in equation form, as described in Appendix B. The block ***IHR*** values would be the same as the block values of Appendix A except for the fact that equations cannot fit the data points of the block data exactly. The ***AHR*** values must be converted to ***AHR*** average block values (AHR_{AVE}), as will be explained below. From this data, system ***IHRs*** (***SIHR***) and system AHR_{AVE} ($SAHR_{AVE}$) are developed. Finally, using the FR 97 Gas Price Forecast described in Appendix F, the corresponding costs are developed which can stand as proxies for MC and MCP.

BLOCK INCREMENTAL HEAT RATES

The equations developed in Appendix B are used to develop the block Incremental Heat Rates (***IHRs***). These ***IHRs*** would be the same as those in Appendix A except for the fact that the equations of Appendix B can never fit the block data of Appendix A exactly. The block ***IHR*** values are reconstructed in the format of Appendix A.

Moss Landing 7 is used to illustrate this process. The relevant heat rate data from Appendix A is summarized in Table E-1. It is necessary to understand that the block 1 ***IHR*** is not really a ***IHR*** as it represents the heat rate for the minimum block, which can not be used in a dispatch decision. Therefore, only blocks 2-5 are applicable.

TABLE E-1: MOSS LANDING 7 DATA FROM APPENDIX A

BLOCK #	CAPACITY		***AHR***	I/O Curve	***IHR***
	(%)	(MW)	(Btu/kWh)	(1000 Btu/hr)	(Btu/kWh)
1	6.8%	50	19,959	997,950	19,959
2	25.0%	185	10,631	1,966,735	7,176
3	50.1%	370	9,268	3,429,160	7,905
4	80.0%	591	8,962	5,296,542	8,450
5	100.0%	739	8,917	6,589,663	8,737

The necessary ***IHR*** block data for each unit is constructed from the respective Input-Output Curve (Btu/hr) of Appendix B which is a third order equation:

$$y=ax^3+bx^2+cx+d$$

Where: y = Input fuel (Btu/hr)
x = Output generation (MW)
a - d = The coefficients defined by Table B-2 in Appendix B.

The block Average Incremental Heat Rates can then be calculated from the Input-Output curve:

$$\begin{aligned}(y_2 - y_1)/ (x_2\text{-}x_1) &= [(ax_2^3 + bx_2^2 + cx_2 + d) - (ax_1^3 + bx_1^2 + cx_1 + d)] / (x_2\text{-}x_1)\\ &= [a(x_2^3 - x_1^3) + b(x_2^2 - x_1^2) + c(x_2 - x_1)]/ (x_2 - x_1)\\ &= a(x_2^2 + x_2\, x_1 + x_1^2) + b(x_2 + x_1) + c\end{aligned}$$

Where: x_1 = Minimum Output of the Block
x_2 = Maximum Output of the Block

For Block 1 of Moss Landing 7, the following coefficients and output values are applicable:

a = -0.0013
b = 2.955
c = 6561.2
d = 662,025

x_1 = 50 MW
x_2 = 185 MW

The corresponding Block 1 Average Incremental Heat Rate is:

$$\begin{aligned}(y_2 - y_1)/ (x_2\text{-}x_1) &= a(x_2^2 + x_2\, x_1 + x_1^2) + b(x_2 + x_1) + c\\ &= -0.0013(185^2+185*50+50^2) + 2.955(185+50) + 6561.2 = \underline{7{,}196}\ \text{Btu/kWh}\end{aligned}$$

The remaining ***IHR*** values can be constructed similarly and are summarized in Table E-2. The rest of the values can then be constructed from the **IHR** values, as was done in Table E-1. But only the ***IHR*** values are of interest here since the necessary $\boldsymbol{AHR_{AVE}}$ values must be calculated as is explained below.

TABLE E-2: MOSS LANDING 7 DATA BASED ON EQUATION.

BLOCK #	CAPACITY		***AHR***	I/O Curve	***IHR***
	(%)	(MW)	(Btu/kWh)	(1000 Btu/hr)	(Btu/kWh)
1	6.8%	50	19,946	997,310	19,946
2	25.0%	185	10,642	1,968,751	7,196
3	50.1%	370	9,266	3,428,360	7,890
4	80.0%	591	8,974	5,303,467	8,485
5	100.0%	739	8,931	6,599,881	8,760

The ***IHR*** values for the other units are calculated similarly and are summarized in Table E-3.

TABLE E-3: BLOCK INCREMENTAL HEAT RATES (*IHRs*)

	BLOCK 2		BLOCK 3		BLOCK 4		BLOCK 5	
	INC MW	***IHR*** Btu/kWh	INC MW	***IHR*** Btu/kWh	INC MW	***IHR*** Btu/kWh	INC MW	***IHR*** Btu/kWh
PG&E UNITS								
Contra Costa 6	39	8,756	85	8,555	102	8,877	68	9,811
Contra Costa 7	39	8,496	85	8,503	102	8,933	68	9,754
Humboldt 1&2	16	10,543	27	10,366	31	11,392	21	13,521
Hunters Point 2	17	10,364	27	10,981	32	11,861	21	12,701
Hunters Point 3	17	9,876	27	10,861	32	12,246	21	13,552
Hunters Point 4	20	8,873	82	9,044	96	9,379	66	9,724
Morro Bay 1&2	20	9,407	82	9,441	96	9,675	66	10,081
Morro Bay 3	39	9,056	84	9,064	101	9,100	68	9,159
Morro Bay 4	39	8,703	84	8,848	101	9,083	68	9,314
Moss Landing 6	135	7,370	185	8,146	221	8,668	148	8,714
Moss Landing 7	135	7,196	185	7,890	221	8,485	148	8,760
Pittsburg 1&2	20	9,079	82	9,003	96	9,391	66	10,331
Pittsburg 3&4	20	9,276	82	8,983	96	9,529	66	11,211
Pittsburg 5	35	8,744	82	8,900	97	9,135	65	9,344
Pittsburg 6	35	8,613	82	8,797	97	9,293	65	9,963
Pittsburg 7	60	8,555	180	8,476	216	8,762	144	9,469
Potrero 3	5	9,066	52	8,924	62	9,276	41	10,341
SCE UNITS								
Alamitos 1&2	70	9,127	90	9,341	90	9,663	80	10,047
Alamitos 3&4	120	8,443	160	8,639	160	8,933	160	9,305
Alamitos 5&6	160	8,155	180	8,656	180	9,074	180	9,375
Cool Water 1	13	9,320	13	9,549	13	9,808	9	10,050
Cool Water 2	16	9,368	16	9,540	16	9,742	14	9,960
Cool Water 3&4	40	7,013	60	7,064	140	7,334	132	8,018
El Segundo 1&2	70	9,224	90	9,394	90	9,631	80	9,898
El Segundo 3&4	120	8,395	160	8,576	160	8,839	190	9,198
Etiwanda 1&2	60	9,264	60	9,627	60	10,104	64	10,719
Etiwanda 3&4	120	8,438	160	8,641	160	8,943	160	9,322
Highgrove 1&2	10	8,413	20	8,438	18	8,471	10	8,495
Highgrove 3&4	14	7,899	26	8,096	30	8,338	9	8,485
Huntington 1&2	100	8,552	100	8,768	100	9,050	90	9,379
Long Beach 8&9	110	9,608	120	9,647	110	9,717	150	9,836
Mandaly 1&2	100	8,443	105	8,799	95	9,279	90	9,842
Ormond Beach 1	120	8,171	130	8,429	120	8,742	130	9,112
Ormond Beach 2	175	8,192	175	8,459	175	8,818	175	9,268
Redondo 5&6	70	8,992	90	9,134	90	9,324	80	9,535
Redondo 7&8	100	8,557	300	8,759	140	9,028	160	9,248
San Bernardino 1&2	28	8,681	28	9,056	28	9,384	28	9,667
SDG&E UNITS								
Encina 1	7	9,082	27	9,353	32	10,140	21	11,202
Encina 2	6	9,630	26	9,818	31	10,368	21	11,111
Encina 3	8	9,840	28	9,965	33	10,325	22	10,810
Encina 4	55	9,473	75	9,625	90	9,991	60	10,484
Encina 5	63	9,019	82	9,208	99	9,660	66	10,270
South Bay 1	6	8,654	36	8,874	43	9,548	29	10,456
South Bay 2	8	8,900	38	8,995	45	9,277	30	9,658
South Bay 3	14	8,940	44	9,089	53	9,511	35	10,080
South Bay 4	-	-	30	10,630	45	10,957	30	11,427

BLOCK AVERAGE HEAT RATES

At first blush, it might appear that the ***AHR*** is calculated similarly but this is not possible because the ***AHR*** and ***IHR*** data in Table E-2 are not directly comparable. The Moss Landing 7 ***IHR*** of 7,196 Btu/kWh for block 2, for example, is an average for the Block 2, for the range from 50 MW to 185 MW. But the corresponding ***AHR*** of 10,642 Btu/kWh is the heat rate at the point of 185 MW. In order to make these values comparable, an average ***AHR*** value for the range of 50 MW to 185 MW has to be calculated. This value is designated as AHR_{AVE} herein, and calculated using calculus. The ***AHR*** curve is integrated over each of its blocks and that value is divided by the number of megawatts associated with the respective block. The process is as follows.

The Input-Output Curve (Btu/hr) is as before represented by the third order equation:

$$y = ax^3+bx^2+cx+d$$

Where: y = Input fuel (Btu/hr)
x = Output generation (MW)
$a - d$ = The coefficients defined by Table B-2 in Appendix B.

And the Average Heat Rate curve (***AHR***) is by definition equal to the Input-Output curve (y) divided by the respective capacity, x:

$$AHR = y/x = (ax^3+bx^2+cx+d)/x$$

The average ***AHR***, AHR_{AVE}, is the integral of ***AHR*** from x_1 to x_2 divided by the quantity $x_2 - x_1$:

$$AHR_{AVE} = [\int AHR\,dx \text{ \{from } X_1 \text{ to } X_2\text{\}}] \ / (x_2 - x_1)$$

Where: x_1 = ***Minimum operating level of the block (MW)***
x_2 = ***Maximum operating level of the block (MW)***

The integration of ***AHR***, ($\int AHR\,dx$), is as follows:

$$\int AHR\,dx = \int [(ax^3+bx^2+cx+d)/x]dx = a/3 \cdot x^3 + b/2 \cdot x^2 + c \cdot x + d \cdot Ln(x)$$

Where: $Ln(x)$ = ***Natural Log of x***

Or in spreadsheet language:

$$\int AHR\,dx = \int [(a*X\hat{}3+b*X\hat{}2+c*X+d)/X]dx = a/3*X\hat{}3+b/2*X\hat{}2+c*X+d*ln(X)$$

The coefficients, $a - d$, along with the values of x_1 and x_2 for each block is copied onto a spreadsheet. The formula for $\int AHR\,dx$ is entered onto the Excel spreadsheet in two places: once for calculating the value of $\int AHR\,dx$ for x_1 and once for x_2. For the first block (from 50 MW to 185 MW) this would be:

$a = -0.0013$ $x_1 = 50$ MW $\int AHR(x_1)\,dx = 1/3*a*x_1\text{^}3+1/2*b*x_1\text{^}2+c*x_1+d*ln(x_1)$
$b = 2.955$ $x_2 = 185$ MW $\int AHR(x_2)\,dx = 1/3*a*x_2\text{^}3+1/2*b*x_2\text{^}2+c*x_2+d*ln(x_2)$
$c = 6561.2$
$d = 662{,}025$

Finally, the two values of $\int AHR\,dx$ are subtracted from one another and the resulting value is divided by the difference of the $x_2 - x_1$ values:

$$AHR_{AVE} = [\int AHR(x_2)\,dx - \int AHR(x_1)\,dx\,] / (x_2 - x_1)$$

Excel then makes the following calculations:

$$\int AHR(x_2)\,dx = a/3*x_2\text{^}3+b/2*x_2\text{^}2+c*x_2+d*ln(x_2)$$
$$= -0.0013/3\cdot 185^3 + 2.955/2\cdot 185^2 + 6561.2\cdot 185 + 662025\cdot \mathrm{Ln}(185) = 4{,}717{,}651.8$$

$$\int AHR(x_1)\,dx = a/3*x_1\text{^}3+b/2*x_1\text{^}2+c*x_1+d*ln(x_1)$$
$$= -0.0013/3\cdot 50^3 + 2.955/2\cdot 50^2 + 6561.2 \cdot 50 + 662025\cdot \mathrm{Ln}(50) = 2{,}921{,}556.6$$

AHR_{AVE} = (4,717,651.8 - 2,921,556.6) / (185 - 50) = 1,796,095.2 / 135 = **13,304 Btu/kWh**

Table E-4 provides the resulting block AHR_{AVE} values for each block of each slow-start IOU unit.

TABLE E-4: BLOCK AVERAGES OF AVERAGE HEAT RATES (AHR_{AVE})

	BLOCK 2		BLOCK 3		BLOCK 4		BLOCK 5	
	INC	***AHR***	INC	***AHR***	INC	***AHR***	INC	***AHR***
	MW	Btu/kWh	MW	Btu/kWh	MW	Btu/kWh	MW	Btu/kWh
PG&E UNITS								
Contra Costa 6	39	11,860	85	10,300	102	9,579	68	9,479
Contra Costa 7	39	12,112	85	10,361	102	9,622	68	9,517
Humboldt 1&2	16	16,853	27	13,245	31	12,142	21	12,167
Hunters Point 2	17	16,865	27	13,382	32	12,517	21	12,433
Hunters Point 3	17	16,339	27	12,974	32	12,336	21	12,471
Hunters Point 4	20	11,642	82	10,585	96	9,985	66	9,854
Morro Bay 1&2	20	12,246	82	11,128	96	10,438	66	10,266
Morro Bay 3	39	12,056	84	10,616	101	9,950	68	9,712
Morro Bay 4	39	11,694	84	10,292	101	9,714	68	9,561
Moss Landing 6	135	13,370	185	9,918	221	9,273	148	9,115
Moss Landing 7	135	13,304	185	9,758	221	9,079	148	8,949
Pittsburg 1&2	20	13,412	82	11,673	96	10,573	66	10,339
Pittsburg 3&4	20	12,905	82	11,388	96	10,408	66	10,341
Pittsburg 5	35	12,186	82	10,598	97	9,907	65	9,712
Pittsburg 6	35	12,870	82	10,899	97	10,075	65	9,929
Pittsburg 7	60	13,001	180	11,062	216	9,977	144	9,705
Potrero 3	5	10,853	52	10,207	62	9,689	41	9,686
SCE UNITS								
Alamitos 1&2	70	17,605	90	12,222	90	11,084	80	10,734
Alamitos 3&4	120	16,210	160	11,407	160	10,311	160	9,960
Alamitos 5&6	160	10,532	180	9,810	180	9,560	180	9,491
Cool Water 1	13	11,259	13	10,587	13	10,343	9	10,264
Cool Water 2	16	11,401	16	10,650	16	10,370	14	10,262
Cool Water 3&4	40	13,307	60	11,822	140	10,361	132	9,506
El Segundo 1&2	70	17,208	90	12,131	90	11,038	80	10,678
El Segundo 3&4	120	15,882	160	11,251	160	10,188	190	9,825
Etiwanda 1&2	60	16,432	60	12,244	60	11,371	64	11,106
Etiwanda 3&4	120	15,141	160	11,005	160	10,078	160	9,798
Highgrove 1&2	10	34,940	20	20,641	18	15,481	10	13,820
Highgrove 3&4	14	44,598	26	24,520	30	17,262	9	15,100
Huntington 1&2	100	12,570	100	10,331	100	9,822	90	9,666
Long Beach 8&9	110	11,404	120	10,506	110	10,230	150	10,107
Mandaly 1&2	100	12,114	105	10,087	95	9,706	90	9,664
Ormond Beach 1	120	10,354	130	9,753	120	9,486	130	9,382
Ormond Beach 2	175	13,188	175	10,168	175	9,595	175	9,442
Redondo 5&6	70	18,702	90	12,511	90	11,144	80	10,661
Redondo 7&8	100	10,808	300	9,995	140	9,633	160	9,548
San Bernardino 1&2	28	18,968	28	13,553	28	12,072	28	11,426
SDG&E UNITS								
Encina 1	7	12,717	27	11,323	32	10,611	21	10,601
Encina 2	6	12,454	26	11,390	31	10,808	21	10,769
Encina 3	8	12,468	28	11,426	33	10,857	22	10,761
Encina 4	55	13,407	75	11,022	90	10,482	60	10,399
Encina 5	63	13,352	82	10,671	99	10,120	66	10,060
South Bay 1	6	11,995	36	10,821	43	10,099	29	10,047
South Bay 2	8	11,487	38	10,526	45	9,912	30	9,774
South Bay 3	14	11,853	44	10,653	53	10,051	35	9,963
South Bay 4	-	-	30	13,010	45	12,147	30	11,860

SYSTEM INCREMENTAL HEAT RATES

If the block ***IHRs*** are sorted by increasing values for each IOU, they can be considered to be a simplified representation of the dispatch in the existing regulated system -- and is therefore a simplistic representation of MC for the respective IOU. These sorted values are shown under the heading ***IHR*** in Table E-5 series: Table E-5-PGE for PG&E, Table E-5-SCE for SCE and Table E-5-SDG for SDG&E. The only restraint is that the Block order can not be violated. That is, Block 2 must be taken before Block 3, Block 3 must be taken before Block 4, and Block 4 must be taken before Block 5. Since ***IHRs*** should always have increasing values, maintaining this restraint is not a problem. The Figure E-1 series show this same data graphically, along with corresponding $\boldsymbol{AHR_{AVE}}$ data which is described in the next section.

The column designated ***IHR x MW*** is the product of each MW increment and its corresponding ***IHR***, which represents the number of Btu that the respective unit can produce in any one hour. The next column is a running sum of these products, which represents the total Btu that the system to that point can generate in one hour. The last column, designated "Cumulative ***SIHR***" is the running sum values divided by the cumulative MW. These ***SIHR*** values are shown in Figure series E-2, along with similar ***AHR*** data which is also described in the next section.

Since ***IHR*** values set the MC in the regulated system – along with variable O&M costs, they can be thought of a proxy for MC. Accordingly, ***SIHR*** values can be thought of as a system MC for the blocks being used at that point, which corresponds to the average MC which could be expected if all these same blocks contributed to the marginal cost equal amounts of time. That is, we will consider ***SIHR*** to be our proxy for MC in a traditional regulated system.

SYSTEM AVERAGE HEAT RATES

The System $\boldsymbol{AHR_{AVE}}$, $\boldsymbol{SAHR_{AVE}}$, values are calculated similarly to ***SIHR*** but the sorting is more complex, intended to be representative of the dispatch in a competitive market with one part bidding. The $\boldsymbol{AHR_{AVE}}$ data is sorted such that blocks are taken in economic order, with the same provision that blocks can not be taken out of physical order. As it turns out, once the first block (Block 2) is taken, its upper blocks are so economic that there is no other Block 2 that can compete. Accordingly, the graphical emulation of this dispatch of heat rates, Figures E-1, show a saw tooth shape where each downward sloping arc (of four blocks) is a unit's heat rate curve. This is a very different shape than that of the conventional ***IHR*** curve.

The $\boldsymbol{SAHR_{AVE}}$ values are calculated similar to the ***SIHR*** values and are also shown in Tables E-5. The $\boldsymbol{SAHR_{AVE}}$ values are the cumulative weighted average of these individual unit $\boldsymbol{AHR_{AVE}}$ values. The corresponding graphs are shown in Figure E-2.

TABLE E-5-PGE: PG&E SYSTEM IHR AND AHR$_{AVE}$ CALCULATIONS

SUMMARY IHR DATA

	UNIT					Cumulative	
PLANT	BLK #	INC MW	IHR Btu/kWh	CUM MW	IHR*MW 1000Btu	IHR*MW 1000Btu	SIHR Btu/kWh
mos7	2	135	7,196	135	971,441	971,441	7,196
mos6	2	135	7,370	270	994,931	1,966,372	7,283
mos7	3	185	7,890	455	1,459,609	3,425,981	7,530
mos6	3	185	8,146	640	1,506,925	4,932,906	7,708
pit7	3	180	8,476	820	1,525,759	6,458,665	7,876
mos7	4	221	8,485	1,041	1,875,107	8,333,772	8,006
con7	2	39	8,496	1,080	331,331	8,665,104	8,023
con7	3	85	8,503	1,165	722,789	9,387,893	8,058
pit7	2	60	8,555	1,225	513,295	9,901,188	8,083
con6	3	85	8,555	1,310	727,171	10,628,359	8,113
pit6	2	35	8,613	1,345	301,456	10,929,814	8,126
mos6	4	221	8,668	1,566	1,915,722	12,845,537	8,203
mor4	2	39	8,703	1,605	339,425	13,184,962	8,215
mos6	5	148	8,714	1,753	1,289,726	14,474,688	8,257
pit5	2	35	8,744	1,788	306,050	14,780,738	8,267
con6	2	39	8,756	1,827	341,490	15,122,229	8,277
mos7	5	148	8,760	1,975	1,296,414	16,418,642	8,313
pit7	4	216	8,762	2,191	1,892,651	18,311,293	8,358
pit6	3	82	8,797	2,273	721,354	19,032,647	8,373
mor4	3	84	8,848	2,357	743,248	19,775,896	8,390
hnp4	2	20	8,873	2,377	177,454	19,953,349	8,394
con6	4	102	8,877	2,479	905,452	20,858,801	8,414
pit5	3	82	8,900	2,561	729,832	21,588,633	8,430
pot3	3	52	8,924	2,613	464,057	22,052,690	8,440
con7	4	102	8,933	2,715	911,212	22,963,902	8,458
pit3&4	3	82	8,983	2,797	736,606	23,700,507	8,474
pit1&2	3	82	9,003	2,879	738,207	24,438,714	8,489
hnp4	3	82	9,044	2,961	741,638	25,180,352	8,504
mor3	2	39	9,056	3,000	353,189	25,533,541	8,511
mor3	3	84	9,064	3,084	761,357	26,294,897	8,526
pot3	2	5	9,066	3,089	45,329	26,340,226	8,527
pit1&2	2	20	9,079	3,109	181,571	26,521,797	8,531
mor4	4	101	9,083	3,210	917,368	27,439,165	8,548
mor3	4	101	9,100	3,311	919,114	28,358,279	8,565
pit5	4	97	9,135	3,408	886,132	29,244,411	8,581
mor3	5	68	9,159	3,476	622,813	29,867,224	8,592
pot3	4	62	9,276	3,538	575,101	30,442,325	8,604
pit3&4	2	20	9,276	3,558	185,523	30,627,848	8,608
pit6	4	97	9,293	3,655	901,420	31,529,268	8,626
mor4	5	68	9,314	3,723	633,373	32,162,641	8,639
pit5	5	65	9,344	3,788	607,366	32,770,007	8,651
hnp4	4	96	9,379	3,884	900,405	33,670,412	8,669
pit1&2	4	96	9,391	3,980	901,583	34,571,995	8,686
mor1&2	2	20	9,407	4,000	188,135	34,760,130	8,690
mor1&2	3	82	9,441	4,082	774,202	35,534,331	8,705
pit7	5	144	9,469	4,226	1,363,571	36,897,902	8,731
pit3&4	4	96	9,529	4,322	914,759	37,812,661	8,749
mor1&2	4	96	9,675	4,418	928,783	38,741,444	8,769
hnp4	5	66	9,724	4,484	641,751	39,383,196	8,783
con7	5	68	9,754	4,552	663,242	40,046,438	8,798
con6	5	68	9,811	4,620	667,170	40,713,607	8,812
hnp3	2	17	9,876	4,637	167,886	40,881,494	8,816
pit6	5	65	9,963	4,702	647,610	41,529,104	8,832
mor1&2	5	66	10,081	4,768	665,338	42,194,442	8,850
pit1&2	5	66	10,331	4,834	681,813	42,876,255	8,870
pot3	5	41	10,341	4,875	423,968	43,300,223	8,882
hnp2	2	17	10,364	4,892	176,181	43,476,404	8,887
hmb1&2	3	27	10,366	4,919	279,882	43,756,286	8,895
hmb1&2	2	16	10,543	4,935	168,689	43,924,976	8,901
hnp3	3	27	10,861	4,962	293,239	44,218,215	8,911
hnp2	3	27	10,981	4,989	296,490	44,514,705	8,923
pit3&4	5	66	11,211	5,055	739,944	45,254,649	8,952
hmb1&2	4	31	11,392	5,086	353,140	45,607,789	8,967
hnp2	4	32	11,861	5,118	379,557	45,987,346	8,985
hnp3	4	32	12,246	5,150	391,877	46,379,222	9,006
hnp2	5	21	12,701	5,171	266,719	46,645,941	9,021
hmb1&2	5	21	13,521	5,192	283,948	46,929,889	9,039
hnp3	5	21	13,552	5,213	284,586	47,214,476	9,057

SUMMARY AHR DATA

		UNIT					Cumulative	
	PLANT	BLK #	INC MW	AHR Btu/kWh	CUM MW	AHR*MW 1000Btu	AHR*MW 1000Btu	SAHR Btu/kWh
1	pot3	2	5	10,853	5	54,266	54,266	10,853
1	pot3	3	52	10,207	57	530,763	585,029	10,264
1	pot3	4	62	9,689	119	600,716	1,185,744	9,964
1	pot3	5	41	9,686	160	397,135	1,582,880	9,893
2	hnp4	2	20	11,642	180	232,845	1,815,724	10,087
2	hnp4	3	82	10,585	262	867,947	2,683,671	10,243
2	hnp4	4	96	9,985	358	958,544	3,642,216	10,174
2	hnp4	5	66	9,854	424	650,366	4,292,582	10,124
3	mor4	2	39	11,694	463	456,063	4,748,644	10,256
3	mor4	3	84	10,292	547	864,561	5,613,206	10,262
3	mor4	4	101	9,714	648	981,103	6,594,309	10,176
3	mor4	5	68	9,561	716	650,147	7,244,456	10,118
4	con6	2	39	11,860	755	462,528	7,706,983	10,208
4	con6	3	85	10,300	840	875,488	8,582,471	10,217
4	con6	4	102	9,579	942	977,042	9,559,513	10,148
4	con6	5	68	9,479	1,010	644,582	10,204,095	10,103
5	mor3	2	39	12,056	1,049	470,181	10,674,276	10,176
5	mor3	3	84	10,616	1,133	891,770	11,566,046	10,208
5	mor3	4	101	9,950	1,234	1,004,983	12,571,029	10,187
5	mor3	5	68	9,712	1,302	660,441	13,231,470	10,162
6	con7	2	39	12,112	1,341	472,386	13,703,857	10,219
6	con7	3	85	10,361	1,426	880,708	14,584,564	10,228
6	con7	4	102	9,622	1,528	981,468	15,566,033	10,187
6	con7	5	68	9,517	1,596	647,154	16,213,187	10,159
7	pit5	2	35	12,186	1,631	426,514	16,639,701	10,202
7	pit5	3	82	10,598	1,713	869,041	17,508,742	10,221
7	pit5	4	97	9,907	1,810	960,937	18,469,679	10,204
7	pit5	5	65	9,712	1,875	631,257	19,100,936	10,187
8	mor1&2	2	20	12,246	1,895	244,911	19,345,848	10,209
8	mor1&2	3	82	11,128	1,977	912,503	20,258,351	10,247
8	mor1&2	4	96	10,438	2,073	1,002,050	21,260,402	10,256
8	mor1&2	5	66	10,266	2,139	677,577	21,937,979	10,256
9	pit6	2	35	12,870	2,174	450,461	22,388,440	10,298
9	pit6	3	82	10,899	2,256	893,708	23,282,147	10,320
9	pit6	4	97	10,075	2,353	977,237	24,259,384	10,310
9	pit6	5	65	9,929	2,418	645,407	24,904,791	10,300
10	pit3&4	2	20	12,905	2,438	258,107	25,162,898	10,321
10	pit3&4	3	82	11,388	2,520	933,821	26,096,719	10,356
10	pit3&4	4	96	10,408	2,616	999,204	27,095,923	10,358
10	pit3&4	5	66	10,341	2,682	682,485	27,778,408	10,357
11	pit7	2	60	13,001	2,742	780,062	28,558,470	10,415
11	pit7	3	180	11,062	2,922	1,991,242	30,549,713	10,455
11	pit7	4	216	9,977	3,138	2,154,948	32,704,661	10,422
11	pit7	5	144	9,705	3,282	1,397,580	34,102,241	10,391
12	mos7	2	135	13,304	3,417	1,796,095	35,898,336	10,506
12	mos7	3	185	9,758	3,602	1,805,199	37,703,535	10,467
12	mos7	4	221	9,079	3,823	2,006,352	39,709,887	10,387
12	mos7	5	148	8,949	3,971	1,324,404	41,034,291	10,333
13	mos6	2	135	13,370	4,106	1,804,959	42,839,250	10,433
13	mos6	3	185	9,918	4,291	1,834,901	44,674,150	10,411
13	mos6	4	221	9,273	4,512	2,049,296	46,723,446	10,355
13	mos6	5	148	9,115	4,660	1,349,026	48,072,472	10,316
14	pit1&2	2	20	13,412	4,680	268,231	48,340,703	10,329
14	pit1&2	3	82	11,673	4,762	957,189	49,297,892	10,352
14	pit1&2	4	96	10,573	4,858	1,014,964	50,312,855	10,357
14	pit1&2	5	66	10,339	4,924	682,388	50,995,243	10,356
15	hnp3	2	17	16,339	4,941	277,769	51,273,012	10,377
15	hnp3	3	27	12,974	4,968	350,302	51,623,314	10,391
15	hnp3	4	32	12,336	5,000	394,742	52,018,056	10,404
15	hnp3	5	21	12,471	5,021	261,888	52,279,943	10,412
16	hmb1&2	2	16	16,853	5,037	269,651	52,549,594	10,433
16	hmb1&2	3	27	13,245	5,064	357,616	52,907,211	10,448
16	hmb1&2	4	31	12,142	5,095	376,412	53,283,622	10,458
16	hmb1&2	5	21	12,167	5,116	255,499	53,539,122	10,465
17	hnp2	2	17	16,865	5,133	286,706	53,825,827	10,486
17	hnp2	3	27	13,382	5,160	361,311	54,187,139	10,501
17	hnp2	4	32	12,517	5,192	400,547	54,587,685	10,514
17	hnp2	5	21	12,433	5,213	261,103	54,848,789	10,522

TABLE E-5-SCE: SCE SYSTEM IHR AND AHR$_{AVE}$ CALCULATIONS

	SUMMARY IHR DATA									SUMMARY AHR DATA							
		UNIT					Cumulative				UNIT					Cumulative	
	PLANT	BLK #	INC MW	***IHR*** Btu/kWh	CUM MW	***IHR*MW*** 1000Btu	***IHR*MW*** 1000Btu	***SIHR*** Btu/kWh		PLANT	BLK #	INC MW	***AHR*** Btu/kWh	CUM MW	***AHR*MW*** 1000Btu	***AHR*MW*** 1000Btu	***SAHR*** Btu/kWh
1	cw34	2	40	7,013	40	280,515	280,515	7,013	1	orb1	2	120	10,354	120	1,242,460	1,242,460	10,354
2	cw34	3	60	7,064	100	423,843	704,358	7,044	1	orb1	3	130	9,753	250	1,267,892	2,510,352	10,041
3	cw34	4	140	7,334	240	1,026,818	1,731,177	7,213	1	orb1	4	120	9,486	370	1,138,317	3,648,669	9,861
4	hig3&4	2	14	7,899	254	110,589	1,841,766	7,251	1	orb1	5	130	9,382	500	1,219,663	4,868,332	9,737
5	cw34	5	132	8,018	386	1,058,398	2,900,164	7,513	2	ala5&6	2	160	10,532	660	1,685,114	6,553,446	9,929
6	hig3&4	3	26	8,096	412	210,501	3,110,665	7,550	2	ala5&6	3	180	9,810	840	1,765,810	8,319,256	9,904
7	ala5&6	2	160	8,155	572	1,304,836	4,415,501	7,719	2	ala5&6	4	180	9,560	1,020	1,720,773	10,040,029	9,843
8	orb1	2	120	8,171	692	980,508	5,396,009	7,798	2	ala5&6	5	180	9,491	1,200	1,708,324	11,748,353	9,790
9	orb2	2	175	8,192	867	1,433,628	6,829,637	7,877	3	red7&8	2	100	10,808	1,300	1,080,843	12,829,196	9,869
10	hig3&4	4	30	8,338	897	250,148	7,079,785	7,893	3	red7&8	3	300	9,995	1,600	2,998,470	15,827,666	9,892
11	els3&4	2	120	8,395	1017	1,007,398	8,087,183	7,952	3	red7&8	4	140	9,633	1,740	1,348,586	17,176,252	9,871
12	hig1&2	2	10	8,413	1027	84,135	8,171,318	7,956	3	red7&8	5	160	9,548	1,900	1,527,641	18,703,893	9,844
13	orb1	3	130	8,429	1157	1,095,717	9,267,035	8,010	4	cw01	2	13	11,259	1,913	146,369	18,850,262	9,854
14	eti3&4	2	120	8,438	1277	1,012,529	10,279,564	8,050	4	cw01	3	13	10,587	1,926	137,631	18,987,893	9,859
15	hig1&2	3	20	8,438	1297	168,768	10,448,332	8,056	4	cw01	4	13	10,343	1,939	134,456	19,122,349	9,862
16	man1&2	2	100	8,443	1397	844,270	11,292,602	8,083	4	cw01	5	9	10,264	1,948	92,374	19,214,723	9,864
17	ala3&4	2	120	8,443	1517	1,013,150	12,305,752	8,112	5	cw02	2	16	11,401	1,964	182,415	19,397,138	9,876
18	orb2	3	175	8,459	1692	1,480,332	13,786,084	8,148	5	cw02	3	16	10,650	1,980	170,402	19,567,541	9,883
19	hig1&2	4	18	8,471	1710	152,474	13,938,558	8,151	5	cw02	4	16	10,370	1,996	165,923	19,733,464	9,887
20	hig3&4	5	9	8,485	1719	76,365	14,014,923	8,153	5	cw02	5	14	10,262	2,010	143,666	19,877,130	9,889
21	hig1&2	5	10	8,495	1729	84,951	14,099,874	8,155	6	lbc8&9	2	110	11,404	2,120	1,254,487	21,131,618	9,968
22	hun1&2	2	100	8,552	1829	855,242	14,955,116	8,177	6	lbc8&9	3	120	10,506	2,240	1,260,742	22,392,360	9,997
23	red7&8	2	100	8,557	1929	855,746	15,810,862	8,196	6	lbc8&9	4	110	10,230	2,350	1,125,296	23,517,655	10,008
24	els3&4	3	160	8,576	2089	1,372,124	17,182,986	8,225	6	lbc8&9	5	150	10,107	2,500	1,516,118	25,033,773	10,014
25	ala3&4	3	160	8,639	2249	1,382,232	18,565,218	8,255	7	man1&2	2	100	12,114	2,600	1,211,366	26,245,140	10,094
26	eti3&4	3	160	8,641	2409	1,382,483	19,947,700	8,280	7	man1&2	3	105	10,087	2,705	1,059,098	27,304,238	10,094
27	ala5&6	3	180	8,656	2589	1,558,076	21,505,776	8,307	7	man1&2	4	95	9,706	2,800	922,045	28,226,283	10,081
28	sbr1&2	2	28	8,681	2617	243,056	21,748,832	8,311	7	man1&2	5	90	9,664	2,890	869,785	29,096,067	10,068
29	orb1	4	120	8,742	2737	1,049,016	22,797,847	8,330	8	hun1&2	2	100	12,570	2,990	1,256,984	30,353,051	10,152
30	red7&8	3	300	8,759	3037	2,627,705	25,425,553	8,372	8	hun1&2	3	100	10,331	3,090	1,033,061	31,386,112	10,157
31	hun1&2	3	100	8,768	3137	876,842	26,302,395	8,385	8	hun1&2	4	100	9,822	3,190	982,224	32,368,336	10,147
32	man1&2	3	105	8,799	3242	923,941	27,226,335	8,398	8	hun1&2	5	90	9,666	3,280	869,928	33,238,264	10,134
33	orb2	4	175	8,818	3417	1,543,113	28,769,448	8,420	9	orb2	2	175	13,188	3,455	2,307,837	35,546,102	10,288
34	els3&4	4	160	8,839	3577	1,414,195	30,183,643	8,438	9	orb2	3	175	10,168	3,630	1,779,318	37,325,420	10,282
35	ala3&4	4	160	8,933	3737	1,429,341	31,612,984	8,459	9	orb2	4	175	9,595	3,805	1,679,122	39,004,542	10,251
36	eti3&4	4	160	8,943	3897	1,430,826	33,043,810	8,479	9	orb2	5	175	9,442	3,980	1,652,347	40,656,889	10,215
37	red5&6	2	70	8,992	3967	629,452	33,673,262	8,488	10	cw34	2	40	13,307	4,020	532,296	41,189,186	10,246
38	red7&8	4	140	9,028	4107	1,263,956	34,937,218	8,507	10	cw34	3	60	11,822	4,080	709,297	41,898,483	10,269
39	hun1&2	4	100	9,050	4207	905,042	35,842,260	8,520	10	cw34	4	140	10,361	4,220	1,450,505	43,348,988	10,272
40	sbr1&2	3	28	9,056	4235	253,562	36,095,822	8,523	10	cw34	5	132	9,506	4,352	1,254,776	44,603,764	10,249
41	ala5&6	4	180	9,074	4415	1,633,296	37,729,117	8,546	11	eti3&4	2	120	15,141	4,472	1,816,911	46,420,675	10,380
42	orb1	5	130	9,112	4545	1,184,559	38,913,677	8,562	11	eti3&4	3	160	11,005	4,632	1,760,748	48,181,424	10,402
43	ala1&2	2	70	9,127	4615	638,866	39,552,542	8,570	11	eti3&4	4	160	10,078	4,792	1,612,465	49,793,888	10,391
44	red5&6	3	90	9,134	4705	822,033	40,374,575	8,581	11	eti3&4	5	160	9,798	4,952	1,567,706	51,361,595	10,372
45	els3&4	5	190	9,198	4895	1,747,566	42,122,141	8,605	12	els3&4	2	120	15,882	5,072	1,905,889	53,267,484	10,502
46	els1&2	2	70	9,224	4965	645,700	42,767,841	8,614	12	els3&4	3	160	11,251	5,232	1,800,080	55,067,564	10,525
47	red7&8	5	160	9,248	5125	1,479,652	44,247,493	8,634	12	els3&4	4	160	10,188	5,392	1,630,072	56,697,636	10,515
48	eti1&2	2	60	9,264	5185	555,834	44,803,327	8,641	12	els3&4	5	190	9,825	5,582	1,866,701	58,564,337	10,492
49	orb2	5	175	9,268	5360	1,621,972	46,425,299	8,661	13	ala3&4	2	120	16,210	5,702	1,945,196	60,509,533	10,612
50	man1&2	4	95	9,279	5455	881,550	47,306,849	8,672	13	ala3&4	3	160	11,407	5,862	1,825,110	62,334,643	10,634
51	ala3&4	5	160	9,305	5615	1,488,738	48,795,587	8,690	13	ala3&4	4	160	10,311	6,022	1,649,777	63,984,420	10,625
52	cw01	2	13	9,320	5628	121,160	48,916,747	8,692	13	ala3&4	5	160	9,960	6,182	1,593,579	65,577,999	10,608
53	eti3&4	5	160	9,322	5788	1,491,457	50,408,203	8,709	14	eti1&2	2	60	16,432	6,242	985,907	66,563,907	10,664
54	red5&6	4	90	9,324	5878	839,196	51,247,400	8,719	14	eti1&2	3	60	12,244	6,302	734,610	67,298,517	10,679
55	ala1&2	3	90	9,341	5968	840,686	52,088,086	8,728	14	eti1&2	4	60	11,371	6,362	682,273	67,980,790	10,685
56	cw02	2	16	9,368	5984	149,892	52,237,979	8,730	14	eti1&2	5	64	11,106	6,426	710,761	68,691,551	10,690
57	ala5&6	5	180	9,375	6164	1,687,520	53,925,499	8,748	15	els1&2	2	70	17,208	6,496	1,204,540	69,896,091	10,760
58	hun1&2	5	90	9,379	6254	844,104	54,769,602	8,758	15	els1&2	3	90	12,131	6,586	1,091,829	70,987,920	10,779
59	sbr1&2	4	28	9,384	6282	262,764	55,032,367	8,760	15	els1&2	4	90	11,038	6,676	993,454	71,981,374	10,782

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TABLE E-5-SCE: SCE SYSTEM IHR AND AHR$_{AVE}$ CALCULATIONS - CONTINUED

	SUMMARY IHR DATA									SUMMARY AHR DATA							
		UNIT					Cumulative				UNIT					Cumulative	
		BLK	INC	IHR	CUM	IHR*MW	IHR*MW	SIHR			BLK	INC	AHR	CUM	AHR*MW	AHR*MW	SAHR
	PLANT	#	MW	Btu/kWh	MW	1000Btu	1000Btu	Btu/kWh		PLANT	#	MW	Btu/kWh	MW	1000Btu	1000Btu	Btu/kWh
60	els1&2	3	90	9,394	6372	845,487	55,877,854	8,769	15	els1&2	5	80	10,678	6,756	854,229	72,835,602	10,781
61	red5&6	5	80	9,535	6452	762,837	56,640,691	8,779	16	ala1&2	2	70	17,605	6,826	1,232,347	74,067,949	10,851
62	cw02	3	16	9,540	6468	152,635	56,793,326	8,781	16	ala1&2	3	90	12,222	6,916	1,099,983	75,167,933	10,869
63	cw01	3	13	9,549	6481	124,142	56,917,468	8,782	16	ala1&2	4	90	11,084	7,006	997,572	76,165,504	10,871
64	lbc8&9	2	110	9,608	6591	1,056,887	57,974,354	8,796	16	ala1&2	5	80	10,734	7,086	858,733	77,024,237	10,870
65	eti1&2	3	60	9,627	6651	577,613	58,551,967	8,803	17	red5&6	2	70	18,702	7,156	1,309,127	78,333,364	10,947
66	els1&2	4	90	9,631	6741	866,751	59,418,718	8,815	17	red5&6	3	90	12,511	7,246	1,125,960	79,459,324	10,966
67	lbc8&9	3	120	9,647	6861	1,157,626	60,576,344	8,829	17	red5&6	4	90	11,144	7,336	1,002,955	80,462,279	10,968
68	ala1&2	4	90	9,663	6951	869,675	61,446,019	8,840	17	red5&6	5	80	10,661	7,416	852,893	81,315,172	10,965
69	sbr1&2	5	28	9,667	6979	270,663	61,716,682	8,843	18	sbr1&2	2	28	18,968	7,444	531,107	81,846,279	10,995
70	lbc8&9	4	110	9,717	7089	1,068,869	62,785,550	8,857	18	sbr1&2	3	28	13,553	7,472	379,489	82,225,769	11,005
71	cw02	4	16	9,742	7105	155,877	62,941,427	8,859	18	sbr1&2	4	28	12,072	7,500	338,005	82,563,773	11,009
72	cw01	4	13	9,808	7118	127,510	63,068,937	8,860	18	sbr1&2	5	28	11,426	7,528	319,940	82,883,714	11,010
73	lbc8&9	5	150	9,836	7268	1,475,363	64,544,300	8,881	19	hig1&2	2	10	34,940	7,538	349,396	83,233,109	11,042
74	man1&2	5	90	9,842	7358	885,739	65,430,039	8,892	19	hig1&2	3	20	20,641	7,558	412,821	83,645,930	11,067
75	els1&2	5	80	9,898	7438	791,833	66,221,872	8,903	19	hig1&2	4	18	15,481	7,576	278,651	83,924,581	11,078
76	cw02	5	14	9,960	7452	139,444	66,361,316	8,905	19	hig1&2	5	10	13,820	7,586	138,196	84,062,777	11,081
77	ala1&2	5	80	10,047	7532	803,745	67,165,061	8,917	20	hig3&4	2	14	44,598	7,600	624,373	84,687,150	11,143
78	cw01	5	9	10,050	7541	90,452	67,255,513	8,919	20	hig3&4	3	26	24,520	7,626	637,514	85,324,663	11,189
79	eti1&2	4	60	10,104	7601	606,260	67,861,772	8,928	20	hig3&4	4	30	17,262	7,656	517,867	85,842,530	11,212
80	eti1&2	5	64	10,719	7665	685,992	68,547,765	8,943	20	hig3&4	5	9	15,100	7,665	135,898	85,978,428	11,217

TABLE E-5-SDG: SDG&E SYSTEM IHR AND AHR$_{AVE}$ CALCULATIONS

	SUMMARY IHR DATA									SUMMARY AHR DATA							
		UNIT					Cumulative				UNIT					Cumulative	
		BLK	INC	IHR	CUM	IHR*MW	IHR*MW	SIHR			BLK	INC	AHR	CUM	AHR*MW	AHR*MW	SAHR
	PLANT	#	MW	Btu/kWh	MW	1000Btu	1000Btu	Btu/kWh		PLANT	#	MW	Btu/kWh	MW	1000Btu	1000Btu	Btu/kWh
1	sba1	2	6	8,654	6	49,761	49,761	8,654	1	sba2	2	8	11,487	8	86,153	86,153	11,487
2	sba1	3	36	8,874	42	317,258	367,019	8,844	1	sba2	3	38	10,526	45	394,724	480,877	10,686
3	sba2	2	8	8,900	49	66,752	433,771	8,852	1	sba2	4	45	9,912	90	446,038	926,915	10,299
4	sba3	2	14	8,940	63	122,921	556,691	8,872	1	sba2	5	30	9,774	120	293,222	1,220,138	10,168
5	sba2	3	38	8,995	100	337,295	893,986	8,918	2	sba3	2	14	11,853	134	162,982	1,383,119	10,341
6	enc5	2	63	9,019	163	568,178	1,462,164	8,957	2	sba3	3	44	10,653	178	466,072	1,849,191	10,418
7	enc1	2	7	9,082	170	61,304	1,523,468	8,962	2	sba3	4	53	10,051	230	527,667	2,376,858	10,334
8	sba3	3	44	9,089	214	397,663	1,921,131	8,988	2	sba3	5	35	9,963	265	348,692	2,725,550	10,285
9	enc5	3	82	9,208	296	755,067	2,676,198	9,049	3	sba1	2	6	11,995	271	68,970	2,794,520	10,321
10	sba2	4	45	9,277	341	417,453	3,093,651	9,079	3	sba1	3	36	10,821	307	386,850	3,181,370	10,380
11	enc1	3	27	9,353	368	250,190	3,343,841	9,099	3	sba1	4	43	10,099	349	433,231	3,614,601	10,345
12	enc4	2	55	9,473	423	521,012	3,864,854	9,148	3	sba1	5	29	10,047	378	287,355	3,901,956	10,323
13	sba3	4	53	9,511	475	499,334	4,364,188	9,188	4	enc2	2	6	12,454	384	74,725	3,976,681	10,356
14	sba1	4	43	9,548	518	409,609	4,773,796	9,218	4	enc2	3	26	11,390	410	296,130	4,272,810	10,421
15	enc4	3	75	9,625	593	721,861	5,495,657	9,269	4	enc2	4	31	10,808	441	337,196	4,610,006	10,449
16	enc2	2	6	9,630	599	57,782	5,553,440	9,273	4	enc2	5	21	10,769	462	223,992	4,833,998	10,463
17	sba2	5	30	9,658	629	289,727	5,843,167	9,291	5	enc3	2	8	12,468	470	93,511	4,927,509	10,495
18	enc5	4	99	9,660	728	956,313	6,799,479	9,341	5	enc3	3	28	11,426	497	314,203	5,241,712	10,547
19	enc2	3	26	9,818	754	255,261	7,054,740	9,358	5	enc3	4	33	10,857	530	358,269	5,599,981	10,566
20	enc3	2	8	9,840	761	73,797	7,128,538	9,362	5	enc3	5	22	10,761	552	236,737	5,836,718	10,574
21	enc3	3	28	9,965	789	274,033	7,402,570	9,383	6	enc1	2	7	12,717	559	85,839	5,922,557	10,600
22	enc4	4	90	9,991	879	899,145	8,301,716	9,446	6	enc1	3	27	11,323	586	302,896	6,225,453	10,633
23	sba3	5	35	10,080	914	352,798	8,654,514	9,470	6	enc1	4	32	10,611	618	340,628	6,566,081	10,632
24	enc1	4	32	10,140	946	325,492	8,980,006	9,493	6	enc1	5	21	10,601	639	226,864	6,792,945	10,631
25	enc5	5	66	10,270	1,012	677,814	9,657,820	9,543	7	sba4	2	30	13,010	669	390,293	7,183,238	10,737
26	enc3	4	33	10,325	1,045	340,712	9,998,533	9,568	7	sba4	4	45	12,147	714	546,615	7,729,853	10,826
27	enc2	4	31	10,368	1,076	323,495	10,322,028	9,591	7	sba4	5	30	11,860	744	355,796	8,085,648	10,868
28	sba1	5	29	10,456	1,105	299,053	10,621,080	9,614	8	enc5	2	63	13,352	807	841,146	8,926,794	11,062
29	enc4	5	60	10,484	1,165	629,024	11,250,104	9,658	8	enc5	3	82	10,671	889	875,006	9,801,800	11,026
30	sba4	3	30	10,630	1,195	318,894	11,568,999	9,683	8	enc5	4	99	10,120	988	1,001,886	10,803,686	10,935
31	enc3	5	22	10,810	1,217	237,817	11,806,816	9,703	8	enc5	5	66	10,060	1,054	663,934	11,467,620	10,880
32	sba4	4	45	10,957	1,262	493,050	12,299,866	9,748	9	enc4	2	55	13,407	1,109	737,388	12,205,008	11,005
33	enc2	5	21	11,111	1,283	231,114	12,530,980	9,770	9	enc4	3	75	11,022	1,184	826,635	13,031,642	11,006
34	enc1	5	21	11,202	1,304	239,716	12,770,695	9,793	9	enc4	4	90	10,482	1,274	943,351	13,974,993	10,969
35	sba4	5	30	11,427	1,334	342,800	13,113,496	9,830	9	enc4	5	60	10,399	1,334	623,912	14,598,905	10,944

FIGURE E-1-PGE

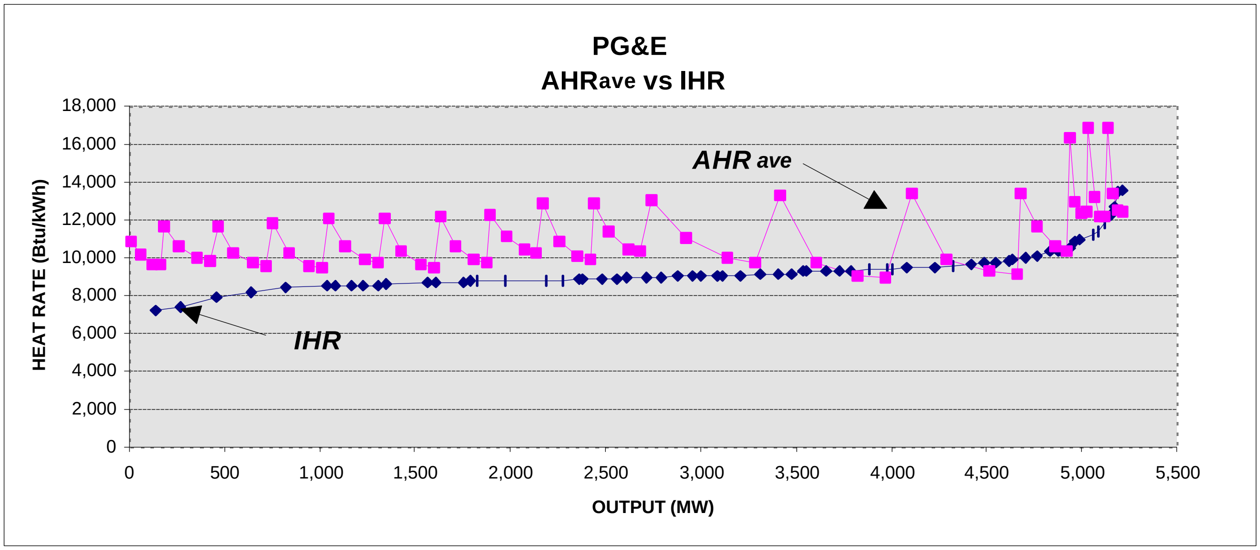


FIGURE E-1-SCE

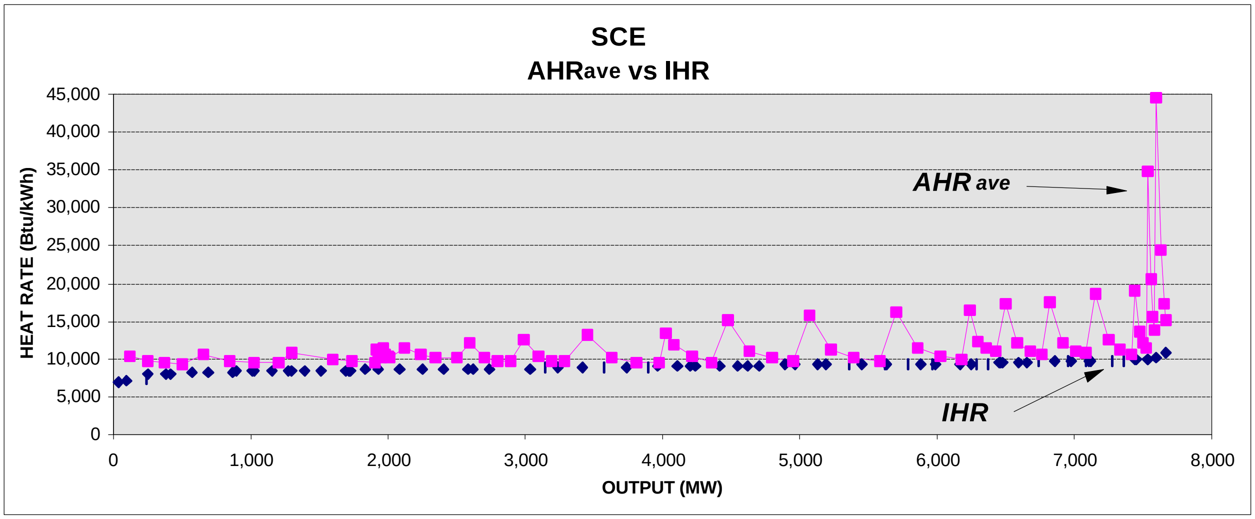


FIGURE E-1-SDG

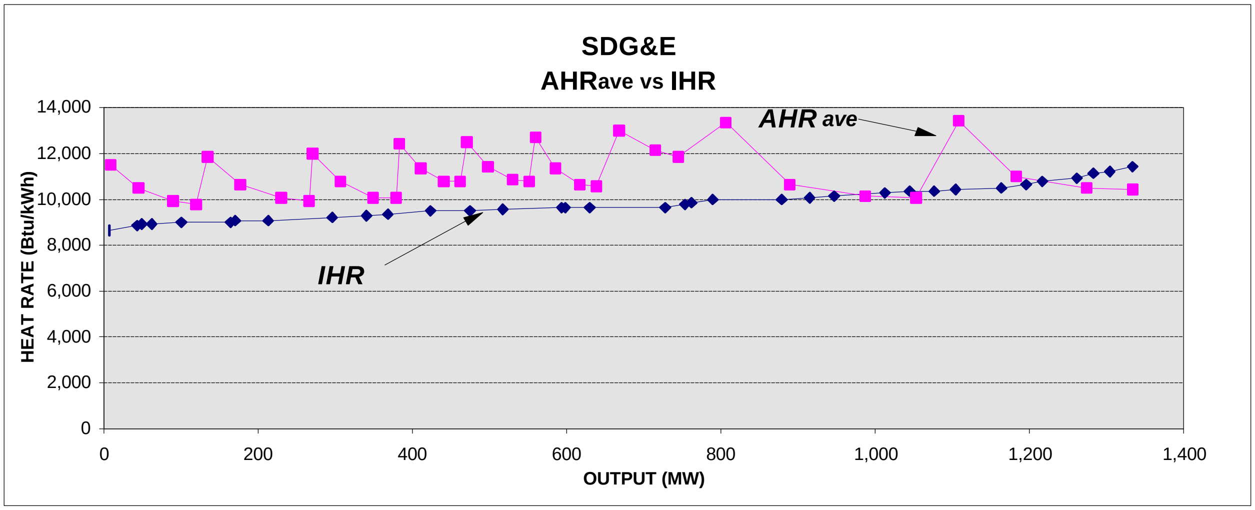


FIGURE E-2-PGE

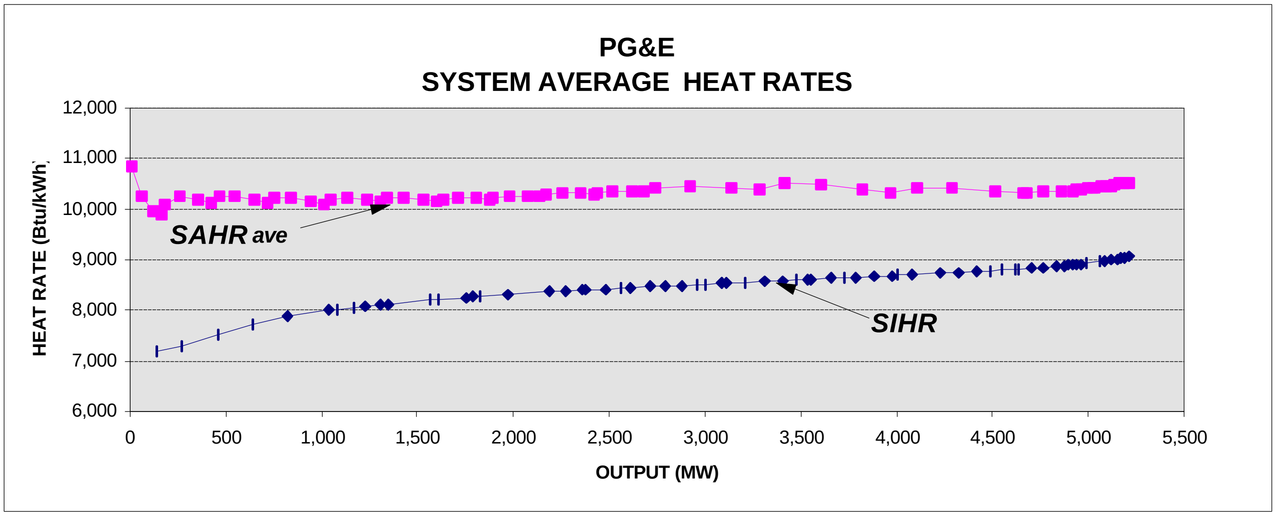


FIGURE E-2-SCE

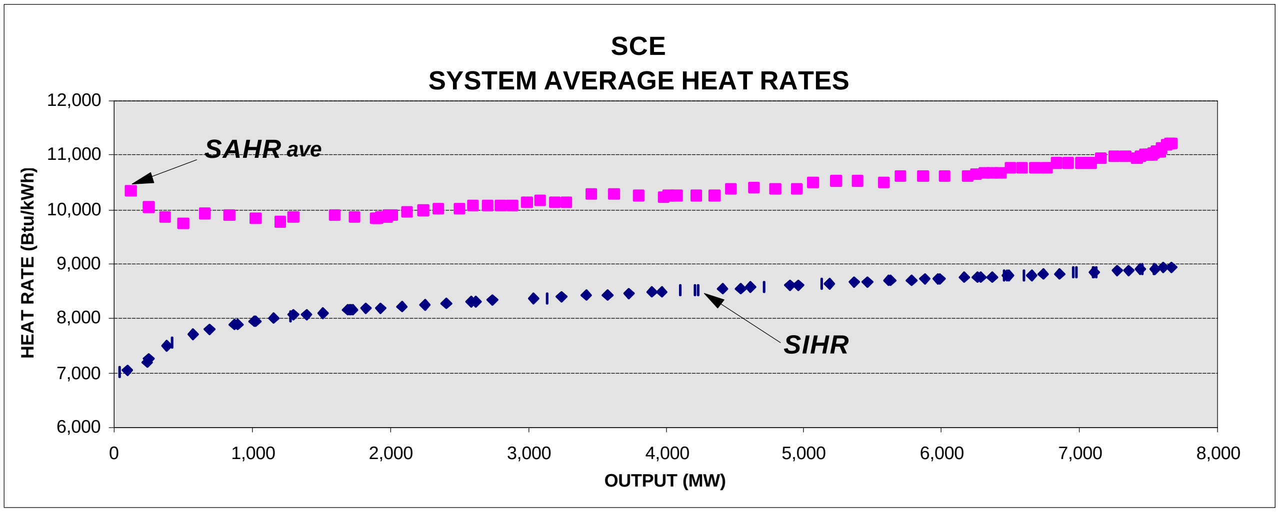
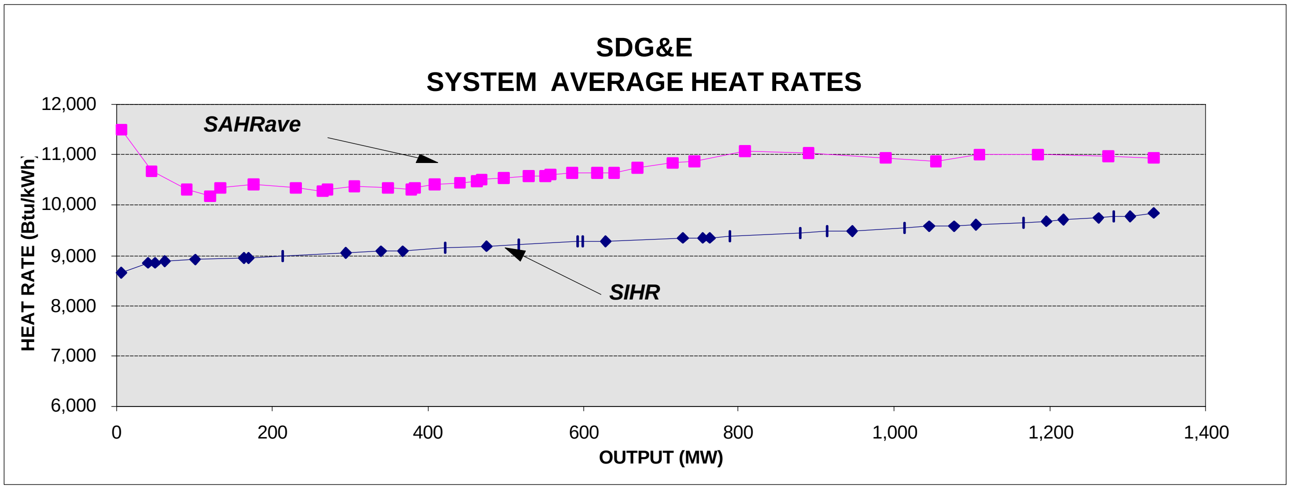


FIGURE E-2-SDG



SYSTEM COSTS

The System Costs are calculated as the ***SIHR*** and the $\boldsymbol{SAHR_{AVE}}$ values multiplied by the relevant fuel costs. SCE must be handled differently as it has two gas prices: one for the Cool Water units and another for the other SCE units. The Cool Water gas price is significantly lower than SCE’s general gas price, which gives the Cool Water units a considerable economic advantage raising them higher up in the economic dispatch order.

The Table E-6 series, on the next page, gives the cost calculations for each of the three IOUs. In each case, $\boldsymbol{SAHR_{AVE}}$ is multiplied by the total price of gas and ***SIHR*** is multiplied by the dispatch price of gas. Table E-7 gives the cost calculations for the three IOUs combined into a single system. Figures E-3 and E-4 give the graphical representations for Tables E-6 and E-7, respectively.

Figure E-4 (Table E-7) can be thought of as a proxy for the entire system. The ***SIHR*** at the dispatch price of gas curve is a proxy for the MC of the regulated system, and $\boldsymbol{SAHR_{AVE}}$ at the total price of gas curve is a proxy for the MCP of the competitive market.

Figure E-5 is a curve that is the ratio of the two curves in Figure 4 (Table E-7). It is the ratio of the MCP proxy to the MC proxy for selected points: at 1000 MW intervals. The curve shows values in the range of 1.26 to 1.45 depending on the output level. These are very significant differences to be sure, but it is important to keep in mind that in any one hour the difference can be much higher than this – as high as 8.5:1 as we have already shown.

The Figure E-5 curve implies that given an extended period of time where each unit is used equally and is allowed to experience all of its various levels equally, the average will be as shown. Remembering our earlier conclusion that this is unlikely since units will tend to operate more at their lower levels, we have to conclude that the 1.26 to 1.45 range is probably low. At the same time, we must recognize that the lowest and highest portions of the curve will tend to be used the least. The least that we can say here is that this ratio will undoubtedly be higher than 1.26 – that is, MCP will no doubt exceed traditional MC by something greater than 26 percent. Based on knowledge of computer simulations, not provided herein, the estimate is easily 30 percent or more.

Figure E-6 is the same as Figure E-5 except that the difference due to the gas price differential has been removed. This Figure represents the difference between Average and Incremental Heat Rates, only. The range is now 1.17 to 1.36, as opposed to the 1.26 to 1.45 of Figure E-5. The effect of using Average instead of Incremental Heat Rates is in the range of something greater than 17 percent. The effect of the gas prices is therefore about 9 percent.

TABLE E-6-PGE: PG&E SYSTEM AVERAGE COST CALCULATIONS

SUMMARY IHR DATA										SUMMARY AHR DATA									
PLANT	BLK #	INC MW	**IHR** Btu/kWh	CUM MW	Disp. **2.31** $/MWh	**IHR*MW** Block	Cumul.	**SIHR** Btu/kWh	**Disp. 2.31** $/MWh	PLANT	BLK #	INC MW	**AHR** Btu/kWh	CUM MW	Total **2.51** $/MWh	**AHR*MW** Block	Cumul.	**SAHR** Btu/kWh	**Total 2.5** $/MWh
mos7	2	135	7,196	135	16.6	971441	971441	7,196	16.6	pot3	2	5	10,853	5	27.2	54266	54266	10,853	27.1
mos6	2	135	7,370	270	17.0	994931	1966372	7,283	16.8	pot3	3	52	10,207	57	25.6	530763	585029	10,264	25.7
mos7	3	185	7,890	455	18.2	1459609	3425981	7,530	17.4	pot3	4	62	9,689	119	24.3	600716	1185744	9,964	24.9
mos6	3	185	8,146	640	18.8	1506925	4932906	7,708	17.8	pot3	5	41	9,686	160	24.3	397135	1582880	9,893	24.7
pit7	3	180	8,476	820	19.6	1525759	6458665	7,876	18.2	hnp4	2	20	11,642	180	29.2	232845	1815724	10,087	25.2
mos7	4	221	8,485	1041	19.6	1875107	8333772	8,006	18.5	hnp4	3	82	10,585	262	26.6	867947	2683671	10,243	25.6
con7	2	39	8,496	1080	19.6	331331	8665104	8,023	18.5	hnp4	4	96	9,985	358	25.1	958544	3642216	10,174	25.4
con7	3	85	8,503	1165	19.6	722789	9387893	8,058	18.6	hnp4	5	66	9,854	424	24.7	650366	4292582	10,124	25.3
pit7	2	60	8,555	1225	19.8	513295	9901188	8,083	18.7	mor4	2	39	11,694	463	29.4	456063	4748644	10,256	25.6
con6	3	85	8,555	1310	19.8	727171	10628359	8,113	18.7	mor4	3	84	10,292	547	25.8	864561	5613206	10,262	25.7
pit6	2	35	8,613	1345	19.9	301456	10929814	8,126	18.8	mor4	4	101	9,714	648	24.4	981103	6594309	10,176	25.4
mos6	4	221	8,668	1566	20.0	1915722	12845537	8,203	18.9	mor4	5	68	9,561	716	24.0	650147	7244456	10,118	25.3
mor4	2	39	8,703	1605	20.1	339425	13184962	8,215	19.0	con6	2	39	11,860	755	29.8	462528	7706983	10,208	25.5
mos6	5	148	8,714	1753	20.1	1289726	14474688	8,257	19.1	con6	3	85	10,300	840	25.9	875488	8582471	10,217	25.5
pit5	2	35	8,744	1788	20.2	306050	14780738	8,267	19.1	con6	4	102	9,579	942	24.0	977042	9559513	10,148	25.4
con6	2	39	8,756	1827	20.2	341490	15122229	8,277	19.1	con6	5	68	9,479	1010	23.8	644582	10204095	10,103	25.3
mos7	5	148	8,760	1975	20.2	1296414	16418642	8,313	19.2	mor3	2	39	12,056	1049	30.3	470181	10674276	10,176	25.4
pit7	4	216	8,762	2191	20.2	1892651	18311293	8,358	19.3	mor3	3	84	10,616	1133	26.6	891770	11566046	10,208	25.5
pit6	3	82	8,797	2273	20.3	721354	19032647	8,373	19.3	mor3	4	101	9,950	1234	25.0	1004983	12571029	10,187	25.5
mor4	3	84	8,848	2357	20.4	743248	19775896	8,390	19.4	mor3	5	68	9,712	1302	24.4	660441	13231470	10,162	25.4
hnp4	2	20	8,873	2377	20.5	177454	19953349	8,394	19.4	con7	2	39	12,112	1341	30.4	472386	13703857	10,219	25.5
con6	4	102	8,877	2479	20.5	905452	20858801	8,414	19.4	con7	3	85	10,361	1426	26.0	880708	14584564	10,228	25.6
pit5	3	82	8,900	2561	20.6	729832	21588633	8,430	19.5	con7	4	102	9,622	1528	24.2	981468	15566033	10,187	25.5
pot3	3	52	8,924	2613	20.6	464057	22052690	8,440	19.5	con7	5	68	9,517	1596	23.9	647154	16213187	10,159	25.4
con7	4	102	8,933	2715	20.6	911212	22963902	8,458	19.5	pit5	2	35	12,186	1631	30.6	426514	16639701	10,202	25.5
pit3&4	3	82	8,983	2797	20.8	736606	23700507	8,474	19.6	pit5	3	82	10,598	1713	26.6	869041	17508742	10,221	25.6
pit1&2	3	82	9,003	2879	20.8	738207	24438714	8,489	19.6	pit5	4	97	9,907	1810	24.9	960937	18469679	10,204	25.5
hnp4	3	82	9,044	2961	20.9	741638	25180352	8,504	19.6	pit5	5	65	9,712	1875	24.4	631257	19100936	10,187	25.5
mor3	2	39	9,056	3000	20.9	353189	25533541	8,511	19.7	mor1&2	2	20	12,246	1895	30.7	244911	19345848	10,209	25.5
mor3	3	84	9,064	3084	20.9	761357	26294897	8,526	19.7	mor1&2	3	82	11,128	1977	27.9	912503	20258351	10,247	25.6
pot3	2	5	9,066	3089	20.9	45329	26340226	8,527	19.7	mor1&2	4	96	10,438	2073	26.2	1002050	21260402	10,256	25.6
pit1&2	2	20	9,079	3109	21.0	181571	26521797	8,531	19.7	mor1&2	5	66	10,266	2139	25.8	677577	21937979	10,256	25.6
mor4	4	101	9,083	3210	21.0	917368	27439165	8,548	19.7	pit6	2	35	12,870	2174	32.3	450461	22388440	10,298	25.7
mor3	4	101	9,100	3311	21.0	919114	28358279	8,565	19.8	pit6	3	82	10,899	2256	27.4	893708	23282147	10,320	25.8
pit5	4	97	9,135	3408	21.1	886132	29244411	8,581	19.8	pit6	4	97	10,075	2353	25.3	977237	24259384	10,310	25.8
mor3	5	68	9,159	3476	21.2	622813	29867224	8,592	19.8	pit6	5	65	9,929	2418	24.9	645407	24904791	10,300	25.7
pot3	4	62	9,276	3538	21.4	575101	30442325	8,604	19.9	pit3&4	2	20	12,905	2438	32.4	258107	25162898	10,321	25.8
pit3&4	2	20	9,276	3558	21.4	185523	30627848	8,608	19.9	pit3&4	3	82	11,388	2520	28.6	933821	26096719	10,356	25.9
pit6	4	97	9,293	3655	21.5	901420	31529268	8,626	19.9	pit3&4	4	96	10,408	2616	26.1	999204	27095923	10,358	25.9
mor4	5	68	9,314	3723	21.5	633373	32162641	8,639	20.0	pit3&4	5	66	10,341	2682	26.0	682485	27778408	10,357	25.9
pit5	5	65	9,344	3788	21.6	607366	32770007	8,651	20.0	pit7	2	60	13,001	2742	32.6	780062	28558470	10,415	26.0
hnp4	4	96	9,379	3884	21.7	900405	33670412	8,669	20.0	pit7	3	180	11,062	2922	27.8	1991242	30549713	10,455	26.1
pit1&2	4	96	9,391	3980	21.7	901583	34571995	8,686	20.1	pit7	4	216	9,977	3138	25.0	2154948	32704661	10,422	26.1
mor1&2	2	20	9,407	4000	21.7	188135	34760130	8,690	20.1	pit7	5	144	9,705	3282	24.4	1397580	34102241	10,391	26.0
mor1&2	3	82	9,441	4082	21.8	774202	35534331	8,705	20.1	mos7	2	135	13,304	3417	33.4	1796095	35898336	10,506	26.3
pit7	5	144	9,469	4226	21.9	1363571	36897902	8,731	20.2	mos7	3	185	9,758	3602	24.5	1805199	37703535	10,467	26.2
pit3&4	4	96	9,529	4322	22.0	914759	37812661	8,749	20.2	mos7	4	221	9,079	3823	22.8	2006352	39709887	10,387	26.0
mor1&2	4	96	9,675	4418	22.3	928783	38741444	8,769	20.3	mos7	5	148	8,949	3971	22.5	1324404	41034291	10,333	25.8
hnp4	5	66	9,724	4484	22.5	641751	39383196	8,783	20.3	mos6	2	135	13,370	4106	33.6	1804959	42839250	10,433	26.1
con7	5	68	9,754	4552	22.5	663242	40046438	8,798	20.3	mos6	3	185	9,918	4291	24.9	1834901	44674150	10,411	26.0
con6	5	68	9,811	4620	22.7	667170	40713607	8,812	20.4	mos6	4	221	9,273	4512	23.3	2049296	46723446	10,355	25.9
hnp3	2	17	9,876	4637	22.8	167886	40881494	8,816	20.4	mos6	5	148	9,115	4660	22.9	1349026	48072472	10,316	25.8
pit6	5	65	9,963	4702	23.0	647610	41529104	8,832	20.4	pit1&2	2	20	13,412	4680	33.7	268231	48340703	10,329	25.8
mor1&2	5	66	10,081	4768	23.3	665338	42194442	8,850	20.4	pit1&2	3	82	11,673	4762	29.3	957189	49297892	10,352	25.9
pit1&2	5	66	10,331	4834	23.9	681813	42876255	8,870	20.5	pit1&2	4	96	10,573	4858	26.5	1014964	50312855	10,357	25.9
pot3	5	41	10,341	4875	23.9	423968	43300223	8,882	20.5	pit1&2	5	66	10,339	4924	26.0	682388	50995243	10,356	25.9
hnp2	2	17	10,364	4892	23.9	176181	43476404	8,887	20.5	hnp3	2	17	16,339	4941	41.0	277769	51273012	10,377	25.9
hmb1&2	3	27	10,366	4919	23.9	279882	43756286	8,895	20.5	hnp3	3	27	12,974	4968	32.6	350302	51623314	10,391	26.0
hmb1&2	2	16	10,543	4935	24.4	168689	43924976	8,901	20.6	hnp3	4	32	12,336	5000	31.0	394742	52018056	10,404	26.0
hnp3	3	27	10,861	4962	25.1	293239	44218215	8,911	20.6	hnp3	5	21	12,471	5021	31.3	261888	52279943	10,412	26.0
hnp2	3	27	10,981	4989	25.4	296490	44514705	8,923	20.6	hmb1&2	2	16	16,853	5037	42.3	269651	52549594	10,433	26.1
pit3&4	5	66	11,211	5055	25.9	739944	45254649	8,952	20.7	hmb1&2	3	27	13,245	5064	33.2	357616	52907211	10,448	26.1
hmb1&2	4	31	11,392	5086	26.3	353140	45607789	8,967	20.7	hmb1&2	4	31	12,142	5095	30.5	376412	53283622	10,458	26.1
hnp2	4	32	11,861	5118	27.4	379557	45987346	8,985	20.8	hmb1&2	5	21	12,167	5116	30.5	255499	53539122	10,465	26.2
hnp3	4	32	12,246	5150	28.3	391877	46379222	9,006	20.8	hnp2	2	17	16,865	5133	42.3	286706	53825827	10,486	26.2
hnp2	5	21	12,701	5171	29.3	266719	46645941	9,021	20.8	hnp2	3	27	13,382	5160	33.6	361311	54187139	10,501	26.3
hmb1&2	5	21	13,521	5192	31.2	283948	46929889	9,039	20.9	hnp2	4	32	12,517	5192	31.4	400547	54587685	10,514	26.3
hnp3	5	21	13,552	5213	31.3	284586	47214476	9,057	20.9	hnp2	5	21	12,433	5213	31.2	261103	54848789	10,522	26.3

TABLE E-6-SCE: SCE SYSTEM AVERAGE COST CALCULATIONS

			SUMMARY IHR DATA												**SUMMARY AHR DATA**				
					Disp.			Disp.								Total			Total
					2.24	DISPATCH		***2.24***	*=Cool Water*							***2.34***	TOTAL		***2.34***
PLANT	BLK	INC	***IHR***	CUM	***2.43***	***Unit Cost * MW***		***2.43***			PLANT	BLK	INC	***AHR***	CUM	***2.61***	***Unit Cost * MW***		***2.61***
	#	MW	Btu/kWh	MW	$/MWh	Unit	Cumul.	$/MWh				#	MW	Btu/kWh	MW	$/MWh	Unit	Cumul.	$/MWh
cw34	2	40	7,013	40	15.7	628	628	15.7		1	cw01	2	13	11,259	13	26.3	343	343	26.3
cw34	3	60	7,064	100	15.8	949	1,578	15.8		1	cw01	3	13	10,587	26	24.8	322	665	25.6
cw34	4	140	7,334	240	16.4	2,300	3,878	16.2		1	cw01	4	13	10,343	39	24.2	315	979	25.1
cw34	5	132	8,018	372	18.0	2,371	6,249	16.8		1	cw01	5	9	10,264	48	24.0	216	1,195	24.9
cw01	2	13	9,320	385	20.9	271	6,520	16.9		2	cw02	2	16	11,401	64	26.7	427	1,622	25.3
cw02	2	16	9,368	401	21.0	336	6,856	17.1		2	cw02	3	16	10,650	80	24.9	399	2,021	25.3
cw02	3	16	9,540	417	21.4	342	7,198	17.3		2	cw02	4	16	10,370	96	24.3	388	2,409	25.1
cw01	3	13	9,549	430	21.4	278	7,476	17.4		2	cw02	5	14	10,262	110	24.0	336	2,745	25.0
cw02	4	16	9,742	446	21.8	349	7,825	17.5		3	orb1	2	120	10,354	230	27.0	3,243	5,988	26.0
cw01	4	13	9,808	459	22.0	286	8,111	17.7		3	orb1	3	130	9,753	360	25.5	3,309	9,297	25.8
cw02	5	14	9,960	473	22.3	312	8,423	17.8		3	orb1	4	120	9,486	480	24.8	2,971	12,268	25.6
cw01	5	9	10,050	482	22.5	203	8,626	17.9		3	orb1	5	130	9,382	610	24.5	3,183	15,452	25.3
hig3&4	2	14	7,899	496	19.2	269	8,894	17.9		4	ala5&6	2	160	10,532	770	27.5	4,398	19,850	25.8
hig3&4	3	26	8,096	522	19.7	512	9,406	18.0		4	ala5&6	3	180	9,810	950	25.6	4,609	24,459	25.7
ala5&6	2	160	8,155	682	19.8	3,171	12,577	18.4		4	ala5&6	4	180	9,560	1,130	25.0	4,491	28,950	25.6
orb1	2	120	8,171	802	19.9	2,383	14,959	18.7		4	ala5&6	5	180	9,491	1,310	24.8	4,459	33,409	25.5
orb2	2	175	8,192	977	19.9	3,484	18,443	18.9		5	red7&8	2	100	10,808	1,410	28.2	2,821	36,230	25.7
hig3&4	4	30	8,338	1007	20.3	608	19,051	18.9		5	red7&8	3	300	9,995	1,710	26.1	7,826	44,056	25.8
els3&4	2	120	8,395	1127	20.4	2,448	21,499	19.1		5	red7&8	4	140	9,633	1,850	25.1	3,520	47,575	25.7
hig1&2	2	10	8,413	1137	20.4	204	21,703	19.1		5	red7&8	5	160	9,548	2,010	24.9	3,987	51,563	25.7
orb1	3	130	8,429	1267	20.5	2,663	24,366	19.2	O	6	lbc8&9	2	110	11,404	2,120	29.8	3,274	54,837	25.9
eti3&4	2	120	8,438	1387	20.5	2,460	26,826	19.3	O	6	lbc8&9	3	120	10,506	2,240	27.4	3,291	58,127	25.9
hig1&2	3	20	8,438	1407	20.5	410	27,236	19.4	O	6	lbc8&9	4	110	10,230	2,350	26.7	2,937	61,064	26.0
man1&2	2	100	8,443	1507	20.5	2,052	29,288	19.4	O	6	lbc8&9	5	150	10,107	2,500	26.4	3,957	65,021	26.0
ala3&4	2	120	8,443	1627	20.5	2,462	31,750	19.5		7	cw34	2	40	13,307	2,540	31.1	1,246	66,267	26.1
orb2	3	175	8,459	1802	20.6	3,597	35,347	19.6		7	cw34	3	60	11,822	2,600	27.7	1,660	67,927	26.1
hig1&2	4	18	8,471	1820	20.6	371	35,718	19.6		7	cw34	4	140	10,361	2,740	24.2	3,394	71,321	26.0
hig3&4	5	9	8,485	1829	20.6	186	35,903	19.6		7	cw34	5	132	9,506	2,872	22.2	2,936	74,257	25.9
hig1&2	5	10	8,495	1839	20.6	206	36,110	19.6		8	man1&2	2	100	12,114	2,972	31.6	3,162	77,419	26.0
hun1&2	2	100	8,552	1939	20.8	2,078	38,188	19.7		8	man1&2	3	105	10,087	3,077	26.3	2,764	80,183	26.1
red7&8	2	100	8,557	2039	20.8	2,079	40,267	19.7		8	man1&2	4	95	9,706	3,172	25.3	2,407	82,590	26.0
els3&4	3	160	8,576	2199	20.8	3,334	43,602	19.8		8	man1&2	5	90	9,664	3,262	25.2	2,270	84,860	26.0
ala3&4	3	160	8,639	2359	21.0	3,359	46,960	19.9		9	hun1&2	2	100	12,570	3,362	32.8	3,281	88,140	26.2
eti3&4	3	160	8,641	2519	21.0	3,359	50,320	20.0		9	hun1&2	3	100	10,331	3,462	27.0	2,696	90,837	26.2
ala5&6	3	180	8,656	2699	21.0	3,786	54,106	20.0		9	hun1&2	4	100	9,822	3,562	25.6	2,564	93,400	26.2
sbr1&2	2	28	8,681	2727	21.1	591	54,697	20.1		9	hun1&2	5	90	9,666	3,652	25.2	2,271	95,671	26.2
orb1	4	120	8,742	2847	21.2	2,549	57,246	20.1		10	orb2	2	175	13,188	3,827	34.4	6,023	101,694	26.6
red7&8	3	300	8,759	3147	21.3	6,385	63,631	20.2		10	orb2	3	175	10,168	4,002	26.5	4,644	106,338	26.6
hun1&2	3	100	8,768	3247	21.3	2,131	65,762	20.3		10	orb2	4	175	9,595	4,177	25.0	4,383	110,721	26.5
man1&2	3	105	8,799	3352	21.4	2,245	68,007	20.3		10	orb2	5	175	9,442	4,352	24.6	4,313	115,033	26.4
orb2	4	175	8,818	3527	21.4	3,750	71,757	20.3		11	eti3&4	2	120	15,141	4,472	39.5	4,742	119,776	26.8
els3&4	4	160	8,839	3687	21.5	3,436	75,193	20.4		11	eti3&4	3	160	11,005	4,632	28.7	4,596	124,371	26.9
ala3&4	4	160	8,933	3847	21.7	3,473	78,666	20.4		11	eti3&4	4	160	10,078	4,792	26.3	4,209	128,580	26.8
eti3&4	4	160	8,943	4007	21.7	3,477	82,143	20.5		11	eti3&4	5	160	9,798	4,952	25.6	4,092	132,671	26.8
red5&6	2	70	8,992	4077	21.9	1,530	83,673	20.5		12	els3&4	2	120	15,882	5,072	41.5	4,974	137,646	27.1
red7&8	4	140	9,028	4217	21.9	3,071	86,744	20.6		12	els3&4	3	160	11,251	5,232	29.4	4,698	142,344	27.2
hun1&2	4	100	9,050	4317	22.0	2,199	88,944	20.6		12	els3&4	4	160	10,188	5,392	26.6	4,254	146,598	27.2
sbr1&2	3	28	9,056	4345	22.0	616	89,560	20.6		12	els3&4	5	190	9,825	5,582	25.6	4,872	151,470	27.1
ala5&6	4	180	9,074	4525	22.0	3,969	93,529	20.7		13	ala3&4	2	120	16,210	5,702	42.3	5,077	156,547	27.5
orb1	5	130	9,112	4655	22.1	2,878	96,407	20.7		13	ala3&4	3	160	11,407	5,862	29.8	4,764	161,311	27.5
ala1&2	2	70	9,127	4725	22.2	1,552	97,960	20.7		13	ala3&4	4	160	10,311	6,022	26.9	4,306	165,617	27.5
red5&6	3	90	9,134	4815	22.2	1,998	99,957	20.8		13	ala3&4	5	160	9,960	6,182	26.0	4,159	169,776	27.5
els3&4	5	190	9,198	5005	22.4	4,247	104,204	20.8		14	eti1&2	2	60	16,432	6,242	42.9	2,573	172,349	27.6
els1&2	2	70	9,224	5075	22.4	1,569	105,773	20.8		14	eti1&2	3	60	12,244	6,302	32.0	1,917	174,267	27.7
red7&8	5	160	9,248	5235	22.5	3,596	109,368	20.9		14	eti1&2	4	60	11,371	6,362	29.7	1,781	176,047	27.7
eti1&2	2	60	9,264	5295	22.5	1,351	110,719	20.9		14	eti1&2	5	64	11,106	6,426	29.0	1,855	177,903	27.7
orb2	5	175	9,268	5470	22.5	3,941	114,660	21.0		15	els1&2	2	70	17,208	6,496	44.9	3,144	181,046	27.9
man1&2	4	95	9,279	5565	22.5	2,142	116,803	21.0		15	els1&2	3	90	12,131	6,586	31.7	2,850	183,896	27.9
ala3&4	5	160	9,305	5725	22.6	3,618	120,420	21.0		15	els1&2	4	90	11,038	6,676	28.8	2,593	186,489	27.9
eti3&4	5	160	9,322	5885	22.7	3,624	124,044	21.1		15	els1&2	5	80	10,678	6,756	27.9	2,230	188,718	27.9

- Continued on Next Page -

TABLE E-6-SCE: SCE SYSTEM AVERAGE COST CALCULATIONS - CONTINUED

					SUMMARY IHR DATA								**SUMMARY AHR DATA**					
					Disp.			Disp.							Total			Total
					2.24	DISPATCH		***2.24***	*=Cool Water*						***2.34***	TOTAL		***2.34***
PLANT	BLK	INC	***IHR***	CUM	***2.43***	***Unit Cost * MW***		***2.43***		PLANT	BLK	INC	***AHR***	CUM	***2.61***	***Unit Cost * MW***		***2.61***
	#	MW	Btu/kWh	MW	$/MWh	Unit	Cumul.	$/MWh			#	MW	Btu/kWh	MW	$/MWh	Unit	Cumul.	$/MWh
red5&6	4	90	9,324	5975	22.7	2,039	126,084	21.1	16	ala1&2	2	70	17,605	6,826	45.9	3,216	191,935	28.1
ala1&2	3	90	9,341	6065	22.7	2,043	128,127	21.1	16	ala1&2	3	90	12,222	6,916	31.9	2,871	194,806	28.2
ala5&6	5	180	9,375	6245	22.8	4,101	132,227	21.2	16	ala1&2	4	90	11,084	7,006	28.9	2,604	197,410	28.2
hun1&2	5	90	9,379	6335	22.8	2,051	134,278	21.2	16	ala1&2	5	80	10,734	7,086	28.0	2,241	199,651	28.2
sbr1&2	4	28	9,384	6363	22.8	639	134,917	21.2	17	red5&6	2	70	18,702	7,156	48.8	3,417	203,068	28.4
els1&2	3	90	9,394	6453	22.8	2,055	136,971	21.2	17	red5&6	3	90	12,511	7,246	32.7	2,939	206,006	28.4
red5&6	5	80	9,535	6533	23.2	1,854	138,825	21.2	17	red5&6	4	90	11,144	7,336	29.1	2,618	208,624	28.4
lbc8&9	2	110	9,608	6643	23.3	2,568	141,393	21.3	17	red5&6	5	80	10,661	7,416	27.8	2,226	210,850	28.4
eti1&2	3	60	9,627	6703	23.4	1,404	142,797	21.3	18	sbr1&2	2	28	18,968	7,444	49.5	1,386	212,236	28.5
els1&2	4	90	9,631	6793	23.4	2,106	144,903	21.3	18	sbr1&2	3	28	13,553	7,472	35.4	990	213,227	28.5
lbc8&9	3	120	9,647	6913	23.4	2,813	147,716	21.4	18	sbr1&2	4	28	12,072	7,500	31.5	882	214,109	28.5
ala1&2	4	90	9,663	7003	23.5	2,113	149,829	21.4	18	sbr1&2	5	28	11,426	7,528	29.8	835	214,944	28.6
sbr1&2	5	28	9,667	7031	23.5	658	150,487	21.4	19	hig1&2	2	10	34,940	7,538	91.2	912	215,856	28.6
lbc8&9	4	110	9,717	7141	23.6	2,597	153,085	21.4	19	hig1&2	3	20	20,641	7,558	53.9	1,077	216,933	28.7
lbc8&9	5	150	9,836	7291	23.9	3,585	156,670	21.5	19	hig1&2	4	18	15,481	7,576	40.4	727	217,661	28.7
man1&2	5	90	9,842	7381	23.9	2,152	158,822	21.5	19	hig1&2	5	10	13,820	7,586	36.1	361	218,021	28.7
els1&2	5	80	9,898	7461	24.1	1,924	160,746	21.5	20	hig3&4	2	14	44,598	7,600	116.4	1,630	219,651	28.9
ala1&2	5	80	10,047	7541	24.4	1,953	162,699	21.6	20	hig3&4	3	26	24,520	7,626	64.0	1,664	221,315	29.0
eti1&2	4	60	10,104	7601	24.6	1,473	164,172	21.6	20	hig3&4	4	30	17,262	7,656	45.1	1,352	222,667	29.1
eti1&2	5	64	10,719	7665	26.0	1,667	165,839	21.6	20	hig3&4	5	9	15,100	7,665	39.4	355	223,021	29.1

TABLE E-6-SDG: SDG&E SYSTEM AVERAGE COST CALCULATIONS

					SUMMARY IHR DATA										**SUMMARY AHR DATA**				
					Disp.				Total						Total				Total
	BLK	INC	CUM	***IHR***	***2.34***	***IHR*MW***		***SHIR***	***2.91***		BLK	INC	CUM	***AHR***	***2.91***	***AHR*MW***		***SHAR***	***2.91***
PLANT	#	MW	MW	Btu/kWh	$/MWh	Block	Cumul.	Btu/kWh	$/MWh	PLANT	#	MW	MW	Btu/kWh	$/MWh	Block	Cumul.	Btu/kWh	$/MWh
sba1	2	7	7	8,560	20.0	59923	59923	8,560	24.9	sba1	2	7	7	11,778	34.3	82446	82446	11,778	34.3
sba1	3	37	44	8,764	20.5	324271	384194	8,732	25.4	sba1	3	37	44	10,613	30.9	392666	475112	10,798	31.4
sba3	2	13	57	8,937	20.9	116177	500371	8,778	25.5	sba1	4	44	88	9,922	28.9	436553	911665	10,360	30.1
enc5	2	59	116	9,016	21.1	531917	1032288	8,899	25.9	sba1	5	29	117	9,857	28.7	285863	1197528	10,235	29.8
sba3	3	43	159	9,082	21.3	390525	1422813	8,949	26.0	sba3	2	13	130	11,880	34.6	154440	1351968	10,400	30.3
sba2	2	8	167	9,127	21.4	73019	1495832	8,957	26.1	sba3	3	43	173	10,680	31.1	459244	1811212	10,469	30.5
enc5	3	79	246	9,190	21.5	725985	2221817	9,032	26.3	sba3	4	51	224	10,062	29.3	513141	2324353	10,377	30.2
sba2	3	37	283	9,287	21.7	343637	2565454	9,065	26.4	sba3	5	34	258	9,961	29.0	338664	2663017	10,322	30.0
sba1	4	44	327	9,368	21.9	412176	2977630	9,106	26.5	sba2	2	8	266	12,099	35.2	96795	2759812	10,375	30.2
enc3	2	8	335	9,374	21.9	74995	3052625	9,112	26.5	sba2	3	37	303	11,007	32.0	407264	3167077	10,452	30.4
enc4	2	53	388	9,472	22.2	502013	3554638	9,161	26.7	sba2	4	45	348	10,352	30.1	465856	3632933	10,439	30.4
sba3	4	51	439	9,487	22.2	483825	4038464	9,199	26.8	sba2	5	30	378	10,259	29.9	307762	3940695	10,425	30.3
enc5	4	94	533	9,605	22.5	902838	4941301	9,271	27.0	enc1	2	7	385	12,632	36.8	88422	4029117	10,465	30.5
enc4	3	74	607	9,617	22.5	711654	5652955	9,313	27.1	enc1	3	27	412	11,483	33.4	310038	4339155	10,532	30.6
enc3	3	27	634	9,635	22.5	260155	5913110	9,327	27.1	enc1	4	32	444	10,831	31.5	346586	4685741	10,553	30.7
enc1	2	7	641	9,736	22.8	68155	5981265	9,331	27.2	enc1	5	21	465	10,737	31.2	225480	4911221	10,562	30.7
enc2	2	6	647	9,763	22.8	58577	6039842	9,335	27.2	enc3	2	8	473	13,155	38.3	105243	5016464	10,606	30.9
sba2	4	45	692	9,763	22.8	439331	6479174	9,363	27.2	enc3	3	27	500	11,675	34.0	315230	5331694	10,663	31.0
enc1	3	27	719	9,815	23.0	265009	6744183	9,380	27.3	enc3	4	33	533	10,933	31.8	360797	5692491	10,680	31.1
enc2	3	26	745	9,889	23.1	257107	7001290	9,398	27.3	enc3	5	22	555	10,891	31.7	239600	5932091	10,688	31.1
enc4	4	87	832	9,966	23.3	867054	7868344	9,457	27.5	enc4	2	53	608	13,472	39.2	714007	6646098	10,931	31.8
sba3	5	34	866	10,027	23.5	340914	8209258	9,480	27.6	enc4	3	74	682	11,055	32.2	818074	7464172	10,945	31.8
enc5	5	63	929	10,163	23.8	640257	8849515	9,526	27.7	enc4	4	87	769	10,494	30.5	912936	8377108	10,894	31.7
sba1	5	29	958	10,169	23.8	294911	9144426	9,545	27.8	enc4	5	59	828	10,398	30.3	613474	8990582	10,858	31.6
enc1	4	32	990	10,231	23.9	327393	9471819	9,567	27.8	enc5	2	59	887	13,485	39.2	795593	9786176	11,033	32.1
enc2	4	31	1021	10,258	24.0	318009	9789828	9,588	27.9	enc5	3	79	966	10,741	31.3	848535	10634711	11,009	32.0
sba4	3	36	1057	10,268	24.0	369663	10159491	9,612	28.0	enc5	4	94	1060	10,144	29.5	953543	11588254	10,932	31.8
sba4	2	1	1058	10,278	24.0	10278	10169769	9,612	28.0	enc5	5	63	1123	10,055	29.3	633474	12221728	10,883	31.7
enc3	4	33	1091	10,375	24.3	342383	10512151	9,635	28.0	enc2	2	6	1129	14,131	41.1	84783	12306511	10,900	31.7
sba2	5	30	1121	10,407	24.4	312208	10824359	9,656	28.1	enc2	3	26	1155	12,451	36.2	323726	12630237	10,935	31.8
enc4	5	59	1180	10,437	24.4	615781	11440141	9,695	28.2	enc2	4	31	1186	11,406	33.2	353600	12983837	10,948	31.9
sba4	4	45	1225	10,741	25.1	483358	11923498	9,733	28.3	enc2	5	21	1207	11,135	32.4	233841	13217677	10,951	31.9
enc2	5	21	1246	10,760	25.2	225956	12149455	9,751	28.4	sba4	2	1	1208	14,726	42.9	14726	13232404	10,954	31.9
enc1	5	21	1267	10,909	25.5	229081	12378536	9,770	28.4	sba4	3	36	1244	13,382	38.9	481746	13714149	11,024	32.1
enc3	5	22	1289	11,377	26.6	250290	12628826	9,797	28.5	sba4	4	45	1289	12,128	35.3	545765	14259914	11,063	32.2
sba4	5	30	1319	11,797	27.6	353905	12982730	9,843	28.6	sba4	5	30	1319	11,847	34.5	355406	14615320	11,081	32.2

FIGURE E-3-PGE

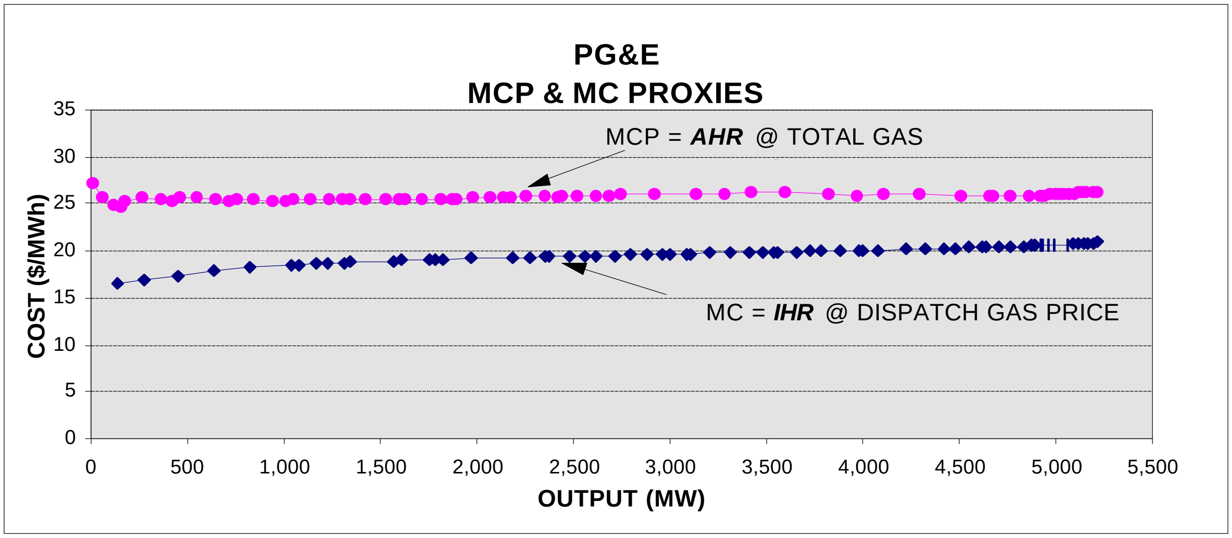


FIGURE E-3-SCE

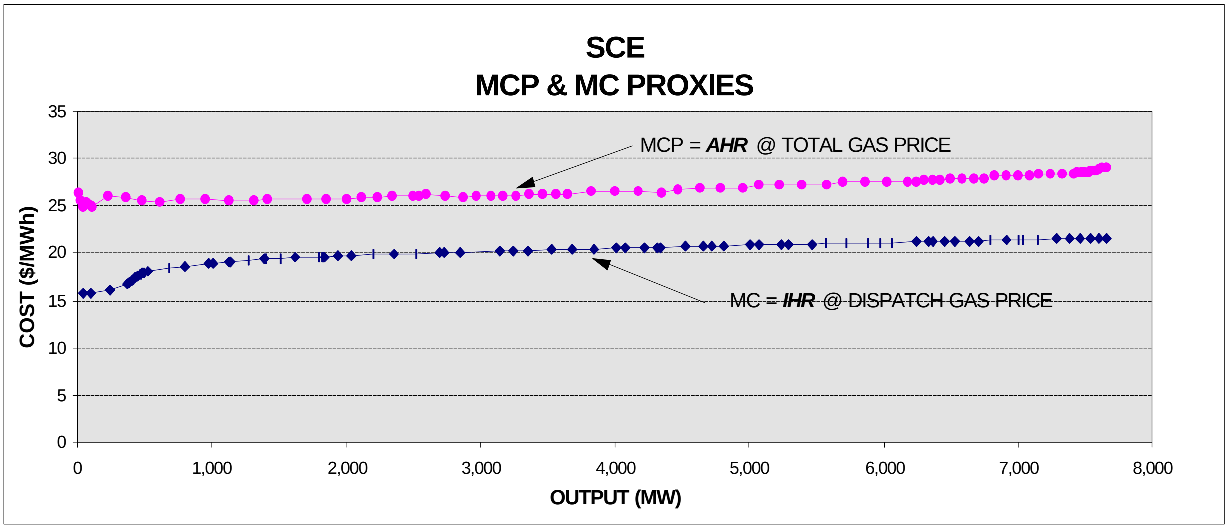


FIGURE E-3-SDG

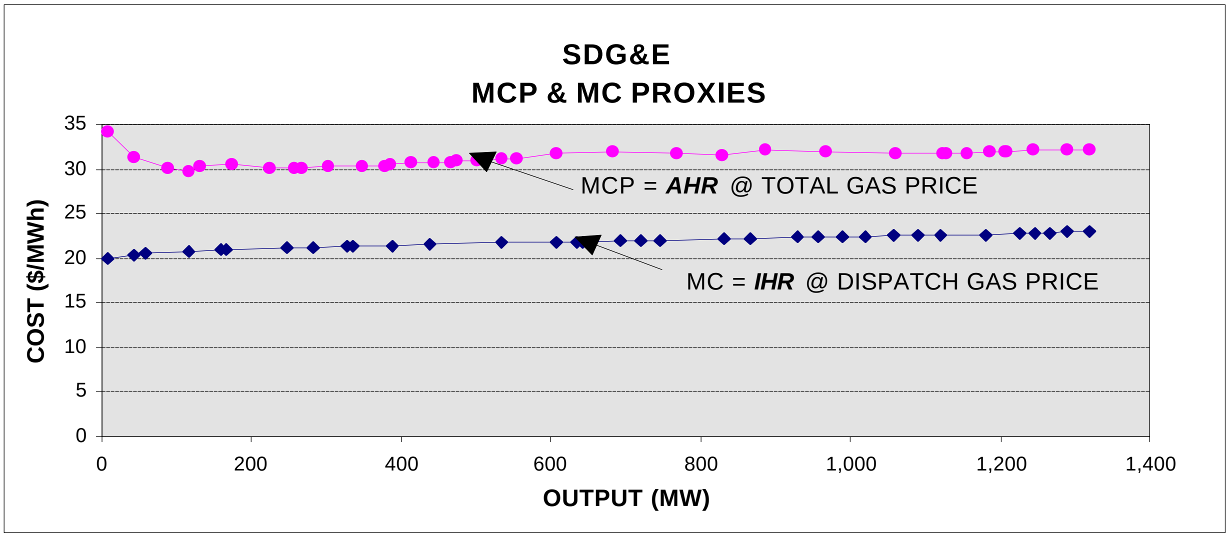


TABLE E-7: ALL IOUs SYSTEM AVERAGE COST CALCULATIONS

SUMMARY IHR DATA (Dispatch Gas Price)										SUMMARY AHR DATA (Total Gas Price)								
					Unit	Unit*MW		System							Unit	Unit*MW		System
	BLK	INC	***IHR***	CUM	Cost	Unit	Cumul.	Cost			BLK	INC	***AHR***	CUM	Total	Unit	Cumul.	Total
PLANT	#	MW	Btu/kWh	MW	$/MWh	$/hr	$/hr	$/MWh		PLANT	#	MW	Btu/kWh	MW	$/MWh	$/hr	$/hr	$/MWh
cw34	2	40	7,013	40	15.7	628	628	15.7	1	cw01	2	13	11,259	13	26.3	343	343	26.3
cw34	3	60	7,064	100	15.8	949	1578	15.8	1	cw01	3	13	10,587	26	24.8	322	665	25.6
cw34	4	140	7,334	240	16.4	2300	3878	16.2	1	cw01	4	13	10,343	39	24.2	315	979	25.1
mos7	2	135	7,196	375	16.6	2244	6122	16.3	1	cw01	5	9	10,264	48	24.0	216	1195	24.9
cw34	5	132	8,018	507	18.0	2371	8493	16.8	2	cw02	2	16	11,401	64	26.7	427	1622	25.3
mos6	2	135	7,370	642	17.0	2298	10791	16.8	2	cw02	3	16	10,650	80	24.9	399	2021	25.3
cw01	2	13	9,320	655	20.9	271	11062	16.9	2	cw02	4	16	10,370	96	24.3	388	2409	25.1
cw02	2	16	9,368	671	21.0	336	11398	17.0	2	cw02	5	14	10,262	110	24.0	336	2745	25.0
cw02	3	16	9,540	687	21.4	342	11740	17.1	3	orb1	2	120	10,354	230	27.0	3243	5988	26.0
cw01	3	13	9,549	700	21.4	278	12018	17.2	3	orb1	3	130	9,753	360	25.5	3309	9297	25.8
mos7	3	185	7,890	885	18.2	3372	15390	17.4	3	orb1	4	120	9,486	480	24.8	2971	12268	25.6
cw02	4	16	9,742	901	21.8	349	15739	17.5	3	orb1	5	130	9,382	610	24.5	3183	15452	25.3
cw01	4	13	9,808	914	22.0	286	16025	17.5	4	pot3	2	5	10,853	615	27.2	136	15588	25.3
mos6	3	185	8,146	1099	18.8	3481	19506	17.7	4	pot3	3	52	10,207	667	25.6	1332	16920	25.4
cw02	5	14	9,960	1113	22.3	312	19818	17.8	4	pot3	4	62	9,689	729	24.3	1508	18428	25.3
cw01	5	9	10,050	1122	22.5	203	20021	17.8	4	pot3	5	41	9,686	770	24.3	997	19425	25.2
pit7	3	180	8,476	1302	19.6	3525	23545	18.1	5	ala5&6	2	160	10,532	930	27.5	4398	23823	25.6
mos7	4	221	8,485	1523	19.6	4331	27877	18.3	5	ala5&6	3	180	9,810	1110	25.6	4609	28432	25.6
con7	2	39	8,496	1562	19.6	765	28642	18.3	5	ala5&6	4	180	9,560	1290	25.0	4491	32923	25.5
con7	3	85	8,503	1647	19.6	1670	30312	18.4	5	ala5&6	5	180	9,491	1470	24.8	4459	37382	25.4
pit7	2	60	8,555	1707	19.8	1186	31497	18.5	6	red7&8	2	100	10,808	1570	28.2	2821	40203	25.6
con6	3	85	8,555	1792	19.8	1680	33177	18.5	6	red7&8	3	300	9,995	1870	26.1	7826	48029	25.7
mos6	4	221	8,668	2013	20.0	4425	37602	18.7	6	red7&8	4	140	9,633	2010	25.1	3520	51548	25.6
mor4	2	39	8,703	2052	20.1	784	38386	18.7	6	red7&8	5	160	9,548	2170	24.9	3987	55536	25.6
mos6	5	148	8,714	2200	20.1	2979	41366	18.8	7	hnp4	2	20	11,642	2190	29.2	584	56120	25.6
pit5	2	35	8,744	2235	20.2	707	42073	18.8	7	hnp4	3	82	10,585	2272	26.6	2179	58299	25.7
con6	2	39	8,756	2274	20.2	789	42862	18.8	7	hnp4	4	96	9,985	2368	25.1	2406	60704	25.6
mos7	5	148	8,760	2422	20.2	2995	45856	18.9	7	hnp4	5	66	9,854	2434	24.7	1632	62337	25.6
pit7	4	216	8,762	2638	20.2	4372	50228	19.0	8	mor4	2	39	11,694	2473	29.4	1145	63482	25.7
pit6	2	35	8,821	2673	20.4	713	50941	19.1	8	mor4	3	84	10,292	2557	25.8	2170	65652	25.7
mor4	3	84	8,848	2757	20.4	1717	52658	19.1	8	mor4	4	101	9,714	2658	24.4	2463	68114	25.6
pit6	3	82	8,868	2839	20.5	1680	54338	19.1	8	mor4	5	68	9,561	2726	24.0	1632	69746	25.6
hnp4	2	20	8,873	2859	20.5	410	54748	19.1	9	pit6	2	35	11,709	2761	29.4	1029	70775	25.6
con6	4	102	8,877	2961	20.5	2092	56840	19.2	9	pit6	3	82	10,352	2843	26.0	2131	72905	25.6
pit5	3	82	8,900	3043	20.6	1686	58526	19.2	9	pit6	4	97	9,751	2940	24.5	2374	75280	25.6
pot3	3	52	8,924	3095	20.6	1072	59598	19.3	9	pit6	5	65	9,625	3005	24.2	1570	76850	25.6
con7	4	102	8,933	3197	20.6	2105	61702	19.3	10	hun3	2	30	11,342	3035	29.6	888	77738	25.6
pit3&4	3	82	8,983	3279	20.8	1702	63404	19.3	10	hun3	3	30	10,862	3065	28.4	851	78588	25.6
pit1&2	3	82	9,003	3361	20.8	1705	65109	19.4	10	hun3	4	30	10,602	3095	27.7	830	79419	25.7
hnp4	3	82	9,044	3443	20.9	1713	66822	19.4	10	hun3	5	35	10,474	3130	27.3	957	80375	25.7
mor3	2	39	9,056	3482	20.9	816	67638	19.4	11	con6	2	39	11,860	3169	29.8	1161	81536	25.7
mor3	3	84	9,064	3566	20.9	1759	69397	19.5	11	con6	3	85	10,300	3254	25.9	2197	83734	25.7
pot3	2	5	9,066	3571	20.9	105	69502	19.5	11	con6	4	102	9,579	3356	24.0	2452	86186	25.7
pit1&2	2	20	9,079	3591	21.0	419	69921	19.5	11	con6	5	68	9,479	3424	23.8	1618	87804	25.6
mor4	4	101	9,083	3692	21.0	2119	72040	19.5	12	hun4	2	30	11,407	3454	29.8	893	88697	25.7
mor3	4	101	9,100	3793	21.0	2123	74163	19.6	12	hun4	3	30	10,926	3484	28.5	855	89553	25.7
pit6	4	97	9,135	3890	21.1	2047	76210	19.6	12	hun4	4	30	10,661	3514	27.8	835	90387	25.7
pit5	4	97	9,135	3987	21.1	2047	78257	19.6	12	hun4	5	45	10,474	3559	27.3	1230	91618	25.7
mor3	5	68	9,159	4055	21.2	1439	79696	19.7	13	mor3	2	39	12,056	3598	30.3	1180	92798	25.8
pot3	4	62	9,276	4117	21.4	1328	81025	19.7	13	mor3	3	84	10,616	3682	26.6	2238	95036	25.8
pit3&4	2	20	9,276	4137	21.4	429	81453	19.7	13	mor3	4	101	9,950	3783	25.0	2523	97559	25.8
mor4	5	68	9,314	4205	21.5	1463	82916	19.7	13	mor3	5	68	9,712	3851	24.4	1658	99216	25.8
pit5	5	65	9,344	4270	21.6	1403	84319	19.7	14	con7	2	39	12,112	3890	30.4	1186	100402	25.8
sba1	2	7	8,560	4277	20.0	140	84459	19.7	14	con7	3	85	10,361	3975	26.0	2211	102613	25.8
hnp4	4	96	9,379	4373	21.7	2080	86539	19.8	14	con7	4	102	9,622	4077	24.2	2463	105076	25.8
pit1&2	4	96	9,391	4469	21.7	2083	88622	19.8	14	con7	5	68	9,517	4145	23.9	1624	106700	25.7
mor1&2	2	20	9,407	4489	21.7	435	89057	19.8	15	pit5	2	35	12,186	4180	30.6	1071	107771	25.8
mor1&2	3	82	9,441	4571	21.8	1788	90845	19.9	15	pit5	3	82	10,598	4262	26.6	2181	109952	25.8
pit7	5	144	9,469	4715	21.9	3150	93995	19.9	15	pit5	4	97	9,907	4359	24.9	2412	112364	25.8
pit3&4	4	96	9,529	4811	22.0	2113	96108	20.0	15	pit5	5	65	9,712	4424	24.4	1584	113949	25.8
pit6	5	65	9,579	4876	22.1	1438	97546	20.0	16	mor1&2	2	20	12,246	4444	30.7	615	114563	25.8

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TABLE E-7: ALL IOUs SYSTEM AVERAGE COST CALCULATIONS - CONTINUED

SUMMARY IHR DATA (Dispatch Gas Price)										SUMMARY AHR DATA (Total Gas Price)								
PLANT	BLK #	INC MW	***IHR*** Btu/kWh	CUM MW	Unit Cost $/MWh	Unit*MW Unit $/hr	Unit*MW Cumul. $/hr	System Cost $/MWh		PLANT	BLK #	INC MW	***AHR*** Btu/kWh	CUM MW	Total $/MWh	Unit*MW Unit $/hr	Unit*MW Cumul. $/hr	System Total $/MWh
sba1	3	37	8,764	4913	20.5	759	98305	20.0	16	mor1&2	3	82	11,128	4526	27.9	2290	116854	25.8
mor1&2	4	96	9,675	5009	22.3	2145	100450	20.1	16	mor1&2	4	96	10,438	4622	26.2	2515	119369	25.8
hnp4	5	66	9,724	5075	22.5	1482	101933	20.1	16	mor1&2	5	66	10,266	4688	25.8	1701	121070	25.8
con7	5	68	9,754	5143	22.5	1532	103465	20.1	17	cw34	2	40	13,307	4728	31.1	1246	122315	25.9
sba3	2	13	8,937	5156	20.9	272	103737	20.1	17	cw34	3	60	11,822	4788	27.7	1660	123975	25.9
con6	5	68	9,811	5224	22.7	1541	105278	20.2	17	cw34	4	140	10,361	4928	24.2	3394	127369	25.8
enc5	2	59	9,016	5283	21.1	1245	106523	20.2	17	cw34	5	132	9,506	5060	22.2	2936	130305	25.8
hnp3	2	17	9,876	5300	22.8	388	106911	20.2	18	man1&2	2	100	12,114	5160	31.6	3162	133467	25.9
hig3&4	2	14	7,899	5314	19.2	269	107179	20.2	18	man1&2	3	105	10,087	5265	26.3	2764	136231	25.9
sba3	3	43	9,082	5357	21.3	914	108093	20.2	18	man1&2	4	95	9,706	5360	25.3	2407	138638	25.9
sba2	2	8	9,127	5365	21.4	171	108264	20.2	18	man1&2	5	90	9,664	5450	25.2	2270	140908	25.9
enc5	3	79	9,190	5444	21.5	1699	109963	20.2	19	pit3&4	2	20	12,905	5470	32.4	648	141556	25.9
mor1&2	5	66	10,081	5510	23.3	1537	111500	20.2	19	pit3&4	3	82	11,388	5552	28.6	2344	143900	25.9
sba2	3	37	9,287	5547	21.7	804	112304	20.2	19	pit3&4	4	96	10,408	5648	26.1	2508	146408	25.9
hig3&4	3	26	8,096	5573	19.7	512	112815	20.2	19	pit3&4	5	66	10,341	5714	26.0	1713	148121	25.9
sba1	4	44	9,368	5617	21.9	964	113780	20.3	20	pit7	2	60	13,001	5774	32.6	1958	150079	26.0
enc3	2	8	9,374	5625	21.9	175	113955	20.3	20	pit7	3	180	11,062	5954	27.8	4998	155077	26.0
pit1&2	5	66	10,331	5691	23.9	1575	115530	20.3	20	pit7	4	216	9,977	6170	25.0	5409	160486	26.0
pot3	5	41	10,341	5732	23.9	979	116510	20.3	20	pit7	5	144	9,705	6314	24.4	3508	163994	26.0
ala5&6	2	160	8,155	5892	19.8	3171	119680	20.3	21	hun1&2	2	100	12,570	6414	32.8	3281	167274	26.1
enc4	2	53	9,472	5945	22.2	1175	120855	20.3	21	hun1&2	3	100	10,331	6514	27.0	2696	169971	26.1
orb2	2	175	8,192	6120	19.9	3484	124339	20.3	21	hun1&2	4	100	9,822	6614	25.6	2564	172534	26.1
hnp2	2	17	10,364	6137	23.9	407	124746	20.3	21	hun1&2	5	90	9,666	6704	25.2	2271	174805	26.1
hmb1&2	3	27	10,366	6164	23.9	647	125392	20.3	22	mos7	2	135	13,304	6839	33.4	4508	179313	26.2
orb1	2	120	8,171	6284	19.9	2383	127775	20.3	22	mos7	3	185	9,758	7024	24.5	4531	183844	26.2
sba3	4	51	9,487	6335	22.2	1132	128907	20.3	22	mos7	4	221	9,079	7245	22.8	5036	188880	26.1
enc5	4	94	9,605	6429	22.5	2113	131020	20.4	22	mos7	5	148	8,949	7393	22.5	3324	192204	26.0
enc4	3	74	9,617	6503	22.5	1665	132685	20.4	23	mos6	2	135	13,370	7528	33.6	4530	196735	26.1
enc3	3	27	9,635	6530	22.5	609	133294	20.4	23	mos6	3	185	9,918	7713	24.9	4606	201340	26.1
hig3&4	4	30	8,338	6560	20.3	608	133902	20.4	23	mos6	4	221	9,273	7934	23.3	5144	206484	26.0
hmb1&2	2	16	10,543	6576	24.4	390	134291	20.4	23	mos6	5	148	9,115	8082	22.9	3386	209870	26.0
enc1	2	7	9,736	6583	22.8	159	134451	20.4	24	pit1&2	2	20	13,412	8102	33.7	673	210543	26.0
enc2	2	6	9,763	6589	22.8	137	134588	20.4	24	pit1&2	3	82	11,673	8184	29.3	2403	212946	26.0
sba2	4	45	9,763	6634	22.8	1028	135616	20.4	24	pit1&2	4	96	10,573	8280	26.5	2548	215493	26.0
hig1&2	2	10	8,413	6644	20.4	204	135820	20.4	24	pit1&2	5	66	10,339	8346	26.0	1713	217206	26.0
orb1	3	130	8,429	6774	20.5	2663	138483	20.4	25	sba1	2	7	11,778	8353	34.3	240	217446	26.0
eti3&4	2	120	8,438	6894	20.5	2460	140943	20.4	25	sba1	3	37	10,613	8390	30.9	1143	218589	26.1
hig1&2	3	20	8,438	6914	20.5	410	141353	20.4	25	sba1	4	44	9,922	8434	28.9	1270	219859	26.1
man1&2	2	100	8,443	7014	20.5	2052	143405	20.4	25	sba1	5	29	9,857	8463	28.7	832	220691	26.1
ala3&4	2	120	8,443	7134	20.5	2462	145867	20.4	26	orb2	2	175	13,188	8638	34.4	6023	226714	26.2
enc1	3	27	9,815	7161	23.0	620	146487	20.5	26	orb2	3	175	10,168	8813	26.5	4644	231358	26.3
orb2	3	175	8,459	7336	20.6	3597	150084	20.5	26	orb2	4	175	9,595	8988	25.0	4383	235741	26.2
hig1&2	4	18	8,471	7354	20.6	371	150455	20.5	26	orb2	5	175	9,442	9163	24.6	4313	240054	26.2
hig3&4	5	9	8,485	7363	20.6	186	150640	20.5	27	sba3	2	13	11,880	9176	34.6	449	240503	26.2
hig1&2	5	10	8,495	7373	20.6	206	150847	20.5	27	sba3	3	43	10,680	9219	31.1	1336	241839	26.2
enc2	3	26	9,889	7399	23.1	602	151448	20.5	27	sba3	4	51	10,062	9270	29.3	1493	243333	26.2
hnp3	3	27	10,861	7426	25.1	677	152126	20.5	27	sba3	5	34	9,961	9304	29.0	986	244318	26.3
hun1&2	2	100	8,552	7526	20.8	2078	154204	20.5	28	sba2	2	8	12,099	9312	35.2	282	244600	26.3
red7&8	2	100	8,557	7626	20.8	2079	156284	20.5	28	sba2	3	37	11,007	9349	32.0	1185	245785	26.3
enc4	4	87	9,966	7713	23.3	2029	158312	20.5	28	sba2	4	45	10,352	9394	30.1	1356	247141	26.3
sba3	5	34	10,027	7747	23.5	798	159110	20.5	28	sba2	5	30	10,259	9424	29.9	896	248036	26.3
ala3&4	3	160	8,639	7907	21.0	3359	162469	20.5	29	enc1	2	7	12,632	9431	36.8	257	248293	26.3
hnp2	3	27	10,981	7934	25.4	685	163154	20.6	29	enc1	3	27	11,483	9458	33.4	902	249196	26.3
eti3&4	3	160	8,641	8094	21.0	3359	166513	20.6	29	enc1	4	32	10,831	9490	31.5	1009	250204	26.4
ala5&6	3	180	8,656	8274	21.0	3786	170299	20.6	29	enc1	5	21	10,737	9511	31.2	656	250860	26.4
sbr1&2	2	28	8,681	8302	21.1	591	170890	20.6	30	enc3	2	8	13,155	9519	38.3	306	251167	26.4
els1-4	2	190	8,715	8492	21.2	4024	174914	20.6	30	enc3	3	27	11,675	9546	34.0	917	252084	26.4
orb1	4	120	8,742	8612	21.2	2549	177463	20.6	30	enc3	4	33	10,933	9579	31.8	1050	253134	26.4
enc5	5	63	10,163	8675	23.8	1498	178961	20.6	30	enc3	5	22	10,891	9601	31.7	697	253831	26.4
sba1	5	29	10,169	8704	23.8	690	179651	20.6	31	enc4	2	53	13,472	9654	39.2	2078	255909	26.5
red7&8	3	300	8,759	9004	21.3	6385	186036	20.7	31	enc4	3	74	11,055	9728	32.2	2381	258289	26.6

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TABLE E-7: ALL IOUs SYSTEM AVERAGE COST CALCULATIONS - CONTINUED

SUMMARY IHR DATA (Dispatch Gas Price)

PLANT	BLK #	INC MW	*IHR* Btu/kWh	CUM MW	Unit Cost $/MWh	Unit*MW Unit $/hr	Unit*MW Cumul. $/hr	System Cost $/MWh
hun1&2	3	100	8,768	9104	21.3	2131	188167	20.7
man1&2	3	105	8,799	9209	21.4	2245	190412	20.7
enc1	4	32	10,231	9241	23.9	766	191178	20.7
orb2	4	175	8,818	9416	21.4	3750	194928	20.7
pit3&4	5	66	11,211	9482	25.9	1709	196638	20.7
enc2	4	31	10,258	9513	24.0	744	197382	20.7
sba4	3	36	10,268	9549	24.0	865	198247	20.8
sba4	2	1	10,278	9550	24.0	24	198271	20.8
enc3	4	33	10,375	9583	24.3	801	199072	20.8
ala3&4	4	160	8,933	9743	21.7	3473	202545	20.8
eti3&4	4	160	8,943	9903	21.7	3477	206022	20.8
sba2	5	30	10,407	9933	24.4	731	206753	20.8
els1-4	3	250	8,963	10183	21.8	5445	212198	20.8
hmb1&2	4	31	11,392	10214	26.3	816	213014	20.9
enc4	5	59	10,437	10273	24.4	1441	214454	20.9
red5&6	2	70	8,992	10343	21.9	1530	215984	20.9
red7&8	4	140	9,028	10483	21.9	3071	219055	20.9
hun1&2	4	100	9,050	10583	22.0	2199	221255	20.9
sbr1&2	3	28	9,056	10611	22.0	616	221871	20.9
ala5&6	4	180	9,074	10791	22.0	3969	225840	20.9
orb1	5	130	9,112	10921	22.1	2878	228718	20.9
hun3	2	30	9,126	10951	22.2	665	229383	20.9
ala1&2	2	70	9,127	11021	22.2	1552	230936	21.0
red5&6	3	90	9,134	11111	22.2	1998	232933	21.0
hun4	2	30	9,137	11141	22.2	666	233600	21.0
sba4	4	45	10,741	11186	25.1	1131	234731	21.0
red7&8	5	160	9,248	11346	22.5	3596	238326	21.0
enc2	5	21	10,760	11367	25.2	529	238855	21.0
els1-4	4	250	9,259	11617	22.5	5625	244480	21.0
eti1&2	2	60	9,264	11677	22.5	1351	245830	21.1
orb2	5	175	9,268	11852	22.5	3941	249772	21.1
man1&2	4	95	9,279	11947	22.5	2142	251914	21.1
ala3&4	5	160	9,305	12107	22.6	3618	255532	21.1
hun3	3	30	9,309	12137	22.6	679	256210	21.1
eti3&4	5	160	9,322	12297	22.7	3624	259834	21.1
red5&6	4	90	9,324	12387	22.7	2039	261874	21.1
hnp2	4	32	11,861	12419	27.4	877	262750	21.2
ala1&2	3	90	9,341	12509	22.7	2043	264793	21.2
ala5&6	5	180	9,375	12689	22.8	4101	268894	21.2
hun1&2	5	90	9,379	12779	22.8	2051	270945	21.2
sbr1&2	4	28	9,384	12807	22.8	639	271584	21.2
enc1	5	21	10,909	12828	25.5	536	272120	21.2
hun4	3	30	9,387	12858	22.8	684	272804	21.2
red5&6	5	80	9,535	12938	23.2	1854	274658	21.2
hun4	4	30	9,568	12968	23.3	698	275355	21.2
els1-4	5	270	9,583	13238	23.3	6287	281642	21.3
hun3	4	30	9,606	13268	23.3	700	282343	21.3
eti1&2	3	60	9,627	13328	23.4	1404	283746	21.3
hnp3	4	32	12,246	13360	28.3	905	284652	21.3
ala1&2	4	90	9,663	13450	23.5	2113	286765	21.3
sbr1&2	5	28	9,667	13478	23.5	658	287423	21.3
hun4	5	45	9,695	13523	23.6	1060	288483	21.3
enc3	5	22	11,377	13545	26.6	586	289068	21.3
man1&2	5	90	9,842	13635	23.9	2152	291221	21.4
hnp2	5	21	12,701	13656	29.3	616	291837	21.4
ala1&2	5	80	10,047	13736	24.4	1953	293790	21.4
hun3	5	35	10,057	13771	24.4	855	294645	21.4
eti1&2	4	60	10,104	13831	24.6	1473	296119	21.4
sba4	5	30	11,797	13861	27.6	828	296947	21.4
hmb1&2	5	21	13,521	13882	31.2	656	297603	21.4
hnp3	5	21	13,552	13903	31.3	657	298260	21.5
eti1&2	5	64	10,719	13967	26.0	1667	299927	21.5

SUMMARY AHR DATA (Total Gas Price)

	PLANT	BLK #	INC MW	*AHR* Btu/kWh	CUM MW	Total $/MWh	Unit*MW Unit $/hr	Unit*MW Cumul. $/hr	System Total $/MWh
31	enc4	4	87	10,494	9815	30.5	2657	260946	26.6
31	enc4	5	59	10,398	9874	30.3	1785	262731	26.6
32	enc5	2	59	13,485	9933	39.2	2315	265046	26.7
32	enc5	3	79	10,741	10012	31.3	2469	267516	26.7
32	enc5	4	94	10,144	10106	29.5	2775	270291	26.7
32	enc5	5	63	10,055	10169	29.3	1843	272134	26.8
33	eti3&4	2	120	15,141	10289	39.5	4742	276876	26.9
33	eti3&4	3	160	11,005	10449	28.7	4596	281472	26.9
33	eti3&4	4	160	10,078	10609	26.3	4209	285680	26.9
33	eti3&4	5	160	9,798	10769	25.6	4092	289772	26.9
34	hnp3	2	17	16,339	10786	41.0	697	290469	26.9
34	hnp3	3	27	12,974	10813	32.6	879	291348	26.9
34	hnp3	4	32	12,336	10845	31.0	991	292339	27.0
34	hnp3	5	21	12,471	10866	31.3	657	292996	27.0
35	enc2	2	6	14,131	10872	41.1	247	293243	27.0
35	enc2	3	26	12,451	10898	36.2	942	294185	27.0
35	enc2	4	31	11,406	10929	33.2	1029	295214	27.0
35	enc2	5	21	11,135	10950	32.4	680	295895	27.0
36	els1-4	2	190	16,141	11140	42.1	8005	303899	27.3
36	els1-4	3	250	11,525	11390	30.1	7520	311419	27.3
36	els1-4	4	250	10,517	11640	27.4	6862	318281	27.3
36	els1-4	5	270	10,188	11910	26.6	7179	325461	27.3
37	hmb1&2	2	16	16,853	11926	42.3	677	326137	27.3
37	hmb1&2	3	27	13,245	11953	33.2	898	327035	27.4
37	hmb1&2	4	31	12,142	11984	30.5	945	327980	27.4
37	hmb1&2	5	21	12,167	12005	30.5	641	328621	27.4
38	ala3&4	2	120	16,210	12125	42.3	5077	333698	27.5
38	ala3&4	3	160	11,407	12285	29.8	4764	338462	27.6
38	ala3&4	4	160	10,311	12445	26.9	4306	342768	27.5
38	ala3&4	5	160	9,960	12605	26.0	4159	346927	27.5
39	hnp2	2	17	16,865	12622	42.3	720	347646	27.5
39	hnp2	3	27	13,382	12649	33.6	907	348553	27.6
39	hnp2	4	32	12,517	12681	31.4	1005	349559	27.6
39	hnp2	5	21	12,433	12702	31.2	655	350214	27.6
40	sba4	2	1	14,726	12703	42.9	43	350257	27.6
40	sba4	3	36	13,382	12739	38.9	1402	351659	27.6
40	sba4	4	45	12,128	12784	35.3	1588	353247	27.6
40	sba4	5	30	11,847	12814	34.5	1034	354281	27.6
41	eti1&2	2	60	16,432	12874	42.9	2573	356854	27.7
41	eti1&2	3	60	12,244	12934	32.0	1917	358772	27.7
41	eti1&2	4	60	11,371	12994	29.7	1781	360552	27.7
41	eti1&2	5	64	11,106	13058	29.0	1855	362408	27.8
42	ala1&2	2	70	17,605	13128	45.9	3216	365624	27.9
42	ala1&2	3	90	12,222	13218	31.9	2871	368495	27.9
42	ala1&2	4	90	11,084	13308	28.9	2604	371099	27.9
42	ala1&2	5	80	10,734	13388	28.0	2241	373340	27.9
43	red5&6	2	70	18,702	13458	48.8	3417	376757	28.0
43	red5&6	3	90	12,511	13548	32.7	2939	379695	28.0
43	red5&6	4	90	11,144	13638	29.1	2618	382313	28.0
43	red5&6	5	80	10,661	13718	27.8	2226	384539	28.0
44	sbr1&2	2	28	18,968	13746	49.5	1386	385925	28.1
44	sbr1&2	3	28	13,553	13774	35.4	990	386916	28.1
44	sbr1&2	4	28	12,072	13802	31.5	882	387798	28.1
44	sbr1&2	5	28	11,426	13830	29.8	835	388633	28.1
45	hig1&2	2	10	34,940	13840	91.2	912	389545	28.1
45	hig1&2	3	20	20,641	13860	53.9	1077	390622	28.2
45	hig1&2	4	18	15,481	13878	40.4	727	391350	28.2
45	hig1&2	5	10	13,820	13888	36.1	361	391710	28.2
46	hig3&4	2	14	44,598	13902	116.4	1630	393340	28.3
46	hig3&4	3	26	24,520	13928	64.0	1664	395004	28.4
46	hig3&4	4	30	17,262	13958	45.1	1352	396356	28.4
46	hig3&4	5	9	15,100	13967	39.4	355	396710	28.4

FIGURE E-4-ALL

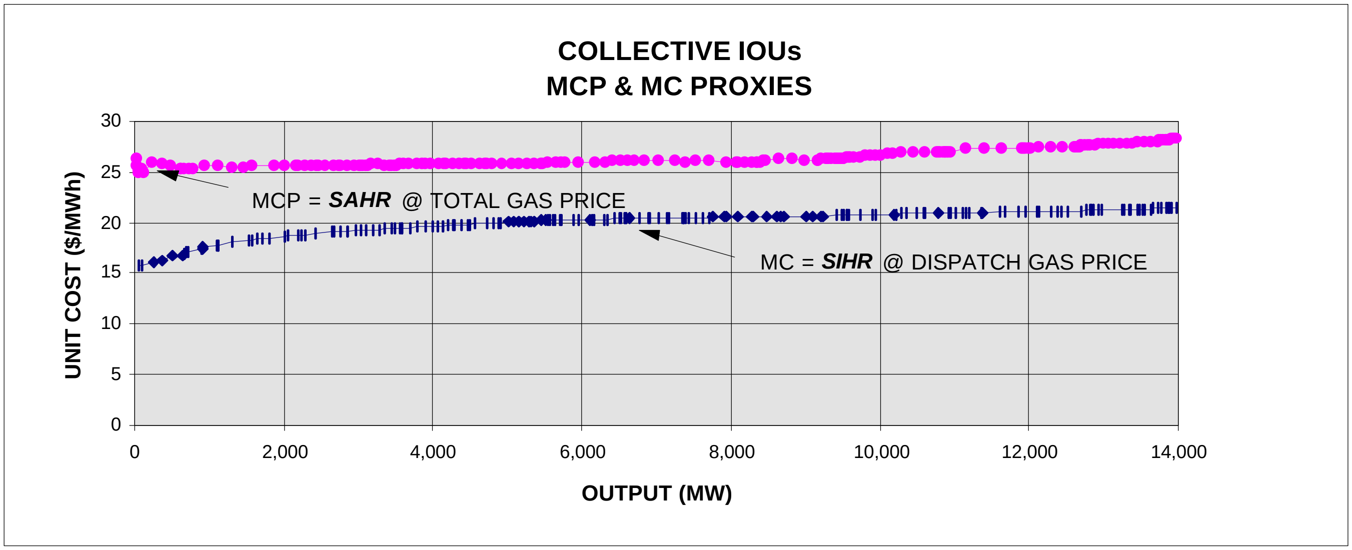


FIGURE E-5

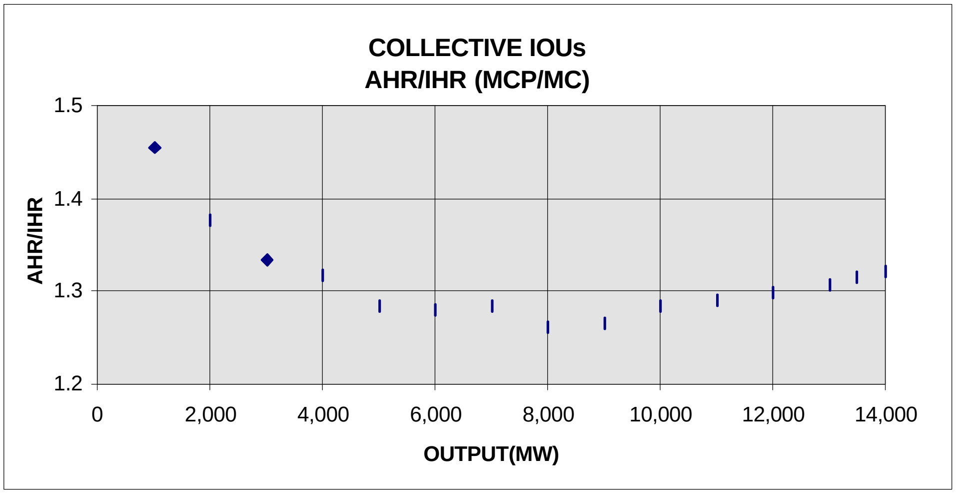
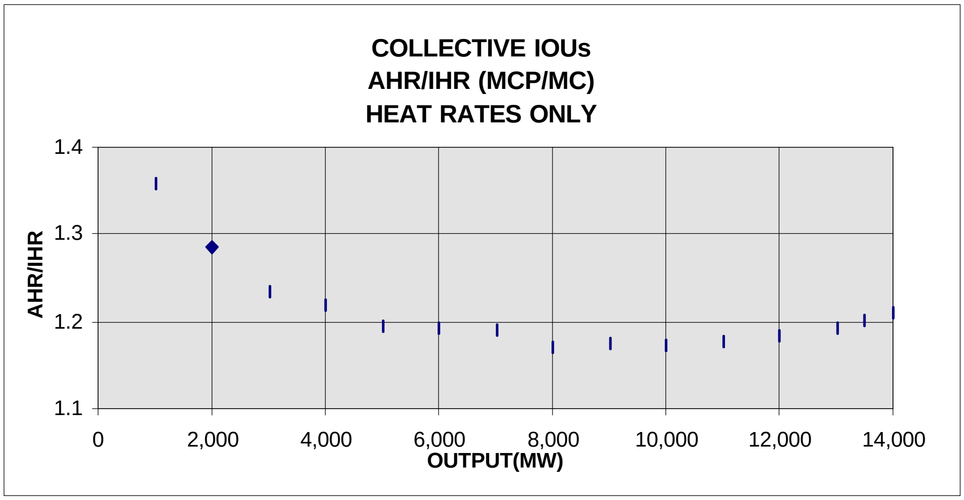


FIGURE E-6



APPENDIX F
FR 97 GAS PRICE FORECAST

This Appendix summarizes the Energy Commission's 1997 Gas Price Forecast (FR 97), which was approved by the Commissioners at their March 18, 1998 Business Meeting. The 1998 dispatch and total gas prices were used in Section VI in demonstrating the difference between traditional marginal cost and the market clearing price of the new competitive market.

Table F-1 summarizes the dispatch and total gas prices in both nominal and real 1998 dollars. The dispatch gas price reflects the variable costs of gas, only. Total gas price also includes the fixed component of gas. Although both of these are provided, Energy Commission Staff expects that the electric utilities will no longer use the dispatch price of gas in the new competitive market and will base all their bidding on the total price of gas.

TABLE F-1: FR 97 GAS PRICE FORECAST

FR 97 GAS PRICE FORECAST (MARCH 18, 1998)

Nominal $/MMBtu

	PG&E		SCE		Cool Water		SDG&E	
Year	Disp	Total	Disp	Total	Disp	Total	Disp	Total
1998	2.31	2.51	2.43	2.61	2.24	2.34	2.34	2.91
1999	2.04	2.24	2.08	2.27	1.90	2.00	2.04	2.56
2000	1.98	2.19	1.97	2.17	1.98	2.08	2.07	2.61
2001	2.07	2.28	2.09	2.29	2.08	2.18	2.18	2.73
2002	2.17	2.38	2.20	2.40	2.17	2.27	2.29	2.85
2003	2.28	2.50	2.34	2.55	2.28	2.38	2.42	2.98
2004	2.40	2.62	2.48	2.69	2.41	2.51	2.56	3.13
2005	2.53	2.75	2.63	2.85	2.55	2.65	2.70	3.28
2006	2.66	2.89	2.78	3.00	2.70	2.80	2.84	3.43
2007	2.80	3.03	2.95	3.17	2.85	2.95	3.01	3.61
2008	2.94	3.18	3.15	3.38	3.01	3.11	3.21	3.81
2009	3.09	3.34	3.33	3.57	3.18	3.28	3.38	3.99
2010	3.25	3.51	3.45	3.69	3.34	3.44	3.51	4.14
2011	3.44	3.70	3.65	3.90	3.52	3.62	3.72	4.36
2012	3.64	3.91	3.87	4.12	3.70	3.80	3.94	4.58
2013	3.86	4.13	4.09	4.35	3.89	3.99	4.16	4.82
2014	4.08	4.36	4.32	4.59	4.09	4.19	4.39	5.06
2015	4.30	4.59	4.55	4.83	4.30	4.40	4.63	5.31
2016	4.54	4.83	4.81	5.10	4.51	4.61	4.89	5.59

Apr 16, 1997 Deflators	
1998	1.00
1999	1.02
2000	1.05
2001	1.08
2002	1.11
2003	1.15
2004	1.18
2005	1.22
2006	1.27
2007	1.31
2008	1.36
2009	1.41
2010	1.46
2011	1.51
2012	1.56
2013	1.62
2014	1.68
2015	1.74
2016	1.80

1998 $/MMBtu

	PG&E		SCE		Cool Water		SDG&E	
Year	Disp	Total	Disp	Total	Disp	Total	Disp	Total
1998	2.31	2.51	2.43	2.61	2.24	2.34	2.34	2.91
1999	1.99	2.19	2.03	2.21	1.85	1.95	1.99	2.49
2000	1.88	2.08	1.88	2.06	1.88	1.98	1.96	2.48
2001	1.91	2.11	1.93	2.11	1.92	2.01	2.01	2.52
2002	1.95	2.14	1.98	2.16	1.95	2.04	2.05	2.56
2003	1.99	2.18	2.04	2.22	1.98	2.07	2.11	2.59
2004	2.03	2.21	2.10	2.28	2.04	2.12	2.16	2.64
2005	2.06	2.25	2.15	2.32	2.09	2.17	2.20	2.68
2006	2.10	2.28	2.19	2.36	2.13	2.21	2.25	2.71
2007	2.13	2.31	2.25	2.42	2.17	2.25	2.29	2.75
2008	2.16	2.34	2.32	2.49	2.22	2.29	2.36	2.81
2009	2.19	2.37	2.36	2.53	2.26	2.33	2.40	2.84
2010	2.23	2.41	2.37	2.53	2.29	2.36	2.41	2.84
2011	2.28	2.45	2.42	2.59	2.33	2.40	2.47	2.89
2012	2.33	2.50	2.47	2.64	2.37	2.43	2.52	2.93
2013	2.38	2.55	2.53	2.69	2.40	2.47	2.57	2.98
2014	2.43	2.60	2.58	2.74	2.44	2.50	2.62	3.02
2015	2.48	2.64	2.62	2.78	2.47	2.53	2.67	3.06
2016	2.52	2.69	2.67	2.83	2.51	2.56	2.72	3.10

After 1998, gas prices drop and do not return to their 1998 level in real dollars until around 2010 and beyond, depending on the utility. This drop is due to vast gas resources in the Gulf of Mexico becoming available.

Figures F-1 through F-4 provide the data of Table F-1 graphically. Figures F-1 and F-2 present the gas prices in nominal (current) dollars; F-1 presents the dispatch price of gas and F-2 presents the total price of gas. Figures F-3 and F-4 present the comparable data in real 1998 dollars.

FIGURE F-1

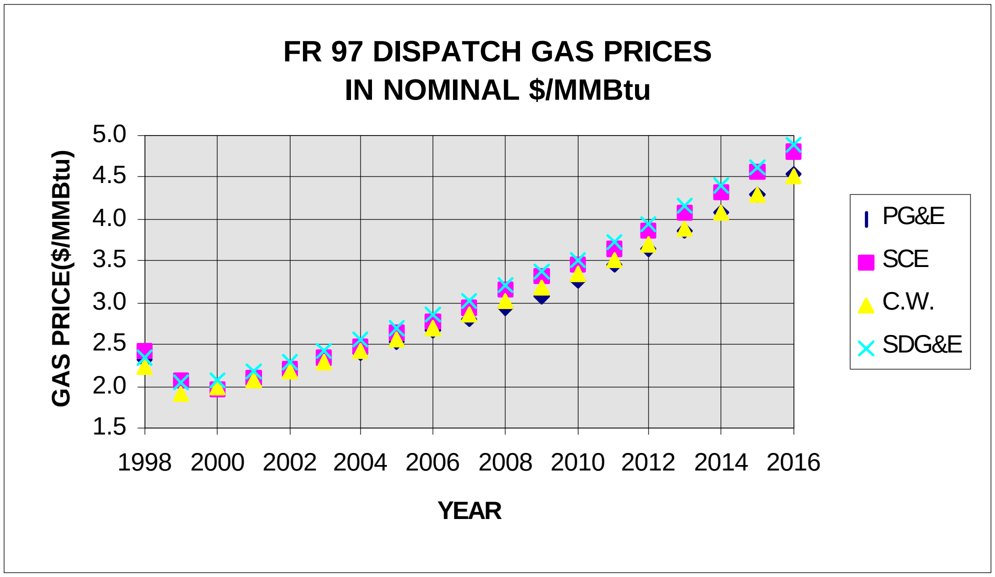


FIGURE F-2

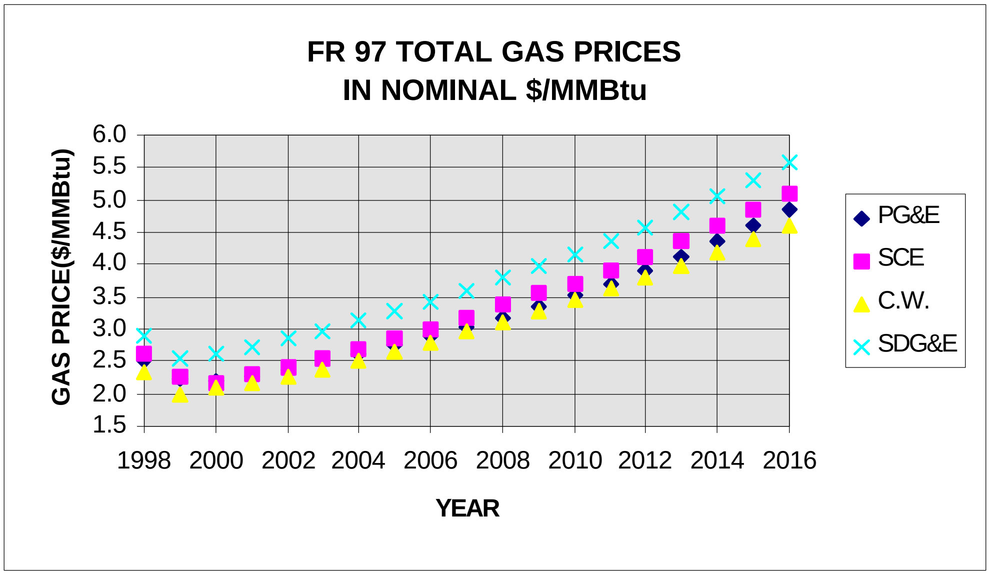


FIGURE F-3

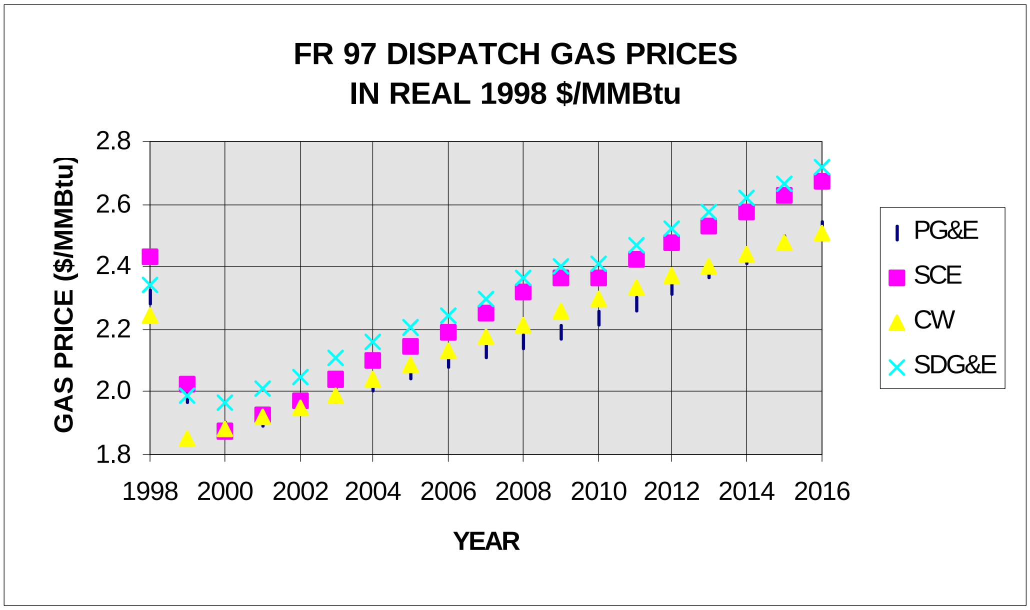


FIGURE F-4