D. El Segundo Generating Station

El Segundo Power, LLC—El Segundo, CA

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1.0 GENERAL SUMMARY

Retrofitting the existing once-through cooling system at El Segundo Generating Station (ESGS) with closed-cycle wet cooling towers poses several significant challenges with respect to potential siting locations and conflicts with local use restrictions. The facility's compact dimensions, the layout of existing structures and the site's proximity to state beaches limit the different wet cooling tower configurations that could be evaluated. In addition, the location of ESGS approximately 2 miles south-southwest of Los Angeles International Airport makes it likely that plume abatement would be necessary to prevent interference with airport operations. Plume-abated cooling towers, therefore, are the preferred option for ESGS.

Despite the probability that plume-abated towers would be required at ESGS, a workable configuration could not be developed. The limited available space at the site coupled with local zoning ordinances restricts the placement of large towers in the facility's southernmost portion. Based on input for other development projects at ESGS, the El Porto community in neighboring Manhattan Beach would likely object to 50–60 foot tall towers located so close to the boundary.

Based on these factors, the preferred option for ESGS is considered logistically infeasible.

If plume-abatement cooling towers were not required, a conventional tower design could be configured at the existing location. The cooling tower configuration designed under the alternative option complies with all identified local use restrictions and includes necessary mitigation measures, where applicable.

The discussion in this chapter, and all cost estimates, evaluates the alternative design based on conventional cooling towers.

1.1 COST

Initial capital and net present costs associated with the installation and operation of wet cooling towers at ESGS are summarized in Table D–1. Annualized costs based on 20-year average values for the various cost elements are summarized in Table D–2. A detailed cost analysis is presented in Section 4.0 of this chapter.

Table D–1. Cumulative Cost Summary

Cost category	Cost ($)	Cost per MWh (capacity) ($/MWh)	Cost per MWh (2006 output) ($/MWh)
Total capital and start-up [a]	78,100,000	13.31	127
NPC_{20} [b]	91,000,000	15.50	147

[a] Includes all costs associated with the construction and installation of cooling towers 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 D–2. Annual Cost Summary

Cost category	Cost ($)	Cost per MWh (capacity) ($/MWh)	Cost per MWh (2006 output) ($/MWh)
Capital and start-up [a]	7,400,000	1.26	11.99
Operations and maintenance	400,000	0.07	0.65
Energy penalty	900,000	0.15	1.46
Total ESGS annual cost	**8,700,000**	**1.48**	**14.10**

[a] Does not include revenue loss associated with shutdown, if any, which is incurred in Year 0 only.

1.2 ENVIRONMENTAL

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

Table D–3. Environmental Summary

		Unit 3	Unit 4
Water use	Design intake volume (gpm)	132,400	131,000
	Cooling tower makeup water (gpm)	7,000	7,000
	Reduction from capacity (%)	95	95
Energy efficiency [a]	Summer heat rate increase (%)	1.08	1.09
	Summer energy penalty (%)	2..07	2..08
	Annual heat rate increase (%)	1.01	1.03
	Annual energy penalty (%)	2..01	2..03
Direct air emissions [b]	PM_{10} emissions (tons/yr) (maximum capacity)	76.17	75.37
	PM_{10} emissions (tons/yr) (2006 capacity utilization)	8.81	7.13

[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.

1.3 OTHER POTENTIAL FACTORS

As noted above, the preferred option is considered infeasible at this location.

The alternative option (conventional cooling towers) can only be sited alongside a recreational trail and state beaches. This placement has the effect of creating a 58-foot high wall running parallel to the beach for nearly 600 feet, from north to south. This may conflict with visual impact standards established by the Coastal Act. Further complicating this option is the towers' location relative to the switchyard, which would be immediately downwind and subject to the adverse effects of salt drift deposition. Siting constraints are discussed further in Section 3.2.3.

2.0 BACKGROUND

The El Segundo Generating Station (ESGS) is a natural gas–fired steam electric generating facility located in the city of El Segundo, Los Angeles County, owned and operated by El Segundo Power, LLC. ESGS currently operates two conventional steam turbine units (Unit 3 and Unit 4) with a combined generating capacity of 670 MW. Units 1 and 2 have been retired from service and are slated to be replaced with a dry cooled combined cycle unit. The facility occupies approximately 22 acres of a 33-acre industrial site bordering Dockweiler and Manhattan state beaches and Santa Monica Bay. The southern boundary of the property borders the city of Manhattan Beach. (See Table D–4 and Figure D–1.)

Table D–4. General Information

Unit	In-service year	Rated capacity (MW)	2006 capacity utilization [a]	Condenser cooling water flow (gpm)
Unit 3	1964	335	11.6%	132,400
Unit 4	1965	335	9.5%	131,000
ESGS Total		**670**	**10.5%**	**263,400**

[a] Quarterly Fuel and Energy Report—2006 (CEC 2006).

Figure D–1. General Vicinity of El Segundo Generating Station

2.1 COOLING WATER SYSTEM

ESGS operates one cooling water intake structure (CWIS) to provide condenser cooling water to the two generating units (Figure D–2). Once-through cooling water is combined with low-volume wastes generated by ESGS and discharged through a single submerged outfall to the Pacific Ocean located approximately 2,100 feet offshore at a depth of 20 feet. Surface water withdrawals and discharges are regulated by NPDES Permit CA0001147, as implemented by Los Angeles Regional Water Quality Control Board (LARWQCB) Order 00-084.[1]

Cooling water is obtained from the Pacific Ocean through a submerged intake conduit terminating 2,000 feet offshore at a depth of approximately 20 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.

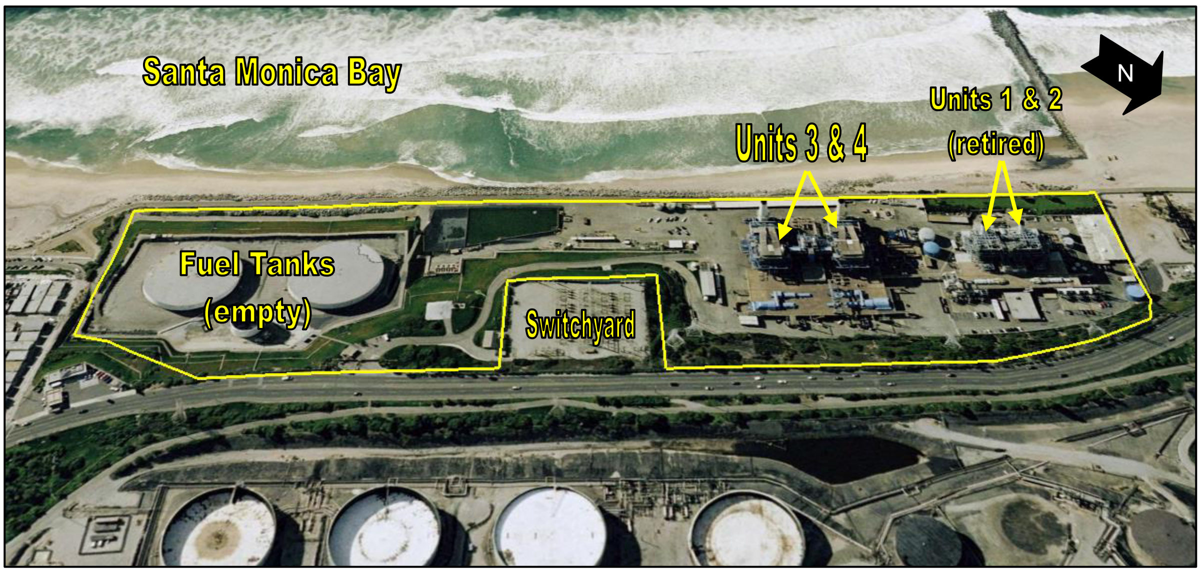

Figure D–2. Site View

The onshore portion of the CWIS comprises four screen bays, each fitted with a vertical traveling screen with 5/8-inch mesh panels. Screens rotate periodically for cleaning based on a pressure differential between the upstream and downstream faces of the screens. Screens are also rotated manually for 8 minutes during each 12-hour shift. 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 in a landfill. Downstream of each screen is a circulating water pump rated at 69,200 gallons per minute (gpm), for a total facility capacity of 276,800 gpm, or 399 million gallons per day (mgd) (El Segundo Power 2005).

At maximum capacity, ESGS maintains a total pumping capacity rated at 398 mgd, with a condenser flow rating of 380 mgd. On an annual basis, ESGS withdraws substantially less than its design capacity due to its low generating capacity utilization (10.5 percent for 2006). When in

[1] LARWQCB Order 00-084 expired on May 10, 2005, but has been administratively extended pending adoption of a renewed order.

operation and generating the maximum load, ESGS 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 ESGS uses a velocity cap to reduce the entrainment of motile fish through the system, although it is commonly thought of as an impingement reduction technology because it targets 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 an 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.

LARWQCB Order 00-084, adopted in 2000, states that “the design, construction and operation of the intake structure [at ESGS] was then considered Best Available Technology (BAT) [*sic*] as required by Section 316(b) of the Clean Water Act” (LARWQCB 2000, Finding 8). This finding was based on ecological studies conducted by Southern California Edison (previous owner) in 1982. The order does not contain any numeric or narrative limitations regarding impingement or entrainment resulting from CWIS operation, but does require bimonthly monitoring of impingement at each intake structure (coinciding with scheduled heat treatments). Based on the record available for review, ESGS has been compliant with this permit requirement.

The LARWQCB has notified ESGS of its intent to revisit requirements under CWA Section 316(b), including a determination of the best technology available (BTA) for minimization of adverse environmental impact, during the current permit reissuance process. A final decision regarding any Section 316(b)–related requirements has not been made as of the publication of this study.

3.0 WET COOLING SYSTEM RETROFIT

3.1 OVERVIEW

This study evaluates the use of saltwater wet cooling towers at ESGS, with the current source water (Pacific Ocean) continuing to provide makeup water to the facility. Conversion of 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 alternative water sources as a replacement for the once-through cooling water currently used at ESGS is a potentially feasible option based on the volume of secondary treated water available in the vicinity. In a wet cooling tower system, the use of reclaimed water as the makeup water source (as opposed to the Pacific Ocean) is an attractive alternative when considering additional benefits its use may provide, such as avoidance of conflicts with effluent limitations or air emission standards. Use of reclaimed water is discussed further in Section 3.4.4.

The configuration of the wet cooling towers—their size and location—were 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 characterization of the facility may lead to different conclusions regarding the physical configuration of the towers.

Based on a review of information provided by El Segundo Power, LLC, and obtained from public records, installation of wet cooling towers at ESGS poses several significant challenges. Space constraints, the facility's general layout, and local use restrictions concerning ambient noise limited the number of possible tower configurations available for evaluation. In addition, the proximity of Los Angeles International Airport (LAX) will likely require incorporating plume abatement technologies into any final tower design, but a workable configuration of plume-abated towers could not be developed for ESGS. The final design of conventional towers described below represents the most plausible installation that could be developed for the facility. Constraints on placement and design are discussed further in Section 3.2.3.

This study developed a conceptual design of wet cooling towers sufficient to meet the cooling demand for each active generating unit at ESGS at its rated output during peak climate conditions. Cost estimates are based on vendor quotes developed using the available information and the various design constraints identified at ESGS.

The overall practicality of retrofitting the two units at ESGS will require an evaluation of factors outside the scope of this study, such as the age and efficiency of the units and their role in the overall reliability of electricity production and transmission in California, particularly the Los Angeles region.

3.2 DESIGN BASIS

3.2.1 CONDENSER SPECIFICATIONS

For this study, the conceptual design of the cooling towers selected for ESGS 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 elevation of the cooling tower risers.[2] The practicality and difficulty of these modifications are dependent on the age and configuration of each unit, but are assumed to be feasible at ESGS. Condenser water boxes for both units are located at grade level and appear to be readily accessible. Additional costs associated with condenser modifications are included in the discussion of capital expenditures (Section 4.3).

Information provided by ESGS 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. Where possible, questionable values were verified or corrected using other known information about the condenser. For example, the data sheets provided by ESGS show turbine exhaust pressures of 1.5 inches HgA for both units under design conditions, but they also list the steam condensate temperature as 93.8 ºF and 93.0 ºF for Units 3 and 4, respectively. These temperatures correspond to backpressure values of 1.60 and 1.56 inches HgA. Based on other information describing the condensers, it appears the reported steam condensate temperatures are correct. Thus, the design backpressure values for Units 3 and 4 used in this study are 1.6 and 1.56 inches HgA. Table D–5 summarizes the condenser design specifications for Units 3 and 4.

Table D–5. Condenser Design Specifications

	Unit 3	Unit 4
Thermal load (MMBTU/hr)	1,440	1,440
Surface area (ft^2)	174,000	172,000
Condenser flow rate (gpm)	132,400	131,000
Tube material	Cu-Ni (90-10)	Cu-Ni (90-10)
Heat transfer coefficient (U_d)	488	511
Cleanliness factor	0.85	0.85
Inlet temperature (°F)	63	63
Temperature rise (°F)	21.76	21.99
Steam condensate temperature (°F)	93.8	92.9
Turbine exhaust pressure (in. HgA)	1.6	1.56

[2] In this context, re-optimization refers to a comprehensive condenser overhaul that reduces thermal efficiency losses associated with a wet cooling tower's higher circulating water temperatures. Modifications discussed in this study are generally limited to reinforcement measures that enable the condenser to withstand increased water pressures.

3.2.2 AMBIENT ENVIRONMENTAL CONDITIONS

ESGS is located in Los Angeles County along the shoreline of the Pacific Ocean approximately 2 miles south-southwest of the south runway at LAX. Cooling water is withdrawn from a submerged offshore location in the Pacific Ocean. Inlet temperature data for 2005 were provided by ESGS and serve as the basis for monthly cooling water temperature values used in this study.

The wet bulb temperature used in the development of the overall cooling tower design was obtained from American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) publications. Data for Los Angeles at LAX indicate a 1 percent ambient wet bulb temperature of 69° F (ASHRAE 2006). An approach temperature of 12° F 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 a temperature of 81° F. Monthly maximum wet bulb temperatures used in the development of energy penalty estimates in Section 4.6 were calculated using data obtained from California Irrigation Management Information System (CIMIS) Monitoring Station 99 in Santa Monica (CIMIS 2006). Climate data used in this analysis are summarized in Table D–6.

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

	Surface (°F)	Ambient wet bulb (°F)
January	59.2	54.3
February	60.3	56.1
March	61.5	57.7
April	63.1	60.7
May	66.0	65.7
June	68.0	68.3
July	71.4	69.3
August	72.2	69.4
September	67.0	65.5
October	63.5	60.3
November	62.0	56.3
December	60.7	55.5

3.2.3 LOCAL USE RESTRICTIONS

3.2.3.1 NOISE

Industrial development at ESGS is regulated by the City of El Segundo Municipal Code and the City of El Segundo Local Coastal Plan (LCP). Chapter 9.06 of the Municipal Code limits contributions from noise sources to 5 dBA above the ambient level for residential areas and 8 dBA above the ambient level for industrial areas. The proximity of the facility's southern boundary to the city of Manhattan Beach will also require compliance with Chapter 5.48 of that city's municipal code, which limits noise impacts in residential areas to an increase of no more than 2 dBA over ambient levels. Based on the areas available to place a wet cooling tower, this study used a noise limit of 65 dBA at a distance of 500 feet in selecting the design elements of the tower installation to comply with noise standards of each city's zoning code. Accordingly, the overall design of the wet cooling tower installation does not require any measures to specifically address noise, such as low-noise fans or barrier walls. A more detailed analysis of the potential impacts of noise on the surrounding areas was developed for the Final Staff Assessment (FSA) of the Application for Certification of the El Segundo Power Redevelopment (ESPR) project in 2002 (CEC 2002a).[3]

3.2.3.2 BUILDING HEIGHT

ESGS is located within the M2 industrial zone as described by the City of El Segundo Municipal Code, which limits the total height of structures to 200 feet. Because of the proximity of ESGS to state beaches and residential areas in Manhattan Beach, and the potential for a large cooling tower to impact visual resources, this study selected a height restriction of 60 feet above grade level. The height of the wet cooling towers designed for ESGS, from grade level to the top of the fan deck, is 58 feet.

3.2.3.3 PLUME ABATEMENT

Local zoning ordinances do not contain any specific criteria for addressing any impact associated with a wet cooling tower plume. The proximity of ESGS to LAX, however, may necessitate incorporating plume abatement measures. As shown in Figure D–1, ESGS is located approximately 2 miles south-southwest of the airport. Community standards for assessing the visual impact associated with a cooling tower plume cannot be determined within the scope of this study, but the proximity of residential areas in Manhattan Beach, which border the southern edge of the property, may also require plume abatement. Further consideration must be made for the proximity of any eventual cooling tower to coastal recreational areas and the potential visual impact on those resources. 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.

Plume abatement towers were initially selected for evaluation at ESGS due to the likelihood they would be required to eliminate potential impact on operations at LAX. Further investigation and consultation with cooling tower vendors, however, indicated that plume-abated towers could not be located at the site given the constraints on available space that would preclude their construction. Accordingly, all towers evaluated for ESGS are of a conventional design.

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

[3] The application for certification for the ESPR was amended by El Segundo Power, LLC, in June 2007 to include dry cooling for the new units.

drift eliminators are included for each cooling tower cell at ESGS, with an accepted efficiency of 0.0005 percent. Because cooling tower PM_{10} emissions are a function of the rate of drift, 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 Isokinetic Drift Test Code published by the Cooling Tower Institute is only required at initial start-up on one representative cell of each tower for an approximate cost of $60,000 per test, or approximately $120,000 for both of the cooling towers at ESGS (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 configuration of the ESGS site, at only 22 acres and with no adjoining areas available for expansion, creates several challenges in selecting a location for wet cooling towers. As shown in Figure D–3, few areas are available that are large enough to accommodate wet cooling towers without the demolition and relocation of existing structures. Because the current site of Units 1 and 2 on the northern end of the property has been reserved for the ESPR project, this study limited consideration of potential sites to two areas on the southern end of the property (Area 1 and Area 2).

Figure D–3. Cooling Tower Siting Area

Demolition of the empty fuel tanks in Area 1 would create sufficient space for a more optimal cooling tower configuration, but this location would place the towers within a short distance of residential areas in Manhattan Beach and complicate compliance with noise ordinances. Furthermore, during the development of the ESPR project, residents of the El Porto community indicated their preference for the fuel tanks to remain to serve as a noise and visual buffer between the neighborhood and the generating units at ESGS (CEC 2002a). Replacement of the tanks with wet cooling towers would likely encounter significant local opposition.

Area 2 is a narrow strip between the Unit 3 and Unit 4 power block and the fuel tanks along the western boundary of the property with an approximate total area of 105,000 square feet (700 feet x 150 feet). The retention basin, used to treat in-plant wastes prior to discharge, currently occupies 30,000 square feet of this area and will have to be relocated or reconfigured to allow construction of the cooling towers. Further complicating the use of this area is the proximity of the beach and a recreational trail that parallels the western edge of ESGS. In this location, the base of the towers will be less than 50 feet from the recreational trail, with the towers rising 58 feet and running alongside the trail for approximately 570 feet. The visual impact created by the towers as seen from the beach may conflict with Coastal Act provisions that require protection of visual resources in coastal areas, although a final evaluation may weigh the relative impacts each option would create (i.e., continued use of once-through cooling versus visual impact of a wet cooling tower).

The switchyard, which juts into the center of the property, is located at an elevation of 70 feet above sea level, while grade level for Area 2 is approximately 20 feet. With prevailing winds from the west and northwest, the proximity of the switchyard to the towers and the elevation at which it is located will create a strong probability of interference with or damage to sensitive equipment resulting from salt drift deposition. Placement of wet cooling towers in this location will likely require relocation of the switchyard or replacement with gas insulated switchgear (GIS) to avoid these effects.

The difficulties surrounding the placement of conventional wet cooling towers at ESGS make incorporation of plume-abated towers at the site unlikely. Because plume-abated towers cannot be arranged in a back-to-back configuration and must be placed in an inline setup, these towers would be substantially longer than the total length of the two conventional towers selected for ESGS. Sufficient area for plume-abated towers might be available if Areas 1 and 2 were both available, but the use of Area 1 was eliminated from consideration, as discussed above.

Despite these limitations, Area 2 was selected as the most appropriate location for the placement of the wet cooling towers designed in this study.

3.3 CONCEPTUAL DESIGN

Based on the design constraints discussed above, two wet cooling towers were selected to replace the current once-through cooling system that currently serves Units 3 and 4 at ESGS. Each tower will operate independently and be dedicated to one unit. Each tower is configured in a multicell, back-to-back arrangement.

3.3.1 SIZE

Each tower is constructed over a concrete collection basin 4 feet deep. The basin is larger than the footprint of the tower structure, 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 ESGS are summarized in Table D–7.

Table D–7. Wet Cooling Tower Design

	Tower 1 (Unit 3)	Tower 2 (Unit 4)
Thermal load (MMBTU/hr)	1,440	1,440
Circulating flow (gpm)	132,400	131,000
Number of cells	10	10
Tower type	Mechanical draft	Mechanical draft
Flow orientation	Counterflow	Counterflow
Fill type	Modular splash	Modular splash
Arrangement	Back-to-back	Back-to-back
Primary tower material	FRP	FRP
Tower dimensions (l x w x h) (ft)	270 x 108 x 58	270 x 108 x 58
Tower footprint with basin (l x w) (ft)	274 x 112	274 x 112

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. Tower 1, serving Unit 3, is located at an approximate distance of 600 feet. Tower 2, serving Unit 4, is located at an approximate distance of 200 feet.

Figure D–4 identifies the approximate location of each tower and supply and return piping.

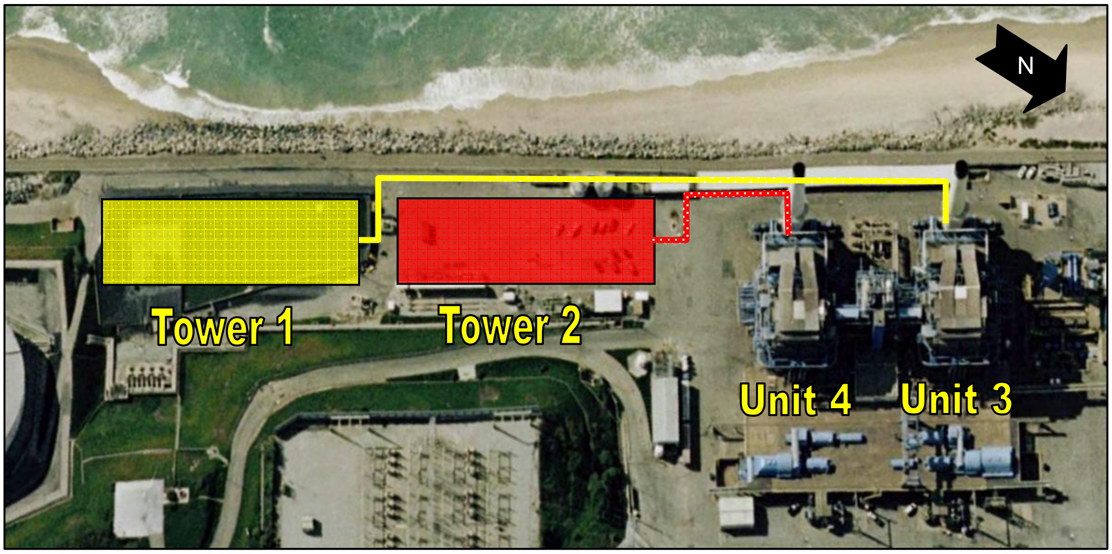

Figure D-4. Location of Cooling Towers

3.3.3 PIPING

The main supply and return pipelines for Tower 1 will be located underground and made of prestressed concrete cylinder pipe (PCCP) suitable for saltwater applications. These pipes range in size from 72 to 84 inches in diameter.

Pipes connecting the Unit 3 condenser to the supply and return lines are made of FRP and placed above ground on pipe racks. The proximity of Unit 4 to Tower 2 allows most pipes to be placed above ground on pipe racks (supply headers to the tower will be placed underground and made of PCCP). Above-ground placement avoids the potential disruption that may be caused by excavation in and around the power block. The condensers at ESGS are located at grade level, enabling a relatively straightforward connection.

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 ESGS.

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 both towers.

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 tower and condensers, and the total head required to deliver water to the top of the cooling tower riser.

A separate, multilevel pump house is constructed for each cooling tower and is 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 50-ton overhead crane is also included to allow for pump servicing.

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

Table D–8. Cooling Tower Fans and Pumps

		Tower 1 (Unit 3)	Tower 2 (Unit 4)
Fans	Number	10	10
	Type	Single speed	Single speed
	Efficiency	0.95	0.95
	Motor power (hp)	211	211
Pumps	Number	2	2
	Type	50% recirculating Mixed flow Suspended bowl Vertical	50% recirculating Mixed flow Suspended bowl Vertical
	Efficiency	0.88	0.88
	Motor power (hp)	1,619	1,619

3.4 ENVIRONMENTAL EFFECTS

Conversion of the existing once-through cooling system at ESGS 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 both of ESGS's steam units, thereby decreasing the facility's overall efficiency. Additional power will also be consumed by the operation of tower fans and circulating pumps. Depending on how ESGS 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 or the purchase of emission credits to meet air quality regulations. 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 utilization capacity for the generating units served by the tower.

If ESGS retains its National Pollutant Discharge Elimination System (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 quantity and characteristics of the discharge. Impacts from the discharge of elevated temperature wastes associated with the current once-through system, if any, will be minimized through the use of a wet cooling system.

3.4.1 AIR EMISSIONS

ESGS is located in the South Central Coast air basin. Air emissions are permitted by the South Coast Air Quality Management District (SCAQMD) (Facility ID 115663).

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 ESGS, this corresponds to a rate of approximately 1.3 gpm based on the maximum combined flow in the two towers. As discussed in Section 3.2.3, drift deposition has the potential to significantly impact the switchyard and transmission equipment.

Total PM_{10} emissions from the ESGS 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 ESGS 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 total dissolved solids (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 ESGS 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 D–9.[4]

Data summarizing the total facility emissions for these pollutants in 2005 are presented in Table D–10 (CARB 2005). In 2005, ESGS operated at an annual capacity utilization of 11.3 percent. Using this rate, the additional PM_{10} emissions from the cooling towers would increase the facility total by approximately 17 tons/year, or 58 percent.[5]

[4] 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).

[5] 2006 emission data are not currently available from the ARB website. For consistency, the comparative increase in PM_{10} emissions estimated here is based on the 2005 ESGS capacity utilization rate instead of the 2006 rate presented in Table D-4. All other calculations in this chapter use the 2006 value.

Table D–9. Full Load Drift and Particulate Estimates

	PM_{10} (lbs/hr)	PM_{10} (tons/year)	Drift (gpm)	Drift (lbs/hr)
Tower 1	17	76	0.66	331
Tower 2	17	75	0.66	328
Total ESGS PM_{10} and drift emissions	**34**	**151**	**1.32**	**659**

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

Pollutant	Tons/year
NO_x	31.2
SO_x	2.3
PM_{10}	29.4

3.4.2 MAKEUP WATER

The volume of makeup water required by the two cooling towers at ESGS is the sum of evaporative loss and the blowdown volume required to maintain the circulating water in the towers at the design TDS concentration. Drift expelled from the tower represents an insignificant volume by comparison and is accounted for by rounding up estimates of evaporative losses. Makeup water volumes are based on design conditions, and may fluctuate seasonally depending on climate conditions and facility operations. Use of wet cooling towers will reduce once-through cooling water withdrawals from the Pacific Ocean by approximately 95 percent over the current design intake capacity. (See Table D–11.)

Table D–11. Makeup Water Demand

	Tower circulating flow (gpm)	Evaporation (gpm)	Blowdown (gpm)	Total makeup water (gpm)
Tower 1	132,400	2,400	4,800	**7,200**
Tower 2	131,000	2,400	4,800	**7,200**
Total ESGS makeup water demand	**263,400**	**4,800**	**9,600**	**14,400**

One circulating water pump rated at 69,200 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 both cooling towers. The capacity of the retained pump exceeds the makeup demand capacity by approximately 55,000 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 to maintain the desired flow reduction. The intake of new water, measured at the intake screens, will be equal to the makeup water demand of the cooling towers. Figure D–5 presents a schematic of this configuration.

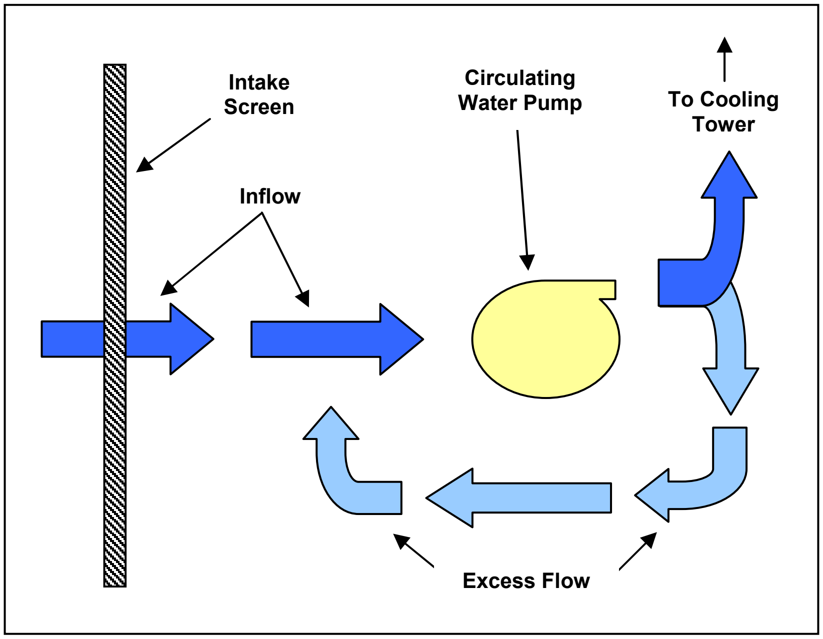

Figure D–5. Schematic of Intake Pump Configuration

The existing once-through cooling system at ESGS 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 125º 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 ESGS includes water treatment for standard operational measures, i.e., fouling and corrosion control. Chemical treatment allowances are included in annual operations and maintenance (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 will not require any pretreatment to enable its use.

3.4.3 NPDES PERMIT COMPLIANCE

At maximum operation, wet cooling towers at ESGS will result in an effluent discharge of approximately 14 mgd of blowdown in addition to other in-plant waste streams—such as boiler blowdown, sanitary wastes, and cleaning wastes. These low-volume wastes may add an additional 1.1 mgd to the total discharge flow from the facility. Unless an alternative discharge is considered, ESGS 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 CA0001147, as implemented by LARWQCB Order 00-084. All wastewaters are discharged to the Pacific Ocean through a submerged conduit extending approximately 2,100 feet offshore. The existing order contains effluent limitations based on the 1997 Ocean Plan and 1972 Thermal Plan.

ESGS 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 ESGS 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 LARWQCB has implemented this provision by establishing a maximum discharge temperature of 105º F during normal operations in Order 00-084 (LARWQCB 2000). Information available for review indicates ESGS has consistently been able to comply 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

The use of reclaimed or alternative water sources could potentially eliminate all surface water withdrawals at ESGS. 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 the lower TDS levels. The SWRCB, in 1975, issued a policy statement requiring the consideration of alternative cooling methods in new power plants, including the use of reclaimed water, over the use of freshwater (SWRCB 1975). There is no similar policy regarding the use of marine waters, but the clear preference of state agencies is to encourage alternative cooling methods, including the use of reclaimed water, wherever possible.

The present volume of available secondary treated water within a 15-mile radius of ESGS (680 mgd) can meet the current once-through cooling demand for Units 3 and 4 (380 mgd), although the volume that is reliably available would require pipeline connections to two different sources to ensure an adequate and consistent flow. In lieu of secondary treated water as a replacement for once-through cooling, reclaimed water can be used as makeup water in cooling towers but 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, ESGS would be required to provide sufficient treatment onsite prior to use in the cooling towers. Currently, the West Basin Municipal Water District (WBMWD) treats approximately 30 mgd of secondary water from Hyperion Wastewater Treatment Plant (WWTP) to tertiary standards. This water is used for various projects throughout the South Bay region, such as the seawater barrier conservation project to protect underground aquifers. WBMWD’s current available capacity is insufficient to meet the makeup water demand for the wet cooling towers at ESGS (WBMWD 2007).

An additional consideration for the use of reclaimed water is the presence of any ammonia or ammonia-forming compounds in the reclaimed water. All of the condenser tubes at ESGS contain copper alloys (Cu-Ni 90-10) and can experience stress-corrosion cracking as a result of the interaction between copper and ammonia. Treatment for ammonia may include the addition of ferrous sulfate as a corrosion inhibitor or require ammonia-stripping towers to pretreat reclaimed water prior to use in the cooling towers (USEPA 2001).

Two publicly owned treatment works (POTWs) were identified within a 15-mile radius of ESGS, with a combined discharge capacity of 680 mgd. Figure D–6 shows the relative locations of these facilities to ESGS.

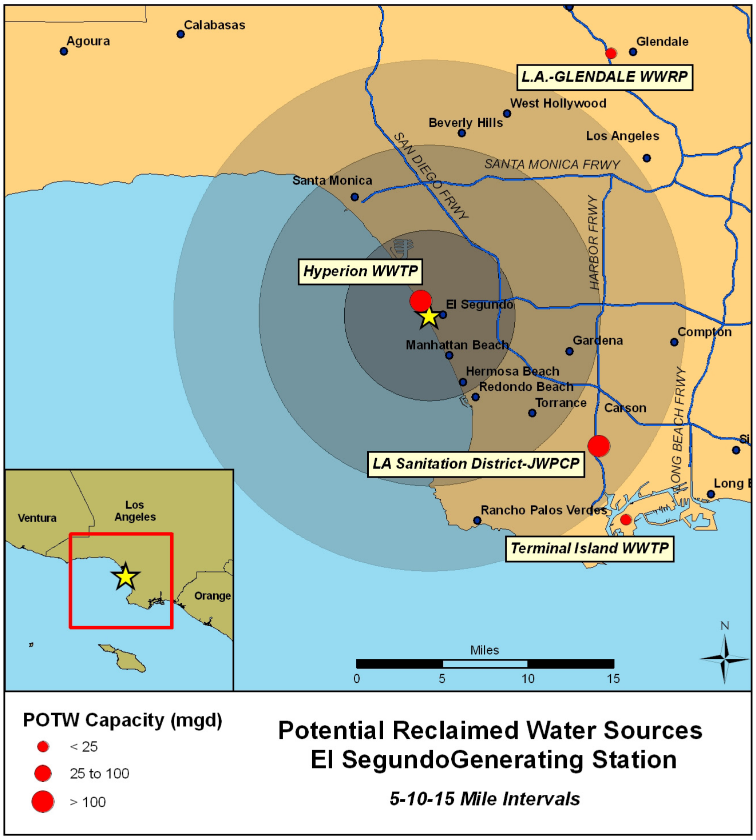

Figure D–6. Reclaimed Water Sources

- *Los Angeles Sanitation District, Hyperion Wastewater Treatment Plant—Los Angeles*
  Discharge volume: 350 mgd
  Distance: 1 mile N
  Treatment level: Secondary

The CEC evaluated the use of secondary treated water from Hyperion as a replacement for once-through cooling in the ESPR FSA in 2002. The assessment determined that the use of Hyperion's water was technically feasible, although the evaluation was based on a once-through demand of 207 mgd that would have been required for the ESPR. Because the distance offshore (2,100 feet) of the ESGS outfall is insufficient to meet water quality standards for public beaches, secondary water used at ESGS would either be returned to Hyperion for discharge through the Hyperion "5 mile" outfall or used for another purpose (CEC 2002a). The final commission decision, however, found that this option was infeasible (CEC 2005).

Any water used in a wet cooling tower at ESGS would have to be treated onsite at the facility. Hyperion does not currently treat to tertiary standards and does not have sufficient area on which to construct a treatment system. WBMWD does not have sufficient excess capacity to meet the demand of a freshwater tower at ESGS (8 to 10 mgd). The 2002 FSA deemed tertiary treatment at ESGS infeasible due to overall size of a treatment facility and the lack of sufficient space at the site (CEC 2002a).

- *Los Angeles Sanitation District, Joint Water Pollution Control Plant (JWPCP)—Carso*n
  Discharge volume: 330 mgd
  Distance: 12 miles SE
  Treatment level: Secondary

  The facility representative at JWPCP indicated that the effluent is not currently considered a potential source of reclaimed water for irrigation due to high TDS concentrations (brine from the Hyperion WWTP is treated at Carson), but the suitability for use as a makeup water source is not currently known. TDS levels may be less than normally found in seawater and thus may be at least comparable to the current makeup water source at ESGS. In the future, a portion of the effluent may be used for a new hydrogen plant under consideration by BP (formerly British Petroleum), but no formal agreement currently exists. Even with such an agreement, sufficient capacity would remain to satisfy the full makeup water demand for freshwater towers at ESGS (8 to 10 mgd).

The costs associated with installing transmission pipelines (excavation/drilling, material, labor), in addition to design and permitting costs, are difficult to quantify in the absence of a detailed analysis of various site-specific parameters that will influence the final configuration. The nearest facility with sufficient capacity to satisfy ESGS's makeup demand (8 to 10 mgd as a freshwater tower) is located approximately 1 mile from the site (Hyperion). Based on data compiled for this study and others, the estimated installed cost of a 24-inch prestressed concrete cylinder pipe, sufficient to provide 10 mgd to ESGS, is $300 per linear foot, or approximately $1.6 million per mile. Additional considerations, such as pump capacity and any required treatment, would increase the total cost.

Regulatory concerns beyond the scope of this investigation may make the use of reclaimed water comparable or preferable to the use of saltwater from marine sources as makeup water. Use of freshwater may reduce or eliminate drift deposition and its associated impacts on sensitive equipment. Reclaimed water may enable ESGS to reduce PM_{10} emissions from the cooling tower, which is a concern given the current nonattainment status of the South Coast air basin, or eliminate potential conflicts with water discharge limitations. ESGS might realize other benefits by using reclaimed water in the form of reduced O&M costs. 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, is a question of the overall cost, availability, and additional environmental benefit that may be realized.

3.4.5 THERMAL EFFICIENCY

The use of wet cooling towers at ESGS will increase the temperature of the condenser inlet water by a range of 9 to 13° F above the surface water temperature, depending on the ambient wet bulb temperature at the time. The generating units at ESGS are designed to operate at the conditions described in Table D–12. The resulting monthly difference between once-through and wet cooling tower condenser inlet temperatures at ESGS is described in Figure D–7.

Table D–12. Design Thermal Conditions

	Unit 3	Unit 4
Design backpressure (in. HgA)	1.6	1.56
Design water temperature (°F)	63	63
Turbine inlet temp (°F)	1,000	1,000
Turbine inlet pressure (psia)	2,400	2,400
Operating heat rate (BTU/kWh) [a]	9,557	9,713

[a] CEC 2002b.

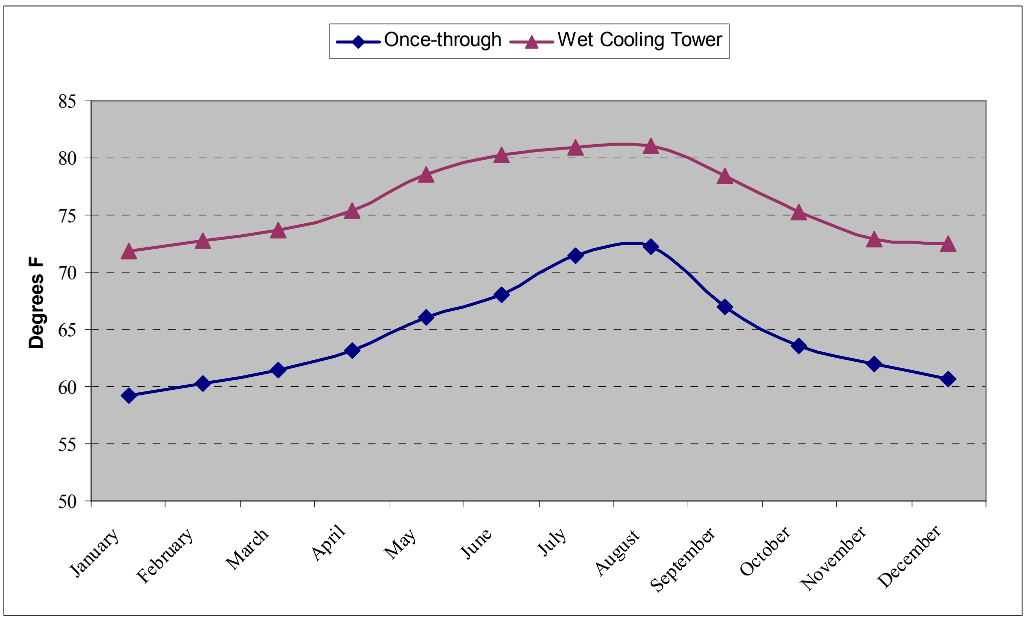

Figure D–7. Condenser Inlet Temperatures

Backpressures for the once-through and wet cooling tower configurations were calculated using the design criteria described in the sections above on a monthly basis using ambient climate data (Table D–6). In general, backpressures associated with the wet cooling tower were elevated by 0.5 to 0.75 inches HgA compared with the current once-through system (Figure D–8 and Figure D–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 maximum load rating.[6] The relative change at different backpressures was compared with the value calculated for the design conditions (i.e., at design

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

turbine inlet and exhaust backpressures) and plotted as a percentage of the maximum operating heat rate to develop estimated correction curves (Figure D–9 and Figure D–11). A comparison was then made between the relative heat rates of the once-through and wet cooling systems for a given month. The difference between these two values represents the net increase in heat rate that would be expected in a converted system.

Table D–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 develop an estimate of the monetized value of these heat rate changes (Section 4.6). Month-by-month calculations are presented in Appendix A.

Table D–13. Summary of Estimated Heat Rate Increases

	Unit 3	Unit 4
Peak (July-August-September)	1.08%	1.09%
Annual average	1.01%	1.03%

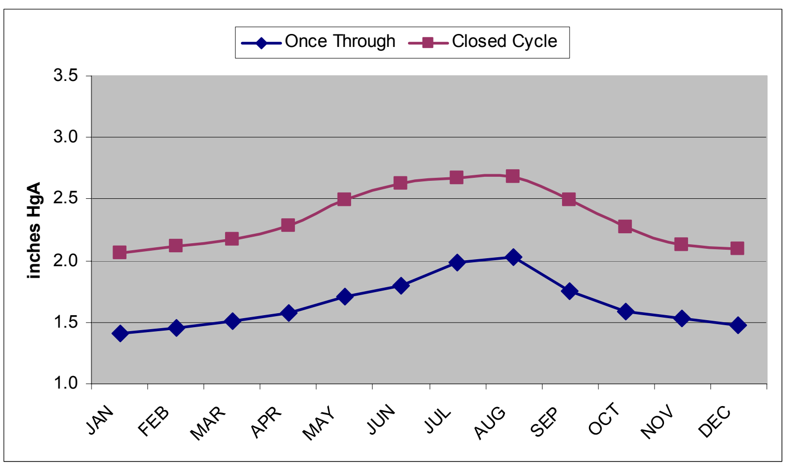

Figure D–8. Estimated Backpressures (Unit 3)

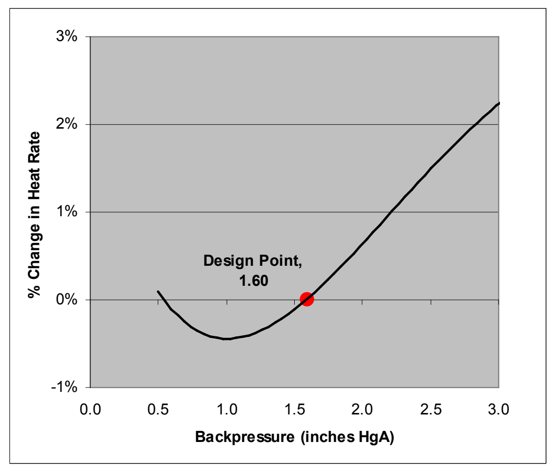

Figure D–9. Estimated Heat Rate Correction (Unit 3)

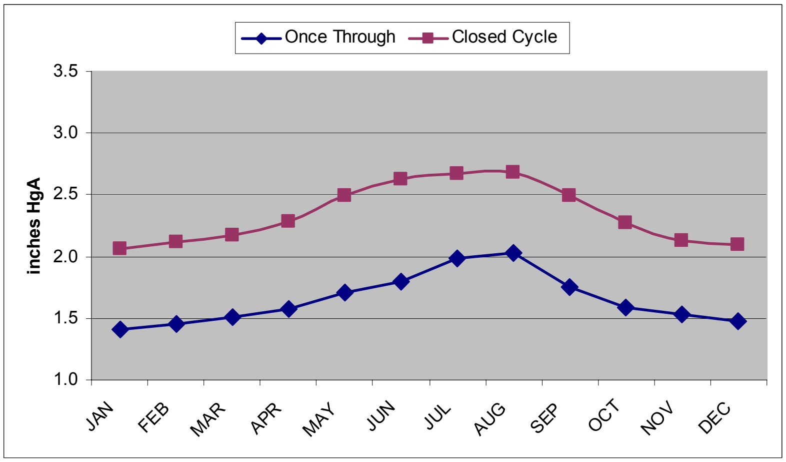

Figure D-10. Estimated Backpressures (Unit 4)

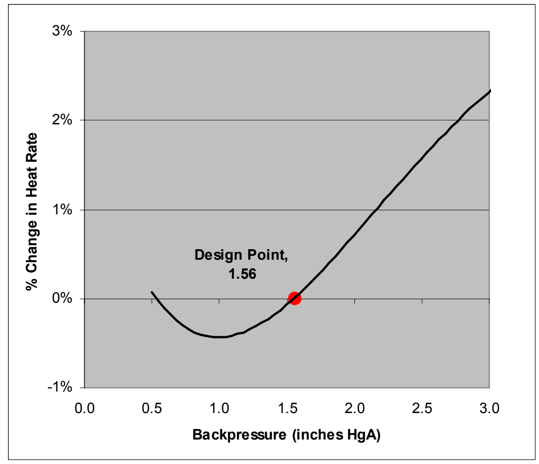

Figure D-11. Estimated Heat Rate Correction (Unit 4)

4.0 RETROFIT COST ANALYSIS

The wet cooling system retrofit estimate for ESGS is based on incorporating conventional wet cooling towers as a replacement for the existing once-through systems 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)
- 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)
- Revenue loss from shutdown (net loss in revenue during construction phase)

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 ESGS conforms to a typical design; no significant variations from a conventional arrangement were needed, although the preferred configuration (plume-abated towers) was infeasible and not evaluated. Table D–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 D–14. Wet Cooling Tower Design-and-Build Cost Estimate

	Unit 3	Unit 4	ESGS Total
Number of cells	10	10	**20**
Cost/cell ($)	630,000	630,000	**630,000**
Total ESGS D&B cost ($)	**6,300,000**	**6,300,000**	**12,600,000**

4.2 OTHER DIRECT COSTS

A significant portion of the cost incurred for the wet cooling tower installation results from the various support structures and materials (pipes, pumps, etc.), as well the necessary equipment and labor required to prepare the cooling tower site and connect the towers to the cooling system. At ESGS, these costs comprise approximately 45 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 3 are discussed below. Other direct costs (non–cooling tower) are summarized in Table D–15.

- *Civil, Structural, and Piping*
  The configuration of the ESGS site allows each tower to be located within relative proximity to the respective generating unit.
- *Mechanical and Electrical*
  Initial capital costs in this category reflect incorporating new pumps (four 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*
  Costs for the demolition and backfilling of the retention basin are included.

Table D–15. Summary of Other Direct Costs

	Equipment ($)	Bulk material ($)	Labor ($)	ESGS total ($)
Civil/structural/piping	4,700,000	10,200,000	9,000,000	**23,900,000**
Mechanical	5,200,000	0	500,000	**5,700,000**
Electrical	1,300,000	2,000,000	1,500,000	**4,800,000**
Demolition	0	500,000	400,000	**900,000**
Total ESGS other direct costs	**11,200,000**	**12,700,000**	**11,400,000**	**35,300,000**

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 reinforcement of the condenser to withstand the increased pressures resulting from incorporation of wet cooling towers. 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 3, 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 ESGS, potential costs in this category include relocation or demolition of small buildings and structures and the potential interference with underground structures. Modifications or upgrades to sensitive equipment may be necessary to counteract drift deposition. Soils were not characterized for this analysis. ESGS is situated at 20 feet above sea level adjacent to the Pacific Ocean. Seawater intrusion or the instability of sandy soils may require additional pilings to support any large structures built at the site. Initial capital costs are summarized in Table D–16.

Table D–16. Summary of Initial Capital Costs

	Cost ($)
Cooling towers	12,600,000
Civil/structural/piping	23,900,000
Mechanical	5,700,000
Electrical	4,800,000
Demolition	900,000
Indirect cost	12,000,000
Condenser modification	2,400,000
Contingency	15,600,000
Total ESGS capital cost	**77,900,000**

4.4 SHUTDOWN

A portion of the work relating to installing wet cooling towers can be completed without significant disruption to the operations of ESGS. Units will be offline depending on the length of time it takes to integrate the new cooling system and conduct acceptance testing. For ESGS, 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 ESGS does not include any loss of revenue associated with shutdown at ESGS.

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

Operations and maintenance (O&M) costs for a wet cooling tower system at ESGS 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 circulating water flow capacity of the towers 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 ESGS (263,800 gpm), are presented in Table D–17. These costs reflect maximum operation.

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

	Year 1 ($)	Year 12 ($)
Management/labor	263,400	381,930
Service/parts	421,440	611,088
Fouling	368,760	534,702
Total ESGS O&M cost	**1,053,600**	**1,527,720**

4.6 ENERGY PENALTY

The energy penalty is divided into two components: increased parasitic use resulting from the additional electrical demand of cooling tower fans and pumps; and the decrease in thermal efficiency resulting from elevated turbine backpressure values. Monetizing the energy penalty at ESGS 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 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"). A more likely option, however, is some combination of the two.

Ultimately, the manner in which ESGS 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 once-through system. 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. [7]

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

[7] Increasing the thermal load to the turbine will raise the circulating water temperature exiting the condenser. The cooling towers selected for this study are designed with a maximum water return temperature of approximately 120º F. Depending on each unit's operating conditions (i.e., condenser outlet temperature), the degree to which the thermal input to the turbine can be increased may be limited.

4.6.1 INCREASED PARASITIC USE (FANS AND PUMPS)

Depending on ambient conditions or the operating load at a given time, ESGS 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., maximum load; no allowance is made for seasonal changes. The increased electrical demand associated with operation of the cooling tower fans is summarized in Table D–18.

Table D–18. Cooling Tower Fan Parasitic Use

	Tower 1	Tower 2	ESGS total
Units served	Unit 3	Unit 4	--
Generating capacity (MW)	335	335	**670**
Number of fans (one per cell)	10	10	**20**
Motor power per fan (hp)	211	211	--
Total motor power (hp)	2,105	2,105	**4,210**
MW total	1.57	1.57	**3.14**
Fan parasitic use (% of capacity)	**0.47%**	**0.47%**	**0.47%**

The addition of new circulating water pump capacity for the wet cooling towers will also increase the parasitic use of electricity at ESGS. Makeup water will continue to be withdrawn from the Pacific Ocean through the use of 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. 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 operation of the cooling tower pumps is summarized in Table D–19.

Table D–19. Cooling Tower Pump Parasitic Use

	Tower 1	Tower 2	ESGS total
Units served	Unit 3	Unit 4	--
Generating capacity (MW)	335	335	**670**
Existing pump configuration (hp)	1,156	1,156	**2,312**
New pump configuration (hp)	3,539	3,539	**7,077**
Difference (hp)	2,383	2,383	**4,765**
Difference (MW)	1.8	1.8	**3.6**
Net pump parasitic use (% of capacity)	**0.53%**	**0.53%**	**0.53%**

4.6.2 HEAT RATE CHANGE

Adjustments to the heat rate were calculated based on the ambient conditions for each month and reflect the estimated difference between operations with once-through and wet cooling tower systems. As noted above, the energy penalty analysis assumes ESGS will increase its fuel consumption to compensate for lost efficiency as well as 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 ESGS may be greater or less. Estimated heat rate changes for each unit at ESGS are presented in Figure D–12 and Figure D–13.

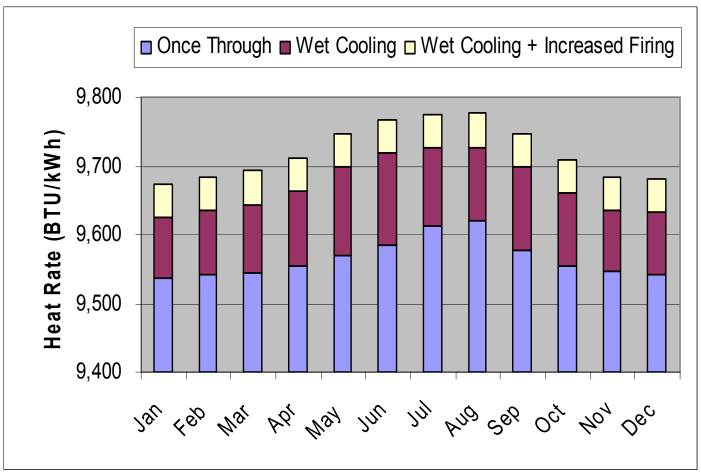

Figure D–12. Estimated Heat Rate Change (Unit 3)

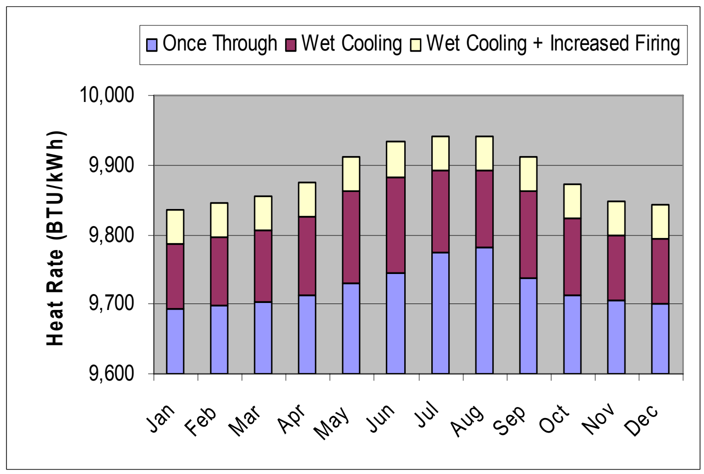

Figure D–13. Estimated Heat Rate Change (Unit 4)

4.6.3 CUMULATIVE ESTIMATE

Using the increased fuel option, the cumulative value of the energy penalty is obtained by first calculating the relative costs of generation ($/MWh) for the once-through and overfired wet cooling systems. The cost of generation for ESGS is based on the relative heat rates developed in Section 4.6.2 and the average monthly wholesale natural gas cost ($/MMBTU) (ICE 2006a). The difference between these two values represents the increased cost, per MWh, that results from incorporating wet cooling towers. The net difference in cost, per month, is applied to the net MWh generated for the particular month, and summed to determine an annual estimate.

Based on 2006 output data, the Year 1 energy penalty for ESGS will be approximately $517,000. In contrast, the value of the energy penalty using the production loss option would be approximately $900,000. Together, these values represent the range of potential energy penalty costs. Table D–20 and Table D–21 summarize the energy penalty estimates for each unit using the increased fuel option.

Table D–20. Unit 3 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	9,537	57.22	9,664	57.98	0.76	27,273	**20,790**
February	5.50	9,541	52.47	9,674	53.20	0.73	0	**0**
March	4.75	9,545	45.34	9,682	45.99	0.65	31,889	**20,726**
April	4.75	9,553	45.38	9,701	46.08	0.70	47,918	**33,622**
May	4.75	9,570	45.46	9,736	46.25	0.79	43,765	**34,527**
June	5.00	9,584	47.92	9,756	48.78	0.86	61,138	**52,695**
July	6.50	9,613	62.48	9,764	63.47	0.98	59,384	**58,337**
August	6.50	9,620	62.53	9,765	63.47	0.94	28,763	**26,996**
September	4.75	9,577	45.49	9,735	46.24	0.75	26,782	**20,162**
October	5.00	9,555	47.78	9,699	48.49	0.72	0	**0**
November	6.00	9,548	57.29	9,675	58.05	0.76	12,603	**9,605**
December	6.50	9,542	62.02	9,670	62.86	0.83	0	**0**
							Unit 3 total	**277,460**

Table D–21. Unit 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	9,694	58.17	9,826	58.96	0.79	22,684	**17,959**
February	5.50	9,699	53.34	9,836	54.10	0.76	15,641	**11,842**
March	4.75	9,704	46.09	9,845	46.77	0.67	16,780	**11,282**
April	4.75	9,712	46.13	9,865	46.86	0.72	25,268	**18,289**
May	4.75	9,730	46.22	9,900	47.03	0.81	23,398	**18,956**
June	5.00	9,745	48.72	9,921	49.61	0.88	40,497	**35,746**
July	6.50	9,775	63.53	9,929	64.54	1.00	73,178	**73,411**
August	6.50	9,782	63.58	9,930	64.54	0.96	35,269	**33,783**
September	4.75	9,737	46.25	9,899	47.02	0.77	25,027	**19,329**
October	5.00	9,714	48.57	9,862	49.31	0.74	0	**0**
November	6.00	9,706	58.24	9,837	59.02	0.79	0	**0**
December	6.50	9,700	63.05	9,833	63.91	0.86	0	**0**
							Unit 4 total	**240,597**

4.7 NET PRESENT COST

The Net Present Cost (NPC) of a wet cooling system retrofit at ESGS is the sum of all annual expenditures over the 20-year life span of the project and discounted according to the year in which the expense is incurred and the selected discount rate. The NPC_{20} represents the total change in revenue streams, in 2007 dollars, that ESGS 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 D–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 ESGS has a relatively low capacity utilization factor, O&M costs for the NPC calculation were estimated at 30 percent of their maximum value. (See Table D–17.)
- *Annual Energy Penalty.* Insufficient information is available to this study to forecast future generating capacity at ESGS. In lieu of annual estimates, this study uses the net MWh output from 2006 as the basis for estimating the energy penalty value for Years 1 through 20, including a year-over-year wholesale price escalation of 5.8 percent (based on the Producer Price Index). The energy penalty value is based on the increased fuel option discussed in Section 4.6. (See Table D–20 and Table D–21.)

Using these values, the NPC_{20} for ESGS is $91 million. Appendix C contains detailed annual calculations used to develop this cost.

4.8 ANNUAL COST

The annual cost incurred by ESGS for the retrofit of the once-through cooling system is the sum of the annual amortized capital cost plus the 20-year 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). The annual cost does not include any loss of revenue associated with shutdown, if any. This loss would be incurred in Year 0 only.

Table D–22. Annual Cost

Discount rate (%)	Capital ($)	Annual O&M ($)	Annual energy penalty ($)	Annual cost ($)
7	7,400,000	400,000	900,000	**8,700,000**

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 annual revenues for ESGS. An approximation of the gross annual revenue can be made 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 liabilities such as taxes or other operational costs.

The estimate of gross annual revenue from electricity sales at ESGS 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 ESGS is summarized in Table D–23. A comparison of annual costs to annual gross revenue is summarized in Table D–24.

Table D–23. Estimated Gross Revenue

	Wholesale price ($/MWh)	Net generation (MWh)		Estimated gross revenue ($2007)		
		Unit 1	Unit 2	Unit 1	Unit 2	ESGS total
January	66	27,273	22,684	1,800,018	1,497,144	**3,297,162**
February	61	0	15,641	0	954,101	**954,101**
March	51	31,889	16,780	1,626,339	855,780	**2,482,119**
April	51	47,918	25,268	2,443,818	1,288,668	**3,732,486**
May	51	43,765	23,398	2,232,015	1,193,298	**3,425,313**
June	55	61,138	40,497	3,362,590	2,227,335	**5,589,925**
July	91	59,384	73,178	5,403,944	6,659,198	**12,063,142**
August	73	28,763	35,269	2,099,699	2,574,637	**4,674,336**
September	53	26,782	25,027	1,419,446	1,326,431	**2,745,877**
October	57	0	0	0	0	**0**
November	66	12,603	0	831,798	0	**831,798**
December	67	0	0	0	0	**0**
ESGS total		**339,515**	**277,742**	**21,219,667**	**18,576,592**	**39,796,259**

Table D–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
39,800,000	7,400,000	19.0	400,000	1.0	900,000	2.3	**8,700,000**	**22**

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 ESGS. As with many existing facilities, the location and configuration of the site complicates the use of some technologies that might be used successfully elsewhere. A more detailed analysis that also comprises a biological evaluation may determine the applicability of one or more of these technologies to ESGS. 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. ESGS currently withdraws its cooling water through a submerged conduit extending approximately 2,000 feet offshore at a depth of 20 feet. Returning any collected organisms to a similar location would be impractical. 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 ESGS 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 to 50 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, thus negating any potential benefit. Use of VSDs may be an economically desirable option when pumps are retrofitted or replaced for other reasons, but VSDs 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 would be required at ESGS (approximately 380 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 ESGS would be located offshore in the Pacific Ocean, west of the facility. Limited information regarding the subsurface currents in the near-shore environment near ESGS is available. 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 ESGS.

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

		Unit 3			Unit 4		
		Once through	Closed cycle	Net increase	Once through	Closed cycle	Net increase
JAN	Backpressure (in. HgA)	1.41	2.06	**0.64**	1.40	2.04	**0.64**
	Heat rate Δ (%)	*-0.21*	*0.71*	***0.93***	*-0.19*	*0.76*	***0.96***
FEB	Backpressure (in. HgA)	1.46	2.12	**0.66**	1.44	2.10	**0.66**
	Heat rate Δ (%)	*-0.17*	*0.82*	***0.99***	*-0.15*	*0.87*	***1.02***
MAR	Backpressure (in. HgA)	1.50	2.17	**0.66**	1.49	2.15	**0.66**
	Heat rate Δ (%)	*-0.12*	*0.91*	***1.03***	*-0.10*	*0.97*	***1.06***
APR	Backpressure (in. HgA)	1.57	2.28	**0.71**	1.56	2.26	**0.70**
	Heat rate Δ (%)	*-0.04*	*1.11*	***1.15***	*-0.01*	*1.17*	***1.18***
MAY	Backpressure (in. HgA)	1.70	2.49	**0.79**	1.69	2.47	**0.79**
	Heat rate Δ (%)	*0.13*	*1.48*	***1.35***	*0.17*	*1.54*	***1.37***
JUN	Backpressure (in. HgA)	1.80	2.62	**0.82**	1.78	2.60	**0.82**
	Heat rate Δ (%)	*0.28*	*1.70*	***1.42***	*0.32*	*1.75*	***1.43***
JUL	Backpressure (in. HgA)	1.98	2.67	**0.69**	1.97	2.65	**0.69**
	Heat rate Δ (%)	*0.59*	*1.78*	***1.19***	*0.63*	*1.83*	***1.20***
AUG	Backpressure (in. HgA)	2.03	2.68	**0.65**	2.01	2.66	**0.65**
	Heat rate Δ (%)	*0.66*	*1.79*	***1.12***	*0.71*	*1.84*	***1.13***
SEP	Backpressure (in. HgA)	1.75	2.49	**0.74**	1.73	2.47	**0.73**
	Heat rate Δ (%)	*0.21*	*1.48*	***1.27***	*0.25*	*1.53*	***1.29***
OCT	Backpressure (in. HgA)	1.59	2.27	**0.68**	1.57	2.25	**0.68**
	Heat rate Δ (%)	*-0.02*	*1.09*	***1.11***	*0.01*	*1.14*	***1.13***
NOV	Backpressure (in. HgA)	1.53	2.12	**0.60**	1.51	2.10	**0.60**
	Heat rate Δ (%)	*-0.10*	*0.83*	***0.93***	*-0.07*	*0.88*	***0.95***
DEC	Backpressure (in. HgA)	1.47	2.10	**0.62**	1.46	2.08	**0.62**
	Heat rate Δ (%)	*-0.15*	*0.78*	***0.94***	*-0.13*	*0.84*	***0.97***

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 800 ft) and cable racks	t	80	--	--	2,500	200,000	17.00	105	142,800	**342,800**
Allocation for sheet piling and dewatering	lot	1	--	--	500,000	500,000	5,000.00	100	500,000	**1,000,000**
Allocation for testing pipes	lot	1	--	--	--	--	2,000.00	95	190,000	**190,000**
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	1	--	--	50,000	50,000	500.00	95	47,500	**97,500**
Backfill for PCCP pipe (reusing excavated material)	m3	9,281	--	--	--	--	0.04	200	74,248	**74,248**
Bedding for PCCP pipe	m3	1,478	--	--	25	36,950	0.04	200	11,824	**48,774**
Bend for PCCP pipe 24" diam (allocation)	ea	12	--	--	3,000	36,000	20.00	95	22,800	**58,800**
Bend for PCCP pipe 30" & 36" diam (allocation)	ea	18	--	--	5,000	90,000	25.00	95	42,750	**132,750**
Bend for PCCP pipe 72" diam (allocation)	ea	12	--	--	18,000	216,000	40.00	95	45,600	**261,600**
Bend for PCCP pipe 84" diam (allocation)	ea	8	--	--	20,000	160,000	50.00	95	38,000	**198,000**
Building architectural (siding, roofing, doors, painting…etc)	ea	2	--	--	250,000	500,000	3,000.00	75	450,000	**950,000**
Butterfly valves 30" c/w allocation for actuator & air lines	ea	28	30,800	862,400	--	--	50.00	85	119,000	**981,400**
Butterfly valves 60" c/w allocation for actuator & air lines	ea	8	75,600	604,800	--	--	60.00	85	40,800	**645,600**
Butterfly valves 72" c/w allocation for actuator & air lines	ea	12	96,600	1,159,200	--	--	75.00	85	76,500	**1,235,700**
Butterfly valves 84" c/w allocation for actuator & air lines	ea	12	124,600	1,495,200	--	--	75.00	85	76,500	**1,571,700**
Check valves 30"	ea	4	44,000	176,000	--	--	16.00	85	5,440	**181,440**
Check valves 60"	ea	4	108,000	432,000	--	--	30.00	85	10,200	**442,200**
Concrete basin walls (all in)	m3	350	--	--	225	78,750	8.00	75	210,000	**288,750**
Concrete elevated slabs (all in)	m3	646	--	--	250	161,500	10.00	75	484,500	**646,000**
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	2,622	--	--	200	524,400	4.00	75	786,600	**1,311,000**
Ductile iron cement pipe 12" diam. for fire water line	ft	800	--	--	100	80,000	0.60	95	45,600	**125,600**

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	4,264	--	--	--	--	0.08	200	68,224	**68,224**
Excavation for PCCP pipe	m3	14,340	--	--	--	--	0.04	200	114,720	**114,720**
Fencing around transformers	m	50	--	--	30	1,500	1.00	75	3,750	**5,250**
Flange for PCCP joints 30"	ea	22	--	--	2,260	49,720	16.00	95	33,440	**83,160**
Flange for PCCP joints 72"	ea	8	--	--	9,860	78,880	25.00	95	19,000	**97,880**
Flange for PCCP joints 84"	ea	16	--	--	13,210	211,360	30.00	95	45,600	**256,960**
Foundations for pipe racks and cable racks	m3	190	--	--	250	47,500	8.00	75	114,000	**161,500**
FRP flange 30"	ea	82	--	--	1,679	137,690	50.00	85	348,500	**486,190**
FRP flange 60'	ea	12	--	--	7,785	93,424	100.00	85	102,000	**195,424**
FRP flange 72"	ea	20	--	--	20,888	417,754	200.00	85	340,000	**757,754**
FRP flange 84"	ea	8	--	--	33,381	267,048	300.00	85	204,000	**471,048**
FRP pipe 60" diam.	ft	200	--	--	615	122,980	0.90	85	15,300	**138,280**
FRP pipe 84" diam.	ft	1,800	--	--	946	1,702,800	1.50	85	229,500	**1,932,300**
Harness clamp 24" c/w external testable joint	ea	20	--	--	1,715	34,300	14.00	95	26,600	**60,900**
Harness clamp 30" & 36"c/w internal testable joint	ea	40	--	--	2,000	80,000	16.00	95	60,800	**140,800**
Harness clamp 72" c/w internal testable joint	ea	80	--	--	2,440	195,200	18.00	95	136,800	**332,000**
Harness clamp 84" c/w internal testable joint	ea	70	--	--	2,845	199,150	20.00	95	133,000	**332,150**
Joint for FRP pipe 84" diam.	ea	60	--	--	5,014	300,828	300.00	85	1,530,000	**1,830,828**
Joint for FRP pipe 60" diam.	ea	10	--	--	1,797	17,974	100.00	85	85,000	**102,974**
PCCP pipe 24" dia. For blowdown	ft	400	--	--	98	39,200	0.50	95	19,000	**58,200**
PCCP pipe 30" dia. for make-up	ft	700	--	--	125	87,500	0.70	95	46,550	**134,050**
PCCP pipe 72" diam.	ft	1,600	--	--	507	811,200	1.30	95	197,600	**1,008,800**
PCCP pipe 84" diam.	ft	1,400	--	--	562	786,800	1.50	95	199,500	**986,300**
Riser (FRP pipe 30" diam X55 ft)	ea	20	--	--	15,350	306,996	150.00	85	255,000	**561,996**
Structural steel for building	t	315	--	--	2,500	787,500	20.00	105	661,500	**1,449,000**
CIVIL / STRUCTURAL / PIPING TOTAL	**--**	**--**	**--**	**4,729,600**	**--**	**10,210,904**	**--**	**--**	**9,070,046**	**24,010,550**
DEMOLITION	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
Allocation for relocation of pumps, pipes, controls and other associated works	lot	1	--	--	125,000	125,000	1,250.00	100	125,000	**250,000**
Excavation and disposal of non contaminated material for the relocated pond	m3	12,750	--	--	--	--	0.12	100	153,000	**153,000**
Filling existing pond (approx 300 ft X 100 ft X 5m deep assumed) with granular material	m3	12,750	--	--	25	318,747	0.04	100	51,000	**369,746**

Description	Unit	Qty	Equipment		Bulk material		Labor			Total cost ($)
			Unit price ($)	Total price ($)	Unit price ($)	Total price ($)	Unit (Mhr)	Rate ($)	Total price ($)	
Membranes and sand bedding	lot	1	--	--	100,000	100,000	1,000.00	100	100,000	**200,000**
DEMOLITION TOTAL	--	--	--	0	--	543,747	--	--	429,000	972,746
ELECTRICAL	--	--	--	--	--	--	--	--	--	--
4.16 kv cabling feeding MCC's	m	1,000	--	--	75	75,000	0.40	85	34,000	**109,000**
4.16kV switchgear - 4 breakers	ea	1	250,000	250,000	--	--	175.00	85	14,875	**264,875**
480 volt cabling feeding MCC's	m	750	--	--	70	52,500	0.40	85	25,500	**78,000**
480V Switchgear - 1 breaker 3000A	ea	4	30,000	120,000	--	--	80.00	85	27,200	**147,200**
Allocation for automation and control	lot	1	--	--	750,000	750,000	7,500.00	85	637,500	**1,387,500**
Allocation for cable trays and duct banks	m	1,300	--	--	75	97,500	1.00	85	110,500	**208,000**
Allocation for lighting and lightning protection	lot	1	--	--	100,000	100,000	1,000.00	85	85,000	**185,000**
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	2	--	--	50,000	100,000	500.00	85	85,000	**185,000**
Local feeder for 200 HP motor 460 V (up to MCC)	ea	20	--	--	15,000	300,000	140.00	85	238,000	**538,000**
Local feeder for 2000 HP motor 4160 V (up to MCC)	ea	4	--	--	40,000	160,000	160.00	85	54,400	**214,400**
Oil Transformer 10/13.3MVA xx-4.16kV	ea	2	190,000	380,000	--	--	150.00	85	25,500	**405,500**
Primary breaker(xxkV)	ea	4	45,000	180,000	--	--	60.00	85	20,400	**200,400**
Primary feed cabling (assumed 13.8 kv)	m	2,000	--	--	175	350,000	0.50	85	85,000	**435,000**
ELECTRICAL TOTAL	--	--	--	1,330,000	--	1,985,000	--	--	1,476,875	4,791,875
MECHANICAL	--	--	--	--	--	--	--	--	--	--
Allocation for ventilation of buildings	ea	2	100,000	200,000	--	--	1,000.00	85	170,000	**370,000**
Cooling tower for unit 3	lot	1	6,300,000	6,300,000	--	--	--	--	--	**6,300,000**
Cooling tower for unit 4	lot	1	6,300,000	6,300,000	--	--	--	--	--	**6,300,000**
Overhead crane 50 ton in (in pump house) Including additional structure to reduce the span	ea	2	500,000	1,000,000	--	--	1,000.00	85	170,000	**1,170,000**
Pump 4160 V 2000 HP	ea	4	1,000,000	4,000,000	--	--	500.00	85	170,000	**4,170,000**
MECHANICAL TOTAL	--	--	--	17,800,000	--	0	--	--	510,000	18,310,000

Appendix C. Net Present Cost Calculation

Project year	Capital/start-up ($)	O & M ($)	Energy penalty ($)		Total ($)	Annual discount factor	Present value ($)
			Unit 3	Unit 4			
0	78,100,000	--	--	--	78,100,000	1	**78,100,000**
1	--	316,080	297,657	258,182	871,919	0.9346	**814,896**
2	--	322,402	315,011	273,234	910,646	0.8734	**795,358**
3	--	328,850	333,376	289,163	951,389	0.8163	**776,619**
4	--	335,427	352,812	306,022	994,260	0.7629	**758,521**
5	--	342,135	373,380	323,863	1,039,378	0.713	**741,077**
6	--	348,978	395,149	342,744	1,086,870	0.6663	**724,182**
7	--	355,957	418,186	362,726	1,136,869	0.6227	**707,928**
8	--	363,077	442,566	383,873	1,189,515	0.582	**692,298**
9	--	370,338	468,368	406,253	1,244,958	0.5439	**677,133**
10	--	377,745	495,673	429,937	1,303,355	0.5083	**662,495**
11	--	385,300	524,571	455,002	1,364,873	0.4751	**648,451**
12	--	467,482	555,154	481,529	1,504,165	0.444	**667,849**
13	--	476,832	587,519	509,602	1,573,953	0.415	**653,191**
14	--	486,369	621,771	539,312	1,647,452	0.3878	**638,882**
15	--	496,096	658,021	570,754	1,724,871	0.3624	**625,093**
16	--	506,018	696,383	604,029	1,806,430	0.3387	**611,838**
17	--	516,138	736,982	639,244	1,892,364	0.3166	**599,123**
18	--	526,461	779,949	676,512	1,982,921	0.2959	**586,746**
19	--	536,990	825,420	715,952	2,078,362	0.2765	**574,667**
20	--	547,730	873,542	757,692	2,178,964	0.2584	**563,044**
Total							**91,619,391**