State Of California | The Resources Agency of California

M e m o r a n d u m

Date : January 23, 2002
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To : DOCKET UNIT

From : California Energy Commission - Cheri Davis
1516 Ninth Street Energy Commission Project Manager
Sacramento, CA 95814-5512

Subject : **EAST ALTAMONT ENERGY CENTER (01-AFC-4)**

Attached please find staff's Visible Plume Analysis for the East Altamont Energy Center. This should be considered a supplement to the Preliminary Staff Assessment (PSA) that was filed on December 6, 2001.

Staff's initial modeling analysis of the visible plumes for the EAEC was completed in early October, 2001. Staff's Visual Resources plume analysis contained in the PSA is based on the results of this initial plume modeling. In response to staff's concerns about the accuracy of the assumptions, the Applicant provided a revised modeling analysis based on a second meteorological file and revised operating data for both the Cooling Tower and the Heat Recovery Steam Generators on October 31st and November 12th. Staff completed new modeling runs using the revised information, and several additional modeling runs to compare to the Applicant's results and to test out the effectiveness of potential mitigation measures. The results of these analyses are presented in this document. Staff's Visual Resources analysis of these results will appear in the Final Staff Assessment.

Staff is requesting comments on this supplement on or before February 15, 2002.

cc: East Altamont Proof of Service

EAST ALTAMONT ENERGY CENTER
COOLING TOWER AND HRSG EXHAUST
VISIBLE PLUME ANALYSIS

William Walters

INTRODUCTION

The following provides the assessment of the East Altamont Energy Center (EAEC) Project cooling tower and heat recovery steam generator (HRSG) exhaust stack visible plumes. Staff completed a modeling analysis for both the Applicant's proposed unabated cooling tower and HRSG designs, and potential plume abated designs.

Staff's initial modeling analysis was completed in early October. Based on staff's concerns about the accuracy of the assumptions, the Applicant provided a revised modeling analysis based on a second meteorological file and revised operating data for both the Cooling Tower and the HRSGs on October 31st and November 12th. Staff then completed additional modeling based on the revised information. Staff also completed several modeling runs to identify the validity, and in some cases the potential invalidity, of the Applicant's revised modeling inputs and modeling approach. Finally, staff modeled potential plume mitigation approaches requested by Energy Commission Visual Resources staff. The results of both the initial and revised modeling analyses are presented in this document.

PROJECT DESCRIPTION

The Applicant has proposed a linear 19-cell conventional wet cooling tower. The Applicant has not proposed to use any methods to abate visible plumes from the cooling tower.

The project includes three separate turbine/heat recovery steam generator (HRSG) systems, each with separate exhaust stacks. The project features very large duct firing capacity, which increases exhaust moisture content, and also features very low exhaust temperatures, which combined with the high exhaust moisture content causes a much higher plume frequency potential than in other recent 7F frame turbine projects. The Applicant has not proposed to use any methods to abate visible plumes from the HRSG exhausts.

COOLING TOWER VISIBLE PLUME MODELING ANALYSIS

INITIAL COOLING TOWER DESIGN PARAMETERS

Staff evaluated the Applicant's AFC (EAEC 2001a, AFC Section 8.11.2.4) and Data Request Responses #6 and #114 to #120 (EAEC 2001n, pages 21-42; EAEC 2001p, pages 72-76; and EAEC 2001ff, pages 4-6) and performed an independent psychrometric analysis and dispersion modeling analysis to determine the frequency and dimensions of the project's proposed unabated wet cooling tower.

The following cooling tower design characteristics, presented below in **Table 1**, were determined through a review of the Applicant's AFC and Data Request Responses, and through additional engineering calculations.

Table 1 – Initial Cooling Tower Design Parameters

Parameter	Cooling Tower Design Parameters
Stack Height	17.37 meters
Number of Cells	19 Cells (1 by 19 configuration)
Equivalent Stack Diameter	44.72 meters (10.6 m per cell)
Tower Dimensions	313 meter length by 16.4 meter width
Tower Heat Rejection	807 MW/hr
Tower Inlet Air Flow Rate	17,192 kg/s
Liquid to Gas (L/G) Ratio	1.03 (hot and annual avg. weather), 0.57 (cold weather)
Exhaust Temperature	48.6°F to 98.6°F
Exit Velocity	Calculated hourly based on other parameters
Exhaust mass flow rate	137,250,000 to 140,951,000 lbs/hr
Exhaust Molecular Weight	28.8 (assumed)
Moisture Content (% by weight)	0.73% to 3.30%

The exhaust temperature and exhaust mass flow rate values were calculated for the hourly ambient conditions modeled through linear interpolation and extrapolation of the data provided by the Applicant for three ambient conditions. The exhaust moisture content was determined by assuming saturated conditions at the calculated exhaust temperature.

INITIAL COOLING TOWER VISIBLE PLUME MODELING ANALYSIS

The Applicant provided an initial plume modeling analysis for the unabated cooling tower; which staff found to be flawed. The Applicant assumed an incorrect (i.e. low) exhaust moisture content, which when plugged into the model produced results that greatly underestimated the potential plume size and frequency. Staff identified this problem to the Applicant and, in a data request, asked the Applicant to provide a corrected analysis. The Applicant responded with a revised modeling analysis that, for the most part, corrected for the initial moisture content assumptions. This subsequent analysis, however, modeled a single cooling tower cell at a time, without identifying plume interaction between the adjacent cells. The Applicant's modeling method only models $1/19^{th}$ of the entire exhaust volume (i.e. water emissions) from the cooling tower, which will cause the plume size from the 19-cell cooling tower to be underestimated. Therefore, this analysis cannot be used to describe the plume dimensions for the 19-cell cooling tower.

The Applicant, in their revised modeling analysis, used a model and modeling techniques that in many ways are similar to Staff's CSVP model and modeling techniques. However, due to the linear nature of the proposed cooling tower and the fact that the tower is nearly aligned with the prevalent wind direction, staff used both the SACTI model and the CSVP model to predict the cooling tower plume frequency and dimensions. The SACTI model uses the tower alignment and dimensions in its modeling analysis, and CSVP model, which is limited to modeling single point sources, is able to determine when plumes are not expected (i.e. determines plume frequency). Therefore, staff considers these two models to compliment each other. For the CSVP modeling runs, staff grouped the 19 cells into a single stack of equivalent diameter; the Applicant did not attempt to group the cooling tower cells in any fashion, so their plume dimension modeling results cannot be directly compared to the results from staff's modeling analysis. However, the frequency results determined from the Applicant's modeling analysis and staff's modeling analysis can be compared. The determination of plume frequency is not impacted by the exhaust volume assumptions used in the modeling analysis as long as the other exhaust parameters are comparable. Staff completed a single cooling tower cell modeling run to qualitatively assess the Applicant's modeling analysis results and likely magnitude of the plume dimension underestimate.

The Applicant provided a 3-year meteorological file that they created by adding Brentwood monitoring station relative humidity data to the meteorological data from the Tracy monitoring station operated by San Joaquin Valley Air Pollution Control District. This data does not have present weather (i.e. rain or fog occurrence) or other visibility data.

Staff modeled the cooling tower plumes using both a modified version of the Combustion Stack Visible Plume (CSVP) model and the Seasonal/Annual Cooling Tower Impact (SACTI) model. The SACTI model is designed to model multiple cell cooling towers, and for the CSVP modeling analysis staff used an equivalent stack diameter assumption in order to model the entire exhaust volume of the tower. **Table 2** provides the CSVP model visible plume frequency results using the Tracy/Brentwood meteorological data.

Table 2 – Staff Initially Predicted Hours with Cooling Tower Steam Plumes Tracy/Brentwood 1997 to 1999 Meteorological Data

		Unabated Cooling Tower	
	Available (hr)	**Plume (hr)**	**Percent**
All Hours	26,280	11,003	41.9%
Daylight Hours	13,374	3,602	26.9%
Seasonal Daylight Hours*	6,000	2,875	47.9%

* - Seasonal conditions occur from November through April.

The CSVP and SACTI model predicted plume size characteristics are provided in **Table 3**.

Table 3 – Staff Initially Predicted Cooling Tower Steam Plume Dimensions Tracy/Brentwood 1997 to 1999 Meteorological Data

	CSVP Model			SACTI Model		
All Hours	**Length (m)**	**Height (m)**	**Width (m)**	**Length (m)**	**Height (m)**	**Width (m)**
50%	No Plume	No Plume	No Plume	30-40	20-30	20-40
10%	1,931	267	111	400-500	90-100	160-180
5%	2,629	547	136	8,000-9,000	>1,000	1,000-1,200
Maximum	5,000	2,830	229	>10,000	>1,000	1,400-1,600
Daylight Hours						
50%	No Plume	No Plume	No Plume	30-40	20-30	20-40
10%	614	527	94	80-90	50-60	60-80
5%	1,033	912	117	4,000-5,000	900-1,000	800-1,000
Maximum	4,849	2,830	213	>10,000	>1,000	1,200-1,400
Seasonal Daylight Hours*						
50%	No Plume	No Plume	No Plume	30-40	30-40	20-40
10%	864	898	113	4,000-5,000	900-1,000	800-1,000
5%	1,408	1,248	134	5,000-6,000	>1,000	1,000-1,200
Maximum	4,869	2,830	213	>10,000	>1,000	1,200-1,400

No Plume – Plumes are not predicted to occur at the listed frequency
* - Seasonal conditions occur from November through April.

Staff uses a plume frequency of 10% of seasonal (November through April) daylight hours as the threshold that triggers the need for a study of the visual impacts from the plumes. Both models predicted very large plumes for more than 10% of seasonal daylight hours. Therefore, staff will need to conduct a study of the visual impacts, the results of which will be presented in the Visual Resources section of the Final Staff Assessment.

REVISED COOLING TOWER OPERATING PARAMETERS

The Applicant provided revised cooling tower exhaust parameters in revised Data Response 117 (EAEC 2001gg, pages 1-4). Namely, they provided revised conditions when the duct firing is not operating and an estimate of the saturation level of the exhaust. The Applicant also provided a separate modeling analysis for one cell of the cooling tower. This modeling analysis uses a new meteorological file, a 1976 Stockton file, which includes data on fog and rain occurrence. The Applicant provided these revised operating parameters and modeling analysis files on October 31st and November 12th, respectively, after staff had completed its initial modeling analysis. The revised operating data are provided in **Table 4**.

Table 4 – Revised Cooling Tower Exhaust Parameters

Parameter	Revised Cooling Tower Exhaust Parameters	
	Duct Fired	No Duct Firing
Exhaust Temperature	72.7°F @ 45°F Ambient 79.6°F @ 61°F Ambient 89.1°F @ 98°F Ambient	61.4°F @ 45°F Ambient 70.3°F @ 61°F Ambient 82.9°F @ 98°F Ambient
Saturation	97.0% @ 45°F Ambient 97.2% @ 61°F Ambient 97.6% @ 98°F Ambient	97.3% @ 45°F Ambient 97.8% @ 61°F Ambient 98.3% @ 98°F Ambient

It is the Applicant's contention that the reasonable worst-case plume formation scenario occurs when duct firing is assumed to be used from 10 am to 8 pm to meet peak demand. Staff has incorporated this as a reasonable worst-case assumption in the modeling analysis. However, it should be noted that there are no specific requirements that would prohibit duct firing from 8 pm through 10 am. As duct firing increases the steam load, it also increases the heat rejection load to the cooling tower. The effect of this reasonable worst-case assumption is to substantially drop the temperature and moisture content from the cooling tower during the overnight and early morning hours. When the cooling load is reduced the cooling tower could be operated with fewer cells on-line, with lower air flow through the cells, or without any change in the flow rate, as is assumed by the Applicant. Staff considers the Applicant's operating approach to be a de facto plume abatement method, which the model indicates will reduce the frequency of plumes. If the project owner were to employ either of the other two methods, the modeled plume frequencies would not change substantially from those modeled in the initial analysis (i.e. shown above in Table 2), but the plume dimensions would be smaller due the reduced overall water mass flow rate being exhausted from the tower.

The exhaust temperature and exhaust mass flow rate values for the revised modeling analysis were calculated for the hourly ambient conditions modeled through linear interpolation and extrapolation of the data provided by the Applicant for the three ambient conditions. The exhaust moisture content was determined by assuming linear interpolation of the saturation percent provided by the applicant for the calculated exhaust temperature. Generally, cooling towers are modeled as fully saturated exhausts; however, staff used the Applicant's calculated values for this assessment. The applicant did not provide, in their latest data response, information adequate to revise the original SACTI modeling analysis, so the revised staff modeling analysis is limited to using the CSVP model.

REVISED COOLING TOWER VISIBLE PLUME MODELING ANALYSIS

Staff modeled the revised cooling tower operating parameters using both meteorological files provided by the Applicant. The revised modeling results using the Tracy/Brentwood meteorological data are provided in **Tables 5** through **7**.

Table 5 – Staff Predicted Hours with Cooling Tower Steam Plumes
Revised Cooling Tower Operating Data
Tracy/Brentwood 1997 to 1999 Meteorological Data

		"Unabated" Cooling Tower			
		Duct Fired		No Duct Firing	
	Available (hr)	Plume (hr)	Percent	Plume (hr)	Percent
All Hours	26,280	10,519	40.0%	5,150	19.6%
Daylight Hours	13,374	3,088	23.1%	1,410	10.5%
Seasonal Daylight Hours*	6,000	2,484	41.4%	1,275	21.25%

* - Seasonal conditions occur from November through April.

**Table 6 – Staff Predicted Hours with Cooling Tower Steam Plumes
Revised Cooling Tower Operating Data
Tracy/Brentwood 1997 to 1999 Meteorological Data**

		Cooling Tower (Duct Firing 10 am to 8 pm) (No Duct Firing 8 pm to 10 am)	
	Available (hr)	**Plume (hr)**	**Percent**
All Hours	26,280	6,426	24.4%
Daylight	13,374	2,154	16.1%
Seasonal Daylight*	6,000	1,965	32.8%

* - Seasonal conditions occur from November through April.

**Table 7 - Staff Predicted Cooling Tower Visible Plume Dimensions
Revised Cooling Tower Operating Data
Tracy/Brentwood 1997 to 1999 Meteorological Data**

	Cooling Tower (Duct Firing 10 am to 8 pm) (No Duct Firing 8 pm to 10 am)		
All Hours	**Length (m)**	**Height (m)**	**Width (m)**
50%	No Plume	No Plume	No Plume
10%	1,959	269	121
5%	2,665	324	144
Maximum	5,000	3,998	298
Seasonal Daylight Hours*			
50%	No Plume	No Plume	No Plume
10%	995	992	136
5%	1,515	1,494	158
Maximum	5,000	3,998	226

No Plume – Plumes are not predicted to occur at the listed frequency.
* - Seasonal conditions occur from November through April.

While the overall plume frequencies are shown to be lower than shown in the original modeling analysis (compare Table 6 with Table 2), the maximum, 5%, and 10% plume dimensions are similar to those found in the original modeling analysis (compare **Table 7** with **Table 3**).

Staff then modeled the revised cooling tower operating data using the Stockton meteorological file provided by the Applicant and compared our modeling results with those provided by the Applicant. The results of this modeling analysis are provided in **Tables 8** through **10**.

Table 8 – Staff Predicted Hours with Steam Plumes
Revised Cooling Tower Operating Data
Stockton 1976 Meteorological Data

		Staff Modeling Results	
		Duct Firing	
	Available (hr)	**Plume (hr)**	**Percent**
All Hours	8,784	2,938	33.4%
Daylight	4,447	781	17.6%
Seasonal Daylight *	2,015	700	34.7%
Seasonal Daylight No Fog/No Rain*	1,649	358	21.7%
		No Duct Firing	
	Available (hr)	**Plume (hr)**	**Percent**
All Hours	8,784	1,141	13.0%
Daylight	4,447	283	6.4%
Seasonal Daylight*	2,015	273	13.5%
Seasonal Daylight No Fog/No Rain*	1,649	83	5.0%

* - Seasonal conditions occur from November through April.

Table 9 – Applicant and Staff Predicted Hours with Steam Plumes
Revised Cooling Tower Operating Data
Stockton 1976 Meteorological Data

		Applicant Modeling Results		**Staff Modeling Results**	
		Duct Firing 10 am to 8 pm – No Duct Firing 8 pm to 10 am			
	Available (hr)	**Plume (hr)**	**Percent**	**Plume (hr)**	**Percent**
All Hours	8,784	1,056	12.0%	1,456	16.6%
Daylight	4,447	459	10.3%	465	10.5%
Seasonal Daylight *	2,015	451	22.4%	450	22.3%
Seasonal Daylight No Fog/No Rain*	1,649	224	13.6%	167	10.1%

* - Seasonal conditions occur from November through April.

The frequency results show that staff's and the Applicant's modeling results are very similar, with the Applicant showing a lower overall frequency and marginally higher plume frequencies for seasonal daylight hours.

Table 10 - Staff Predicted Cooling Tower Steam Plume Dimensions
Revised Cooling Tower Operating Data
Stockton 1976 Meteorological Data

	Duct Firing 10 am to 8 pm - No Duct Firing 8 pm to 10 am		
All Hours	**Length (m)**	**Height (m)**	**Width (m)**
50%	No Plume	No Plume	No Plume
10%	960	226	88
5%	1,797	348	110
Maximum	5,000	3,742	263
Seasonal Daylight No Fog No Rain Hours*			
50%	No Plume	No Plume	No Plume
10%	371	178	57
5%	720	330	91
Maximum	4,340	2,114	193

No Plume – Plumes are not predicted to occur at the listed frequency.
* - Seasonal conditions occur from November through April.

The Applicant provided plume dimension modeling results for only a single cell of the 19-cell cooling tower. This modeling analysis dramatically underestimates the plume dimensions for the entire cooling tower. In order to show how large the Applicant's modeled plumes may have been if all 19-cells were modeled, staff modeled a single cell of the cooling tower and compares the two analyses in **Table 11**.

Table 11 – Applicant and Staff Predicted Cooling Tower Steam Plume Dimensions
Revised Cooling Tower Operating Data
Stockton 1976 Meteorological Data
One-Cell Modeling Basis

	Applicant Modeling Results			**Staff Modeling Results**		
All Hours	**Length (m)**	**Height (m)**	**Width (m)**	**Length (m)**	**Height (m)**	**Width (m)**
50%	No Plume	No Plume	No Plume	No Plume	No Plume	No Plume
10%	40	55	ND	175	82	18
5%	60	77	17	296	99	22
Maximum	1,100	255	163	827	444	47
Seasonal Daylight Hours No Fog No Rain*						
50%	No Plume	No Plume	No Plume	No Plume	No Plume	No Plume
10%	40	59	ND	74	38	12
5%	50	77	16	135	84	19
Maximum	200	145	86	618	266	36

No Plume – Plumes are not predicted to occur at the listed frequency.
ND – No data.
* - Seasonal conditions occur from November through April.

Staff's modeling results do in general show longer and higher plumes than modeled by the Applicant; however, it should be noted that in the Applicant's results table the plume width data was not available for all hours with plume length and height data. In general, while comparing data, staff noted that the plume width was greater in the Applicant's results. This is possibly a function of plume downwash caused by the wind's flow around the cooling tower structure and other large structures near the cooling tower, which is calculated in the Applicant's modeling analysis, but is not currently available in the CSVP model. In fact, while the Applicant only modeled a single cooling tower cell, the downwash parameters were for the entire 19-cell tower; therefore, staff considers the modeling methods used by the Applicant to be inconsistent and potentially misleading. However, the important parameters of comparison are the significant differences in staff's one cell plume dimension modeling results and staff's 19-cell plume dimension modeling results (Compare staff's results in Table 11 to Table 10). This comparison shows the magnitude by which the Applicant's one-cell modeling results may underestimate the plume dimensions for the entire cooling tower.

ALTERNATIVE NON-ABATED COOLING TOWER DESIGN ANALYSIS

The Applicant has provided information for a cooling tower with a very low liquid to gas (L/G) ratio design (1.03 when duct firing and 0.57 without duct firing), which is substantially lower than that proposed for any other recent project before the commission. The end effect of the lower L/G design is to lower the cooling tower exhaust temperature and moisture content which reduces the modeled plume frequency and dimension. Because reducing L/G increases both the footprint size and cost of the cooling tower, the Applicant could seek a higher L/G design to lower project capital costs. Additionally, staff is concerned that during very cold weather operating at a 0.57 L/G could cause icing inside the tower, which could damage the tower. Staff is concerned that if the design is modified to a higher and more "normal" L/G ratio, the plume frequency will increase substantially. In order to see what might happen to plume frequency and plume dimensions if the design were to change, staff modeled plumes for an equivalent 1.35 L/G cooling tower. This cooling tower was designed for a site in the San Joaquin Valley for another project that is owned by the EAEC Applicant. The partial load (i.e. no duct firing) case cannot be modeled as no equivalent data exists for the 1.35 L/G cooling tower; therefore, only full load with duct firing (i.e. cooling tower maximum design heat rejection) was modeled for comparison.

The modeled frequency comparison for the "alternative" cooling tower design and Applicant's proposed cooling tower design using the 1976 Stockton meteorological data are provided in **Table 12**.

Table 12 – Staff Predicted Hours with Steam Plumes
1.05 L/G Cooling Tower vs. 1.35 L/G Cooling Tower Design Comparison
Stockton 1976 Meteorological Data

		1.05 L/G Design – Duct Fired		1.35 L/G Design – Duct Fired	
	Available (hr)	**Plume (hr)**	**Percent**	**Plume (hr)**	**Percent**
All Hours	8,784	2,938	33.4%	5,336	60.7%
Daylight	4,447	781	17.6%	1,829	41.1%
Seasonal Daylight*	2,015	700	34.7%	1,310	65.0%
Seasonal Daylight No Fog/No Rain*	1,649	358	21.7%	949	57.6%

* - Seasonal conditions occur from November through April.

As can be seen from **Table 12** the cooling tower design, even between two different unabated wet designs, can influence the plume frequency significantly. The modeling results indicate that if the cooling tower design is modified to a 1.35 L/G design the predicted plume frequency for the seasonal daylight no fog/no rain hours would more than double.

Table 13 provides the predicted plume dimensions for the two cooling tower L/G designs.

Table 13 - Predicted Cooling Tower Steam Plume Dimensions (meters)
1.35 L/G Cooling Tower vs. 1.05 L/G Cooling Tower Design Comparison
Stockton 1976 Meteorological Data

	1.05 L/G Design – Duct Fired			1.35 L/G Design – Duct Fired		
All Hours	**Length (m)**	**Height (m)**	**Width (m)**	**Length (m)**	**Height (m)**	**Width (m)**
50%	No Plume	No Plume	No Plume	415	157	55
10%	2,174	348	125	2,200	417	125
5%	2,944	646	154	2,945	692	152
Maximum	5,000	4,557	324	5,000	4,146	301
Seasonal Daylight Hours No Fog No Rain*						
50%	No Plume	No Plume	No Plume	260	153	46
10%	782	404	100	823	557	103
5%	1,245	665	124	1,213	763	121
Maximum	5,000	3,416	296	5,000	3,169	278

No Plume – Plumes are not predicted to occur at the listed frequency.
* - Seasonal conditions occur from November through April.

The plume dimension results show that the maximum, 5% and 10% plume dimensions are similar for the two cooling tower design cases; however, the higher L/G design case has a significantly higher frequency of plume predicted.

HRSG VISIBLE PLUME MODELING ANALYSIS

Staff evaluated the Applicant’s Data Request Response #7 and #119 (EAEC 2001n, pages 42-61; EAEC 2001p, pages 74-76; EAEC 2001ff, pages 4-6) was performed an independent psychrometric analysis and dispersion modeling analysis. The Combustion Stack Visible Plume (CSVP) model was used to estimate the worst-case potential plume frequency, and provide data on predicted plume length, width, and height for each HRSG stack.

HRSG PARAMETERS

Based on the stack exhaust parameters anticipated by the Applicant for each HRSG stack, the frequency and size of visual plumes can be estimated. The operating data for these stacks are provided in **Table 14**.

Table 14 - HRSG Stack Exhaust Parameters

	HRSG Stack Exhaust Parameters		
Parameter	**Unabated HRSG Full Load – With Duct Firing and Power Augmentation**	**Unabated HRSG Full Load – With Duct Firing, No Power Augmentation**	**Unabated HRSG Full Load – No Duct Firing or Power Augmentation**
Stack Height	53.34 meters		
Stack Diameter	5.64 meters		
Exhaust Temperature	331-360°K (135-188°F)		
Exit Velocity	Calculated for each hour modeled		
Exhaust Mass Flow Rate	3,414,714 to 4,128,241 lbs/hr	3,196,873 to 3,910,400 lbs/hr	3,108,980 to 3,822,507 lbs/hr
Exhaust Molecular Weight	28.5 lbs/lb-mol (est.)		
Moisture Content (% by wt)	9.03 to 9.36%	7.15 to 7.48%	5.30 to 5.63%

INITIAL STAFF HRSG PLUME MODELING ANALYSIS

The Applicant compiled a three-year meteorological data set from Tracy/Brentwood, which was used by staff to model the HRSG plume potential using the CSVP model. The predicted HRSG visible plume occurrence frequency estimated by the CSVP model are shown in **Table 15.**

Table 15 – Staff Predicted Hours with HRSG Steam Plumes Tracy/Brentwood 1997 to 1999 Meteorological Data

		Unabated HRSG Worst Case	
	Available (hr)	**Plume (hr)**	**Percent**
All Hours	26,280	22,461	85.5%
Daylight	13,374	10,054	75.2%
Seasonal Daylight*	6,000	5,840	97.3%
		Unabated HRSG – Duct Firing	
	Available (hr)	**Plume (hr)**	**Percent**
All Hours	26,280	16,949	64.5%
Daylight	13,374	6,357	47.5%
Seasonal Daylight*	6,000	4,343	72.4%
		Unabated HRSG – No Duct Firing or Power Augmentation	
	Available (hr)	**Plume (hr)**	**Percent**
All Hours	26,280	5,056	19.2%
Daylight	13,374	1,366	10.2%
Seasonal Daylight*	6,000	1,148	19.1%

* - Seasonal conditions occur from November through April.
Worst case - Duct firing and power augmentation on at maximum capacity.

These results indicate that the unusually low temperatures being proposed for the HRSG exhausts will result in a high occurrence of visible water vapor plumes. The unabated seasonal daylight plume frequency for each HRSG stack is predicted to be above 10% of seasonal daylight hours and would trigger the need for a study of the visual impacts of the plume. The visual impact analysis for the cooling tower plumes will be provided in the Visual Resources section of the Final Staff Assessment.

For the proposed HRSG exhaust conditions, the maximum temperature where a visible plume is predicted is 83.2°F, when the relative humidity is 100%. The CSVP predicted plume size characteristics are provided in **Table 16**.

Table 16 - Staff Predicted HRSG Steam Plume Dimensions (meters)
Tracy/Brentwood 1997 to 1999 Meteorological Data

	Unabated HRSG - Worst Case		
All Hours	**Length (m)**	**Height (m)**	**Width (m)**
50%	132	92	19
10%	571	200	43
5%	745	261	53
Maximum	2,634	1,099	127
Seasonal Daylight Hours*			
50%	137	130	27
10%	378	344	53
5%	518	464	60
Maximum	2,051	1,099	111
	Unabated HRSG – Duct Firing		
All Hours	**Length (m)**	**Height (m)**	**Width (m)**
50%	93	77	14
10%	471	185	36
5%	618	226	44
Maximum	2,171	972	108
Seasonal Daylight Hours*			
50%	100	103	20
10%	311	294	44
5%	431	400	51
Maximum	1,699	972	95
	Unabated HRSG – No Duct Firing or Power Augmentation		
All Hours	**Length (m)**	**Height (m)**	**Width (m)**
50%	No Plume	No Plume	No Plume
10%	318	155	24
5%	457	182	33
Maximum	1,741	854	89
Seasonal Daylight Hours*			
50%	No Plume	No Plume	No Plume
10%	210	197	32
5%	320	281	41
Maximum	1,369	854	79

No Plume – Plumes are not predicted to occur at the listed frequency
* - Seasonal conditions occur from November through April.
Worst Case – Duct firing and power augmentation on at maximum capacity.

The results provided above are for each of the three HRSG exhausts. The separation between the stacks is approximately 40 meters; therefore, occasionally under certain wind conditions, it is possible for the plumes to combine in a single large plume.

REVISED HRSG OPERATING PARAMETERS

The Applicant provided revised HRSG exhaust temperature parameters in revised Data Response 119 (EAEC 2001gg, pages 4-6). The Applicant also provided a separate plume modeling analysis for the HRSGs. This modeling analysis uses a new meteorological file, a 1976 Stockton file, which includes data on fog and rain occurrence. The Applicant provided these revised operating parameters and modeling analysis files on October 31st and November 12th, respectively, after staff had completed its initial modeling analysis. The revised operating data are provided in **Table 17**.

Table 17 – Revised HRSG Stack Exhaust Parameters

Parameter	HRSG Stack Exhaust Parameters		
	Unabated HRSG Full Load – With Duct Firing and Power Augmentation	**Unabated HRSG Full Load – With Duct Firing, No Power Augmentation**	**Unabated HRSG Full Load - No Duct Firing or Power Augmentation**
Exhaust Temperature	341.67°K (155°F)	341.67°K (155°F)	360°K (188°F)

REVISED STAFF HRSG PLUME MODELING ANALYSIS

The predicted HRSG visible plume occurrence frequency estimated by the CSVP model using the revised HRSG exhaust temperatures and the Tracy/Brentwood meteorological data are shown in **Table 18.**

Table 18 – Staff Predicted Hours with HRSG Steam Plumes
Revised HRSG Operating Data
Tracy/Brentwood 1997 to 1999 Meteorological Data

		Unabated HRSG Worst Case	
	Available (hr)	**Plume (hr)**	**Percent**
All Hours	26,280	18,419	70.1%
Daylight	13,374	7,255	54.2%
Seasonal Daylight*	6,000	5,100	85.0%
		Unabated HRSG – Duct Firing	
	Available (hr)	**Plume (hr)**	**Percent**
All Hours	26,280	13,313	50.7%
Daylight	13,374	4,446	33.2%
Seasonal Daylight*	6,000	3.625	60.4%
		Unabated HRSG – No Duct Firing or Power Augmentation	
	Available (hr)	**Plume (hr)**	**Percent**
All Hours	26,280	2,669	10.2%
Daylight	13,374	748	5.6%
Seasonal Daylight*	6,000	748	12.5%

* - Seasonal conditions occur from November through April.
Worst case - Duct firing and power augmentation on at maximum capacity.

The frequencies are lower than those originally modeled; however, they are still well above the significance criteria of 10% of seasonal daylight hours. Staff then determined the plume frequencies using the duct firing schedule provided by the Applicant. **Table 19** shows the estimated plume frequencies using the revised exhaust temperatures and duct firing schedule assuming power augmentation (worst-case) and no power augmentation.

**Table 19 – Staff Predicted Hours with HRSG Steam Plumes
Revised HRSG Operating and Duct Firing Schedule Data
Tracy/Brentwood 1997 to 1999 Meteorological Data**

		Unabated HRSG Worst Case (10 am to 8 pm) Unabated HRSG – No Duct Firing (8 pm to 10 am)	
	Available (hr)	**Plume (hr)**	**Percent**
All Hours	26,280	7,650	29.1%
Daylight	13,374	4,327	32.4%
Seasonal Daylight*	6,000	3,785	63.1%
		Unabated HRSG – Duct Firing (10 am to 8 pm) Unabated HRSG – No Duct Firing (8 pm to 10 am)	
	Available (hr)	**Plume (hr)**	**Percent**
All Hours	26,280	5,578	21.2%
Daylight	13,374	2,627	19.6%
Seasonal Daylight*	6,000	2,541	42.4%

* - Seasonal conditions occur from November through April.
Worst case - Duct firing and power augmentation on at maximum capacity.

The plume frequency results shown above are still well above the significance criteria of 10% of seasonal daylight hours. Even with the potential exclusion of 400 or so seasonal daylight hours per year with rain, fog, or other visibility limiting phenomena, the seasonal daylight plume frequency predicted using this meteorological data set shows plume frequencies that would be well above 10% of seasonal daylight hours.

The predicted HRSG plume dimensions using the revised exhaust temperatures and duct firing schedule assuming power augmentation (worst-case) and no power augmentation are shown in **Table 20**.

Table 20 - Staff Predicted HRSG Steam Plume Dimensions (meters) Revised HRSG Operating and Duct Firing Schedule Data Tracy/Brentwood 1997 to 1999 Meteorological Data

	Unabated HRSG Worst Case (10 am to 8 pm) Unabated HRSG – No Duct Firing (8 pm to 10 am)		
All Hours	**Length (m)**	**Height (m)**	**Width (m)**
50%	No Plume	No Plume	No Plume
10%	308	166	32
5%	457	218	41
Maximum	1,985	874	100
Seasonal Daylight Hours*			
50%	105	94	20
10%	283	293	47
5%	376	397	55
Maximum	1,369	874	82
	Unabated HRSG – Duct Firing (10 am to 8 pm) Unabated HRSG – No Duct Firing (8 pm to 10 am)		
All Hours	**Length (m)**	**Height (m)**	**Width (m)**
50%	No Plume	No Plume	No Plume
10%	276	155	27
5%	431	190	36
Maximum	1,741	854	89
Seasonal Daylight Hours*			
50%	No Plume	No Plume	No Plume
10%	242	251	41
5%	334	346	48
Maximum	1,369	854	79

No Plume – Plumes are not predicted to occur at the listed frequency
* - Seasonal conditions occur from November through April.
Worst Case – Duct firing and power augmentation on at maximum capacity.

Staff modeled the revised HRSG operating data using the Stockton meteorological file provided by the Applicant and compared our modeling results with those provided by the Applicant. The results of this modeling analysis are provided in **Tables 21** through **23**.

Table 21 – Staff Predicted Hours with HRSG Steam Plumes
Revised HRSG Operating Data
Stockton 1976 Meteorological Data

		Staff Modeling Results	
		Unabated HRSG Worst Case	
	Available (hr)	Plume (hr)	Percent
All Hours	8,784	5,823	66.3%
Daylight	4,447	2,153	48.4%
Seasonal Daylight*	2,015	1,635	81.1%
Seasonal Daylight No Fog/No Rain*	1,649	1,271	77.1%
		Unabated HRSG – Duct Firing	
	Available (hr)	Plume (hr)	Percent
All Hours	8,784	3,995	45.5%
Daylight	4,447	1,206	27.1%
Seasonal Daylight*	2,015	1,036	51.4%
Seasonal Daylight No Fog/No Rain*	1,649	680	41.2%
		Unabated HRSG – No Duct Firing or Power Augmentation	
	Available (hr)	Plume (hr)	Percent
All Hours	8,784	1,051	12.0%
Daylight	4,447	245	5.5%
Seasonal Daylight*	2,015	240	11.9%
Seasonal Daylight No Fog/No Rain*	1,649	88	5.3%

* - Seasonal conditions occur from November through April.
Worst case - Duct firing and power augmentation on at maximum capacity.

The modeling results using the 1976 Stockton file show that the modeled frequencies are marginally lower than those found using the three year Tracy/Brentwood meteorological file, and may therefore slightly underestimate the plume frequency potential.

Table 22 – Applicant and Staff Predicted Hours with HRSG Steam Plumes Revised HRSG Operating and Duct Firing Schedule Data Stockton 1976 Meteorological Data

		Applicant Modeling Results		Staff Modeling Results	
		Unabated HRSG Worst Case (10 am to 8 pm) Unabated HRSG – No Duct Firing (8 pm to 10 am)			
	Available (hr)	Plume (hr)	Percent	Plume (hr)	Percent
All Hours	8,784	ND	ND	2,544	29.0%
Daylight	4,447	ND	ND	1,280	28.8%
Seasonal Daylight*	2,015	ND	ND	1,217	60.4%
Seasonal Daylight No Fog/No Rain*	1,649	ND	ND	934	56.6%
		Unabated HRSG – Duct Firing (10 am to 8 pm) Unabated HRSG – No Duct Firing (8 pm to 10 am)			
	Available (hr)	Plume (hr)	Percent	Plume (hr)	Percent
All Hours	8,784	1,614	18.4%	1,801	20.5%
Daylight	4,447	737	16.6%	676	15.2%
Seasonal Daylight*	2,015	725	36.0%	669	33.2%
Seasonal Daylight No Fog/No Rain*	1,649	434	26.3%	392	23.8%

ND – No Data
* - Seasonal conditions occur from November through April.
Worst Case – Duct firing and power augmentation on at maximum capacity.

The frequency results show that staff's and the Applicant's modeling results are very similar, with the Applicant showing a lower overall frequency and marginally higher plume frequencies for seasonal daylight hours. However, the Applicant did not provide modeling results when duct firing and power augmentation are both in use, which may underestimate the potential plume frequency.

Table 23 – Applicant and Staff Predicted HRSG Steam Plume Dimensions (meters)
Revised HRSG Operating and Duct Firing Schedule Data
Stockton 1976 Meteorological Data

	Applicant Modeling Results			Staff Modeling Results		
	Unabated HRSG Worst Case (10 am to 8 pm) Unabated HRSG – No Duct Firing (8 pm to 10 am)					
All Hours	**Length (m)**	**Height (m)**	**Width (m)**	**Length (m)**	**Height (m)**	**Width (m)**
50%	ND	ND	ND	No Plume	No Plume	No Plume
10%	ND	ND	ND	315	154	29
5%	ND	ND	ND	436	187	35
Maximum	ND	ND	ND	1,457	928	77
Seasonal Daylight Hours No Fog No Rain*						
50%	ND	ND	ND	104	95	19
10%	ND	ND	ND	209	178	33
5%	ND	ND	ND	268	216	39
Maximum	ND	ND	ND	1,329	683	73
	Unabated HRSG – Duct Firing (10 am to 8 pm) Unabated HRSG – No Duct Firing (8 pm to 10 am)					
All Hours	**Length (m)**	**Height (m)**	**Width (m)**	**Length (m)**	**Height (m)**	**Width (m)**
50%	No Plume	No Plume	No Plume	No Plume	No Plume	No Plume
10%	140	121	46	283	148	25
5%	200	151	68	415	174	31
Maximum	2,500	817	611	1,329	928	77
Seasonal Daylight Hours No Fog No Rain*						
50%	No Plume	No Plume	No Plume	No Plume	No Plume	No Plume
10%	120	130	49	159	141	25
5%	160	153	66	227	179	31
Maximum	800	310	169	1,329	683	70

ND – No data.
* - Seasonal conditions occur from November through April.
No Plume – Plumes are not predicted to occur at the listed frequency.
Worst Case – Duct firing and power augmentation on at maximum capacity.

Staff's modeling results do in general show longer and higher plumes than those modeled by the Applicant. However, in general, the Applicant predicted plumes with greater width, and the overall effect is that the Applicant's results predict larger plume volumes (i.e. greater plume bulk) than predicted by staff.

Plume downwash would be one mechanism that might cause the plumes to have greater width and reduced height. Plume downwash occurs when the wind, through its interaction with large structures, forces the plume closer to the ground. However, staff does not believe that downwash significantly affects the HRSG stacks (i.e. the stacks were designed to reduce or eliminate downwash), and staff cannot determine why the Applicant's plume widths are calculated to be so much larger than those calculated by staff while the length and height are calculated to be smaller.

COOLING TOWER PLUME ABATEMENT METHODS

Cooling tower plumes can be abated through cooling apparatus design modification. Two potential abatement methods are provided for discussion: 1) air-cooled condensers; and 2) wet/dry cooling systems. The use of once-through cooling would also eliminate plumes; however, this option is not available at this project location.

AIR-COOLED CONDENSERS (DRY COOLING)

Air-cooled condensers, in place of a wet cooling tower, completely eliminate the potential for plume formation; however, this technology is much more expensive (as much as 10 times as expensive) than a traditional cooling tower, requires more space, and creates a much higher structure that may itself impact project aesthetics. The operating costs are also higher due to the higher electrical demand for the fans. Based solely on economic criteria, a project developer will generally only consider air-cooled condensers for power plant installations when water constraints will not allow for wet cooling technologies. However, due to overriding environmental considerations (i.e. water use and visual impacts) many states, such as New York, Oregon, and Colorado to name a few, have mandated dry cooling for all or most of their new power projects that have been licensed within the last 15 years.

WET/DRY COOLING TOWERS

Wet/dry cooling tower systems can also be used to lessen or completely eliminate plume formation during normal weather conditions. Wet/dry systems are also more expensive (approximately 1.5 to 3 times as expensive) than traditional cooling towers and have higher operating costs. However, the relative cost of these systems is decreasing as their use has become more frequent and more cooling tower manufacturers are entering this market. The size of these systems is dependent on the specific design; however, in general these towers will either increase the footprint size or the height compared to a conventional wet cooling tower. Water use will decrease in proportion to the heat duty of the dry section of the wet/dry tower. Noise emissions from wet/dry towers are dependent on the specific design, and are generally thought to be higher than for wet cooling, but in some cases are essentially equivalent to the noise emissions from conventional wet cooling towers.

OVERSIZING TOWER AIR FLOW

Increasing tower air flow rates (i.e. decreasing L/G) can reduce the frequency, size and density of plume formation. The increase in air flow causes the exhaust temperature and moisture content to move down the saturation line which then requires less dispersion to dissipate the plume, resulting in less frequent and shorter plumes. This may be accomplished through providing oversized variable speed fans and motors and additional air intake area. However, this method is not as effective as the other plume abatement methods and would increase the size of the cooling tower, which may increase the capital cost as much as a wet/dry or hybrid design and would likely have a higher associated operating cost. Whether by design or not, the Applicant's cooling tower design in effect uses this method to reduce plume formation.

Power plants have recently been proposed that use all three of these design modifications to eliminate or mitigate cooling tower plumes. The appropriate abatement design is based on each project's plume sensitivity. According to Don Dobney of Marley Cooling Tower (Dobney 2001), due to the reasonably high winter temperatures in most of California, it is generally cheaper to add a small dry cooling section (i.e. like their "ClearFlow" design) to a cooling tower than oversize the airflow. This method would also be more effective and have lower operating costs.

HRSG PLUME ABATEMENT METHODS

There are two methods that can be used alone or together, to reduce HRSG plume formation. These two methods are 1) increasing the stack temperature, and 2) decreasing the water content of the exhaust.

INCREASE STACK TEMPERATURE

Stack temperature can be increased by transferring less heat in the HRSG. This method is relatively easy to monitor, but will result in a small loss in efficiency and total MW production. This method is used at the Crockett facility, where an economizer bypass is used to increase stack temperatures to eliminate HRSG plumes during cold weather. This method has also been proposed for several other facilities, including two other facilities proposed by the EAEC project Applicant.

DECREASE EXHAUST WATER CONTENT

The water content in HRSG exhausts comes from three major sources: 1) water from the ambient inlet air; 2) water produced in the combustion process; and 3) water added for power augmentation. It is not feasible or desirable to reduce the water content of the ambient air. Therefore, the most feasible method for the EAEC project to reduce the HRSG exhaust water content is to reduce duct firing or power augmentation. As can be seen in the plume frequency results provided in Table 5 reducing duct firing and power augmentation can lower the plume frequency significantly.

This method is generally not considered desirable to project applicants due to the fact that it restricts the operations and power output of the facility. However, it should be noted that power produced by duct firing is less efficient than power produced without duct firing, so limiting duct firing actually increases overall fuel efficiency.

STAFF ASSUMED PLUME ABATED DESIGN MODELING

Considering the frequent large plumes predicted for the proposed unabated cooling tower and HRSG designs, staff has modeled potential plume abated designs for consideration.

Staff performed this modeling analysis using the Tracy/Brentwood meteorological data set. After a comparison of the Stockton data set with the Tracy/Brentwood data set and other area data sets it was found that the single year Stockton data set had significantly lower average and median relative humidities, which would likely underestimate plume frequency and plume dimensions. Therefore, while staff did provide modeling results using both data sets, staff considers the Tracy/Brentwood meteorological data set to be more representative of site conditions.

ABATED COOLING TOWER VISIBLE PLUME MODELING ANALYSIS

For comparison with the proposed project designs the following minimum plume abated designs have been assumed by staff and modeled for the cooling tower and HRSG:

- Cooling tower abated to 38°F and 80% relative humidity as is currently proposed by Calpine for Russell City. Cooling tower operating data provided for Russell City has been used in this modeling analysis.

Table 24 provides the abated cooling tower plume frequency modeling results.

Table 24 – Staff Predicted Hours with Abated Cooling Tower Steam Plumes Tracy/Brentwood 1997 to 1999 Meteorological Data

		Abated Cooling Tower	
	Available (hr)	**Plume (hr)**	**Percent**
All Hours	26,280	2,027	7.71%
Daylight Hours	13,374	582	4.35%
*Seasonal Daylight Hours	6,000	582	9.70%

* - Seasonal conditions occur from November through April.

The plume frequency modeled for staff's assumed design is below the 10% seasonal daylight impact study threshold trigger value. It should be noted that 524 of the 582 daylight hours (90%) that are predicted to have a plume have ambient relative humidities at or above 95%; therefore, it is assumed that many of these hours would be during fog or rain hours that are not considered hours that are impacted by visual water vapor plumes.

ABATED HRSG VISIBLE PLUME MODELING ANALYSIS

For comparison with the proposed project designs the following minimum plume abated designs have been assumed and modeled for the cooling tower and HRSG:

- HRSG with economizer bypass that would allow the stack temperature to be raised to a minimum of 270°F. Again, this is the same as the HRSG plume mitigation currently proposed by Calpine for Russell City.

Staff understands that the specific HRSG abatement design assumptions do not reflect the EAEC's high-powered density design; however, the Applicant did not respond to staff's request to provide project specific HRSG abatement information (CEC 2001i, page 5; EAEC 2001z, pages 1-3), so staff was forced to use the Russell City abatement design as a starting point in the HRSG abatement discussion for this project. Additionally, staff received revised HRSG exhaust temperature information and revised HRSG and cooling tower modeling analyses from the Applicant in November. This new information, and the project specific HRSG abatement design questions and considerations, will be addressed in the Final Staff Assessment. Staff has serious concerns about the visual impacts that would occur as a result of the unabated water vapor plumes predicted for this project, and we hope that the Applicant will work with us in a good faith effort to address our concerns and answer our questions regarding potential plume abatement designs.

Table 25 provides the abated HRSG plume frequency modeling results.

Table 25 – Staff Predicted Hours with Abated HRSG Steam Plumes Tracy/Brentwood 1997 to 1999 Meteorological Data

		Abated HRSG Worst Case	
	Available (hr)	**Plume (hr)**	**Percent**
All Hours	26,280	4,147	15.78%
Daylight	13,374	1,124	8.40%
Seasonal Daylight*	6,000	1,102	18.37%
		Abated HRSG – Duct Firing	
	Available (hr)	**Plume (hr)**	**Percent**
All Hours	26,280	1,609	6.12%
Daylight	13,374	492	3.68%
Seasonal Daylight*	6,000	492	8.20%
		Abated HRSG – No Duct Firing and No Power Augmentation	
	Available (hr)	**Plume (hr)**	**Percent**
All Hours	26,280	315	1.20%
Daylight	13,374	100	0.75%
Seasonal Daylight*	6,000	100	1.67%

* - Seasonal conditions occur from November through April.
Worst case for plume is operating with duct firing and power augmentation on.

It should be noted that 805 of the 1,102 seasonal daylight hours (77%) that are predicted to have a plume during worst case operation have ambient relative humidities at or above 95%; therefore, it is assumed that many of these hours would be during fog or rain hours that are not considered hours that are impacted by visual water vapor plumes. Additionally, it is reasonable to expect that maximum duct firing and power augmentation would not generally occur during the cold morning hours, before 10 am, where a plume is most frequently predicated to occur. Therefore, staff expects that the actual operating plume frequency with the staff assumed design would be well below the 10% seasonal daylight impact study threshold trigger value.

CONCLUSIONS

Visible Plumes From The Proposed Eaec Wet Cooling Tower And Hrsg Exhaust Would Occur More Frequently Than 10% Of Seasonal Daylight Hours. Therefore, A Plume Impact Analysis Of The Cooling Tower And Hrsg Exhaust Plumes Will Need To Be Included In The Visual Resources Section Of The Final Staff Assessment.

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