G. HUNTINGTON BEACH GENERATING STATION

AES HUNTINGTON BEACH, LLC—HUNTINGTON BEACH, CA

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1.0 GENERAL SUMMARY

Retrofitting the existing once-through cooling system at Huntington Beach Generating Station (HBGS) with closed-cycle wet cooling towers is technically and logistically feasible based on this study's design criteria, and will reduce cooling water withdrawals from Los Cerritos Channel by approximately 95 percent. Impingement and entrainment impacts would be reduced by a similar proportion.

The preferred option selected for HBGS includes 4 conventional wet cooling towers (without plume abatement), with individual cells arranged in an inline configuration to accommodate limited space at the site. A desalination facility has been proposed for HBGS and would be co-located on the existing property. This study assumes placement of the desalination plant will be the same as discussed in previous studies and reserves sufficient space for those facilities. Siting constraints and placement are discussed in Section 3.2.3.

Space limitations would appear to preclude plume-abated towers in the design if they were required to mitigate visual impacts. Initial capital costs for the towers would also increase by a factor of 2 or 3.

Construction-related shutdowns are estimated to take approximately 4 weeks per unit (concurrent), although HBGS is not expected to incur any financial loss as a result based on 2006 capacity utilization rates for all units.

The cooling tower configuration designed under the preferred option complies with all identified local use restrictions and includes necessary mitigation measures, where applicable.

1.1 COST

Initial capital and net present costs associated with installing and operating wet cooling towers at HBGS are summarized in Table G–1. Annualized costs based on 20-year average values for the various cost elements are summarized in Table G–2.

Table G–1. Cumulative Cost Summary

Cost category	Cost ($)	Cost per MWh (rated capacity) ($/MWh)	Cost per MWh (2006 output) ($/MWh)
Total capital and start-up [a]	132,600,000	17.20	116
NPC_{20} [b]	160,400,000	20.80	141

[a] Includes all costs associated with the cooling tower construction and installation and shutdown loss, if any.
[b] NPC_{20} includes all capital costs, operation and maintenance costs, and energy penalty costs over 20 years discounted at 7 percent.

Table G–2. Annual Cost Summary

Cost category	Cost ($)	Cost per MWh (capacity) ($/MWh)	Cost per MWh (2006 output) ($/MWh)
Capital and start-up	12,500,000	1.62	10.96
Operations and maintenance	900,000	0.12	0.79
Energy penalty	2,000,000	0.26	1.75
Total HBGS annual cost	**15,400,000**	**2.00**	**13.50**

1.2 ENVIRONMENTAL

Environmental changes associated with a cooling tower retrofit for HBGS are summarized in Table G–3 and discussed further in Section 3.4.

Table G–3. Environmental Summary

		Units 1 & 2	Units 3 & 4
Water use	Design intake volume (gpm)	168,000	168,000
	Cooling tower makeup water (gpm)	9,200	9,200
	Reduction from capacity	95%	95%
Energy efficiency [a]	Summer heat rate increase	1.59%	1.59%
	Summer energy penalty	2.76%	2.70%
	Annual heat rate increase	1.20%	1.20%
	Annual energy penalty	2.36%	2.31%
Direct air emissions [b]	PM_{10} emissions (tons/yr) (maximum capacity)	96.66	96.66
	PM_{10} emissions (tons/yr) (2006 capacity utilization)	17.93	10.84

[a] Reflects the comparative increase between once-through and wet cooling systems, but does not account for any operational changes to address the change in efficiency, such as increased fuel consumption (see Section 4.6).

[b] Reflects emissions from the cooling tower only; does not include any increase in stack emissions.

2.0 BACKGROUND

HBGS is a natural gas-fired steam electric generating facility located in the city of Huntington Beach, Orange County, owned and operated by AES Huntington Beach, LLC. The facility site occupies 83 acres of a 106-acre parcel along the Pacific Ocean, directly across the Pacific Coast Highway from Huntington State Beach. HBGS currently operates four steam generating units (Units 1−4); Unit 5 is a combustion turbine retired from service in 2002. (See Table G–4 and Figure G–1.)

Table G−4. General Information

Unit	In-service year	Rated capacity (MW)	2006 capacity utilization [a]	Condenser cooling water flow (gpm)
Unit 1	1958	215	20.4%	84,000
Unit 2	1958	215	16.7%	84,000
Unit 3	2003 [b]	225	11.6%	84,000
Unit 4	2003 [b]	225	10.8%	84,000
HBGS total		**880**	**12.9%**	**336,000**

[a] Quarterly Fuel and Energy Report—2006 (CEC 2006).
[b] Units 3 and 4 were retired in 1995 but re-entered service in 2003 following an emergency re-tool certification from the CEC following the 2001 energy crisis.

2.1 COOLING WATER SYSTEM

HBGS operates one cooling water intake structure (CWIS) to provide condenser cooling water to all four steam generating units. (Figure G–2). Once-through cooling water is combined with low volume wastes generated by HBGS and discharged through a submerged structure approximately 1,200 feet offshore in the Pacific Ocean. Surface water withdrawals and discharges are regulated by NPDES Permit CA0001163 as implemented by Santa Ana Regional Water Quality Control Board (SARWQCB) Order R8-2006-0011.

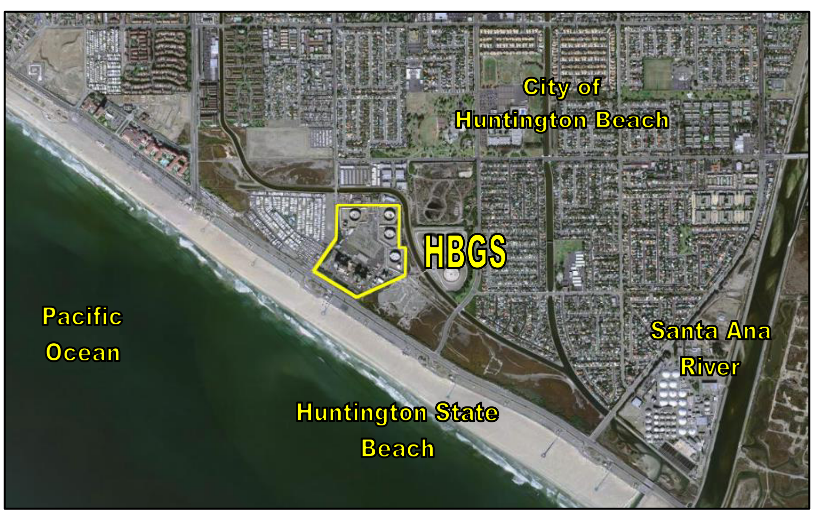

Figure G−1. General Vicinity of Huntington Beach Generating Station

Figure G–2. Site View

One CWIS serves all four steam units at HBGS. Water is withdrawn through a submerged conduit extending approximately 1,500 feet offshore in the Pacific Ocean and terminating at an approximate depth of 17 feet. The submerged end of the conduit is fitted with a velocity cap to minimize the entrainment of motile fish into the system by converting the vertical flow to a lateral flow, thus triggering a flight response from fish.

The onshore portion of the intake consists of four 11-foot wide screen bays (one for each unit), each fitted with a stationary screen and vertical traveling screen. Vertical traveling screens are fitted with 3 mesh panels and are typically rotated twice per shift for a period of 20 minutes. A high- pressure spray removes any debris or fish that have become impinged on the screen face. Captured debris is collected in a dumpster for disposal at a landfill. The approach velocity to the traveling screens ranges from 0.80 feet per second (fps) to 1.04 fps for each unit; through-screen velocities can be approximated by doubling the approach velocity.

Downstream of each traveling screen are two circulating water pumps. The six pumps used for Units 1–3 are rated at 42,000 gallons per minute (gpm), or 60 million gallons per day (mgd). The two pumps used for Unit 4 are rated at 46,300 gpm, or 67 mgd (AES 2005)

At maximum capacity, HBGS maintains a total pumping capacity rated at 514 mgd. On an annual basis, HBGS withdraws substantially less than its design capacity due to its low generating capacity utilization (12.9 percent for 2006). When in operation and generating the maximum load, HBGS can be expected to withdraw water from the Pacific Ocean at a rate approaching its maximum capacity.

2.2 SECTION 316(B) PERMIT COMPLIANCE

The CWIS currently in operation at HBGS uses a velocity cap to reduce the entrainment of motile fish through the system, although the caps are commonly thought of as impingement-reduction technologies because they target larger organisms. Velocity caps have been shown to reduce impingement rates when compared with a shoreline intake structure. Likewise, the location of the intake structure in a deep, offshore setting may contribute to lower rates of entrainment when compared with a shoreline intake if the near-shore environment is more biologically productive. This study did not evaluate the effectiveness of either measure.

The current order does not contain numeric or narrative limitations regarding impingement or entrainment resulting from CWIS operation, but does require impingement monitoring at the intake structure during heat treatment operations and at least once per month. Because the current orders were adopted following implementation of the Phase II rule but prior to the Second Circuit Court's decision and EPA's notice of suspension, the order contains a requirement to adhere to the rule's compliance schedule as well as a re-opener provision to incorporate any modifications necessary to comply with the performance standards.

The Phase II compliance schedule requirements consist of various data collection provisions and studies that were to be submitted in support of an eventual best technology available (BTA) determination made by the SARWQCB. Based on the record available for review, HBGS has been compliant with this permit requirement. No information from the SARWQCB is available indicating how it intends to proceed with the permit requirements in light of the changes to the Phase II rule.

As part of the Unit 3 and 4 emergency re-tool certification, the California Energy Commission (CEC) required HBGS to conduct an updated impingement and entrainment study to assess the affects of the increased intake volume on the surrounding aquatic environment (CEC 2001). A technical working group consisting of HBGS, the California Department of Fish and Game, National Marine Fisheries Service, and the US Fish and Wildlife service oversaw the study's design and provided comments on the final report. AES completed the study in April 2005.

3.0 WET COOLING SYSTEM RETROFIT

3.1 OVERVIEW

This study evaluates saltwater cooling towers as a retrofit option at HBGS, with the current source water (the Pacific Ocean) continuing to provide makeup water to the facility. Converting the existing once-through cooling system to wet cooling towers will reduce the facility's current intake capacity by approximately 95 percent; rates of impingement and entrainment will decline by a similar proportion. Use of reclaimed water was considered for HBGS but not analyzed in detail because the available volume cannot serve as a replacement for once-through cooling water. The proximity of available sources, however, may make reclaimed water an attractive alternative as makeup water for a wet cooling tower system when considering additional benefits its use may provide, such as avoidance of conflicts with effluent limitations or air emission standards.

A previous analysis of the use of alternative water sources in a wet cooling tower configuration was conducted by Powers Engineering in 2007. That study and other water sources are discussed in Section 3.4.4.

The wet cooling towers' configuration—their size, arrangement, and location—was based on best professional judgment (BPJ) using the criteria outlined in Chapter 5 and designed to meet the performance benchmarks in the most cost-effective manner. Information not available to this study that offers a more complete facility characterization may lead to different conclusions regarding the cooling towers' physical configuration.

This study developed a conceptual design of wet cooling towers sufficient to meet each active generating unit's cooling demand at its rated output during peak climate conditions and configured to allow for the construction of the proposed desalination facility at the site. Cost estimates are based on vendor quotes developed using the available information and the various design constraints identified at HBGS.

The overall practicality of retrofitting both units at HBGS will require an evaluation of factors outside the scope of this study, such as each unit's age and efficiency and its role in the overall reliability of electricity production and transmission in California, particularly the Los Angeles and San Diego regions.

3.2 DESIGN BASIS

3.2.1 CONDENSER SPECIFICATIONS

For this study, the wet cooling tower conceptual design selected for HBGS is based on the assumption that the condenser flow rate and thermal load to each will remain unchanged from the current system. Although no provision is included to re-optimize the condenser performance for service with a cooling tower, some modifications to the condenser (tube sheet and water box reinforcement) may be necessary to handle the increased water pressures that will result from the increased total pump head required to raise water to the cooling tower riser elevation. The practicality and difficulty of these modifications are dependent on each unit's age and configuration but are assumed to be feasible at HBGS. Condenser water boxes for both units are located at grade level and appear to be readily accessible. Additional costs for condenser modifications are included in the discussion of capital expenditures (Section 4.3).

Information provided by HBGS was largely used as the basis for the cooling tower design. In some cases, the data were incomplete or conflicted with values obtained from other sources. Some information and assumptions used in this study were obtained from a wet cooling tower analysis prepared by Sargent and Lundy, LLC in 2006. Where possible, questionable values were verified or corrected using other known information about the condenser.

For example, the condenser specification data sheets provided by AES did not contain information detailing the total surface area or heat transfer coefficients for the condenser tubes. In lieu of this information, a replacement value was calculated based on other known characteristics about the system (e.g., design inlet temperature, condenser rise, thermal load, tube material, etc.) using Heat Exchange Institute guidelines (HEI 2007). The resulting calculation is referred to as the "U-A" value and is substituted into the relevant equations as necessary.

Parameters used in the development of the cooling tower design are summarized in Table G–5.

Table G–5. Condenser Design Specifications

	Units 1 & 2	Units 3 & 4
Thermal load (MMBTU/hr)	950	950
Surface area (ft^2)	NA	NA
Condenser flow rate (gpm)	84,000	84,000
Tube material	NA	NA
Heat transfer coefficient (U_d)	NA	NA
"U-A" value (BTU/hr·°F)	~82,600,000	~82,600,000
Cleanliness factor	0.85	0.85
Inlet temperature (°F)	63	63
Temperature rise (°F)	22.63	22.63
Steam condensate temperature (°F)	92.7	92.7
Turbine exhaust pressure (in. HgA)	1.55	1.55

3.2.2 AMBIENT ENVIRONMENTAL CONDITIONS

HBGS is located in Orange County along the Pacific Ocean. Cooling water is withdrawn at the from a submerged offshore intake structure. Inlet temperature data specific to HBGS were not provided by AES. As a substitute, monthly temperature data was obtained from the National Oceanographic and Atmospheric Administration (NOAA) *Coastal Water Temperature Guide—Dana Point, CA* (NOAA 2007).

The wet bulb temperature used to develop the overall cooling tower design in this study was obtained from the Sargent and Lundy report, which selected a one percent ambient wet bulb temperature of 69.5° F based on climate data for the Marine Corps Air Station in Tustin (Sargent and Lundy 2006). A 12° F approach temperature was selected based on the site configuration and vendor input. At the design wet bulb and approach temperatures, the cooling towers will yield "cold" water at 81.5° F.

Monthly maximum wet bulb temperatures used in the development of energy penalty estimates in Section 4.6 were obtained from National Climatic Data Center (NCDC) climate normals for Newport Beach Harbor in Newport Beach, California (NCDC 2006). Climate data used in this analysis are summarized in Table G–6.

Table G–6. Surface Water and Ambient Wet Bulb Temperatures

	Surface (°F)	Ambient wet bulb (°F)
January	57.2	52.3
February	58.3	54.1
March	59.5	55.7
April	61.1	58.7
May	61.4	63.7
June	62.6	66.3
July	64.1	68.4
August	63.9	69.5
September	62.0	66.5
October	60.9	62.0
November	59.3	58.6
December	58.7	53.5

3.2.3 LOCAL USE RESTRICTIONS

3.2.3.1 NOISE

Industrial development at HBGS is regulated by the city of Huntington Beach General Plan and the Coastal Element that serves as the city's Local Coastal Program (LCP). The facility area is designated as General Industrial. According to the city's municipal code, HBGS is located in Noise Zone 4, which restricts external noise levels to 70 dBA at anytime of the day. Due to the proximity of residential areas (approximately 300 feet from the property's western boundary at some points), this study selected a noise limitation of 60 dBA measured at 800 feet when designing the wet cooling towers. Compliance with this restriction does not require noise abatement measures such as low noise fans or barrier walls.

3.2.3.2 BUILDING HEIGHT

The developed portion of HBGS is located within the General Industrial zone according to the city's General Plan. This zone is dedicated to industrial uses and establishes a building height restriction of 40 feet although the facility is designated as a pre-existing use and may be able to obtain a greater height limit. The height of the wet cooling towers designed for HBGS, from grade level to the top of the fan deck, is 39 feet and complies with the existing height limit.

3.2.3.3 PLUME ABATEMENT

Local zoning ordinances do not contain any specific criteria for addressing impacts associated with a wet cooling tower plume. Using the selection criteria for this study, plume abatement measures were not considered for HBGS; all towers are a conventional design. The plume from wet cooling towers at HBGS is not expected to adversely impact nearby infrastructure Community standards for assessing the visual impact associated with a cooling tower plume cannot be determined within the scope of this study.

The proximity of nearby residential and coastal recreational and protected areas, and the potential visual impact on these resources, may require plume abatement measures. CEC siting guidelines and Coastal Act provisions evaluate the total size and persistence of a visual plume with respect to aesthetic standards for coastal resources; significant visual changes resulting from a persistent plume would likely be subject to additional controls.

Depending on the scope of the proposed desalination facility to be co-located at the site, plume-abated towers may face greater obstacles with respect to placement; these towers are taller than a conventional design and may conflict with permitted building height restrictions. If required, plume-abated towers would increase the initial capital cost by 2−3 times that of conventional towers.

3.2.3.4 DRIFT AND PARTICULATE EMISSIONS

Drift elimination measures that are considered best available control technology (BACT) are required for all cooling towers evaluated in this study, regardless of their location. State-of-the-art drift eliminators are included for each cooling tower cell at HBGS, with an accepted efficiency of 0.0005 percent. Because cooling tower PM_{10} emissions are a function of the drift rate, drift eliminators are also considered BACT for PM_{10} emissions from wet cooling towers. This efficiency can be verified by a proper in situ test, which accounts for site-specific climate, water, and operating conditions. Testing based on the Cooling Tower Institute's Isokinetic Drift Test Code is required at initial start-up on only one representative cell of each tower for an approximate cost of $60,000 per test, or approximately $240,000 for all four cooling towers at HBGS (CTI 1994). This cost is not itemized in the final analysis and is instead included as part of the indirect cost estimate (Section 4.3).

3.2.3.5 FACILITY CONFIGURATION AND AREA CONSTRAINTS

The existing site's configuration, as currently understood, allows for the placement of wet cooling towers without significant disruption to other facility operations. Alternative configurations are limited by the future construction of a desalination facility at the site. Available areas are shown in Figure G–3.

Area 1 and Area 2 are currently occupied by three empty fuel tanks. Both areas have been reserved for the desalination facility and are unavailable for wet cooling towers.

Area 3 is an L-shaped parcel bordering the northern and northeastern property lines. Although use of this area places the cooling towers at their greatest possible distance from the generating units, it is the only sufficiently-sized area available unless the switchyard was relocated. This study did not consider using the switchyard area because of the complexity and cost associated with relocation.

Figure G–3. Cooling Tower Siting Locations

3.3 CONCEPTUAL DESIGN

Based on the design constraints discussed above two wet cooling tower complexes, each consisting of two towers, were selected to replace the current once-through cooling system at HBGS, for a total of four towers. Each tower complex will operate independently and be dedicated to one unit pair (Tower Complex 1 serves Units 1 and 2; Tower Complex 2 serves Units 3 and 4). Separate pump houses are constructed for each complex. Each tower is configured in a multicell, inline arrangement.

3.3.1 SIZE

Each tower is constructed over a concrete collection basin 4 feet deep. The basin is larger than the tower structure's footprint, extending an additional 2 feet in each direction. The concrete used for construction is suitable for saltwater applications. The principal tower material is fiberglass reinforced plastic (FRP), with stainless steel fittings. These materials are more resistant to the higher corrosive effects of saltwater.

The size of each tower is primarily based on the thermal load rejected to the tower by the surface condenser and a 12° F approach to the ambient wet bulb temperature. Flow rates through each condenser remain unchanged.

General characteristics of the wet cooling towers selected for HBGS are summarized in Table G–7.

Table G–7. Wet Cooling Tower Design

	Tower Complex 1 (Units 1 & 2)	Tower Complex 2 (Units 3 & 4)
Thermal load (MMBTU/hr)	1,900	1,900
Circulating flow (gpm)	168,000	168,000
Number of cells	14	14
Tower type	Mechanical draft	Mechanical draft
Flow orientation	Counterflow	Counterflow
Fill type	Modular splash	Modular splash
Arrangement	Inline	Inline
Primary tower material	FRP	FRP
Tower dimensions (l x w x h) (ft) [a]	378 x 48 x 39	378 x 48 x 39
Tower footprint with basin (l x w) (ft) [a]	382 x 52	382 x 52

[a]Two individual towers with these dimensions form each cooling tower complex.

3.3.2 LOCATION

The initial site selection for each tower was based on the desire to locate each tower as close as possible to the respective generating units to minimize the supply and return pipe distances and any increases in total pump head and brake horsepower. At HBGS, the linear distance between the generating units and towers is large (approximately 4,000 feet) but does not present any significant challenges for placing the supply and return pipelines (Figure G–4).

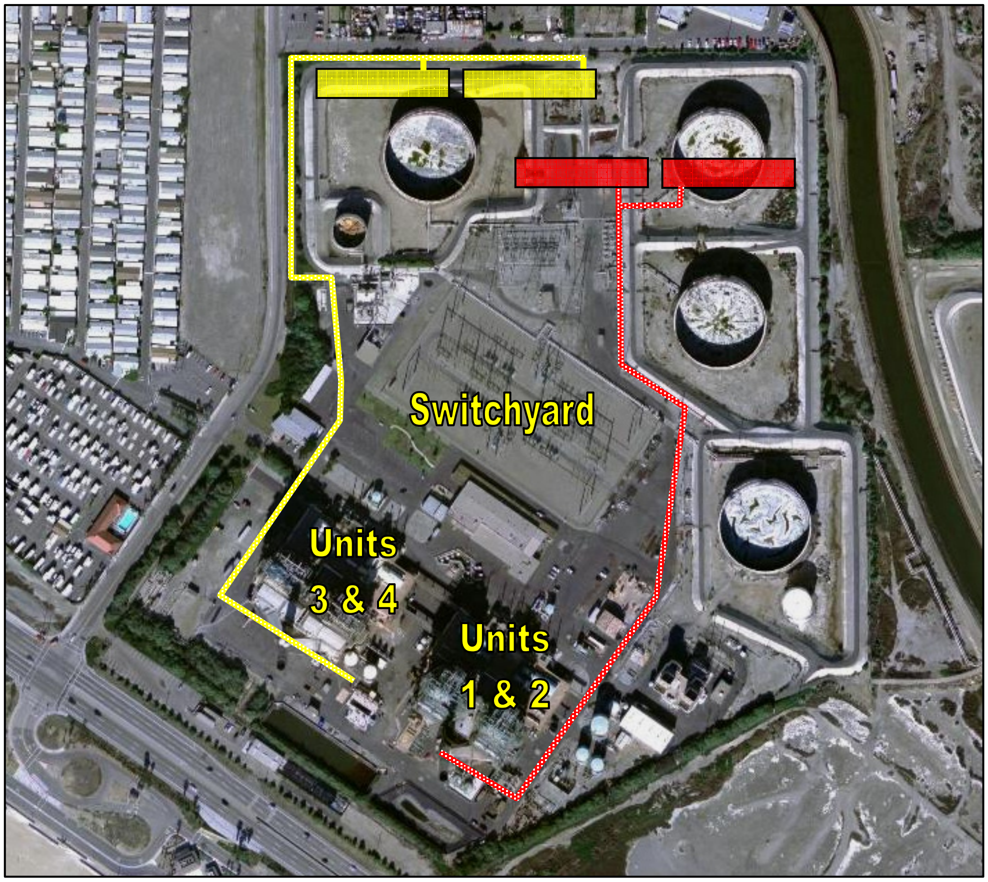

Figure G–4. Cooling Tower Locations

3.3.3 PIPING

The main supply and return pipelines to and from both towers will be located underground and made of prestressed concrete cylinder pipe (PCCP) suitable for saltwater applications. These pipes are 72 inches in diameter. The distance between the towers and their respective generating units requires roughly 15,000 feet of PCCP for the supply and return lines. Pipes connecting the condensers to the supply and return lines are made of FRP and placed above ground on pipe racks. Above ground placement avoids the potential disruption that may be caused by excavation in and around the power block. The condensers at HBGS are all located at grade level, enabling a relatively straightforward connection.

All riser piping (extending from the foot of the tower to the level of water distribution) is constructed of FRP.

Potential interference with underground obstacles and infrastructure is a concern, particularly at existing sites that are several decades old and have been substantially modified or rebuilt in the interim. Avoidance of these obstacles is considered to the degree practical in this study. Associated costs are included in the contingency estimate and are generally higher than similar estimates for new facilities (Section 4.3).

Appendix B details the total quantity of each pipe size and type for HBGS.

3.3.4 FANS AND PUMPS

Each tower cell uses an independent single-speed fan. The fan size and motor power are the same for each cell in each tower.

This analysis includes new pumps to circulate water between the condensers and cooling towers. Pumps are sized according to the flow rate for each tower, the relative distance between the towers and condensers, and the total head required to deliver water to the top of each cooling tower riser. A separate, multilevel pump house is constructed for each tower and sized to accommodate the motor control centers (MCCs) and appropriate electrical switchgear. The electrical installation includes all necessary transformers, cabling, cable trays, lighting, and lightning protection. A 30-ton overhead crane is also included to allow for pump servicing.

Fan and pump characteristics associated with wet cooling towers at HBGS are summarized in Table G–8. The net electrical demand of fans and new pumps is discussed further as part of the energy penalty analysis in Section 4.6.

Table G–8. Cooling Tower Fans and Pumps

		Tower Complex 1 (Units 1 & 2)	Tower Complex 2 (Units 3 & 4)
Fans	Number	14	14
	Type	Single speed	Single speed
	Efficiency	0.95	0.95
	Motor power (hp)	211	211
Pumps	Number	4	4
	Type	50 % recirculating Mixed flow Suspended bowl Vertical	50 % recirculating Mixed flow Suspended bowl Vertical
	Efficiency	0.88	0.88
	Motor power (hp)	1,295	1,295

3.4 ENVIRONMENTAL EFFECTS

Converting the existing once-through cooling system at HBGS to wet cooling towers will significantly reduce the intake of seawater from the Pacific Ocean and will presumably reduce impingement and entrainment by a similar proportion. Because closed-cycle systems will almost always result in condenser cooling water temperatures higher than those found in a comparable once-through system, wet towers will increase the operating heat rates at all four of HBGS's steam units, thereby decreasing the facility's overall efficiency. Additional power will also be consumed by the tower fans and circulating pumps.

Depending on how HBGS chooses to address this change in efficiency, total stack emissions may increase for pollutants such as PM_{10}, SO_x, and NO_x, and may require additional control measures (e.g., electrostatic precipitation, flue gas desulfurization, and selective catalytic reduction) or the purchase of emission credits to meet air quality regulations. The availability of emission reduction credits (ERCs) and their associated cost was not evaluated as part of this study, but may limit the air emission compliance options available to HBGS.

No control measures are currently available for CO_2 emissions, which will increase, on a per-kWh basis, by the same proportion as any change in the heat rate. The towers themselves will constitute an additional source of PM_{10} emissions, the annual mass of which will largely depend on the capacity utilization rate for the generating units served by each tower.

If HBGS retains its NPDES permit to discharge wastewater to the Pacific Ocean with a wet cooling tower system, it may have to address revised effluent limitations resulting from the substantial change in the discharge quantity and characteristics. Thermal impacts from the current once-through system, if any, will be minimized with wet cooling towers.

3.4.1 AIR EMISSIONS

HBGS is located in the South Coast air basin. Air emissions are permitted by the South Coast Air Quality Management District (SCAQMD) (Facility ID 115389).

Drift volumes are expected to be within the range of 0.5 gallons for every 100,000 gallons of circulating water in the towers. At HBGS, this corresponds to a rate of approximately 1.7 gpm based on the maximum combined flow in all four towers. Salt drift deposition is not expected to a concern at HBGS with wet cooling towers. Their location is generally downwind from sensitive structures and more than 1,500 feet from the nearest potentially affected residences. Any drift would be expected to settle out within than distance.

Total PM_{10} emissions from the HBGS cooling towers are a function of the number of hours in operation, overall water quality in the tower, and evaporation rate of drift droplets prior to deposition on the ground. Makeup water at HBGS will be obtained from the same source currently used for once-through cooling water (Pacific Ocean). At 1.5 cycles of concentration and assuming an initial TDS value of 35 parts per thousand (ppt), the water within the cooling towers will reach a maximum TDS level of roughly 53 ppt. Any drift droplets exiting the tower will have the same TDS concentration.

The cumulative mass emission of PM_{10} from HBGS will increase as a result of the direct emissions from the cooling towers themselves. Stack emissions of PM_{10}, as well as SO_x, NO_x, and other pollutants, will increase due to the drop in fuel efficiency, although the cumulative increase will depend on actual operations and emission control technologies currently in use. Maximum drift and PM_{10} emissions from the cooling towers are summarized in Table G–9.[1]

[1] This is a conservative estimate that assumes all dissolved solids present in drift droplets will be converted to PM_{10}. Studies suggest this may overestimate actual emission profiles for saltwater cooling towers (Chapter 4).

Data summarizing the total facility emissions for these pollutants in 2005 are presented in Table G–10 (CARB 2005). In 2005, HBGS operated at an annual capacity utilization rate of 20.25 percent. Using this rate, the additional PM_{10} emissions from the cooling towers would increase the facility total by approximately 39 tons/year, or 99 percent.[2]

Table G–9. Full Load Drift and Particulate Estimates

	PM_{10} (lbs/hr)	PM_{10} (tons/year)	Drift (gpm)	Drift (lbs/hr)
Tower Complex 1	22	97	0.8	420
Tower Complex 2	22	97	0.8	420
Total HBGS PM_{10} and drift emissions	**44**	**194**	**1.6**	**840**

Table G–10. 2005 Emissions of SO_x, NO_x, PM_{10}

Pollutant	Tons/year
NO_x	71.3
SO_x	7.2
PM_{10}	40.6

3.4.2 MAKEUP WATER

The volume of makeup water required by both cooling towers at HBGS is the sum of evaporative loss and the blowdown volume required to maintain the circulating water in each tower at the design TDS concentration. Drift expelled from the towers represents an insignificant volume by comparison and is accounted for by rounding up evaporative loss estimates. Makeup water volumes are based on design conditions, and may fluctuate seasonally depending on climate conditions and facility operations. Wet cooling towers will reduce once-through cooling water withdrawals from the Pacific Ocean by approximately 95 percent over the current design intake capacity.

Table G–11. Makeup Water Demand

	Tower circulating flow (gpm)	Evaporation (gpm)	Blowdown (gpm)	Total makeup water (gpm)
Tower Complex 1	168,000	3,200	6,200	**9,400**
Tower Complex 2	168,000	3,200	6,200	**9,400**
Total HBGS makeup water demand	**336,000**	**6,400**	**12,400**	**18,800**

One circulating water pump, rated at 84,000 gpm, which is currently used to provide once-through cooling water to the facility, will be retained in a wet cooling system to provide makeup water to each cooling tower. The retained pump's capacity exceeds the makeup demand by approximately 65,000 gpm. Any excess capacity will be routed through a bypass conduit and returned to the wet well at a point located behind the intake screens. Recirculating the excess capacity in this manner reduces additional cost that would be incurred if new pumps were required while maintaining the desired flow reduction. The intake of new water, measured at the

[2] 2006 emission data are not currently available from the Air Resources Board website. For consistency, the comparative increase in PM_{10} emissions estimated here is based on the 2005 HBGS capacity utilization rate instead of the 2006 rate presented in Table G-4. All other calculations in this chapter use the 2006 value.

intake screens, will be equal to the cooling towers' makeup water demand. Figure G–5 presents a schematic of this configuration.

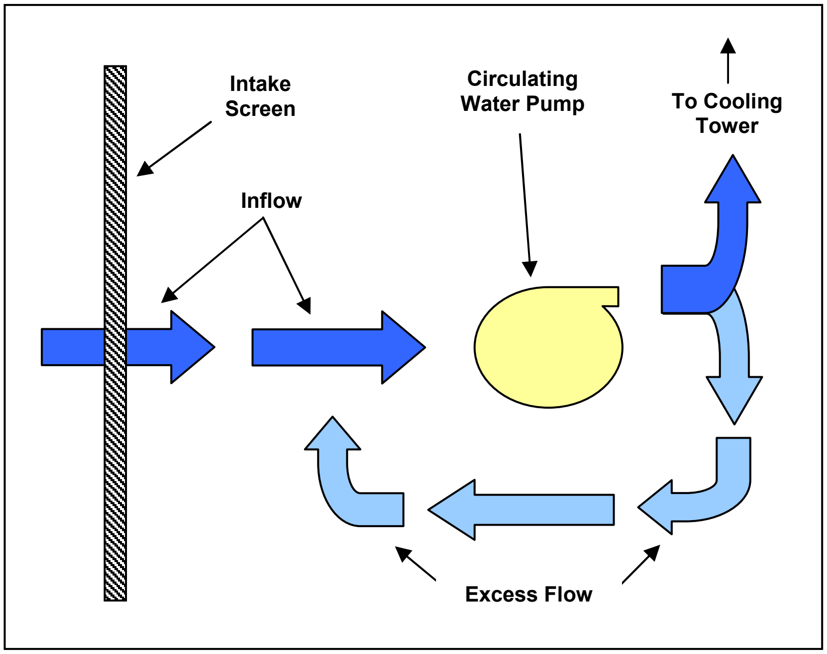

Figure G–5. Schematic of Intake Pump Configuration

The existing once-through cooling system at HBGS does not treat water withdrawn from the Pacific Ocean with the exception of screening for debris and larger organisms and periodic chlorination to control biofouling in the condenser tubes. Heat treatments are also periodically used to control mussel growth on pipes and condenser tubes by raising the temperature of the circulating water to 122º F. Conversion to a wet cooling tower system will not interfere with chlorination or heat treatment operations.

Makeup water will continue to be withdrawn from the Pacific Ocean.

The wet cooling tower system proposed for HBGS includes water treatment for standard operational measures, i.e., corrosion inhibitors, biocides, and anti-scaling agents. An allowance for these additional chemical treatments is included in annual O&M costs. It is assumed that the current once-through cooling water quality will be acceptable for use in a seawater cooling tower (with continued screening and chlorination) and will not require any pretreatment to enable its use.

3.4.3 NPDES PERMIT COMPLIANCE

At maximum operation, wet cooling towers at HBGS will result in an effluent discharge of approximately 17 mgd of blowdown in addition to other in-plant waste streams—such as boiler blowdown, floor drain wastes, and cleaning wastes. These low volume wastes may add an additional 1.5 mgd to the total discharge flow from the facility. Unless an alternative discharge is considered, HBGS will be required to modify its existing individual wastewater discharge (NPDES) permit.

Current effluent limitations for conventional and priority pollutants, as well as thermal discharge limitations, are contained in NPDES Permit CA0001163 as implemented by SARWQCB Order R82006-0011. All once-through cooling water and process wastewaters are discharged through a submerged outfall extending approximately 1,200 feet offshore into the Pacific Ocean. The existing order contains effluent limitations based on the 2005 Ocean Plan and the 1972 Thermal Plan.

HBGS will be required to meet technology-based effluent limitations for cooling tower blowdown established under the Effluent Limitation Guidelines (ELGs) for Steam Electric Facilities (40 CFR 423.13(d)(1)). These ELGs set numeric limitations for chromium and zinc (0.2 mg/L and 1.0 mg/L, respectively) while establishing narrative criteria for priority pollutants (no detectable quantity). Because ELGs are technology-based limitations, mixing zones or dilution factors are not applicable when determining compliance; limits must be met at the point of discharge from the cooling tower prior to commingling with any other waste stream. ELGs for cooling tower blowdown target priority pollutants that are contributed by maintenance chemicals and do not apply when limits may be exceeded as a result of background concentrations or other sources. Further discussion can be found in Chapter 4, Section 3.6.

Conversion to wet cooling towers will alter the volume and composition of a facility's wastewater discharge because wet towers concentrate certain pollutants in the effluent waste stream. The cooling towers designed for HBGS operate at 1.5 cycles of concentration, i.e., the blowdown discharge will contain a dissolved solids concentration 50 percent higher than the makeup water.

Changes to discharge composition may affect compliance with water quality objectives included in the Ocean Plan. If compliance with these objectives becomes problematic, alternative treatment or discharge methods may be necessary. Compliance may be achieved by altering the discharge configuration in such a way as to increase dilution (e.g., diffuser ports), or by seeking a mixing zone and dilution credits as permissible under the Ocean Plan. Alternately, some low volume waste streams (e.g., boiler blowdown, laboratory drains) may be diverted, with necessary permits, for treatment at a POTW.

If more pollutant-specific treatment methods, such as filtration or precipitation technologies, become necessary to meet WQBELs, the initial capital cost may range from $2 to $5.50 per 1,000 gallons of treatment capacity, with annual costs of approximately $0.5 per gallon of capacity, depending on the method of treatment (FRTR 2002). Hazardous material disposal fees and permits would further increase costs.

This evaluation did not include alternative discharge or effluent treatment measures in the conceptual design because the variables used to determine final WQBELs, which would be used to determine the type and scope of the desired compliance method, cannot be quantified here. Likewise, the final cost evaluation (Section 4.0) does not include any allowance for these possibilities.

Thermal discharge standards are based on narrative criteria established for coastal discharges under the Thermal Plan, which requires existing discharges of elevated-temperature wastes to comply with effluent limitations necessary to assure the protection of designated beneficial uses. The SARWQCB has implemented this provision in Order R8-2006-0011 by establishing a maximum discharge temperature of that may not exceed the receiving water's natural temperature by more than 30º F during normal operations (SARWQCB 2006). No information was available to review HBGS's compliance with this requirement. Because cooling tower blowdown will be taken from the "cold" side of the tower, conversion to a wet cooling system will significantly reduce the discharge temperature (to less than 81º F) and the size of any related thermal plume in the receiving water.

3.4.4 RECLAIMED WATER

Reclaimed or alternative water sources used in conjunction with wet cooling towers could eliminate all surface water withdrawals at HBGS. Doing so would completely eliminate impingement and entrainment concerns, and might enable the facility to avoid possible effluent quality and permit compliance issues, depending on the quality of reclaimed water available for use. In addition, wet cooling towers using reclaimed water would be expected to have lower PM_{10} emissions due to lower TDS levels. The California State Water Resources Control Board (SWRCB), in 1975, issued a policy statement requiring the consideration of alternative cooling methods in new power plants, including reclaimed water, over the use of freshwater (SWRCB 1975). There is no similar policy regarding marine waters, but the clear preference of state agencies is to encourage alternative cooling methods, including reclaimed water, wherever possible.

The present volume of available reclaimed water within a 15-mile radius of HBGS (62 mgd) does not meet the current once-through cooling demand; thus, reclaimed water is only applicable as a source of makeup water for a wet cooling tower system. This study did not pursue a detailed investigation of reclaimed water's use because the conversion of HBGS's once-through cooling system to saltwater cooling towers meets the performance benchmarks for impingement and entrainment impact reductions discussed in the 2006 California Ocean Protection Council (OPC) Resolution on Once-Through Cooling Water (see Chapter 1).

To be acceptable for use as makeup water in cooling towers, reclaimed water must meet tertiary treatment and disinfection standards under California Code of Regulations (CCR) Title 22. If the reclaimed water is not treated to the required levels, HBGS would be required to arrange for sufficient treatment, either onsite or at the source facility, prior to its use in the cooling towers.

Two alternative water sources were identified within a 15-mile radius of HBGS, with a combined discharge capacity of 62 mgd. Figure G–6 shows the relative locations of these facilities to HBGS.

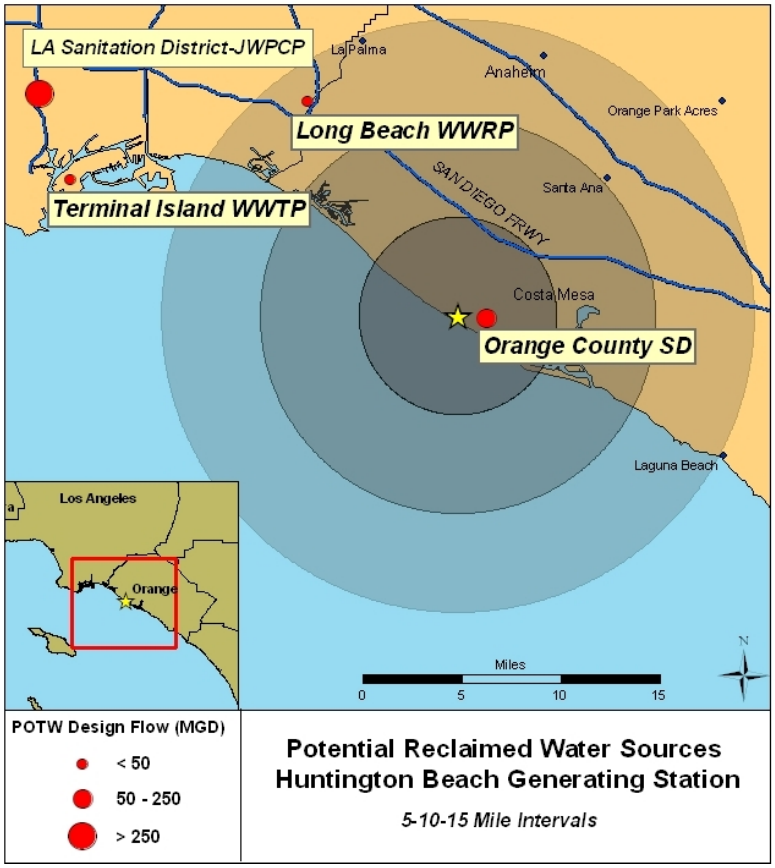

Figure G–6. Reclaimed Water Sources

- *Orange County Sanitation District (OCSD)—Huntington Beach*
  Discharge volume: 232 mgd
  Distance: 2 miles E
  Treatment level: Secondary

  The OCSD discharges secondary treated effluent from two POTWs (Fountain Valley and Huntington Beach) through a combined outfall to the Pacific Ocean. Sufficient capacity exists to supply the full makeup water demand for freshwater towers at HBGS (10 to 12 mgd), although HBGS would be required to provide treatment to tertiary standards prior to use in a cooling tower

- *Long Beach Water Reclamation Plant—Long Beach*
  Discharge volume: 20 mgd
  Distance: 12 miles NW
  Treatment level: Tertiary

  Approximately 25 percent is currently used for irrigation projects in the vicinity. The remaining capacity could supply the makeup water demand for freshwater cooling towers at HBGS.

Powers Engineering prepared an assessment of the cost and feasibility of using either of these sources to supply makeup water to wet cooling towers at HBGS. Water from the Long Beach facility would have to be purchased at a price of approximately $1.30/1,000 gallons, or up to $15,600 per day based on the maximum usage of the four cooling towers. A lower capacity utilization rate (HBGS operated at 12.9 percent in 2006) would require proportionally less water at a lower total cost. The transmission pipeline from Long Beach would be approximately 12 miles long and sized to provide the required flow to HBGS. The Powers report estimates the installed cost of a 24-inch pipeline at $200 per linear foot, or $12.7 million (Powers 2007).[3]

The volume of water discharged from the OCSD ocean outfall (approximately 230 mgd) is more than sufficient to meet the needs of freshwater cooling towers at HBGS and would not have to be purchased from the sanitation district. This water is not treated to tertiary standards, however, and would require some measure of treatment prior to use in a wet cooling tower. The Powers report estimates the initial capital cost for a package treatment system sufficient to treat the freshwater makeup water demand of 12 mgd at $2 million. Installed pipe costs were not included (Powers 2007).

Based on data compiled for this study and others, the estimated installed cost of a 24-inch pipeline, sufficient to provide 12 mgd to HBGS, is $300 per linear foot, or approximately $1.6 million per mile. Costs may be higher if transmission lines must cross through heavily urbanized areas or intersect major infrastructure, such as freeways or flood control channels.

Regulatory concerns beyond the scope of this investigation, however, may make reclaimed water (as a makeup water source) comparable or preferable to marine water from the Pacific Ocean. Reclaimed water may enable HBGS to eliminate potential conflicts with water discharge limitations or reduce PM_{10} emissions from the cooling tower, which is a concern given the South Coast air basin's current nonattainment status.

At any facility where wet cooling towers are a feasible alternative, reclaimed water may be used as a makeup water source. The practicality of its use, however, depends on the overall cost, availability, and additional environmental benefit that may occur.

3.4.5 THERMAL EFFICIENCY

Wet cooling towers at HBGS will increase the condenser inlet water temperature by a range of 13 to 17° F above the surface water temperature, depending on the ambient wet bulb temperature at the time. The generating units at HBGS are designed to operate at the conditions described in Table G–12. The resulting monthly difference between once-through and wet cooling tower condenser inlet temperatures is described in Figure G–7.

[3] The Powers Engineering estimate is based on the U.S. EPA, 1999 Drinking Water Infrastructure Needs Study - Modeling the Cost of Infrastructure, EPA 816-R-01-005, February 2001, p. Appendix A-12. Costs are escalated to 2006 dollars.

Table G–12. Design Thermal Conditions

	Units 1 & 2	Units 3 & 4
Design backpressure (in. HgA)	1.55	1.55
Design water temperature (°F)	63	63
Turbine inlet temp (°F)	1,000	1,000
Turbine inlet pressure (psia)	2,150	2,150
Full load heat rate (BTU/kWh) [a]	9,750	9,500

[a] CEC 2006.

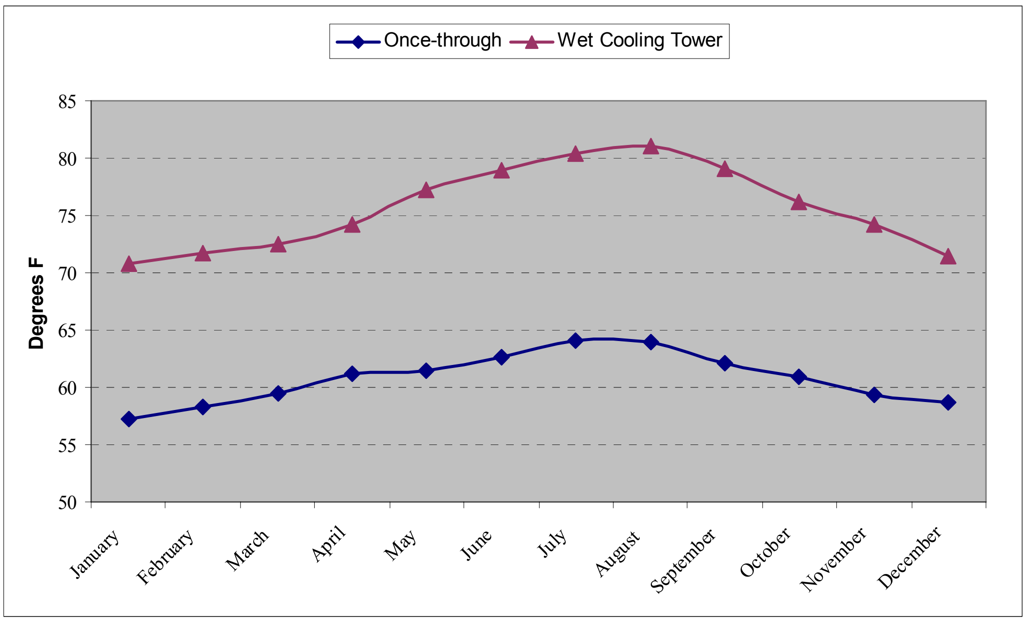

Figure G–7. Condenser Inlet Temperatures

Backpressures for the once-through and wet cooling tower configurations were calculated for each month using the design criteria described in the sections above and ambient climate data. In general, backpressures associated with the wet cooling tower were elevated by 0.6 to 1.0 inches HgA compared with the current once-through system (Figure G–8 and Figure G–10).

Heat rate adjustments were calculated by comparing the theoretical change in available energy that occurs at different turbine exhaust backpressures, assuming the thermal load and turbine inlet pressure remain constant, i.e., at the full load rating.[4] The relative change at different backpressures was compared with the value calculated for the design conditions (i.e., at design

[4] Changes in thermal efficiency estimated for HBGS are based on the design specifications provided by the facility. This may not reflect system modifications that might influence actual performance. In addition, the age of the units and the operating protocols used by HBGS might result in different calculations.

turbine inlet and exhaust backpressures) and plotted as a percentage of the full load operating heat rate (Table G–12) to develop estimated correction curves (Figure G–9 and Figure G–11).

The difference between the estimated once-through and closed-cycle heat rates for each month represents the approximate heat rate increase that would be expected when converting to wet cooling towers.

Table G–13 summarizes the annual average heat rate increase for each unit as well as the increase associated with the peak demand period of July-August-September. Monthly values were used to calculate the monetized value of these heat rate changes (Section 4.6.2). Month-by-month calculations are presented in Appendix A.

Table G–13. Summary of Estimated Heat Rate Increases

	Units 1 & 2	Units 3 & 4
Peak (July-August-September)	1.59%	1.59%
Annual average	1.20%	1.20%

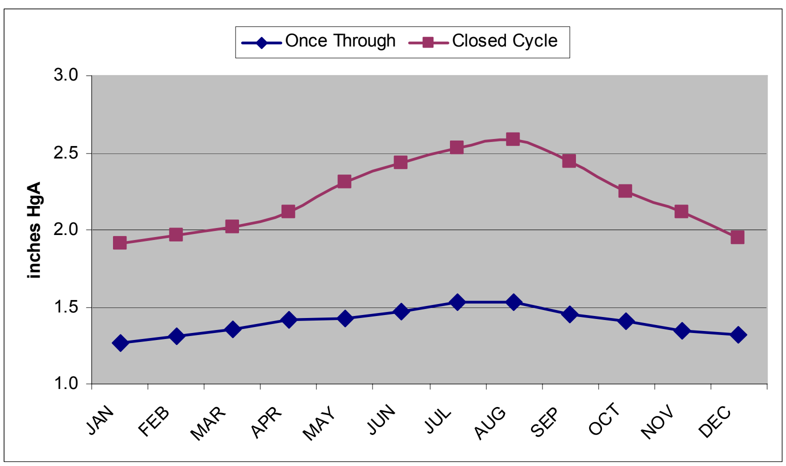

Figure G–8. Estimated Backpressures (Units 1 & 2)

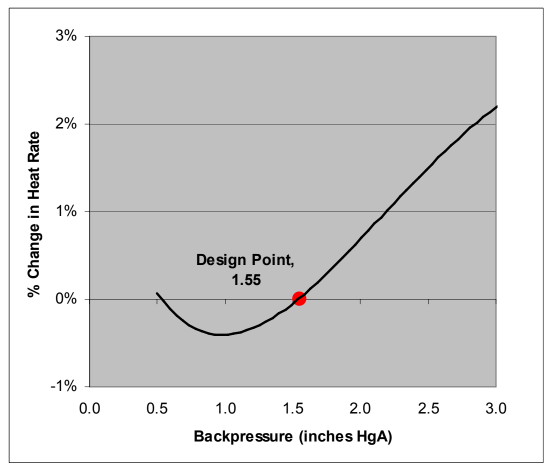

Figure G–9. Estimated Heat Rate Correction (Units 1 & 2)

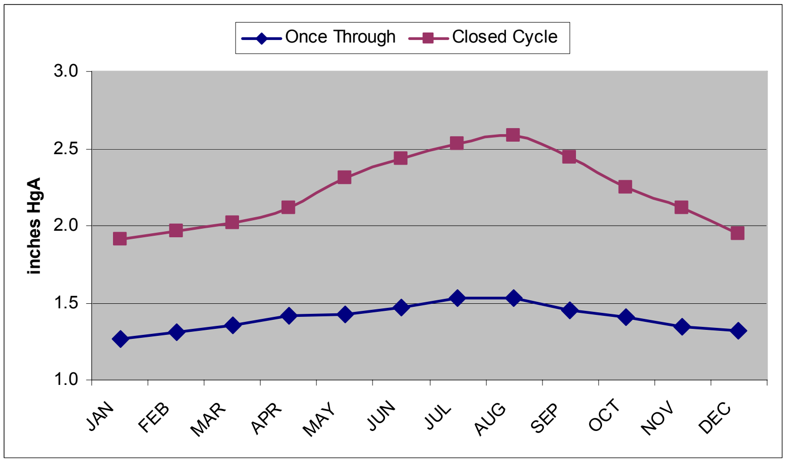

Figure G–10. Estimated Backpressures (Units 3 & 4)

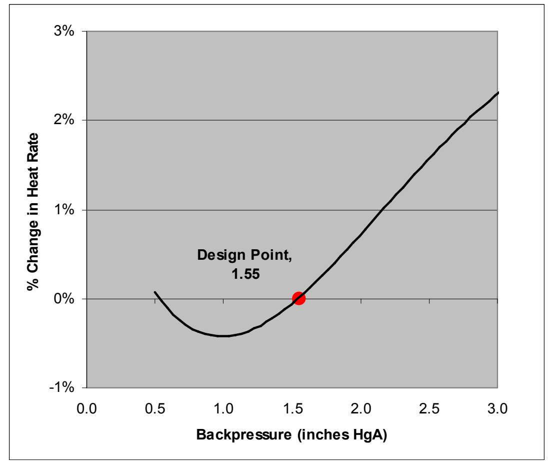

Figure G–11. Estimated Heat Rate Correction (Units 3 & 4)

4.0 RETROFIT COST ANALYSIS

The wet cooling system retrofit estimate for HBGS is based on incorporating conventional wet cooling towers as a replacement for the existing once-through system for each unit. Standard cost elements for this project include the following:

- Direct (cooling tower installation, civil/structural, mechanical, piping, electrical, and demolition)
- Indirect (smaller project costs not itemized)
- Contingency (allowance for unknown project variables)
- Revenue loss from shutdown (net loss in revenue during construction phase)
- Operations and maintenance (non–energy related cooling tower operations)
- Energy penalty (includes increased parasitic use from fans and pumps as well as decreased thermal efficiency)

The cost analysis does not include allowances for elements that are not quantified in this study, such as land acquisition, effluent treatment, or air emission reduction credits. The methodology used to develop cost estimates is discussed in Chapter 5.

4.1 COOLING TOWER INSTALLATION

In general, the cooling tower configuration selected for HBGS conforms to a typical design; no significant variations from a conventional arrangement were needed. Table G–14 summarizes the design-and-build cost estimate for each tower developed by vendors, inclusive of all labor and management required for their installation.

Table G–14. Wet Cooling Tower Design-and-Build Cost Estimate

	Units 1 & 2	Units 3 & 4	HBGS total
Number of cells	14	14	**28**
Cost/cell ($)	279,286	279,286	**279,286**
Total HBGS D&B cost ($)	**3,910,000**	**3,910,000**	**7,820,000**

4.2 OTHER DIRECT COSTS

A significant portion of wet cooling tower installation costs result from the various support structures, materials, equipment and labor necessary to prepare the cooling tower site and connect the towers to the condenser. At HBGS, these costs comprise approximately 90 percent of the initial capital cost. Line item costs are detailed in Appendix B.

Deviations from or additions to the general cost elements discussed in Chapter 5 are discussed below. Other direct costs (non–cooling tower) are summarized in Table G–15.

- *Civil, Structural, and Piping*
  The cooling towers' location with respect to the generating units represents the largest single increase in cost over an average configuration. More than 15,000 feet of large diameter pipe are required to service the cooling towers.
- *Mechanical and Electrical*
  Initial capital costs in this category reflect the new pumps (eight total) to circulate cooling water between the towers and condensers. No new pumps are required to provide makeup water from the Pacific Ocean. Electrical costs are based on the battery limit after the main feeder breakers.
- *Demolition*
  Demolition of one of the remaining empty fuel tanks is included. This study assumes the tank has been decommissioned and does not require hazardous material handling and disposal.

Table G–15. Summary of Other Direct Costs

	Equipment ($)	Bulk material ($)	Labor ($)	HBGS total ($)
Civil/structural/piping	6,200,000	27,700,000	15,900,000	**49,800,000**
Mechanical	14,600,000	0	400,000	**15,000,000**
Electrical	2,000,000	3,900,000	2,600,000	**8,500,000**
Demolition	0	0	400,000	**400,000**
Total HBGS other direct costs	**22,800,000**	**31,600,000**	**19,300,000**	**73,700,000**

4.3 INDIRECT AND CONTINGENCY

Indirect costs are calculated as 25 percent of all direct costs (civil/structural, mechanical, electrical, demolition, and cooling towers).

An additional allowance is included for condenser water box and tube sheet reinforcement to withstand the increased pressures associated with a recirculating system. Each condenser may require reinforcement of the tube sheet bracing with 6-inch x 1-inch steel, and water box reinforcement/replacement with 5/8-inch carbon steel. Based on the estimates outlined in Chapter 5, a conservative estimate of 5 percent of all direct costs is included to account for possible condenser modifications.

The contingency cost is calculated as 25 percent of the sum of all direct and indirect costs, including condenser reinforcement. At HBGS, potential costs in this category include relocating or demolishing small buildings and structures and potential interferences from underground structures.

Soils were not characterized for this analysis. Initial capital costs are summarized in Table G–16.

Table G–16. Summary of Initial Capital Costs

	Cost ($)
Cooling towers	7,800,000
Civil/structural/piping	49,800,000
Mechanical	15,000,000
Electrical	8,500,000
Demolition	400,000
Indirect cost	20,400,000
Condenser modification	4,100,000
Contingency	26,500,000
Total HBGS capital cost	**132,500,000**

4.4 SHUTDOWN

A portion of the work relating to installing wet cooling towers can be completed without significant disruption to the operations of HBGS. Units will be offline depending on the length of time it takes to integrate the new cooling system and conduct acceptance testing. For HBGS, a conservative estimate of 4 weeks per unit was developed. Based on 2006 generating output, however, no shutdown is forecast for either unit. Therefore, the cost analysis for HBGS does not include any loss of revenue associated with shutdown at HBGS.

This analysis did not consider shutdown with respect to the required availability of a particular generating unit, nor can it automatically be assumed that the generating profile for 2006 will be the same in each subsequent year. Net output data from 2006 may not reflect any contractual obligations that mandate a particular unit's availability during a given time period.

4.5 OPERATIONS AND MAINTENANCE

O&M costs for a wet cooling tower system at HBGS include routine maintenance activities; chemicals and treatment systems to control fouling and corrosion in the towers; management and labor; and an allowance for spare parts and replacement. Annual costs are calculated based on the combined tower flow rate using a base cost of \$4.00/gpm in Year 1 and \$5.80/gpm in Year 12, with an annual escalator of 2 percent (USEPA 2001). Year 12 costs increase based on the assumption that maintenance needs, particularly for spare parts and replacements, will be greater for years 12–20. Annual O&M costs, based on the design circulating water flow for the two cooling towers at HBGS (336,000 gpm), are presented in Table G–17. These costs reflect maximum operation.

Table G–17. Annual O&M Costs (Full Load)

	Year 1 cost ($)	Year 12 cost ($)
Management/labor	336,000	487,200
Service/parts	537,600	779,520
Fouling	470,400	682,080
Total HBGS O&M cost	**1,344,000**	**1,948,800**

4.6 ENERGY PENALTY

The energy penalty is divided into two components: increased parasitic use from the added electrical demand from tower fans and pumps; and the decrease in thermal efficiency from elevated turbine backpressures. Monetizing the energy penalty at HBGS requires some assumption as to how the facility will choose to alter its operations to compensate for these changes, if at all. One option would be to accept the reduced amount of revenue-generating electricity available for sale and absorb the economic loss ("production loss option"). A second option would be to increase the firing rate to the turbine (i.e., consume more fuel) and produce the same amount of revenue-generating electricity as had been obtained with the once-through cooling system ("increased fuel option"). The degree to which a facility is able, or prefers, to operate at a higher firing rate, however, produces the more likely scenario—some combination of the two.

Ultimately, the manner in which HBGS would alter operations to address efficiency changes is driven by considerations unknown to this study (e.g., corporate strategy, contractual obligations, operating protocols and turbine pressure tolerances). In all summary cost estimates, this study calculates the energy penalty's monetized value by assuming the facility will use the increased fuel option to compensate for reduced efficiency and generate the amount of electricity equivalent to the estimated shortfall. With this option, the energy penalty is equivalent to the financial cost of additional fuel and is nominally less costly than the production loss option. This option, however, may not reflect long-term costs such as increased maintenance or system degradation that may result from continued operation at a higher-than-designed turbine firing rate.

The energy penalty for HBGS is calculated by first estimating the increased parasitic demand from the cooling tower pumps and fans, expressed as a percentage of each unit's rated capacity. Likewise, the change in the unit's heat rate is also expressed as a capacity percentage.

4.6.1 INCREASED PARASITIC USE (FANS AND PUMPS)

Depending on ambient conditions or the operating load at a given time, HBGS may be able to take one or more cooling tower cells offline and still obtain the required level of cooling. This would also reduce the cumulative electrical demand from the fans. For the purposes of this study, however, operations are evaluated at the design conditions, i.e., full load; no allowance is made for seasonal changes. The increased electrical demand from cooling tower fan operation is summarized in Table G–18.

Table G–18. Cooling Tower Fan Parasitic Use

	Tower Complex 1	Tower Complex 2	HBGS total
Units served	Units 1&2	Units 3&4	--
Generating capacity (MW)	430	450	**880**
Number of fans (one per cell)	14	14	**28**
Motor power per fan (hp)	211	211	--
Total motor power (hp)	2,947	2,947	**5,895**
MW total	2.20	2.20	**4.40**
Fan parasitic use (% of capacity)	**0.51%**	**0.49%**	**0.50%**

Additional circulating water pump capacity for the wet cooling towers will also increase the parasitic electricity usage at HBGS. Makeup water will continue to be withdrawn from the Pacific Ocean with one of the existing circulating water pumps; the remaining pumps will be retired.

The net increase in pump-related parasitic usage is the difference between the new wet cooling tower configuration (new plus retained pumps) and the existing once-through configuration. For calculation purposes, this study assumes full-load operation to estimate the cost of increased parasitic use. Final estimates, therefore, allocate the retained pump's electrical demand to each tower based on the proportion of the facility's generating capacity it services. Operating fewer towers or tower cells will alter the allocation of the retained pump's electrical demand, but not the total demand.

Because one of the main design assumptions maintains the existing flow rate through each condenser, the new circulating pumps are single speed and are assumed to operate at their full rated capacity when in use. The increased electrical demand associated with cooling tower pump operation is summarized in Table G–19.

Table G–19. Cooling Tower Pump Parasitic Use

	Tower Complex 1	Tower Complex 2	HBGS total
Units served	Units 1&2	Units 3&4	--
Generating capacity (MW)	430	450	**880**
Existing pump configuration (hp)	1,600	1,600	**3,200**
New pump configuration (hp)	5,382	5,382	**10,764**
Difference (hp)	3,782	3,782	**7,564**
Difference (MW)	2.8	2.8	**5.6**
Net pump parasitic use (% of capacity)	**0.66%**	**0.63%**	**0.64%**

4.6.2 HEAT RATE CHANGE

Heat rate adjustments were calculated based on each month's ambient climate conditions and reflect the estimated difference between operations with once-through and wet cooling tower systems. As noted above, the energy penalty analysis assumes HBGS will increase its fuel consumption to compensate for lost efficiency and the increased parasitic load from fans and pumps. The higher turbine firing rate will increase the thermal load rejected to the condenser, which, in turn, results in a higher backpressure value and corresponding increase in the heat rate. No data are available describing the changes in turbine backpressures above the design thermal loads. For the purposes of monetizing the energy penalty only, this study conservatively assumed an additional increase in the heat rate of 0.5 percent at the higher firing rate; the actual effect at HBGS may be greater or less. Changes in the heat rate for each unit at HBGS are presented in Figure G–12 and Figure G–13.

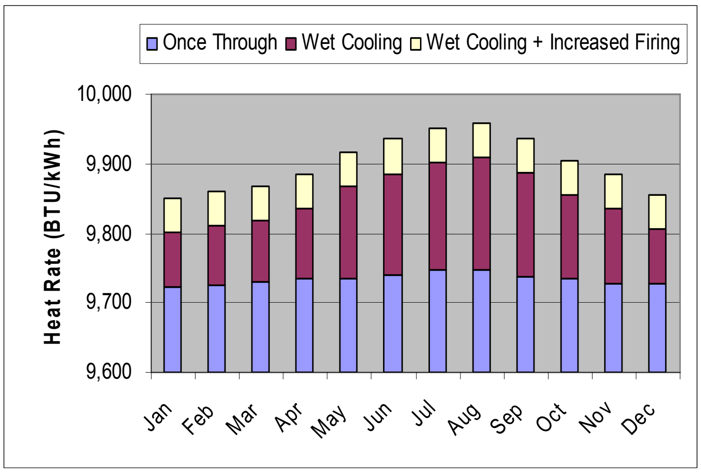

Figure G–12. Estimated Heat Rate Change (Units 1 & 2)

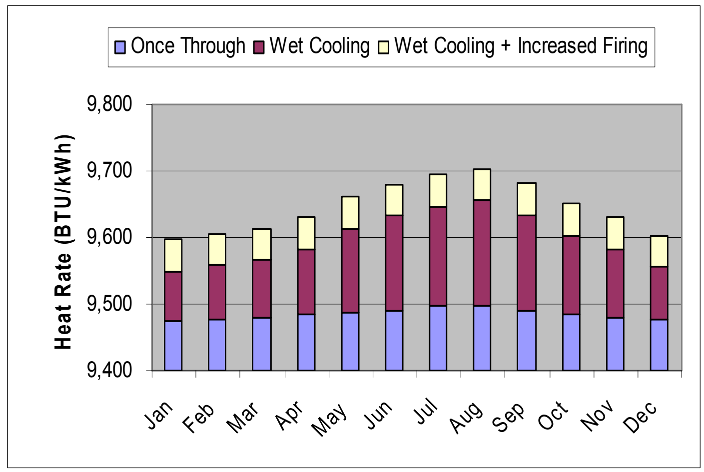

Figure G–13. Estimated Heat Rate Change (Units 3 & 4)

4.6.3 CUMULATIVE ESTIMATE

Using the increased fuel option, the energy penalty's cumulative value is obtained by first calculating the relative costs of generation ($/MWh) for the once-through system and the wet cooling system adjusted for a higher turbine firing rate. The cost of generation for HBGS is based on the relative heat rates developed in Section 4.6.2 and the average monthly wholesale natural gas cost ($/MMBTU) (ICE 2006a). The difference between these two values represents the monthly increased cost, per MWh, that results from converting to wet cooling towers. This value is then applied to the net MWh generated for the each month and summed to calculate the annual cost.

Based on 2006 output data, the Year 1 energy penalty for HBGS will be approximately $1.1 million. In contrast, the energy penalty's value calculated with the production loss option would be approximately $1.9 million. Together, these values represent the range of potential energy penalty costs for HBGS. Table G–20 and Table G–21 summarize the energy penalty estimates for each unit using the increased fuel option.

Table G–20. Units 1 & 2 Energy Penalty—Year 1

Month	Fuel cost ($/MMBTU)	Once-through system		Wet towers w/ increased firing		Difference ($/MWh)	2006 output (MWh)	Net cost ($)
		Heat rate (BTU/kWh)	Cost ($/MWh)	Heat rate (BTU/kWh)	Cost ($/MWh)			
January	6.00	9,723	58.34	9,850	59.10	0.76	60,424	46,020
February	5.50	9,726	53.49	9,859	54.22	0.73	49,005	35,881
March	4.75	9,729	46.21	9,867	46.87	0.65	51,096	33,451
April	4.75	9,735	46.24	9,884	46.95	0.71	39,652	28,118
May	4.75	9,736	46.25	9,916	47.10	0.86	44,134	37,802
June	5.00	9,741	48.70	9,935	49.68	0.97	81,503	79,283
July	6.50	9,748	63.36	9,951	64.68	1.32	120,493	158,954
August	6.50	9,747	63.35	9,959	64.73	1.38	82,262	113,462
September	4.75	9,738	46.26	9,936	47.20	0.94	79,832	75,199
October	5.00	9,734	48.67	9,905	49.53	0.86	28,155	24,082
November	6.00	9,729	58.37	9,884	59.30	0.93	26,014	24,203
December	6.50	9,727	63.22	9,856	64.06	0.84	36,018	30,245
							Units 1 & 2 total	**686,700**

Table G–21. Units 3 & 4 Energy Penalty—Year 1

Month	Fuel cost ($/MMBTU)	Once-through system		Wet towers w/ increased firing		Difference ($/MWh)	2006 output (MWh)	Net cost ($)
		Heat rate (BTU/kWh)	Cost ($/MWh)	Heat rate (BTU/kWh)	Cost ($/MWh)			
January	6.00	9,474	56.84	9,598	57.59	0.74	18,171	13,485
February	5.50	9,476	52.12	9,606	52.83	0.71	25,048	17,869
March	4.75	9,480	45.03	9,614	45.67	0.64	9,037	5,765
April	4.75	9,485	45.05	9,631	45.75	0.69	81,187	56,095
May	4.75	9,486	45.06	9,662	45.89	0.83	5,120	4,273
June	5.00	9,491	47.45	9,680	48.40	0.95	62,961	59,676
July	6.50	9,498	61.73	9,695	63.02	1.29	163,804	210,549
August	6.50	9,497	61.73	9,704	63.07	1.34	24,122	32,418
September	4.75	9,488	45.07	9,682	45.99	0.92	27,026	24,805
October	5.00	9,484	47.42	9,651	48.26	0.83	0	0
November	6.00	9,479	56.87	9,630	57.78	0.91	10,995	9,967
December	6.50	9,477	61.60	9,603	62.42	0.82	14,679	12,010
							Units 3 & 4 total	**446,912**

4.7 NET PRESENT COST

The Net Present Cost (NPC) of a wet cooling system retrofit at HBGS is the sum of all annual expenditures over the project's 20-year life span discounted according to the year in which the expense is incurred and the selected discount rate. The NPC represents the total change in revenue streams, in 2007 dollars, that HBGS can expect over 20 years as a direct result of converting to wet cooling towers. The following values were used to calculate the NPC at a 7 percent discount rate:

- *Capital and Start-up.* Includes all capital, indirect, contingency, and shutdown costs. All costs in this category are incurred in Year 0. (See Table G–16.)
- *Annual O&M.* Base cost values for Year 1 and Year 12 are adjusted for subsequent years using a 2 percent year-over-year escalator. Because HBGS has a relatively low capacity utilization factor, O&M costs for the NPC calculation were estimated at 50 percent of their maximum value. (See Table G–17.)
- *Annual Energy Penalty.* Insufficient information is available to this study to forecast future generating output at HBGS. In lieu of annual estimates, this study uses the net MWh output from 2006 as the calculation basis for Years 1 through 20. Wholesale prices include a year-over-year price escalator of 5.8 percent (based on the Producer Price Index). The energy penalty values are based on the increased fuel option discussed in Section 4.6. (See Table G–20 and Table G–21.)

Using these values, the NPC_{20} for HBGS is \$160 million. Appendix C contains detailed annual calculations used to develop this cost.

4.8 ANNUAL COST

The annual cost incurred by HBGS for a wet cooling tower retrofit is the sum of annual amortized capital costs plus the annual average of O&M and energy penalty expenditures. Capital costs are amortized at a 7 percent discount rate over 20 years. O&M and energy penalty costs are calculated in the same manner as for the NPC_{20} (Section 4.7). Revenue losses from a construction-related shutdown, if any, are incurred in Year 0 only and not included in the annual cost summarized in Table G–22.

Table G–22. Annual Cost

Discount Rate (%)	Capital Cost ($)	Annual O&M ($)	Annual energy penalty ($)	Annual cost ($)
7.00	12,500,000	900,000	2,000,000	**15,400,000**

4.9 COST-TO-GROSS REVENUE COMPARISON

Limited financial data are available to conduct a detailed analysis of the economic impact that a wet cooling system retrofit will have on HBGS's annual revenues. The facility's gross annual revenue can be approximated using 2006 net generating data (CEC 2006) and average wholesale prices for electricity as recorded at the SP 15 trading hub (ICE 2006b). This estimate, therefore, does not reflect any changes that may result from different wholesale prices or contract agreements that may increase or decrease the gross revenue summarized below, nor does it account for annual fixed revenue requirements or other variable costs.

The estimate of gross annual revenue from electricity sales at HBGS is a straightforward calculation that multiplies the monthly wholesale cost of electricity by the amount generated for the particular month. The estimated gross revenue for HBGS is summarized in Table G–23. A comparison of annual costs to annual gross revenue is summarized in Table G–24.

Table G–23. Estimated Gross Revenue

	Wholesale price ($/MWh)	Net generation (MWh)		Estimated gross revenue ($)		
		Units 1 & 2	Units 3 & 4	Units 1 & 2	Units 3 & 4	HBGS total
January	66	60,424	18,171	3,987,984	1,199,286	**5,187,270**
February	61	49,005	25,048	2,989,305	1,527,928	**4,517,233**
March	51	51,096	9,037	2,605,896	460,887	**3,066,783**
April	51	39,652	81,187	2,022,252	4,140,537	**6,162,789**
May	51	44,134	5,120	2,250,834	261,120	**2,511,954**
June	55	81,503	62,961	4,482,665	3,462,855	**7,945,520**
July	91	120,493	163,804	10,964,863	14,906,164	**25,871,027**
August	73	82,262	24,122	6,005,126	1,760,906	**7,766,032**
September	53	79,832	27,026	4,231,096	1,432,378	**5,663,474**
October	57	28,155	0	1,604,835	0	**1,604,835**
November	66	26,014	10,995	1,716,924	725,670	**2,442,594**
December	67	36,018	14,679	2,413,206	983,493	**3,396,699**
HBGS total		**698,588**	**442,150**	**45,274,986**	**30,861,224**	**76,136,210**

Table G–24. Cost-Revenue Comparison

Estimated gross annual revenue ($)	Initial capital		O&M		Energy penalty		Total annual cost	
	Cost ($)	% of gross	Cost ($)	% of gross	Cost ($)	% of gross	Cost ($)	% of gross
76,100,000	12,500,000	16.4	900,000	1.2	2,000,000	2.6	**15,400,000**	**20.2**

5.0 OTHER TECHNOLOGIES

Within the scope of this study, and using the OPC resolution's stated goal of reducing impingement and entrainment by 90–95 percent as a benchmark, the effectiveness of other technologies commonly used to address such impacts could not be conclusively determined for use at HBGS.

Among these technologies, however, and within the framework of this study, fine-mesh wedgewire screens exhibit the greatest potential for successful deployment. A final conclusion as to their applicability will have to be based on a more detailed site-specific investigation of the source water's physical characteristics. A more detailed analysis that also comprises a biological evaluation may determine the applicability of one or more of these technologies to HBGS. A brief summary of the applicability of these technologies follows.

5.1 MODIFIED RISTROPH SCREENS—FINE MESH

The principal concern with this technology is the successful return of viable organisms captured on the screens to the source water body. HBGS currently withdraws its cooling water through a submerged conduit extending approximately 1,500 feet offshore at a depth of 18 feet. It is unclear whether organisms could be returned to a near-shore location closer to the facility and remain viable.

5.2 BARRIER NETS

Barrier nets are unproven in an open ocean environment.

5.3 AQUATIC FILTRATION BARRIERS

Aquatic filtration barriers (AFBs) are unproven in an open ocean environment.

5.4 VARIABLE SPEED DRIVES

Variable speed drives (VSDs) were not considered for analysis at HBGS because the technology alone cannot be expected to achieve the desired level of reductions in impingement and entrainment, nor could it be combined with another technology to yield the desired reductions.

Pumps that have been retrofitted with VSDs can reduce overall flow intake volumes by 10–35 percent over the current once-through configuration (USEPA 2001). The actual reduction, however, will vary based on the cooling water demand at different times of the year. At peak demand, the pumps will essentially function as standard circulating water pumps and withdraw water at the maximum rated capacity, negating any potential benefit. Use of VSDs may be an economically desirable option when pumps are retrofitted or replaced for other reasons, but were not considered further for this study.

5.5 CYLINDRICAL FINE MESH WEDGEWIRE

Fine-mesh cylindrical wedgewire screens have not been deployed or evaluated at open coastal facilities for applications as large as required at HBGS (approximately 484 mgd). To function as intended, cylindrical wedgewire screens must be submerged in a water body with a consistent ambient current of 0.5 fps. Ideally, this current would be unidirectional so that screens may be oriented properly and any debris impinged on the screens will be carried downstream when the airburst cleaning system is activated.

Fine-mesh wedgewire screens for HBGS would be located offshore in the Pacific Ocean, west of the facility. Information regarding the subsurface currents in the near-shore environment close to HBGS is limited. Data suggest that these currents are multidirectional, depending on the tide and season, and fluctuate in terms of velocity, with prolonged periods below 0.5 fps (SCCOOS 2006).

To attain sufficient depth (approximately 20 feet) and an ambient current that might allow deployment, screens would need to be located 2,000 feet or more offshore. Discussions with vendors who design these systems indicated that distances more than 1,000 to 1,500 feet become problematic due to the inability of the airburst system to maintain adequate pressure for sufficient cleaning (Someah 2007). Together, these considerations preclude further evaluation of fine-mesh cylindrical wedgewire screens at HBGS.

6.0 REFERENCES

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Appendix A. Once-Through and Closed-Cycle Thermal Performance

		Units 1 & 2			Units 3 & 4		
		Once through	Closed cycle	Net increase	Once through	Closed cycle	Net increase
JAN	Backpressure (in. HgA)	1.27	1.91	**0.64**	1.27	1.91	**0.64**
	Heat rate Δ (%)	*-0.28*	*0.52*	***0.80***	*-0.28*	*0.52*	***0.80***
FEB	Backpressure (in. HgA)	1.31	1.97	**0.66**	1.31	1.97	**0.66**
	Heat rate Δ (%)	*-0.25*	*0.61*	***0.86***	*-0.25*	*0.61*	***0.86***
MAR	Backpressure (in. HgA)	1.35	2.02	**0.66**	1.35	2.02	**0.66**
	Heat rate Δ (%)	*-0.21*	*0.70*	***0.91***	*-0.21*	*0.70*	***0.91***
APR	Backpressure (in. HgA)	1.41	2.12	**0.70**	1.41	2.12	**0.70**
	Heat rate Δ (%)	*-0.16*	*0.87*	***1.03***	*-0.16*	*0.87*	***1.03***
MAY	Backpressure (in. HgA)	1.43	2.31	**0.89**	1.43	2.31	**0.89**
	Heat rate Δ (%)	*-0.15*	*1.20*	***1.34***	*-0.15*	*1.20*	***1.34***
JUN	Backpressure (in. HgA)	1.47	2.43	**0.96**	1.47	2.43	**0.96**
	Heat rate Δ (%)	*-0.10*	*1.39*	***1.49***	*-0.10*	*1.39*	***1.49***
JUL	Backpressure (in. HgA)	1.54	2.53	**0.99**	1.54	2.53	**0.99**
	Heat rate Δ (%)	*-0.02*	*1.55*	***1.57***	*-0.02*	*1.55*	***1.57***
AUG	Backpressure (in. HgA)	1.53	2.58	**1.06**	1.53	2.58	**1.06**
	Heat rate Δ (%)	*-0.03*	*1.64*	***1.67***	*-0.03*	*1.64*	***1.67***
SEP	Backpressure (in. HgA)	1.45	2.44	**0.99**	1.45	2.44	**0.99**
	Heat rate Δ (%)	*-0.12*	*1.41*	***1.53***	*-0.12*	*1.41*	***1.53***
OCT	Backpressure (in. HgA)	1.41	2.25	**0.84**	1.41	2.25	**0.84**
	Heat rate Δ (%)	*-0.16*	*1.09*	***1.25***	*-0.16*	*1.09*	***1.25***
NOV	Backpressure (in. HgA)	1.34	2.12	**0.77**	1.34	2.12	**0.77**
	Heat rate Δ (%)	*-0.22*	*0.87*	***1.09***	*-0.22*	*0.87*	***1.09***
DEC	Backpressure (in. HgA)	1.32	1.95	**0.63**	1.32	1.95	**0.63**
	Heat rate Δ (%)	*-0.24*	*0.58*	***0.82***	*-0.24*	*0.58*	***0.82***

Note: Heat rate delta represents change from design value calculated according to estimated ambient conditions for each month.

Appendix B. Itemized Capital Costs

Description	Unit	Qty	Equipment		Bulk material		Labor			Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	
CIVIL / STRUCTURAL / PIPING	--	--	--	--	--	--	--	--	--	--
Allocation for other accessories (bends, water hammers…)	lot	1	--	--	500,000	500,000	4,000.00	85	340,000	**840,000**
Allocation for pipe racks (approx 1200 ft) and cable racks	t	120	--	--	2,500	300,000	17.00	105	214,200	**514,200**
Allocation for sheet piling and dewatering	lot	2	--	--	500,000	1,000,000	5,000.00	100	1,000,000	**2,000,000**
Allocation for testing pipes	lot	2	--	--	--	--	2,000.00	95	380,000	**380,000**
Allocation for Tie-Ins to existing condenser's piping	lot	1	--	--	250,000	250,000	2,000.00	85	170,000	**420,000**
Allocation for trust blocks	lot	2	--	--	25,000	50,000	250.00	95	47,500	**97,500**
Backfill for PCCP pipe (reusing excavated material)	m3	41,287	--	--	--	--	0.04	200	330,296	**330,296**
Bedding for PCCP pipe	m3	6,928	--	--	25	173,200	0.04	200	55,424	**228,624**
Bend for PCCP pipe 30" & 36" diam (allocation)	ea	30	--	--	5,000	150,000	25.00	95	71,250	**221,250**
Bend for PCCP pipe 72" diam (allocation)	ea	100	--	--	18,000	1,800,000	40.00	95	380,000	**2,180,000**
Building architectural (siding, roofing, doors, painting…etc)	ea	4	--	--	57,500	230,000	690.00	75	207,000	**437,000**
Butterfly valves 30" c/w allocation for actuator & air lines	ea	34	30,800	1,047,200	--	--	50.00	85	144,500	**1,191,700**
Butterfly valves 36" c/w allocation for actuator & air lines	ea	6	33,600	201,600	--	--	50.00	85	25,500	**227,100**
Butterfly valves 54" c/w allocation for actuator & air lines	ea	24	60,900	1,461,600	--	--	55.00	85	112,200	**1,573,800**
Butterfly valves 72" c/w allocation for actuator & air lines	ea	24	96,600	2,318,400	--	--	75.00	85	153,000	**2,471,400**
Check valves 30"	ea	6	44,000	264,000	--	--	16.00	85	8,160	**272,160**
Check valves 36"	ea	4	48,000	192,000	--	--	24.00	85	8,160	**200,160**
Check valves 54"	ea	8	87,000	696,000	--	--	26.00	85	17,680	**713,680**
Concrete basin walls (all in)	m3	627	--	--	225	141,075	8.00	75	376,200	**517,275**
Concrete elevated slabs (all in)	m3	433	--	--	250	108,250	10.00	75	324,750	**433,000**
Concrete for transformers and oil catch basin (allocation)	m3	200	--	--	250	50,000	10.00	75	150,000	**200,000**
Concrete slabs on grade (all in)	m3	3,403	--	--	200	680,600	4.00	75	1,020,900	**1,701,500**
Ductile iron cement pipe 12" diam. for fire water line	ft	3,000	--	--	100	300,000	0.60	95	171,000	**471,000**

Description	Unit	Qty	Equipment		Bulk material		Labor			Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	
Excavation and backfill for fire line, blowdown & make-up (using excavated material for backfill except for bedding)	m3	21,853	--	--	--	--	0.08	200	349,648	**349,648**
Excavation for PCCP pipe	m3	63,980	--	--	--	--	0.04	200	511,840	**511,840**
Fencing around transformers	m	50	--	--	30	1,500	1.00	75	3,750	**5,250**
Flange for PCCP joints 30"	ea	8	--	--	2,260	18,080	16.00	95	12,160	**30,240**
Flange for PCCP joints 36"	ea	6	--	--	2,765	16,590	18.00	95	10,260	**26,850**
Flange for PCCP joints 72"	ea	32	--	--	9,860	315,520	25.00	95	76,000	**391,520**
Foundations for pipe racks and cable racks	m3	280	--	--	250	70,000	8.00	75	168,000	**238,000**
FRP flange 30"	ea	100	--	--	1,679	167,915	50.00	85	425,000	**592,915**
FRP flange 36"	ea	20	--	--	2,500	50,000	70.00	85	119,000	**169,000**
FRP flange 54"	ea	80	--	--	5,835	466,794	80.00	85	544,000	**1,010,794**
FRP flange 72"	ea	16	--	--	20,888	334,203	200.00	85	272,000	**606,203**
FRP pipe 54" diam.	ft	200	--	--	426	85,140	0.80	85	13,600	**98,740**
FRP pipe 72" diam.	ft	2,400	--	--	851	2,043,360	1.20	85	244,800	**2,288,160**
Harness clamp 30" & 36"c/w internal testable joint	ea	310	--	--	2,000	620,000	16.00	95	471,200	**1,091,200**
Harness clamp 72" c/w internal testable joint	ea	800	--	--	2,440	1,952,000	22.00	95	1,672,000	**3,624,000**
Joint for FRP pipe 54" diam.	ea	6	--	--	1,324	7,946	85.00	85	43,350	**51,296**
Joint for FRP pipe 72" diam.	ea	66	--	--	3,122	206,039	200.00	85	1,122,000	**1,328,039**
PCCP pipe 30" dia. for blowdown	ft	3,000	--	--	125	375,000	0.70	95	199,500	**574,500**
PCCP pipe 36" dia. for make-up water line	ft	3,000	--	--	160	480,000	0.80	95	228,000	**708,000**
PCCP pipe 72" diam.	ft	15,600	--	--	890	13,884,000	2.00	95	2,964,000	**16,848,000**
Riser (FRP pipe 30" diam X 40 ft)	ea	28	--	--	15,350	429,794	150.00	85	357,000	**786,794**
Structural steel for building	t	190	--	--	2,500	475,000	20.00	105	399,000	**874,000**
CIVIL / STRUCTURAL / PIPING TOTAL	**--**	**--**	**--**	**6,180,800**	**--**	**27,732,007**	**--**	**--**	**15,913,828**	**49,826,635**
DEMOLITION	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
Demolition of 1 tank approx 250 ft diameter	ea	1	--	--	--	--	3,500.00	100	350,000	**350,000**
DEMOLITION TOTAL	**--**	**--**	**--**	**0**	**--**	**0**	**--**	**--**	**350,000**	**350,000**
ELECTRICAL	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
4.16 kv cabling feeding MCC's	m	3,000	--	--	75	225,000	0.40	85	102,000	**327,000**
4.16kV switchgear - 7 breakers	ea	1	325,000	325,000	--	--	230.00	85	19,550	**344,550**
480 volt cabling feeding MCC's	m	1,500	--	--	70	105,000	0.40	85	51,000	**156,000**
480V Switchgear - 1 breaker 3000A	ea	4	30,000	120,000	--	--	80.00	85	27,200	**147,200**

Description	Unit	Qty	Equipment		Bulk material		Labor			Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	
Allocation for automation and control	lot	1	--	--	1,300,000	1,300,000	13,000.00	85	1,105,000	**2,405,000**
Allocation for cable trays and duct banks	m	3,000	--	--	75	225,000	1.00	85	255,000	**480,000**
Allocation for lighting and lightning protection	lot	1	--	--	200,000	200,000	2,000.00	85	170,000	**370,000**
Dry Transformer 2MVA xxkV-480V	ea	4	100,000	400,000	--	--	100.00	85	34,000	**434,000**
Lighting & electrical services for pump house building	ea	4	--	--	20,000	80,000	250.00	85	85,000	**165,000**
Local feeder for 1200 HP motor 4160 V (up to MCC)	ea	8	--	--	42,000	336,000	150.00	85	102,000	**438,000**
Local feeder for 200 HP motor 460 V (up to MCC)	ea	28	--	--	15,000	420,000	140.00	85	333,200	**753,200**
Oil Transformer 10/13.3MVA xx-4.16kV	ea	4	190,000	760,000	--	--	150.00	85	51,000	**811,000**
Primary breaker(xxkV)	ea	8	45,000	360,000	--	--	60.00	85	40,800	**400,800**
Primary feed cabling (assumed 13.8 kv)	m	6,000	--	--	175	1,050,000	0.50	85	255,000	**1,305,000**
ELECTRICAL TOTAL	**--**	**--**	**--**	**1,965,000**	**--**	**3,941,000**	**--**	**--**	**2,630,750**	**8,536,750**
MECHANICAL	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
Allocation for ventilation of buildings	ea	4	25,000	100,000	--	--	250.00	85	85,000	**185,000**
Cooling tower for unit 3	lot	1	3,910,000	3,910,000	--	--	--	--	--	**3,910,000**
Cooling tower for unit 1	lot	1	3,910,000	3,910,000	--	--	--	--	--	**3,910,000**
Cooling tower for unit 2	lot	1	3,910,000	3,910,000	--	--	--	--	--	**3,910,000**
Cooling tower for unit 4	lot	1	3,910,000	3,910,000	--	--	--	--	--	**3,910,000**
Overhead crane 30 ton in (in pump house)	ea	4	75,000	300,000	--	--	100.00	85	34,000	**334,000**
Pump 4160 V 1200 HP	ea	8	800,000	6,400,000	--	--	420.00	85	285,600	**6,685,600**
MECHANICAL TOTAL	**--**	**--**	**--**	**22,440,000**	**--**	**0**	**--**	**--**	**404,600**	**22,844,600**

Appendix C. Net Present Cost Calculation

Project year	Capital/start-up ($)	O & M ($)	Energy penalty ($)		Total ($)	Annual discount factor	Present value ($)
			Units 1 & 2	Units 3 & 4			
0	132,500,000	--	--	--	132,500,000	1	132,500,000
1	--	672,000	686,699	446,911	1,805,610	0.9346	1,687,523
2	--	685,440	726,734	472,965	1,885,139	0.8734	1,646,481
3	--	699,149	769,103	500,539	1,968,791	0.8163	1,607,124
4	--	713,132	813,941	529,721	2,056,794	0.7629	1,569,128
5	--	727,394	861,394	560,603	2,149,392	0.713	1,532,516
6	--	741,942	911,613	593,287	2,246,842	0.6663	1,497,071
7	--	756,781	964,760	627,875	2,349,417	0.6227	1,462,982
8	--	771,917	1,021,006	664,480	2,457,403	0.582	1,430,209
9	--	787,355	1,080,531	703,220	2,571,105	0.5439	1,398,424
10	--	803,102	1,143,526	744,217	2,690,845	0.5083	1,367,757
11	--	819,164	1,210,193	787,605	2,816,963	0.4751	1,338,339
12	--	993,888	1,280,747	833,522	3,108,158	0.444	1,380,022
13	--	1,013,766	1,355,415	882,117	3,251,298	0.415	1,349,289
14	--	1,034,041	1,434,436	933,544	3,402,021	0.3878	1,319,304
15	--	1,054,722	1,518,063	987,970	3,560,755	0.3624	1,290,418
16	--	1,075,816	1,606,566	1,045,569	3,727,951	0.3387	1,262,657
17	--	1,097,333	1,700,229	1,106,525	3,904,087	0.3166	1,236,034
18	--	1,119,279	1,799,353	1,171,036	4,089,667	0.2959	1,210,133
19	--	1,141,665	1,904,255	1,239,307	4,285,227	0.2765	1,184,865
20	--	1,164,498	2,015,273	1,311,559	4,491,330	0.2584	1,160,560
Total							**160,430,836**