

Geothermal Module in the NEMS Renewable Model - AEO 2002

The geothermal module in the NEMS renewable model is called GEO2000 and was written in 2000, replacing an earlier version. The current model includes water-based (hydrothermal) geothermal and does not include hot dry rock resources, because they are not considered to be cost competitive in the time horizon of the model. All of the geothermal resources in the model are located in the 3 western EMM regions, which are numbered 11, 12, and 13 (NWP, RA, and CNV, respectively). A small amount of resources are in Hawaii, but these are not considered in the model.

Input Files

There are two input files read by the model, *wgesite* and *wgeparm*. In general, *wgesite* contains information for each resource site while *wgeparm* contains information for each existing generation unit.

The first part of the input file *wgesite* contains information for each of 51 sites in the three western EMM regions where there are geothermal resources. The information includes the site id, site name and state, the technology type, capacities in 1990 and four potential capacity levels, capacity factor, CO₂ and H₂S emissions rates, capital costs for exploration, drilling, field, and plant, O & M costs for field and plant, and the heat rate. The technology type is either binary plants which use lower heat, designated by a 1 in the file, or dual flash plants which use higher heat, designated by a 2 in the input file. The values in the *wgesite* input file for AEO 2002 are shown in Table A, at the end of this report. The potential capacity levels are lower than in the AEO 2001. This input file also contains information on annual build limits for each of the 51 sites. The annual build limits were added for AEO 2002 and are described in the model documentation as necessary in order to better represent industry practice of gradual expansion at geothermal sites. The limits in the input file are specified by year and by site, but are the same for all 51 sites and are equal to 25 MW for each site through the year 2015 and are 50 MW for each site in all later years.

The input file *wgeparm* primarily contains information for all the 47 existing geothermal plants/units. These plants are identified as being at 18 of the resource sites discussed above (there are multiple units at some sites). The information for each plant includes the site id, site name and state, the plant name and id, vintage, prime mover, EFD type, summer capacity, and start year. The EFD type is a code used by the electricity fuel dispatch module and for all geothermal units it is 23. The values in the *wgeparm* input file for AEO 2002 are shown in Table B, at the end of this report. This input file also contains three numbers which are used to partition the available supply when creating the geothermal supply curves as will be discussed later. These values are 0.25, 0.75, and 1.00.

Model Operation

The basic model process consists of four steps as described in the documentation:

- 1) The model determines the amount of resources already used and subtracts them from the potential amount available to be added.

- 2) The model determines the costs for all the geothermal supply segments and then arrays them in increasing cost order.
- 3) The model determines from the electricity module the maximum price (avoided cost) that is likely to be competitive and uses this to frame the geothermal costs it returns to the electricity module.
- 4) The model provides to the electricity module the geothermal supply in the form of three steps of available capacity, along with various associated attributes such as capital and O&M cost, that can then be used in competing with other technologies.

Accounting for Already Existing Capacity. As the existing plant/unit characteristic inputs are read in from the input file *wgeparm*, the summer capacity for all of the existing units at each site is summed up to get a total amount of existing capacity for each site. This existing capacity is then subtracted from the four categories of potential capacity for each site to leave the amount of capacity that is remaining at each site. (The subtraction is made from the first category, and then if any is remaining from the second category, etc.). This leaves four categories of potential capacity for each site that have been decremented by the amount of already existing capacity.

COE for Each Site and Category of Potential Capacity. The geothermal model calculates a leveled cost of electricity (COE) for each site and category of potential capacity, based upon the cost information in the input file and upon some information that the renewables module receives from other electricity modules. The COE is the cost of energy and is an annualized cost. The calculation is made for each category of potential capacity at each site. The capital costs for each of these categories is the same set of capital costs for the site, but modified by some factors depending upon the specific category. These are given by:

$$\begin{aligned} \text{CapCost1} &= 1.0 * \text{DrillCapCost} + 1.0 * \text{ExplorCapCost} + 1.0 * \text{FieldCapCost} + 1.0 * \text{PlantCapCost} , \\ \text{CapCost2} &= 1.33 * \text{DrillCapCost} + 1.0 * \text{ExplorCapCost} + 1.33 * \text{FieldCapCost} + 1.0 * \text{PlantCapCost} , \\ \text{CapCost3} &= 1.0 * \text{DrillCapCost} + 2.0 * \text{ExplorCapCost} + 1.0 * \text{FieldCapCost} + 1.0 * \text{PlantCapCost} , \\ \text{CapCost4} &= 1.33 * \text{DrillCapCost} + 2.0 * \text{ExplorCapCost} + 1.33 * \text{FieldCapCost} + 1.0 * \text{PlantCapCost} . \end{aligned}$$

The calculation of the COE for each of the four categories of potential capacity at each of the sites is given by:

$$\begin{aligned} \text{COE} &= [(\text{CapCost} * \text{FixedChargeFac} * \text{LearnFac} * \text{OptFac}) + (\text{FieldOMCost} + \text{PlantOMCost})] * \\ & [1.0 / (\text{CapacityFactor} * 8760)] * 1000 . \end{aligned}$$

The variables *DrillCapCost*, *ExplorCapCost*, *FieldCapCost*, *PlantCapCost*, *FieldOMCost*, *PlantOMCost*, and *CapacityFactor* are read from the *wgesite* input file. The variables *FixedChargeFac*, *LearnFac*, and *OptFac* are received from the electricity modules, and their values are shown in Table D at the end of this report. *FixedChargeFac* is the fractional amount of the capital cost that becomes the annualized amount (based upon an interest/discount rate). *LearnFac* is a factor that reduces the capital cost based upon a learning function and cumulative capacity. *OptFac* is an optimism factor that can be used to increase the capital cost of the first amount of capacity. It is set to 1.0 for geothermal.

Building Geothermal Supply Curves. The potential capacities for each site and category are first sorted by the COE for each region. Then the unplanned capacity for geothermal (the capacity additions

that have previously been selected and are already being developed) is subtracted. This unplanned capacity is received from the electricity module. Each site and category has a bound on how much of that site can be developed in any one year, so the available resource at each site and category is limited to this bound. The available supply for each site and category is then added to create a cumulative amount of available capacity at each step. Steps that have zero available capacity are not considered.

This process is illustrated in Table 1, below. The table shows the sorted (by COE) geothermal curve data for Region 11 in 2005, for each site and category. (A section of the table is removed merely for brevity.) It can be seen that the COE for each site and category shows a starting level of \$28.25 dollars and goes up to \$1525.53 (dollar values are in 1987 dollars). It can be seen that there were 89 sites/categories assessed for this region. It can also be seen by looking at the Site ID that one category of site 28 has the lowest COE, and that other categories from site 28 also show up a little further down the list. All four categories from site 25 are show in the truncated table. The available supply in column 4 has already had the previously selected “unplanned” capacity removed from it. Column 5 shows the supply bounds for each site for each year. Note that since the whole amount of the supply bound for site 28 was used in the first row, there is nothing left to be used from site 28 in row 6. The cumulative supply simply adds the bounded amounts of supply as we move down the list.

Table 1. Sorted Geothermal Curve Data, Year 2005

Seq	Site Id	Site Reg	Avail. Supply	Supply Bound	Cumul. Supply	COE
1	28	11	152.0	25.0	25.0	28.25
2	25	11	0.0	0.0	25.0	28.35
3	25	11	68.3	25.0	50.0	28.67
4	21	11	0.0	0.0	50.0	28.99
5	21	11	84.3	25.0	75.0	29.12
6	28	11	250.0	0.0	75.0	29.21
7	25	11	100.0	0.0	75.0	30.45
8	25	11	100.0	0.0	75.0	30.77
9	26	11	84.5	25.0	100.0	30.81
10	26	11	100.0	0.0	100.0	31.57
11	27	11	100.0	25.0	125.0	31.70
12	21	11	100.0	0.0	125.0	31.74
13	21	11	100.0	0.0	125.0	31.86
14	27	11	100.0	0.0	125.0	32.37
15	26	11	100.0	0.0	125.0	33.97
16	26	11	100.0	0.0	125.0	34.72
17	27	11	100.0	0.0	125.0	34.87
(Many steps not shown here for brevity.)						
85	8	11	400.0	0.0	644.2	165.69
86	2	11	25.2	25.0	669.2	201.93
87	2	11	60.0	0.0	669.2	215.16
88	4	11	8.6	8.6	677.9	1291.61
89	4	11	20.0	16.4	694.2	1525.53

An EMM (Electricity Market Module) “signal” price is passed to the geothermal model by the ECP (Electricity Capacity Planning Module). This signal price is meant to represent the highest level for a competitive price and is used as the upper bound on the supply curve to be constructed. The signal price is set to be equal to 20% above the EMM calculated “avoided cost”. However, it is possible that no available geothermal capacity is available at this signal price. In that case, the model will incrementally increase the signal price to a level at which some small amount of geothermal capacity is available.

For all the sites with non-zero capacity availability, the maximum COE is found for each region that is closest to the EMM signal price. The geothermal supply curve will consist of the characteristics of those sites/categories that are at or below this signal price. The supply curve consists of three segments

between the lowest COE and the COE at the signal price. The first segment consists of the sites/categories with a COE below 25% of the difference between the high COE and the low COE. The second segment consists of those remaining up to 75% and the third segment consists of those remaining up to 100%. (These segment breaks are read in from input file *wgeparm* and were noted above.)

This process can be shown by looking back to Table 1 and by also looking at Table 2, below. Table 2 shows the three segments from the supply curve and other characteristics, for Region 11 in 2005, corresponding to the information in Table 1. At the bottom of Table 2 it can be seen that the EMM signal price is 33.09. This sets the upper bound for the supply curve. In Table 1, it can be seen that this value falls between the sites numbered 14 and 15. This means that the supply curve will be built from sites 1 to 14.

The lowest COE, for site 1, is 28.25 and the highest COE, for site 14, is 32.37. The difference between these two is 4.12. The first segment consists of the sites up to 25% of this difference which is 1.03. So the first segment are the sites with COEs between 28.25 and 29.28. In Table 1 it can be seen that these are the sites from 1 to 6. The second segment consists of the remaining sites up to 75% of the difference and it can be seen that these are the sites 7 to 9. The third segment consists of the sites from 10 to 14.

Table 2 shows the results of this process. Columns 2 and 3 again show the minimum and maximum COEs and column 4 shows the upper bound on the COE for each segment. The price column shows the weighted average price for each segment given by the COE for each piece of available supply, weighted by the amount of available supply. (Going back to Table 1 it can be seen that the price of 28.68 for segment 1 is the weighted average of 25 units at 28.25, 25 units at 28.67, and 25 units at 29.12.) The quantity column shows the cumulative available supply for that segment. The columns for capital cost, O&M cost, heat rate, capacity factor, and CO2 emissions rate are all also weighted averages over the sites/categories that go into that segment.

Table 2. Geothermal Curve Info, Year 2005

Seg	Minimum COE	Maximum COE	Up Bound COE	Price	Quantity	Capital Cost	O & M Cost	Heat Rate	Capacity Factor	CO2 Rate
1	28.25	32.37	29.28	28.68	75.00	1347.8	50.8	31770.	0.950	18.70
2			31.34	30.81	25.00	1489.6	48.8	32032.	0.950	18.80
3			32.37	31.70	25.00	1530.6	50.5	33522.	0.950	19.44
EMM Signal :		33.09		Weighted Average EMM Values:				32173.	0.950	18.87

Table C at the end of this report provides the same information as Table 2, but for the years 2000, 2005, 2010, 2015, and 2020 and for all three regions.

Some of the values that are used by the geothermal model that come from the electricity model are shown in Table 3, for year 2005. These are repeated at the end of the report in Table D, but for more years. The table shows the fixed charge factors, the learning factors, and the optimism factors that are used in calculating the COE, and the signal price that was discussed above. The table also shows the geothermal capacity additions that are chosen by the electricity model.

Table 3. Geothermal Info from EMM, Year 2005

Region	Fix Chg Factor	Learning Factor	Optimism Factor	Signal Price
11	0.144	0.967	1.000	33.09
12	0.144	0.967	1.000	38.78
13	0.144	0.967	1.000	39.76

Model Results for AEO 2002

Table 4 shows the resulting geothermal capacity for AEO 2002 by year and by region.

Table 4. Geothermal Capacity for AEO 2002

Year	NWP Region 11	RA Region 12	CNV Region 13	U.S. Total
2000	0.226	0.332	2.293	2.851
2001	0.237	0.332	2.293	2.862
2002	0.238	0.333	2.335	2.906
2003	0.280	0.333	2.377	2.990
2004	0.331	0.333	2.308	2.972
2005	0.370	0.333	2.350	3.053
2006	0.464	0.333	2.350	3.147
2007	0.505	0.333	2.350	3.188
2008	0.578	0.333	2.372	3.282
2009	0.697	0.333	2.372	3.402
2010	0.809	0.333	2.372	3.514
2011	0.960	0.333	2.372	3.664
2012	1.074	0.333	2.447	3.854
2013	1.250	0.333	2.497	4.079
2014	1.382	0.333	2.547	4.262
2015	1.515	0.333	2.566	4.413
2016	1.640	0.333	2.566	4.538
2017	1.749	0.333	2.566	4.648
2018	1.874	0.333	2.591	4.798
2019	1.999	0.333	2.616	4.948
2020	2.118	0.333	2.666	5.116

Table A. Inventory of Available Geothermal Resources

Total number of sites: 51

Site ID	Site Name	ST	Tech Type	Capacities				Cap Fac	CO2 Rate	H2S Rate	Capital Costs				O&M Costs		Heat Rate		
				1990	Pot1	Pot2	Pot3				Pot4	Explor	Drill	Field	Plant	Field		Plant	
1	Stillwater	BS&RG	NV	1	21.	30.	0.	0.	45.	0.80	0.00	0.00	48.15	165.27	195.40	2133.20	29.79	53.94	36371.
2	San Emidio	BS&RG	NV	1	0.	30.	0.	0.	60.	0.80	0.00	0.00	66.19	917.52	896.66	6520.01	110.70	133.46	67663.
3	Soda Lake	BS&RG	NV	1	25.	40.	0.	0.	60.	0.80	0.00	0.00	37.11	198.43	216.85	2131.77	31.28	53.88	36338.
4	Wabuska	BS&RG	NV	1	2.	10.	0.	0.	20.	0.80	0.00	0.00	84.53	2315.73	33063.56	17570.90	1313.33	345.41	397035.
5	Rye Patch	BS&RG	NV	1	0.	15.	0.	0.	20.	0.80	0.00	0.00	170.48	313.10	193.33	1569.19	34.00	50.55	32218.
6	Long Valley (LT)	YVOLS	CA	1	20.	50.	50.	50.	50.	0.80	0.00	0.00	5.81	163.21	202.37	1986.51	30.49	51.10	33791.
7	Surprise Valley	BS&RG	CA	1	0.	250.	250.	250.	100.	0.80	0.00	0.00	10.04	400.58	328.91	2323.31	48.15	67.53	48581.
8	Wendell	BS&RG	CA	1	1.	250.	400.	0.	0.	0.80	0.00	0.00	3.27	305.00	1324.41	4380.28	135.50	112.48	128222.
9	Cove Creek	BS&RG	ID	1	0.	25.	75.	175.	25.	0.80	0.00	0.00	99.84	378.07	316.13	2248.03	51.87	65.86	46830.
10	Raft River	BS&RG	ID	1	0.	30.	165.	220.	100.	0.80	0.00	0.00	96.40	1227.67	538.60	3647.48	65.51	97.10	81202.
11	Fallon	BS&RG	NV	1	0.	50.	0.	0.	100.	0.80	0.00	0.00	51.52	317.86	249.44	2178.18	38.31	64.28	45376.
12	Steamboat HS	BS&RG	NV	1	21.	75.	75.	225.	100.	0.80	0.00	0.00	56.81	317.21	142.57	1883.89	26.93	57.71	38878.
13	Alvord Desert	CSCAD	OR	1	0.	100.	100.	0.	100.	0.80	0.00	0.00	16.15	253.43	278.34	1974.42	37.79	56.67	40594.
14	Klamath Falls	CSCAD	OR	1	0.	100.	400.	400.	100.	0.80	0.00	0.00	18.06	269.15	230.56	1791.87	34.38	52.81	36767.
15	Vale	BS&RG	OR	1	0.	100.	100.	100.	100.	0.80	0.00	0.00	4.91	358.80	466.10	2638.60	60.44	70.67	55986.
16	Cove Fort	BS&RG	UT	1	10.	150.	350.	150.	100.	0.80	0.00	0.00	20.56	404.38	249.44	2178.18	38.83	64.28	45376.
17	Mt. Baker	CSCAD	WA	1	0.	25.	175.	25.	100.	0.80	0.00	0.00	190.56	1716.38	724.80	3157.05	73.57	81.55	69409.
18	Brady HS	BS&RG	NV	2	0.	50.	0.	0.	100.	0.95	45.62	0.47	29.05	179.34	195.75	2011.48	29.06	56.45	40345.
19	Fish Lake	BS&RG	NV	2	0.	30.	0.	0.	70.	0.95	44.03	0.46	88.44	419.32	263.80	1733.91	44.95	50.28	38825.
20	Long Valley (HT)	YVOLS	CA	2	0.	50.	50.	50.	50.	0.95	19.29	0.45	9.06	605.77	167.84	1338.99	51.07	101.45	31865.
21	Medicine Lake	CSCAD	CA	2	0.	100.	100.	100.	100.	0.95	18.25	0.00	7.29	389.36	107.65	863.55	19.59	31.02	30671.
22	Island Park	YVOLS	ID	2	0.	100.	100.	100.	100.	0.95	19.91	0.45	19.93	517.20	130.16	1205.20	41.17	40.68	34508.
23	Beowawe	BS&RG	NV	2	17.	50.	80.	100.	20.	0.95	20.44	0.45	75.43	568.51	179.28	1300.48	28.96	41.98	35622.
24	Desert Peak	BS&RG	NV	2	17.	100.	400.	150.	100.	0.95	20.33	0.45	41.61	636.83	179.28	1277.70	29.19	41.53	35395.
25	Dixie Valley	BS&RG	NV	2	50.	100.	100.	100.	100.	0.95	18.95	0.45	19.14	308.00	72.92	954.99	12.85	34.15	32399.
26	3 Creeks Butte	CSCAD	OR	2	0.	100.	100.	100.	100.	0.95	18.80	0.00	44.94	465.19	105.79	873.72	17.58	31.20	32032.
27	Newberry	CSCAD	OR	2	0.	100.	100.	100.	100.	0.95	19.44	0.00	39.52	445.80	126.75	918.52	18.46	32.02	33522.
28	Roosevelt HS	BS&RG	UT	2	30.	250.	250.	0.	0.	0.95	18.91	0.45	9.45	111.35	61.38	1111.92	16.67	38.07	32240.
29	Power Ranches	BS&RG	AZ	1	0.	190.	285.	190.	100.	0.80	0.00	0.00	21.69	306.87	137.92	1822.46	26.05	55.83	38878.
30	Hot Springs Ranch	BS&RG	CO	1	0.	540.	810.	0.	0.	0.80	0.00	0.00	4.72	831.07	655.89	2941.69	79.36	80.73	66236.
31	Paradise HS	DFRAC	CO	1	0.	25.	75.	25.	75.	0.80	0.00	0.00	63.99	531.79	793.73	3239.80	83.09	87.34	74641.
32	Wuניתa	RIOGR	CO	1	0.	205.	310.	205.	100.	0.80	0.00	0.00	10.23	453.39	570.77	2941.10	64.16	80.68	66939.
33	Lower R.G. Rift	RIOGR	NM	1	0.	120.	0.	0.	100.	0.80	0.00	0.00	34.31	2840.53	1872.23	4823.07	170.93	122.48	124126.
34	Valles Caldera	RIOGR	NM	2	0.	100.	100.	100.	100.	0.95	347.99	0.44	21.57	710.68	119.65	989.45	29.05	35.55	28392.
35	Buckeye HS	BS&RG	CA	1	0.	250.	385.	250.	100.	0.80	0.00	0.00	4.32	1215.32	4693.94	7689.10	363.54	185.94	222759.
36	East Mesa	IMVAL	CA	1	107.	360.	0.	0.	100.	0.80	0.00	0.00	6.39	190.03	166.53	1831.12	29.44	52.56	38919.
37	Glamis	IMVAL	CA	1	0.	275.	405.	0.	0.	0.80	0.00	0.00	7.49	955.75	1492.69	4053.65	149.25	98.65	95920.
38	Heber	IMVAL	CA	1	50.	250.	0.	0.	100.	0.80	0.00	0.00	15.05	489.07	239.93	1891.29	24.96	53.80	40197.
39	Kelly HS	CSCAD	CA	1	0.	300.	460.	880.	100.	0.80	0.00	0.00	6.93	632.10	877.55	3395.18	98.15	86.08	79013.
40	Randsburg	YVOLS	CA	1	0.	25.	60.	75.	90.	0.80	0.00	0.00	65.54	211.00	241.58	2111.48	32.93	53.09	37067.
41	Routt HS	DFRAC	CA	1	0.	65.	100.	65.	100.	0.80	0.00	0.00	13.70	47.82	89.22	1378.94	20.47	45.83	29261.
42	Sespe HS	YVOLS	CA	1	0.	125.	205.	125.	100.	0.80	0.00	0.00	19.25	1501.39	1711.44	4320.44	168.85	111.58	103879.
43	Wilbur HS	YVOLS	CA	1	0.	100.	100.	100.	100.	0.80	0.00	0.00	2.46	320.42	657.48	2938.36	78.27	80.79	65918.
44	Brawley	IMVAL	CA	2	0.	150.	150.	200.	100.	0.95	95.51	0.46	40.35	676.93	137.32	1292.23	46.63	81.89	32043.
45	Clear Lake	YVOLS	CA	2	0.	500.	400.	0.	0.	0.95	17.53	0.45	7.11	247.97	79.59	1136.79	33.05	72.83	27740.
46	Coso	YVOLS	CA	2	250.	650.	0.	0.	100.	0.95	18.63	0.45	6.14	407.30	129.38	1280.99	43.89	90.15	30721.
47	Lassen	CSCAD	CA	2	0.	116.	134.	0.	100.	0.95	20.45	0.00	25.86	507.15	199.54	1048.81	24.16	33.95	35676.
48	Salton Sea	IMVAL	CA	2	185.	500.	500.	0.	500.	0.95	89.81	0.45	9.06	362.81	90.87	1197.12	21.08	70.24	29655.
49	Westmorland	IMVAL	CA	2	0.	50.	100.	100.	100.	0.95	101.48	0.46	99.70	989.94	262.74	1385.49	78.81	94.71	34046.
50	Kilauea SW Rift	YVOLS	HI	2	0.	50.	100.	50.	100.	0.95	343.81	0.44	149.15	2715.92	414.18	961.48	140.09	36.98	27799.
51	Puna	YVOLS	HI	2	0.	100.	400.	100.	100.	0.95	333.71	0.44	59.67	1430.22	257.57	903.63	78.24	35.26	25566.

Table B. Inventory of Existing Geothermal Plants

Total number of plants: 47

Site ID	Site Name	ST	Plant Name	Plant ID	Vintage	Prime Mover	EFD Type	Summer Capacity	Start Year
1	Stillwater	BS&RG NV	Stillwater Facility	50765	1	ST	23	21.00	1989
2	San Emidio	BS&RG NV	Empire Facility	50760	1	ST	23	4.80	1987
4	Wabuska	BS&RG NV	Tad's Ent	52023	1	ST	23	1.35	1986
5	Rye Patch	BS&RG NV	Rye Patch	54112	1	ST	23	15.75	1900
6	Long Valley (LT)	YVOLS CA	Ples I	10479	1	OT	23	15.00	1990
			Mammoth Pacific I	10480	1	OT	23	10.00	1984
			Mammoth Pacific II	10481	1	OT	23	15.00	1990
			Mammoth-Pacific IIIa	ZZZCA	11	ST	23	4.75	1999
			Mammoth-Pacific IIIb	ZZZCA	11	ST	23	4.75	1999
8	Wendell	BS&RG CA	HL Power Plant	10777	1	ST	23	33.91	1989
			Amedee Geothermal Ve	50964	1	OT	23	3.00	1988
11	Fallon	BS&RG NV	Soda Lake Geothermal	52174	1	ST	23	26.10	1990
			Brady Power Project	54474	1	ST	23	25.09	1992
12	Steamboat HS	BS&RG NV	Steamboat Hills Geot	50654	1	ST	23	12.36	1988
			Steamboat 1	50763	1	ST	23	8.89	1986
			Steamboat 1A Power P	52138	1	ST	23	2.60	1988
			Steamboat II	54665	1	ST	23	22.60	1992
			Steamboat III	54666	1	ST	23	22.60	1992
16	Cove Fort	BS&RG UT	Bud L Bonnett	7370	1	GE	23	12.20	1989
21	Medicine Lake	CSCAD CA	AB1890/Four Mile Hil	ZZZCA	11	ST	23	47.40	2001
23	Beowawe	BS&RG NV	Beowawe Geothermal P	10287	1	ST	23	15.93	1985
25	Dixie Valley	BS&RG NV	Oxbow Geothermal Cor	52015	1	ST	23	56.68	1988
28	Roosevelt HS	BS&RG UT	Blundell	299	1	GE	23	23.00	1984
36	East Mesa	IMVAL CA	GEM-I (Mc	10762	1	ST	23	12.05	1979
			GEM III	10763	1	ST	23	18.74	1989
			Ormesa 1H	50762	1	ST	23	14.40	1989
			Ormesa 1 E Facility	50764	1	ST	23	14.40	1988
			Ormesa I	50766	1	ST	23	31.20	1986
			GEM II	54038	1	ST	23	18.74	1989
			Ormesa Geothermal II	54724	1	OT	23	24.00	1987
38	Heber	IMVAL CA	Second Imperial Geot	54111	1	ST	23	48.00	1993
			Heber Geothermal Com	54689	1	ST	23	48.72	1985
			Heber	7022	1	GE	23	40.00	1900
46	Coso	YVOLS CA	Coso Finance Partner	10873	1	ST	23	86.39	1988
			Coso Power Developer	10874	1	ST	23	84.33	1989
			Coso Energy Developo	10875	1	ST	23	84.33	1989
48	Salton Sea	IMVAL CA	J M Leathers	10631	1	ST	23	33.54	1989
			A W Hoch	10632	1	ST	23	33.54	1988
			J J Elmore	10634	1	ST	23	33.54	1988
			Salton Sea Unit 3	10759	1	ST	23	50.56	1989
			Salton Sea Unit 1	10878	1	ST	23	9.37	1982
			Salton Sea Unit 2	10879	1	ST	23	18.72	1990
			Vulcan	50210	1	ST	23	37.20	1985
			Salton Sea Unit 4	54996	1	ST	23	47.79	1996
			AB1890 - Salton Sea/	ZZZCA	11	ST	23	46.55	2000
			Salton Sea	ZZZCA	1	ST	23	32.30	1996
51	Puna	YVOLS HI	Puna Geothermal Vent	52028	1	ST	23	32.79	1992

Table C. Geothermal Curve Info for 2000, 2005, 2010, 2015, and 2020

Geothermal Curve Info, Year 2000

Region 11											
Seg	Minimum COE	Maximum COE	Up Bound COE	Price	Quantity	Capital Cost	O & M Cost	Heat Rate	Capacity Factor	C02 Rate	
1	29.60	37.36	31.54	29.92	75.00	1339.0	50.8	31770.	0.950	18.70	
2			35.42	32.83	50.00	1510.1	49.6	32777.	0.950	19.12	
3			37.36	0.00	0.00	0.0	0.0	0.	0.000	0.00	
EMM Signal :		39.59		Weighted Average EMM Values:				32173.	0.950	18.87	

Region 12											
Seg	Minimum COE	Maximum COE	Up Bound COE	Price	Quantity	Capital Cost	O & M Cost	Heat Rate	Capacity Factor	C02 Rate	
1	40.52	40.90	40.61	40.52	25.00	1841.3	64.6	28392.	0.950	347.99	
2			40.81	0.00	0.00	0.0	0.0	0.	0.000	0.00	
3			40.90	0.00	0.00	0.0	0.0	0.	0.000	0.00	
EMM Signal :		41.71		Weighted Average EMM Values:				28392.	0.950	347.99	

Region 13											
Seg	Minimum COE	Maximum COE	Up Bound COE	Price	Quantity	Capital Cost	O & M Cost	Heat Rate	Capacity Factor	C02 Rate	
1	38.67	43.02	39.76	38.78	50.00	1626.4	82.0	31708.	0.950	18.99	
2			41.93	41.14	50.00	1594.8	78.8	29458.	0.880	44.90	
3			43.02	0.00	0.00	0.0	0.0	0.	0.000	0.00	
EMM Signal :		43.14		Weighted Average EMM Values:				30583.	0.910	31.95	

Geothermal Curve Info, Year 2005

Region 11											
Seg	Minimum COE	Maximum COE	Up Bound COE	Price	Quantity	Capital Cost	O & M Cost	Heat Rate	Capacity Factor	C02 Rate	
1	28.25	32.37	29.28	28.68	75.00	1347.8	50.8	31770.	0.950	18.70	
2			31.34	30.81	25.00	1489.6	48.8	32032.	0.950	18.80	
3			32.37	31.70	25.00	1530.6	50.5	33522.	0.950	19.44	
EMM Signal :		33.09		Weighted Average EMM Values:				32173.	0.950	18.87	

Region 12											
Seg	Minimum COE	Maximum COE	Up Bound COE	Price	Quantity	Capital Cost	O & M Cost	Heat Rate	Capacity Factor	C02 Rate	
1	38.61	38.61	38.61	38.61	25.00	1841.3	64.6	28392.	0.950	347.99	
2			38.61	0.00	0.00	0.0	0.0	0.	0.000	0.00	
3			38.61	0.00	0.00	0.0	0.0	0.	0.000	0.00	
EMM Signal :		38.78		Weighted Average EMM Values:				28392.	0.950	347.99	

Region 13											
Seg	Minimum COE	Maximum COE	Up Bound COE	Price	Quantity	Capital Cost	O & M Cost	Heat Rate	Capacity Factor	C02 Rate	
1	36.82	39.18	37.41	37.10	50.00	1626.4	82.0	31708.	0.950	18.99	
2			38.59	0.00	0.00	0.0	0.0	0.	0.000	0.00	
3			39.18	38.78	25.00	1659.9	91.3	29655.	0.950	89.81	
EMM Signal :		39.76		Weighted Average EMM Values:				31024.	0.950	42.60	

Geothermal Curve Info, Year 2010

Region 11											
Seg	Minimum COE	Maximum COE	Up Bound COE	Price	Quantity	Capital Cost	O & M Cost	Heat Rate	Capacity Factor	C02 Rate	
1	28.68	35.44	30.37	28.68	25.00	1294.1	54.7	32240.	0.950	18.91	
2			33.75	31.87	100.00	1519.4	49.2	32156.	0.950	18.86	
3			35.44	0.00	0.00	0.0	0.0	0.	0.000	0.00	
EMM Signal :		36.11		Weighted Average EMM Values:				32173.	0.950	18.87	

Region 12											
Seg	Minimum COE	Maximum COE	Up Bound COE	Price	Quantity	Capital Cost	O & M Cost	Heat Rate	Capacity Factor	C02 Rate	
1	39.21	39.21	39.21	39.21	25.00	1841.3	64.6	28392.	0.950	347.99	
2			39.21	0.00	0.00	0.0	0.0	0.	0.000	0.00	
3			39.21	0.00	0.00	0.0	0.0	0.	0.000	0.00	
EMM Signal :		39.45		Weighted Average EMM Values:				28392.	0.950	347.99	

Region 13											
Seg	Minimum COE	Maximum COE	Up Bound COE	Price	Quantity	Capital Cost	O & M Cost	Heat Rate	Capacity Factor	C02 Rate	
1	37.41	37.41	37.41	37.41	19.20	1781.4	58.1	35676.	0.950	20.45	
2			37.41	0.00	0.00	0.0	0.0	0.	0.000	0.00	
3			37.41	0.00	0.00	0.0	0.0	0.	0.000	0.00	
EMM Signal :		37.73		Weighted Average EMM Values:				35676.	0.950	20.45	

Geothermal Curve Info, Year 2015

Region 11											
Minimum	Maximum	Up Bound	Capital	O & M	Heat	Capacity	C02				

Seg	COE	COE	COE	Price	Quantity	Cost	Cost	Rate	Factor	Rate	
1	29.17	35.49	30.75	29.83	43.32	1414.0	51.5	32307.	0.950	18.93	
2			33.91	31.93	31.74	1545.7	50.6	31276.	0.950	18.50	
3			35.49	34.31	43.26	1695.6	49.5	32661.	0.950	19.07	
EMM Signal :		36.65		Weighted Average EMM Values:				32160.	0.950	18.87	

Region 12											
Seg	Minimum COE	Maximum COE	Up Bound COE	Price	Quantity	Capital Cost	O & M Cost	Heat Rate	Capacity Factor	CO2 Rate	
1	38.56	38.92	38.65	38.56	25.00	1841.3	64.6	28392.	0.950	347.99	
2			38.83	0.00	0.00	0.0	0.0	0.	0.000	0.00	
3			38.92	0.00	0.00	0.0	0.0	0.	0.000	0.00	
EMM Signal :		39.64		Weighted Average EMM Values:				28392.	0.950	347.99	

Region 13											
Seg	Minimum COE	Maximum COE	Up Bound COE	Price	Quantity	Capital Cost	O & M Cost	Heat Rate	Capacity Factor	CO2 Rate	
1	37.33	38.73	37.68	37.33	25.00	1471.5	105.9	27740.	0.950	17.53	
2			38.38	0.00	0.00	0.0	0.0	0.	0.000	0.00	
3			38.73	38.73	25.00	1659.9	91.3	29655.	0.950	89.81	
EMM Signal :		38.77		Weighted Average EMM Values:				28697.	0.950	53.67	

Geothermal Curve Info, Year 2020

Region 11											
Seg	Minimum COE	Maximum COE	Up Bound COE	Price	Quantity	Capital Cost	O & M Cost	Heat Rate	Capacity Factor	CO2 Rate	
1	35.70	35.70	35.70	35.70	35.85	1759.1	50.5	33522.	0.950	19.44	
2			35.70	0.00	0.00	0.0	0.0	0.	0.000	0.00	
3			35.70	0.00	0.00	0.0	0.0	0.	0.000	0.00	
EMM Signal :		37.22		Weighted Average EMM Values:				33522.	0.950	19.44	

Region 12											
Seg	Minimum COE	Maximum COE	Up Bound COE	Price	Quantity	Capital Cost	O & M Cost	Heat Rate	Capacity Factor	CO2 Rate	
1	38.79	39.15	38.88	38.79	50.00	1841.3	64.6	28392.	0.950	347.99	
2			39.06	0.00	0.00	0.0	0.0	0.	0.000	0.00	
3			39.15	0.00	0.00	0.0	0.0	0.	0.000	0.00	
EMM Signal :		40.26		Weighted Average EMM Values:				28392.	0.950	347.99	

Region 13											
Seg	Minimum COE	Maximum COE	Up Bound COE	Price	Quantity	Capital Cost	O & M Cost	Heat Rate	Capacity Factor	CO2 Rate	
1	37.51	40.06	38.15	37.51	50.00	1471.5	105.9	27740.	0.950	17.53	
2			39.43	38.94	6.89	1659.9	91.3	29655.	0.950	89.81	
3			40.06	40.06	50.00	1529.7	66.3	29261.	0.800	0.00	
EMM Signal :		40.14		Weighted Average EMM Values:				28575.	0.880	13.99	

Table D. Geothermal Info from EMM for 2000, 2005, 2010, 2015, and 2020

Geothermal Info from EMM, Year 2000

Region	Fix Chg Factor	Learning Factor	Optimism Factor	Signal Price
11	0.148	1.000	1.000	39.59
12	0.148	1.000	1.000	41.71
13	0.148	1.000	1.000	43.14

Geothermal Info from EMM, Year 2005

Region	Fix Chg Factor	Learning Factor	Optimism Factor	Signal Price
11	0.144	0.967	1.000	33.09
12	0.144	0.967	1.000	38.78
13	0.144	0.967	1.000	39.76

Geothermal Info from EMM, Year 2010

Region	Fix Chg Factor	Learning Factor	Optimism Factor	Signal Price
11	0.152	0.936	1.000	36.11
12	0.152	0.936	1.000	39.45
13	0.152	0.936	1.000	37.73

Geothermal Info from EMM, Year 2015

Region	Fix Chg Factor	Learning Factor	Optimism Factor	Signal Price
11	0.155	0.900	1.000	36.65
12	0.155	0.900	1.000	39.65
13	0.155	0.900	1.000	38.77

Geothermal Info from EMM, Year 2020

Region	Fix Chg Factor	Learning Factor	Optimism Factor	Signal Price
11	0.159	0.881	1.000	37.22
12	0.159	0.881	1.000	40.26
13	0.159	0.881	1.000	40.14