Appendix VIII-3

Cooling Tower Evaluation

Economic and Environmental Review of Closed Cooling Water Systems for the Hudson River Power Plants

Prepared for

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Economic and Environmental Review of Closed Cooling Water Systems for the Hudson River Power Plants

APPENDIX A. COST ESTIMATING AND ECONOMIC ANALYSES OF COOLING TOWER SYSTEMS

Economic and Environmental Review of Closed Cooling Water Systems for the Hudson River Power Plants

1. Introduction

Power Tech Associates, P.C. was requested by the Central Hudson Gas and Electric Corp., Consolidated Edison Company of New York, Inc., New York Power Authority, and Southern Energy New York to prepare a report on the design and consequences of installing closed cooling water systems at four power plants on the lower Hudson River. The plants included in the study are Bowline Point Units 1 & 2, Indian Point Unit 2 and Unit 3, and Roseton Units 1 & 2 (the Hudson River Plants). Extensive studies of closed cooling system installations at each of these plants have been performed in the past. [References 1, 2, 3, 4, 5, 6]. These studies indicated that cooling towers were the technology of choice for closed cooling systems, and focussed on the design, cost and impacts of such systems. The current effort included: detailed review of these studies; revision of designs including different cooling tower types; new cost estimates; and new performance and economic analyses to reflect conditions in 1999. In addition, the environmental impacts assessments in the original studies were adjusted to reflect differences in cooling tower design and performance where applicable. This study does not reflect current modeling or field studies to determine the effects of air impacts such as fogging, icing and plume abatement.

At present, the Hudson River Plants employ once-through cooling systems which withdraw large quantities of water from the Hudson River, transfer waste heat to the water, and return it to the river. A class of alternatives to these systems are closed-cycle systems which transfer waste heat to a recirculating fluid, typically water, which in turn transfers heat to the atmosphere through evaporation, convection, or both. Closed cycle cooling systems require significantly smaller volumes of river water. They can use evaporative ponds, spray ponds, or cooling towers to transfer heat to the atmosphere. Cooling towers are the most commonly used means for accomplishing the required heat rejection, as evaporative ponds and spray ponds tend to require substantially more space. Because of the limited space available at each site, realistic choices for closed cooling systems for the Hudson River plants are limited to cooling tower based systems.

Cooling towers can be of several types and are characterized by whether or not air makes contact with the cooling water and water is evaporated, and the means by which air is circulated through the tower. In wet cooling towers, the water to be cooled is pumped to the top of an array of fill material which it cascades over, either splashing or running in thin films, or both, to maximize the surface area of water which is exposed to the air. The air flows through the fill either in counter or cross flow to the water. Some of the warm water evaporates and the remaining water is cooled. In dry cooling towers, the water circulates through the inside of tubes and the air flows around the outside of the tubes with no direct contact with or evaporation of the water. Some towers use a combination of these two designs.

Wet cooling towers can produce potentially deleterious environmental impacts in four ways which are essentially absent in the case of dry towers. These are plumes, drift, evaporation, and blowdown. Plumes are the result of the vapor added to the air in the heat rejection process condensing into visible moisture droplets and can result in fog, icing, and significant visual impacts. Drift is the entrainment of droplets of cooling water directly into the air. While the quantity of water contained in these droplets is many orders of magnitude smaller than the quantity of vapor which results from the evaporation process, these droplets contain dissolved and suspended minerals and other substances that are absent from the vapor. Among other effects, drift can result in the deposit of damaging salts on surrounding vegetation.

Typically, the majority of the heat rejection from a wet cooling tower is through the evaporation of water. Approximately ten gallons of water is evaporated per minute for each MW of plant output. This evaporation represents a net withdrawal from the river. Because of the evaporation of cooling water, salts and other chemicals concentrate in the closed cooling system. In order to keep the concentrations of these substances below levels where they have deleterious effects on materials and operations, some cooling water is discharged as blowdown. This blowdown is generally returned to the river and may be the source of heated water with higher concentrations of salts which occur naturally in the river and any other chemicals which were present in the water originally, as well as those chemicals added to the water circulated in the closed cooling system. Because of the need for blowdown, extra water, beyond that required to make up for evaporation, is withdrawn from the river. The total make up flow is usually in the range of one and one quarter to two times the evaporation rate.

While dry towers avoid many of the impacts of wet towers, the efficiency of the heat transfer mechanism without direct contact and evaporation is so low that dry towers are essentially impractical as potential retrofits to the Hudson River Plants. The low efficiency of the heat transfer mechanism results in cooling water temperatures that are too high to be acceptable because of the plants' turbine designs, and in space requirements that exceed the available area. In general dry towers are only used for new generating facilities, and then only when even modest water withdrawals or very minor plume effects are objectionable.

While the use of totally dry towers is not considered technically or economically feasible for the Hudson River Plants, the addition of a dry cooling section to an otherwise wet type cooling tower may offer significant benefits in reducing the frequency of plume formation and resultant fogging or icing. The inclusion of the dry sections make wet/dry towers tend to be somewhat taller and considerably more costly than wet towers. A wet dry tower which would yield virtually no fogging or icing in the Hudson River would be approximately ten feet taller and would result in a system cost approximately 15 % greater than an equivalent all wet tower.

In natural draft cooling towers, a large cylindrical structure with a hyperbolic profile is constructed above the fill or cooling tubes and a chimney effect is created to promote air flow through the fill or tubes. These towers tend to be quite large and would be on the order of from 400 to nearly 600 feet high for the Hudson River Plants. Mechanical draft towers use large fans located above the fill or tubes to draw the air through the tower. Mechanical draft towers for the Hudson River plants would be on the order of fifty feet high. While natural draft cooling towers offer the advantage of reduced energy consumption, lower noise levels, and less localized fogging, icing, and drift deposition, the overwhelming aesthetic impact caused by their sheer bulk makes them poor candidates for the Hudson River plants.

Studies performed in the 1970s [References 1, 2, 3, 4, 6] determined that natural draft hyperbolic type towers were in some cases the economically optimum type of cooling towers for the Hudson River Plants. However, the differences in costs between natural draft and mechanical draft towers were minor except at Indian Point 3. At Indian Point 3, the arrangement of the mechanical towers required substantially more excavation and other site work than the natural cooling system design. For this study, a new arrangement was developed to reduce the cost differences between mechanical and natural draft tower systems.

For purposes of evaluating alternatives for the existing Hudson River Plants, this study has focused on closed cooling systems using wet/dry mechanical draft towers because they address the issues of aesthetics, fogging, and icing

2. Technology Review

In steam cycle power plants, such as the Hudson River Plants, after the steam produced in the boilers or steam generators flows through the turbines providing the energy required to rotate them and produce electricity, it is condensed in large heat exchanger vessels. These vessels, called condensers, are filled with thousands of tubes through which circulating water flows. The circulating water is warmed in the condenser as it absorbs the heat given off by the condensing steam. The circulating water is often also used to remove heat from auxiliary cooling systems in the plants, but these loads are minor in comparison to the condensers.

In the case of the current configuration for the Hudson River Plants, the circulating water is drawn directly from the river and returned to it. This configuration is termed once through cooling. The alternative considered here is closed cycle cooling, where the warmed circulating water flows from the outlet of the condensers to a heat rejection device such as a cooling tower or spray pond, and is recirculated back to the condensers.

The temperature and amount of circulating water entering the condenser help determine the temperature and therefore the pressure at which the steam condenses. The condensing pressure influences the amount of power that can be generated, as well as the thermal efficiency with which it is generated. As the condensing pressure rises, less energy is extracted from the steam by the turbine, and power generation and efficiency decline. The steam turbines in large power plants, including the Hudson River Plants, are highly engineered so that each of the many stages operate efficiently in relatively narrow ranges of pressure and temperature. Operating beyond these ranges, in addition to reducing performance, can lead to substantial equipment damage. Thus, it is important for a closed cooling system to maintain the circulating water conditions in a range which can allow acceptable condensing pressures.

In the vast majority of closed cycle systems, the heat from the circulating water is rejected to the atmosphere. This may be done using cooling ponds, spray ponds, or cooling towers.

2.1 Cooling Ponds

For cooling ponds to provide adequate heat removal, the surface area of the ponds must be large enough for sufficient exchange of heat by evaporation and contact with the air. The large, relatively smooth surfaces of the ponds make for inefficient contact between the air and water so that large areas are required. Studies of the use of cooling ponds for the Hudson River Plants indicated that between several hundred and a few thousand acres would be needed.[References 2, 3] None of the plant sites have areas of this magnitude available.

Several techniques have been developed to enhance the efficiencies of cooling ponds. Spray heads are among the most effective of these methods. Water is drawn from the ponds, ejected through spray heads, and allowed to splash back into the ponds. The droplets formed by the spray heads have large surface to volume ratios and evaporative cooling can take place efficiently as they travel through the air. The splashing further increase the amount of liquid surface in contact with the air. These benefits come with the costs of increased complexity in systems and equipment, and the energy costs for pumping. Spray ponds also produce localized fogging and icing and deposition of solids, such as salt, to a much greater extent than cooling towers. Spray ponds or canals for the Hudson River plants were studied, and the sizes can be expected to range from 40 to 100 acres [References 2 and 3]. Again, this exceeds the amount of land available for such purposes at the plant sites.

2.2 Wet Cooling Towers

The devices most commonly used to transfer heat from the circulating water to the atmosphere in closed loop cooling systems are cooling towers. Cooling towers may be wet or dry and use natural circulation or mechanically impelled air flow to cool the water. A typical wet tower consists of a framework on the order of forty five feet high supporting fill material consisting of a large array of baffles designed to promote water flowing downward as a thin film while air flows upward through the narrow channels the baffles form. Headers with spray nozzles are arrayed above the fill. Mechanical draft towers are typically constructed as cells which may be round or, as is more usually the case, square or nearly so. Many cells are usually located in single rows to form large towers, although towers consisting of double rows of cells are used in some cases to better fit available spaces. Water is pumped up to the headers and sprayed along the top of the fill. It then flows in thin films down over the thousands of square feet of fill surface to a basin located beneath the tower, which collects the water and channels it to a sump where recirculating pumps are located.

A large space is provided between the bottom of the fill and the basin, which allows air to enter. The air flows upward through the packing, making close contact with the extensive water surface. In the case of mechanical draft towers, the air is drawn through the packing by fans located at the top of the tower. This flow pattern is designated counterflow because the air flows in the opposite direction, or counter to, the water flow direction. An alternative to this is the crossflow pattern. In crossflow towers air is drawn in through the sides of the tower and it flows across the path of the falling water (see Figure 2 – 1). In crossflow towers, the large space between the bottom of the fill and the basin is not required, but the efficiency of the contact between the water and air tends to be lower.

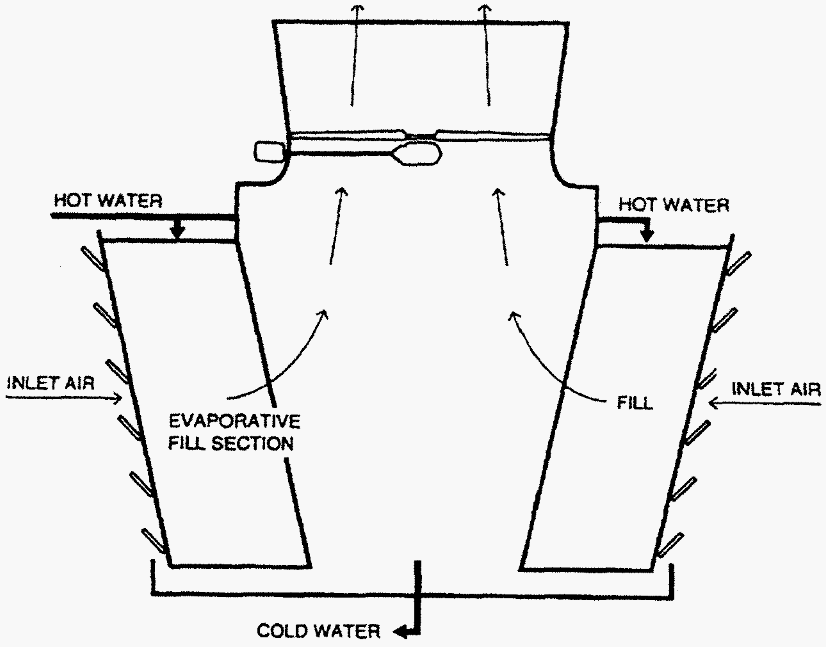

Figure 2 - 1 Air And Water Flow In A Cross Flow Mechanical Draft Cooling Tower {Courtesy of The Marley Cooling Tower Company - Ref. 7}

Natural draft towers are usually circular with a large open space in the center so that the packing forms a ring. Large hollow cylindrical structures with hyperbolic profiles that are the most noticeable feature of these towers are built above the

ring shaped arrays of fill. These cylindrical structures essentially serve as chimneys which promote the upward flow of the air that has flowed through the fill and been made more buoyant by warming and evaporation. This chimney effect draws air through the fill in place of the fans used in mechanical draft towers, thus reducing noise and eliminating the power loads associated with the fans.

The cylindrical "chimneys" add substantially to the cost of natural draft towers so that they normally have higher capital costs then mechanical draft towers for the same conditions and loads. The absence of fans with their associated power requirements reduces their operating costs. For this reason, natural draft towers may have lower evaluated costs over the life of a power plant. The shorter the life of a plant and the lower the cost of replacement electric power or replacing generation capability, the less likely the natural draft tower is to prove the economic choice. Studies indicated that, except in the case of Indian Point 3 where the terrain presents special circumstances, the total evaluated cost differences between natural and mechanical draft towers for the Hudson River plants would be in the range of a few percent of the overall costs. Natural draft cooling towers of the capacity required for the Hudson River Plants range in height from nearly four hundred to six hundred feet.

When wet cooling towers are used, the condenser inlet temperature, which is the same as the cooling tower outlet temperature, is largely determined by the ambient wet bulb temperature and the cooling tower design. The wet bulb temperature is essentially the minimum temperature which water may be cooled to by contact with air at a given temperature and moisture content. A cooling tower with ideal contact between the air and the water would be required for the cooling water to reach this temperature. Since the amount of air which can be drawn through the tower, the surface area of water that can be obtained for a given flow rate, and the length of the contact time between the water and air are all limited in a real design, cooling towers for power plants cool water to no closer than several degrees above the ambient wet bulb temperature. The temperature difference between the water leaving the tower and the wet bulb temperature is known as the approach. For a given flow rate and heat load, the lower the approach, the larger and more costly the tower.

Closed cooling systems are generally designed to provide a satisfactory cooling water temperature for a design condition such as the wet bulb temperature which is not exceeded more than 5% of the time during the summer. A tower designed for a 10 degree approach at 75 F wet bulb and a 2.8 billion Btu/hr heat load and a flow of 320,000 gal per minute (gpm) will deliver 85 F cooling water under these conditions. At higher wet bulb temperatures the cooling water temperature will be higher. For cooling towers in the range of interest for this study the change in cooling water temperature is about half the change in ambient wet bulb temperature. Thus an increase in wet bulb temperature to 81F will result in an increase in cooling water temperature to about 88 F, and a decrease in wet bulb to 65 F will result in a cooling tower outlet water temperature of about 80 F. With cooler weather and lower wet bulb temperatures, the cooling tower outlet temperature will drop and the reduction in unit output (derating) caused by the use of a closed cooling systems will decline. In fact, there may be no temperature based derating for much of the year.

With wet cooling towers, the majority of the heat transfer from the water to the atmosphere occurs through evaporation. The evaporation leads to several environmental effects including plume formation. Plume formation occurs when the air exiting the tower carries enough moisture for droplets of water to form. The droplets can form as the moist warm air which has been in contact with the water mixes with cooler air from outside the tower, if the temperature of the resulting mixture of water and vapor is below the saturation temperature for the amount of moisture present.

2.3 Wet/Dry Cooling Towers

Since the plume from a wet cooling tower is caused by the moisture content of the air above the cooling tower exceeding the saturation level for the air temperature, two mechanisms may be invoked to reduce the frequency of plume formation.

The amount of moisture transferred to the air can be reduced and the temperature of the air can be increased. Incorporating a dry heat transfer section into a mechanical cooling tower can accomplish both. In a dry heat transfer section, the warm water flows through tubes and air flows around the outside of the tubes removing heat from the water (see Figure 2 – 2). Thus, the air is heated without having absorbed any additional moisture. This process tends to be much less efficient per unit of surface area than the direct contact in wet towers and totally dry towers are very much larger than their wet tower equivalents.

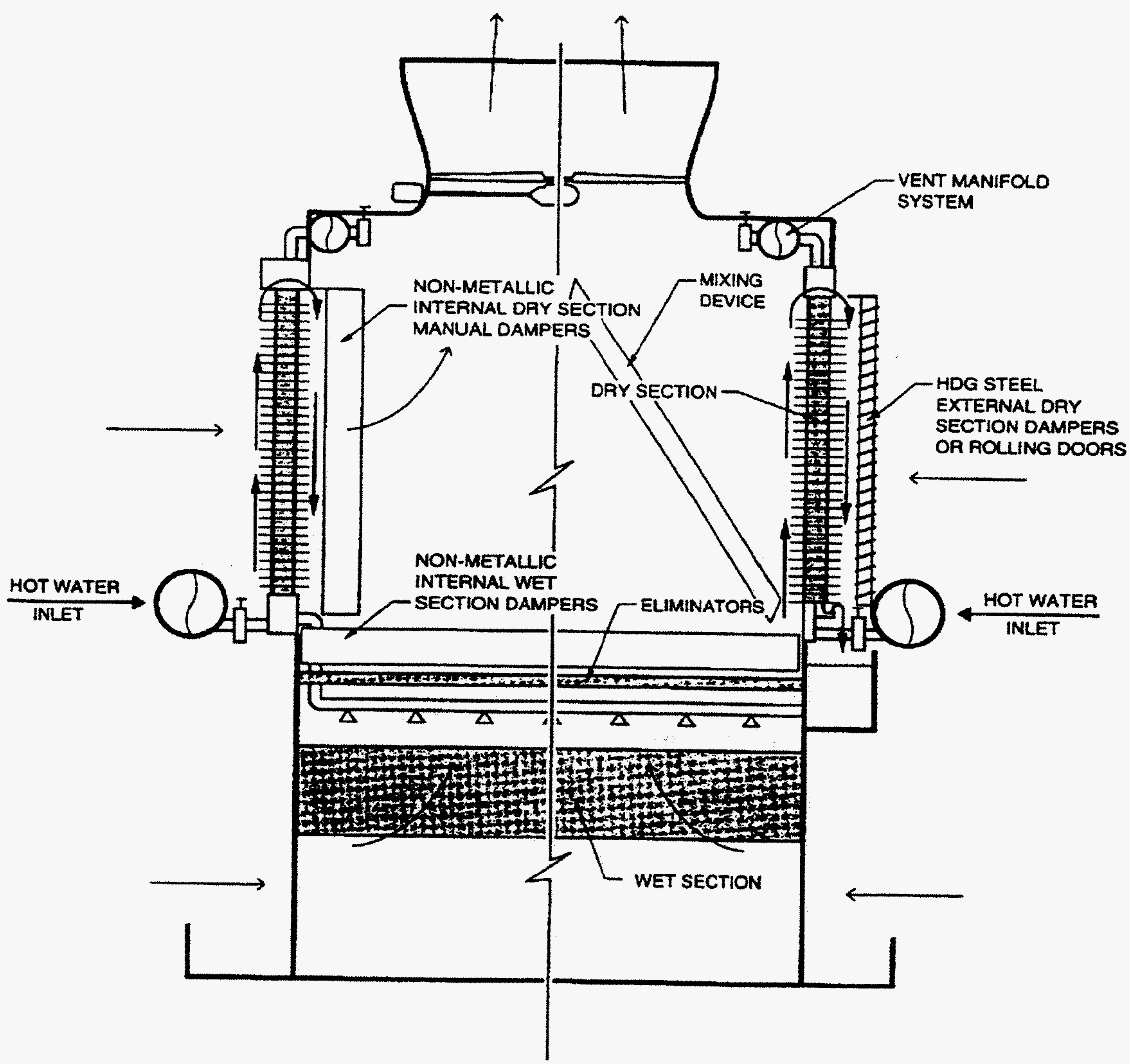

Figure 2 – 2 Schematic Diagram For Wet-Dry Tower {Courtesy of The Marley Cooling Tower Company - Ref.7}

A dry section in a wet tower, by providing a stream of relatively warm dry air to be mixed with the air from the wet sections, can dramatically reduce the tendency for droplet formation. These sections are space consuming and costly. A wet dry/tower designed to eliminate plumes under most conditions in the Hudson

Valley region will cost on the order of twice as much as the equivalent mechanical draft wet tower. However, since the direct cost of wet towers are much less than one quarter of the cost for closed cooling systems, the effect of using wet/dry towers is much less than a 25 percent increase in the overall construction costs, and wet/dry towers are viewed as the alternative which should receive primary consideration.

2.4 Dry Cooling Towers

Two different configurations may be used for dry cooling. In one configuration the water used in the condenser to remove heat from the steam then flows through large arrays of tubes or channels arranged in towers. Large fans are used to force air to flow around these tubes or channels and remove the heat from the water.

The second dry tower configuration is where the steam from the turbine is routed directly to the large radiator like towers. The towers, in effect, replace the traditional water cooled condensers. With the use of these dry condensers, the intermediate loop of cooling water between the condenser and the cooling tower is eliminated and the condensation temperature can more closely approach that of the ambient air.

The major obstacle to using the first configuration is that air flowing around the tubes is not very effective at heat removal so that both very large towers and a substantial temperature difference between the ambient air temperature and the cooling water are required. This, coupled with the temperature difference required between the steam and the condenser cooling water, results in condensing temperatures very much higher than the ambient air temperature, even when very large towers are used. For example, a dry cooling tower system covering approximately three and one half times the area of a wet tower and standing twice as high, would cool water to a temperature more than thirty degrees higher than the wet tower. This higher cooling water temperature would result in steam condensing at a thirty degree higher temperature which would yield large performance penalties. Even more important, such a cooling system would require substantial reductions in steam flow when ambient temperatures were high, to prevent damaging the turbines. For the Hudson River Plants, reductions in steam flow would have to begin once the ambient dry bulb temperature reached the mid 70's. Thus, this type of dry cooling system is inappropriate for further study.

To use the second dry tower configuration i.e., dry condensers, on the existing plants would require removal of the existing condensers and the routing of four to six fourteen foot diameter ducts from under the turbines to large air cooled condensers. While no detailed engineering investigations were made, the probability of being able to route such large lines in the congested area where structural members provide critical support to the turbine generator is believed to be small. The modifications, if feasible at all, would take several months of plant down time. Once the ducts left the turbine building they would have to traverse several hundred feet to open areas large enough for the dry condensers. The dry condensers for this application would occupy approximately more than three times the area of wet (or wet/dry) mechanical draft towers. At 120 feet high, the dry condensers would be more than twice the height of the wet/dry towers chosen as the basis for evaluation.

The construction cost for a dry condenser system would be more than $100 million greater for each station than a wet/dry system. The extended shutdowns required for condenser removal and duct installation would impose further penalties of many millions of dollars and more than 4 MW of additional power beyond that needed for wet/dry tower systems would be required at each station.

No large power plant originally designed and constructed for once through cooling has been backfitted to utilize dry towers and serious questions remain about the technical feasibility, and in the case of the Indian Point Units, licensing issues involved.

Due to the higher capital costs, lower generation efficiency (a result of a higher condensing temperatures) and higher power requirements (a result of more and larger fans being needed), dry towers are usually used only where water is in such short supply that the make-up water required for a wet tower would result in a significant environmental impact. Dry towers eliminate many of the impacts associated with evaporative cooling (plumes, drift, blowdown), but more noise associated with the fans is produced, and there are increased visual impacts of the extensive structures which are typically much larger and higher than mechanical draft evaporative towers. More land must be cleared for the additional tower units required by the less efficient cooling.

3. System Design Descriptions

3.1 General

The designs for each plant are based on similar cooling tower technology, viz. mechanical draft wet/dry towers. Based on a conservative approach, the wet/dry mechanical draft type tower was chosen as the best way to evaluate economic and environmental concerns associated with retrofitting cooling towers to the Hudson River Plants.

The designs for the individual plants are described in the following sections.

3.2 Bowline Point

The Bowline Point Station is located on the west side of the Hudson River in the town of West Havestraw. The plant comprises two essentially identical 606 MW units. The existing circulating water system is described in Section IV.B.3 of the Draft Environmental Impact Statement (DEIS).

The closed cooling water system design selected as the base case in this study includes four wet/dry mechanical draft cooling towers, two for each of the two units. The cooling towers are located on a 13 acre site approximately 800 feet to the east of the units in a large level area between the units and the Hudson River. Each of the cooling towers is 432 feet long by 42 feet wide, by 50 high (from top of basin to the fan deck) and comprises 8 cells. A fan with a ten foot high vent stack is located centrally at the top of each cell. These tower structures are of pressure treated Douglas fir with stainless steel hardware. The dry section comprises Type 316 stainless steel tubes with aluminum fins. Below the dry section is the fill, which is of PVC, treated to resist fouling.

Each of the four cooling towers is designed to cool 160,500 gpm from 108°F to 90°F at a 75°F air inlet wet bulb temperature. The towers are designed to provide no visible plume at 20°F dry bulb temperature and 14.4°F wet bulb temperature. The fans are of low speed, low noise design and the towers are provided with inlet air baffles and splash shields to reduce noise to 50 dBA at 400 ft from the tower.

Each cooling tower is located above a concrete basin which collects the water falling through the fill and flowing from the tubes of the dry cooling section. The water in the basins of each pair of towers drains to a common sump where the cooling tower circulating pumps are located. The three cooling tower circulating pumps in each sump are capable of circulating 321,000 gpm to a unit's condensers through 120 inch diameter, concrete lined carbon steel pipes. The inner surfaces of all large circulating water pipes are cement mortar lined per AWWA C205, with the buried outside surfaces coated with coal tar per AWWA C203.

The system includes a Taprogge tube cleaning system which recirculates balls through the condenser tubes to reduce fouling. Water treatment systems are provided both for the cooling system and to provide the necessary cleanup of the blowdown. These systems include hypochlorite generation and injection, dechlorination of blowdown, with chlorine monitoring, and sulfuric acid injection into the cooling tower basins.

A makeup system is provided to withdraw river water from the existing intake structure. It includes 3 pumps located behind stationary screens and racks. The makeup system is sized to withdraw up to 20,000 gpm from the river.

The maximum evaporation rate is approximately 9,000 gpm. This evaporation rate, coupled with the 9,000 gpm capacity of the blowdown system, results in a cooling water concentration factor of two, i.e., the concentration of nonvolatile substances in the water supplied from the river is doubled in the cooling water as a result of evaporation.

The closed system design includes the capability to return to once through cooling if allowed or required. Cooling water to auxiliary loads is provided by four 8,000 gpm service water pumps, two for each unit, which take suction from the circulating water systems.

3.3 Indian Point 2

Indian Point 2 is located on the east side of the Hudson River in the town of Buchanan. Indian Point 2 is a pressurized water reactor plant with a net capacity of approximately 940 MW. The existing circulating water system has a throughput of 870,000 gpm and is described in Section IV.B.2 of the DEIS.

The closed cooling water system design selected as the base case in this study includes four wet/dry mechanical draft cooling towers. The cooling towers are located on 15 acres along the river to the north of the plant, approximately 1,000 feet to the north of the unit in a large wooded area.

Each of the cooling towers is 430 feet long by 42 feet wide, by 50 feet from the top of basin to the fan deck and comprises 8 cells. Each cell has a fan with a ten foot high vent stack located centrally at the top. The tower structures are of pressure treated Douglas fir with stainless steel hardware. The dry section comprises Type 316 stainless steel tubes with aluminum fins. Below the dry section is the fill, which is of PVC, treated to resist fouling. Each of the four cooling towers is designed to cool 150,000 gpm from 115°F to 90°F at a 75°F air inlet wet bulb temperature. The towers are designed to provide no visible plume at 20°F dry bulb temperature and 14.4°F wet bulb temperature. The fans are of low speed, low noise design and the towers are provided with inlet air baffles and splash shields to reduce noise to 50 dBA at 400 ft from the tower.

Each cooling tower is located above a concrete basin which collects the water falling through the fill and flowing from the tubes of the dry cooling section. All four towers are at the same elevation with the water level in the basins at about elevation 40 feet. The cooled water flows by gravity from each basin via a 90 inch pipe, to one of the two 120 inch headers, which collect all water in a common 13 foot wide, 15 foot high concrete tunnel. From this tunnel the water flows through three 120 inch pipes, one to each of the three condensers. After passing through the condensers, the heated water discharges to a common 13 foot wide 15 foot high concrete tunnel which feeds the four cooling tower circulating pumps. Each pump delivers water to one of the cooling towers via a 90 inch pipe line. All circulating water pipes are made of welded carbon steel. The inner surfaces are cement mortar lined per AWWA C205, with the buried outside surfaces coated with coal tar per AWWA C203.

Most of the piping is placed underground on a bed of sand and gravel within excavated trenches. Concrete anchor blocks are provided where changes in direction occur and where needed to support or restrain the pipe. The underground tunnels are made of reinforced concrete construction located outside the turbine building.

The cooling tower circulating water pumps are of the vertical shaft, dry pressurized type located in an excavated pump pit. The electric motor is located above the pump. All four pumps and their electrical motor control switchgear are enclosed in a pump house. An overhead gantry crane is provided for repair and if necessary, removal of the motor drives and pumps.

The system includes a Taprogge tube cleaning system which recirculates balls through the condenser tubes to reduce fouling. Water treatment systems are provided both for the cooling system and to provide the necessary cleanup of the blowdown. These systems include hypochlorite generation and injection, dechlorination of blowdown with residual chlorine level monitors, and sulfuric acid injection into the cooling tower basins.

A makeup system is provided to withdraw river water from the existing intake structure. It includes three pumps located behind appropriate screens and racks. The makeup system is sized to withdraw up to 24,000 gpm from the river.

The maximum evaporation rate is approximately 12,000 gpm. This evaporation rate, coupled with the 12,000 gpm capacity of the blowdown system, results in a cooling water concentration factor of two, i.e., the concentration of nonvolatile substances in the water supplied from the river is doubled in the cooling water as a result of evaporation. The closed system design includes the capability to return to once through cooling if allowed or required.

Cooling water to auxiliary loads, including safety system loads will continue to be provided by the service water pumps of the existing once through system.

3.4 Indian Point 3

Indian Point 3 is located on the east side of the Hudson River in the town of Buchanan. Indian Point 3 is a pressurized water reactor plant with a net capacity of approximately 970 MW. The existing circulating water system has a throughput of 870,000 gpm and is described in Section IV.B.2 of the DEIS.

The closed cooling water system design selected as the base case in this study includes two wet/dry mechanical draft cooling towers. The cooling towers are located on two sites to the south of the unit. Each site is approximately 6 acres. One site is located along the river and is approximately 350 feet to the south of the turbine building. The second site is approximately 400 feet to the east of the first. The location of the towers is on a steeply sloping shoreline. Extensive excavation is required and the tower site directly on the river will require substantial fill to provide a level area.

Each of the cooling towers is 432 feet long by 90 feet wide, 50 feet from the top of the basin to the fan deck, and comprises 16 cells arranged in two rows of 8 cells back to back. Each cell has a fan with a ten foot high vent stack located centrally at the top. The tower structures are of pressure treated Douglas fir with stainless steel hardware. The dry section comprises Type 316 stainless steel tubes with aluminum fins. Below the dry section is the fill, which is of PVC, treated to resist fouling. Each of the two cooling towers is designed to cool 300,000 gpm from 115°F to 90°F at a 75°F air inlet wet bulb temperature. The towers are designed to provide no visible plume at 20°F dry bulb temperature and 14.4°F wet bulb temperature. The fans are of low speed, low noise design and the towers are provided with inlet air baffles and splash shields to reduce noise to 50 dBA at 400 ft from the tower.

Each cooling tower is located above a concrete basin which collects the water falling through the fill and flowing from the tubes of the dry cooling section. The towers are installed at the same elevation with the water level in the basins at about elevation 50 feet. The cooled water flows by gravity from the basins via 120 inch diameter buried pipes to the turbine building where it is distributed to 6-84 inch pipes feeding the six condenser water boxes. The heated water is discharged from the condenser water boxes via 84 inch diameter pipes into the existing concrete discharge tunnel and from there to the open discharge channel which was designed to serve all three Indian Point units. The current discharge channel will be partly blocked off and the flow diverted to the new cooling tower circulating water pump house. Four vertical shaft wet pit, mixed flow cooling tower feed pumps are located in this pump house. Each pump discharges into a 120 inch pipe that feeds one cooling tower section of 8 cells.

All circulating water pipes are made of welded carbon steel with the inner surface cement mortar lined per AWWA C-205, and the buried outside surfaces coated with coal tar per AWWA C-203 specifications. Most of the circulating water pipe is placed on a bed of sand and gravel within excavated trenches. Concrete anchor blocks are provided where changes in direction occur, and where needed to support or restrain the pipe.

The system includes a Taprogge tube cleaning system which recirculates balls through the condenser tubes to reduce fouling. Water treatment systems are provided both for the cooling system and to provide the necessary cleanup of the blowdown. These systems include hypochlorite generation and injection, dechlorination of blowdown with residual chlorine level monitors, and sulfuric acid injection into the cooling tower basins.

A makeup system is provided to withdraw river water from the existing intake structure. It includes two pumps located behind appropriate screens and racks. The makeup system is sized to withdraw up to 24,000 gpm from the river.

The maximum evaporation rate is approximately 12,000 gpm. This evaporation rate coupled, with the 12,000 gpm capacity of the blowdown system, results in a cooling water concentration factor of two, i.e., the concentration of nonvolatile substances in the water supplied from the river is doubled in the cooling water as a result of evaporation. The closed system design includes the capability to return to once through cooling if allowed or required.

Cooling water to auxiliary loads, including safety system loads will continue to be provided by the service water pumps of the existing once through system.

3.5 Roseton

The Roseton Station is located on the west side of the Hudson River in the town of Roseton, just north of Newburgh. The plant comprises two essentially identical 600 MW units. The existing circulating water system is described in Section IV.B.1 of the DEIS.

The closed cooling water system design selected as the base case in this study includes four wet/dry mechanical draft cooling towers, two for each of the two units. Each of the cooling towers is 432 feet long by 42 feet wide, by 50 feet high (from top of basin to fan deck) and comprises 8 cells. Each cell has a fan with a ten foot high vent stack located centrally at the top. The tower structures are of pressure treated Douglas fir with stainless steel hardware. The dry section comprises Type 316 stainless steel tubes with aluminum fins. Below the dry section is the fill, which is of PVC, treated to resist fouling.

Each of the four cooling towers is designed to cool 160,500 gpm from 115°F to 90°F at a 75°F air inlet wet bulb temperature. The towers are designed to provide no visible plume at 20°F dry bulb temperature and 14.4°F wet bulb temperature. The fans are of low speed, low noise design and the towers are provided with inlet air baffles and splash shields to reduce noise to 50 dBA at 400 ft from the tower.

Each cooling towers is located above a concrete basin which collects the water falling through the fill and flowing from the tubes of the dry cooling section. The water in the basins of each pair of towers drains to a sump where the cooling tower circulating pumps are located.

The three cooling tower circulating pumps in each basin are capable of circulating 321,000 gpm to each unit's condensers through concrete lined carbon steel pipes.

The system includes a Taprogge tube cleaning system which recirculates balls through the condenser tubes to reduce fouling. Water treatment systems are provided both for the cooling system and to provide the necessary cleanup of the blowdown. These systems include hypochlorite generation and injection, dechlorination of blowdown with residual chlorine level monitors, and sulfuric acid injection into the cooling tower basins.

A makeup system is provided to withdraw river water from the exisiting intake structure. It includes three pumps located behind stationary screens and racks. The makeup system is sized to withdraw up to 20,000 gpm from the river.

The maximum evaporation rate is approximately 9,000 gpm. This evaporation rate, coupled with the 9,000 gpm capacity of the blowdown system, results in a cooling water concentration factor of two, i.e., the concentration of nonvolatile substances in the water supplied from the river is doubled in the cooling water as a result of evaporation.

The closed system design includes the capability to return to once through cooling if allowed or required. Cooling water to auxiliary loads is provided by six 6,000 gpm service water pumps, three for each generating unit. These pumps take suction from the 12 ft diameter circulating water intake tunnel. The service water system discharges into the 12 ft diameter circulating water discharge tunnel.

4. Economic Analysis

4.1 General Approach

The economic analysis of the use of cooling towers at the Hudson River plants included selecting the closed system designs, estimating their costs, and evaluating the effects of lost energy production and generation capacity. The comparative evaluation of the costs of retrofitting wet/dry cooling towers at the existing Hudson River Power Plants include not only the direct construction costs, but also operating and maintenance costs associated with the additional equipment; replacement energy and capacity costs due to equipment related deratings; and replacement energy and capacity costs during cooling tower tie-in and other periods during construction when plant operation may not be allowed. Details of the capital cost estimates and examples of economic analyses for each plant are contained in Appendix A.

The process of optimizing a closed cooling system for an existing plant revolves around two principal parameters, the flow rate and the condenser inlet temperature. These two parameters determine the condensing pressure of the steam and thus the output and efficiency that will result when the new system is installed and operated at the existing unit. As discussed in Section 2, the amount of power a plant generates, and the efficiency with which it generates it decrease, as the condensing pressure for the steam used in the cycle increases. Thus a cooling system which provides more and cooler water for the condenser allows the steam to condense at a lower pressure so more power can be generated and less fuel is needed per unit of power produced. On the other hand, the larger the flow, the greater the pumping power costs. Similarly, the costs for piping, valves and cooling towers rise with increasing flow rates. The greater the cooling offered by a tower (the smaller the approach to the wet bulb temperature) the more it costs and, with mechanical draft towers, the more fan power is required. Thus, the choice of the most economical closed cooling system is a tradeoff of lost capability from the generator versus increased capital and operating costs for the cooling system.

The optimization process requires developing estimates of the costs of the system, the power consumed by the pumps and fans, the operation and maintenance costs for the system, and the value of the lost capacity and power generation resulting from the closed system for a reasonable range of flow rates and condenser inlet temperatures. Designs from earlier studies were reviewed and generally found to be reasonable points of departure for revisions. Cooling tower manufacturers were contacted for information on costs, dimensions, performance, and power needs. Vendors of other major items were contacted for up to date cost data. The system arrangements were modified as deemed suitable for the latest site conditions and cooling tower design information. Material quantities were developed and capital cost estimates prepared.

Power consumption for pumps was estimated based on arrangements, pipe sizes, tower elevations, and flow rates. Power consumption for fans was based on manufacturers data. Operation and maintenance costs were estimated based on typical power plant experience for similar systems.

As noted above, closed cooling systems are generally designed to provide a satisfactory cooling water temperature for a design condition such as the wet bulb temperature which is not exceeded more than 5% of the time during the summer. In the case of the Hudson River Plants this is about 75 F wet bulb. A more stringent condition is that the plant remain available for conditions which are not exceeded more than 1% of the summer hours. This would be approximately 81 F wet bulb.

The value of electric generation has traditionally included two components, capacity and energy. In order to assure that the demand for electricity can be met, utilities have been required to provide adequate generation capacity equal to the largest anticipated load plus a margin for both planned and unplanned outages. The cost for providing this capacity was included both in the rates for electric energy use for residential customers and the demand charge for larger customers. It is not clear what form capacity payments will take in future, deregulated markets. A reasonable approach would include capacity payments on a monthly basis with seasonal adjustments in the capacity payment since more power will be needed in the peak summer season. This means that some of the capacity during these months would be supplied by units which run less of the time and must be able to write off their capital costs over fewer hours of chargeable availability, and thus would be more expensive. The seasonal peak in the value of capacity can be expected to coincide with the summer months and therefore, with the period for higher deratings. This probable scenario was reflected in the economic analysis.

Since a plant owner is paid for capacity on the basis that it will be available under the most demanding conditions, it makes sense that the summer capacity derating be for the more stringent condition indicated above, viz. 81 F wet bulb. The derating is the difference in power available from the units with their current cooling systems operating with a river temperature which occurs no more than 1% of the summer hours and the same unit with a closed cooling water system at 81 F wet bulb.

The price of electrical energy follows a similar pattern, with higher prices for energy in the summer months. Energy use tends to peak during weekdays and the most expensive, least efficient plants on a system may be required to meet load and reserve requirements. Thus energy prices follow a daily and weekly pattern with prices considerably higher during weekdays, and lower at night and on weekends, when commercial and industrial loads are lower.

To reflect the variable nature of the price of electric energy, the year was divided into two seasons, each with off peak and on peak periods.

Wholesale prices from the PJM grid for 1998 [Reference 8] were used as a basis for energy prices used in the economic analysis of the effects of closed cooling systems on the Hudson River Plants. The PJM grid serves the Pennsylvania, New Jersey, and Maryland region and is interconnected with the New York Power Pool. It is the largest independently operated transmission system in the United States with a peak load of over 48,000 MW. PJM prices were chosen because they were considered to be a conservative indicator for the unregulated transactions that will be typical of the power market in New York in the future.

The evaluation of the value of lost capacity and power generation required a multiple step approach. A computer routine was developed which, using the original design conditions as input, determined the condensing pressure as a function of the new cooling water flow rates and inlet temperatures. Manufacturers' and test data supplied by the utilities was used to determine the unit capacities as a function of condensing pressure.

The additional auxiliary power loads were principally from the cooling tower fans and the increased pump power required to raise the water to the top of the fill in the towers and to provide the pressure drop associated with tubes and spray nozzles in the towers. These additional pressure requirements generally overshadowed any decreases in power resulting from the generally lower flow rates used in the closed cooling systems. The pressure drop through the new circulating water lines was compared with estimates for the existing lines. The pressure drop through the condenser was adjusted from values for the existing once through systems to those appropriate for the new closed system flow rates. All the estimates of the closed system pressure drops were based on the pressure drop information received from the cooling tower manufacturers, data from the original plant studies, and the designs and layouts produced as part of the cost estimating effort. Fan power was taken from the cooling tower manufacturers data.

The loss of capacity and the increased power consumption for the closed cooling system were combined into an overall derating which varied seasonally. Climate data from Stewart Air Field were reviewed to verify peak values which were used to determine capacity deratings, and to establish seasonal average conditions to be used in determining the average energy production deratings. Note that the full value for both capacity and energy production losses are used since the reduced plant output is not accompanied by any reduction in operating costs and the deratings must be made up by other facilities without any lesser expense accruing to the Hudson River Plants.

The annual value of the lost capacity was calculated as the product of the derating for the season and the monthly capacity charge for that season. It was assumed that each of the plants would experience about one month of outage during the winter months. The value of the lost energy production was calculated for each season for on peak and off peak periods. The expected plant load was obtained from the utilities.

All costs were exclusive of escalation and current actual interest rates were adjusted downward to reflect the value that would be used in the case of zero inflation. It was assumed that current interest rates include 4% to account for current and expected inflation so that a 8% total rate indicates a 4% escalation free interest rate. The escalation free interest rate applied to Indian Point 3 was 3%, in recognition of the fact that a public agency may obtain funds at lower rates.

The annual costs included the interest and capital recovery payments for the closed cooling systems' total capital costs (including interest during construction and owner's costs), property taxes, and operating and maintenance costs. This was added to the value of lost energy production and capacity to develop a total annual cost. The annual cost for each year was then discounted by the "true" (escalation free) interest rate and summed to arrive at the total 1999 cost.

Other costs attributable to the installation of the closed cooling systems are the loss of production and capacity during the periods the plants must be shut down for construction and commissioning beyond the normal shutdowns of the plants. In the cases of Roseton and Bowline, this period was estimated at one month beyond normal outages. Since the energy production costs for these plants are comparable to alternative sources, only lost capacity costs were included. It was assumed that the additional down time would occur in the winter months.

The fuel and other variable operating power production costs for the nuclear plants are well below that for alternative sources, and the additional downtime for construction and commissioning can have a substantial economic impact. This is especially true considering the safety issues that have to be addressed during excavation (particularly when blasting is required), tying the new system into the plant, and the extensive testing which must follow. The cost of lost capacity for the nuclear plants was estimated at four months of full plant capacity at winter rates for two different periods, the first during the blasting and the second during the tying in. The value of the lost energy production was estimated at eight months at full capacity at winter rates less $8.00 per MWh to approximate the fuel and other variable operating costs that will not be incurred while the plants are shut down.

The values of lost capacity and energy production during the construction and tying in were discounted from the years in which they would occur back to 1999.

In calculating the costs it was assumed that design, permitting and other pre-construction activities for the Indian Point Units could be completed in 40 months. Considering the potential for delays associated with filling along the Hudson River and major modifications to nuclear power plants, this is considered aggressive. Similarly, the three year construction schedule assumed is not conservative. Extensive delays in receiving permits and approvals would further reduce the period during which the cooling towers would provide any benefits. While extended delays would reduce the present value of the eventual major capital expenditures by postponing them to the future, legal, management, technical support and other licensing and procedural costs which are not included in these estimates can be expected to rise significantly.

The Roseton and Bowline Plants were assumed to complete permitting and other pre-construction activities by mid 2003 and construction was estimated to be completed by the end of 2005. This is also considered non-conservative and assumes agreement is reached on implementing the towers early in 2000, a circumstance that is unlikely.

Optimization/sensitivity studies indicated that the total evaluated cost of the closed cooling systems remained fairly constant over the range of practical flow rates and reasonably achievable approaches. The design basis cases were chosen to be in the middle of the range of reasonable alternatives, and any differences between these cases and the calculated optimums were well within the precision of the estimates.

4.2 Results for Bowline Point Station

The total reliable capacity of the two units at the Bowline Point Station is rated at approximately 1215 MW in the summer and 1151 MW in the winter [Reference 9]. The closed cooling water system selected for the Bowline Station comprises a total of four (two per unit) wet/dry mechanical draft towers. The cooling water flow was chosen at 321,000 gpm per unit.

The total capital cost for the closed cooling water system including owner's costs but exclusive of interest during construction was estimated at $112,594,265. Table 4 – 1 provides a summary of the cost estimate.

The total deratings for both units of the Bowline Station, were estimated to be:

- 35 MW at maximum summer conditions of 81 F Wet Bulb;
- 29 MW weighted average during summer hours 71 F Wet Bulb
- 17 MW at maximum non summer conditions and
- 7 MW during average non summer hours

For purposes of calculating lost energy production it was necessary to estimate the annual hours of operation for each of four rate periods. The Bowline units were assumed to run at full power for the 720 hours of the peak periods during the summer season, for the equivalent of 500 full power hours during the off peak periods of the summer, for the equivalent of 1200 full power hours of the on peak periods during the winter, and the equivalent of 1000 full power hours of the off peak periods during the winter. These figures are approximately consistent with overall annual capacity factors determined from data provided for 1998 by the utility with some minor adjustment to reflect potential increases in load resulting from NOx restrictions on coal fired plants in the New York.

Table 4- 1 Summary of Capital Cost Estimate for Bowline Point

Description	Materials	Labor	Total
1. Site Preparation	1,195,128	899,555	2,094,683
2. Cooling Towers			
- Wet/Dry CT	15,943,320	5,066,615	21,009,935
- Excavation/Backfill	2,553,152	1,196,109	3,749,261
- Piling	6,795,327	1,443,410	8,238,737
- Concrete Basin	1,269,019	1,181,944	2,450,963
3. CW Piping			
- Civil Works	4,909,981	1,802,875	6,712,856
- Pipe	7,742,731	4,153,794	11,896,525
4. CW Pumphouse			
- Civil/Structural Works	1,539,802	623,054	2,162,855
- Pumps	3,256,200	887,700	4,143,900
- Cranes and Accessories	1,185,900	914,600	2,100,500
5. Water Treatment			
- Condenser Tube Cleaning	1,005,000	1,076,000	2,081,000
- Chemical and Waste Treatment	1,246,200	833,900	2,080,100
6. Electrical & I/C			
- Electrical	4,004,000	2,173,000	6,177,000
- I&C	250,000	170,000	420,000
Total Direct Cost (TDC)	**52,895,760**	**22,422,554**	**75,318,315**
7. Freight & Insurance (5% of TDC Materials)			2,644,788
8. Engineering & Design (6% of TDC)			4,519,099
9. Indirect & Undistributed Costs (10% of TDC)			7,531,831
10. Construction Mgt & Supervision (4% of TDC)			3,012,733
11. Sales Tax (7.25% of Building Materials)			696,301
12. Contingency & Contractor Profit (20% of TDC)			15,063,663
Turnkey Contract Cost (TCC)			**$108,786,729**
12. Owner's Costs (3% of TCC)			3,263,602
13. Start-up & Testing (0.5% of TCC)			543,934
TOTAL PROJECT COST			**$112,594,265**

The annual value of the lost energy was calculated by taking the hours of operation for each of the four rate periods and multiplying them by the average summer condition or average non-summer condition deratings as appropriate and then by the appropriate rate. Rates used for these calculations were $68 per MWh for summer peak; $30 per MWh for summer off-peak; $25 per MWh for winter (non-summer) peak; and $22 per MWh for winter (non-summer) off-peak.

Capacity was assigned a value of $3500 per month for the five summer months and $1000 per month for the non-summer months. The annual value of the lost capacity was thus calculated by taking the maximum summer condition derating listed above and multiplying it by the value of $3500 per MW month and then by five to account for the five summer months. Similarly, the maximum non-summer condition derating was multiplied by $1000 per MW month and then by six.

The annual operating and maintenance costs for the closed cooling system at Bowline were estimated to be $700,000 per year for the first ten years and then $800,000 per year for subsequent years. This figure includes cooling water treatment and maintenance and repair of fans, pumps, tower structure, and components. It also reflects some reduction in the maintenance of the components for the once through system to reflect its status as a standby, rather than an operating, system. Property taxes were assumed to be equal to 3.9% of the cost of the system. Insurance and capitalized replacements were estimated at 1% per year. Construction was projected to begin in mid 2003 and end in 2005. Operation with the cooling towers was analyzed for periods ending in 2012, 2022, and 2032, corresponding to 40, 50, and 60 year plant life, respectively.

The total 1999 present value of the annual costs during the period with cooling towers in operation was calculated to be $181,614,149, assuming the plant would operate until 2022, yielding a fifty year life. The 1999 present value of the lost capacity during the tying in was estimated to be $973,068. The resultant total 1999 present value was calculated to be approximately $183,000,000.

This amount is the cost of the additional resources which will have to be dedicated to generating the same amount of electricity with the closed cooling system as would have been generated with the existing once through system for the period of 2005 through 2022. See Table 4 - 5 for results for other operating periods.

4.3 Results for Indian Point 2

With the existing once through cooling system, Indian Point 2 has a capacity of 931 MW in the summer and 951 MW in the winter [Reference 9]. The closed cooling water system selected for Indian Point 2 comprises a total of four wet/dry mechanical draft towers. The cooling water flow was chosen at 600,000 gpm.

The total capital cost for the closed cooling water system including owner's costs but exclusive of interest during construction was estimated at $161,170,000. Table 4 - 2 provides a summary of the cost estimate.

The total deratings for Indian Point 2, were estimated to be:
- 60MW at maximum summer conditions of 81 F Wet Bulb;
- 70 MW weighted average during summer hours 71 F Wet Bulb
- 50 MW at maximum non summer conditions and
- 25 MW average non summer hours

For purposes of calculating lost energy production, it was necessary to estimate the annual hours of operation for each of four rate periods. Indian Point 2 was assumed to run at full power whenever the unit was available. This resulted in 720 full power hours of the peak periods during the summer season, 1296 full power hours for the off peak periods of the summer, 2040 full power hours for the on peak periods during the winter, and 3900 full power hours for the off peak periods during the winter. These figures allow for eight weeks of down time during the winter season.

The annual value of the lost energy was calculated by taking the hours of operation for each of the four rate periods and multiplying them by the average summer condition or average non-summer condition deratings as appropriate and then by the appropriate rate. Rates used for these calculations were $68 per MWh for summer peak; $30 per MWh for summer off-peak; $25 per MWh for winter (non-summer) peak; and $22 per MWh for winter (non-summer) off-peak.

Capacity was assigned a value of $3500 per month for the five summer months and $1000 per month for the non-summer months. The annual value of the lost capacity was thus calculated by taking the maximum summer condition derating listed above and multiplying it by the value of $3500 per MW month and then by five to account for the five summer months. Similarly, the maximum non-summer condition derating was multiplied by $1000 per MW month and then by six.

The annual operating and maintenance costs for the closed cooling system at Indian Point 2 were estimated to be $950,000 per year for the first ten years and $1,050,000 per year afterward. This figure includes cooling water treatment and maintenance and repair of fans, pumps, and tower structure and components. It also reflects some reduction in the maintenance of the components for the once through system to reflect its status as a standby, rather than an operating, system. Annual property taxes were assumed to be equal to 4% of the cost of the system and insurance and capitalized replacement costs were estimated at 1% per year. Construction was projected to begin 2004 and end in 2007. Operation with the cooling towers was analyzed for periods ending in 2013, 2023, and 2033 corresponding to 40, 50, and 60 year plant life respectively.

Table 4 - 2 Summary of Capital Cost Estimate for Indian Point 2

Description	Materials	Labor	Total
1. Site Preparation	4,622,258	5,960,220	10,582,478
2. Cooling Towers			
- Wet/Dry CT	16,800,000	5,700,000	22,500,000
- Excavation/Backfill	3,318,851	2,324,400	5,643,251
- Piling	0	0	0
- Concrete Basin	3,416,123	2,427,900	5,844,023
3. CW Piping			
- Civil Works	3,319,764	6,372,960	9,692,724
- Pipe	15,219,750	13,283,288	28,503,038
4. CW Pumphouse			
- Civil/Structural Works	1,856,736	1,128,600	2,985,336
- Pumps	3,465,000	1,440,000	4,905,000
- Cranes and Accessories	630,000	500,000	1,130,000
5. Water Treatment			
- Condenser Tube Cleaning	1,575,000	1,200,000	2,775,000
- Chemical and Waste Treatment	1,302,000	1,240,000	2,542,000
6. Electrical & I/C			
- Electrical	7,050,000	3,750,000	10,800,000
- I&C	500,000	300,000	800,000
Total Direct Cost (TDC)	**63,075,481**	**45,627,368**	**108,702,849**
7. Freight & Insurance (5% of TDC Materials)			3,153,774
8. Engineering & Design (6% of TDC)			6,522,171
9. Indirect & Undistributed Costs (10% of TDC)			10,870,285
10. Construction Mgt & Supervision (4% of TDC)			4,348,114
11. Sales Tax (7.25% of Building Materials)			382,282
12. Contingency & Contractor Profit (20% of TDC)			21,740,570
Turnkey Contract Cost (TCC)			**$155,720,044**
12. Owner's Costs (3% of TCC)			4,671,601
13. Start-up & Testing (0.5% of TCC)			778,600
TOTAL PROJECT COST			**$161,170,246**

The total 1999 present value of the sum of the annual costs during the period with cooling towers in operation ending in 2023 was calculated to be $295,187,584. The 1999 present value of the lost capacity during the tying in was estimated to be $69,300,000 and the resultant total 1999 present value was calculated to be approximately $364,000,000.

This amount is the cost of the additional resources which will have to be dedicated to generating the same amount of electricity with the closed cooling system as would have been generated with the existing once through system for the period of 2004 through 2023. See Table 4 - 5 for results for other periods of operation.

4.4 Results for Indian Point 3

With the existing once through cooling system, Indian Point 3 has a capacity of 970 MW in the summer and 990 MW in the winter [Reference 9]. The closed cooling water system selected for Indian Point 3 comprises a total of two wet/dry mechanical draft towers. The cooling water flow was chosen at 600,000 gpm.
The total capital cost for the closed cooling water system including owner's costs but exclusive of interest during construction was estimated at $202,112,000. Table 4 - 3 provides a summary of the cost estimate.

The total deratings for Indian Point 3, were estimated to be:

- 71 MW at maximum summer conditions of 81 F Wet Bulb;
- 55 MW weighted average during summer hours 71 F Wet Bulb
- 36 MW at maximum non summer conditions and
- 12 MW average non summer hours.

For purposes of calculating lost energy production, Indian Point 2 was assumed to run at full power whenever the unit was available. This resulted in 720 full power hours of the peak periods during the summer season, 1296 full power hours for the off peak periods of the summer, 2040 full power hours for the on peak periods during the winter, and 3900 full power hours for the off peak periods during the winter. These figures allow for eight weeks of down time during the winter season.

The value of the lost capacity and energy generation due to deratings was calculated in the same manner as for Indian Point 2.

The annual operating and maintenance costs for the closed cooling system at Indian Point 3 were estimated to be $1,000,000 per year for the first ten years and then $1,100,000 per year for subsequent years. This figure includes cooling water treatment and maintenance and repair of fans, pumps, and tower structure and components. It also reflects some reduction in the maintenance of the components for the once through system to reflect its status as a standby, rather than an operating, system. It was assumed that no property taxes would be paid. Insurance and capital replacement costs were estimated at 1% per year of the

Table 4 - 3 Summary of Capital Cost Estimate for Indian Point 3

Description	Materials	Labor	Total
1. Site Preparation	24,049,043	29,235,750	53,284,793
2. Cooling Towers			
- Wet/Dry CT	17,535,000	6,150,000	23,685,000
- Excavation/Backfill	3,220,388	2,753,802	5,974,190
- Piling	0	0	0
- Concrete Basin	3,543,593	2,435,700	5,979,293
3. CW Piping			
- Civil Works	1,599,738	2,123,920	3,723,658
- Pipe	8,294,015	6,631,072	14,925,087
4. CW Pumphouse			
- Civil/Structural Works	3,317,143	1,526,532	4,843,675
- Pumps	4,032,000	1,780,000	5,812,000
- Cranes and Accessories	892,500	700,000	1,592,500
5. Water Treatment			
- Condenser Tube Cleaning	1,575,000	1,200,000	2,775,000
- Chemical and Waste Treatment	1,302,000	1,240,000	2,542,000
6. Electrical & I/C			
- Electrical	7,050,000	3,750,000	10,800,000
- I&C	500,000	300,000	800,000
Total Direct Cost (TDC)	**76,910,419**	**59,826,776**	**136,737,195**
7. Freight & Insurance (5% of TDC Materials)			3,845,521
8. Engineering & Design (6% of TDC)			8,204,232
9. Indirect & Undistributed Costs (10% of TDC)			13,673,720
10. Construction Mgt & Supervision (4% of TDC)			5,469,488
11. Sales Tax (TBD)			
12. Contingency & Contractor Profit (20% of TDC)			27,347,439
Turnkey Contract Cost (TCC)			**$195,277,594**
12. Owner's Costs (3% of TCC)			5,858,328
13. Start-up & Testing (0.5% of TCC)			976,388
TOTAL PROJECT COST			**$202,112,310**

original system cost. Construction was projected to begin 2004 and end in 2007. Operation with the cooling towers was analyzed for periods ending in 2016, 2026, and 2036, corresponding to 40, 50, and 60 year plant life, respectively.

The total 1999 present value of the annual costs during the period from 2008 through 2026 was calculated to be $ $288,833,290 and the 1999 present value of the lost capacity during the tying in was estimated to be $77,200,000. The resultant total 1999 present value was calculated to be approximately $366,000,000.

This amount is the cost of the additional resources which will have to be dedicated to generating the same amount of electricity with the closed cooling system as would have been generated with the existing once through system for the period of 2004 through 2026. See Table 4 – 5 for values other operating periods.

4. 5 Results for Roseton Station

Roseton Station reliable capacity is rated at approximately 1205 MW for summer and 1196 for MW winter [Reference 9]. The closed cooling water system selected for the Roseton Station comprises a total of four (two per unit) wet/dry mechanical draft towers. The cooling water flow was chosen at 321,000 gpm per unit.

The total capital cost for the closed cooling water system including owner's costs but exclusive of interest during construction was estimated at $112,880,000. Table 4 - 4 provides a summary of the cost estimate.
The total deratings for both units of the Roseton Station, were estimated to be:

- 34MW at maximum summer conditions of 81 F Wet Bulb;
- 27 MW weighted average during summer hours 71 F Wet Bulb
- 18 MW at maximum non summer conditions and
- 10 MW average non summer hours.

For purposes of calculating lost energy production, the Roseton units were assumed to run at full power for the 720 hours of the peak periods during the summer season, for the equivalent of 500 full power hours during the off peak periods of the summer, for the equivalent of 1200 full power hours of the on peak periods during the winter, and the equivalent of 1000 full power hours of the off peak periods during the winter. These figures are approximately consistent of data provided for 1998 by the utility with some minor adjustment to reflect potential increases in load resulting from NOx restrictions on coal fired plants in the New York.

The annual operating and maintenance costs for the closed cooling system at Roseton were estimated to be $700,000 per year for the first ten years and then $800,000 per year for subsequent years. This figure includes cooling water treatment and maintenance and repair of fans, pumps, and tower structure and components. It also reflects some reduction in the maintenance of the components for the once through system to reflect its status as a standby, rather than an operating, system. Property taxes were assumed to be equal to 1.2% of the cost of the system per year. Insurance and capitalized replacements were estimated at 1% of the original cost. Construction was projected to begin in mid 2003 and end in 2005. Operation with the cooling towers was analyzed for periods ending in 2014, 2024, and 2034, corresponding to 40, 50 and 60 year plant life, respectiviely.

The total 1999 present value of the sum of the annual costs during the period of operation with cooling towers ending in 2024 was calculated to be $162,357,346 and the 1999 present value of the lost capacity during the tying in was estimated to be $1,011,000. The resultant total 1999 present value was calculated to be approximately $163,000,000.

This amount is the cost of the additional resources which will have to be dedicated to generating the same amount of electricity with the closed cooling system as would have been generated with the existing once through system for the period of 2005 through 2024. See Table 4 – 5 for values for other periods of operation.

Table 4 - 4 Summary of Capital Cost Estimate for Roseton

Description	Materials	Labor	Total
1. Site Preparation	2,546,588	1,577,221	4,123,809
2. Cooling Towers			
- Wet/Dry CT	15,943,320	5,153,256	21,096,576
- Excavation/Backfill	6,801,941	964,990	7,766,931
- Piling	6,098,348	1,423,295	7,521,643
- Concrete Basin	1,221,780	1,095,460	2,317,240
3. CW Piping			
- Civil Works	3,439,229	1,179,626	4,618,855
- Pipe	6,298,335	3,012,914	9,311,249
4. CW Pumphouse			
- Civil/Structural Works	1,551,358	614,281	2,165,639
- Pumps	2,834,100	902,880	3,736,980
- Cranes and Accessories	1,185,900	930,240	2,116,140
5. Water Treatment			
- Condenser Tube Cleaning	1,005,000	1,076,000	2,081,000
- Chemical and Waste Treatment	1,246,200	848,160	2,094,360
6. Electrical & I/C			
- Electrical	3,684,000	2,456,000	6,140,000
- I&C	250,000	170,000	420,000
Total Direct Cost (TDC)	**54,106,099**	**21,404,323**	**75,510,422**
7. Freight & Insurance (5% of TDC Materials)			2,705,305
8. Engineering & Design (6% of TDC)			4,530,625
9. Indirect & Undistributed Costs (10% of TDC)			7,551,042
10. Construction Mgt & Supervision (4% of TDC)			3,020,417
11. Sales Tax (7.25% of Building Materials)			643,183
12. Contingency & Contractor Profit (20% of TDC)			15,102,084
Turnkey Contract Cost (TCC)			**$109,063,078**
12. Owner's Costs (3% of TCC)			3,271,892
13. Start-up & Testing (0.5% of TCC)			545,315
TOTAL PROJECT COST			**$112,880,286**

4.6 Summary of Economic Analysis

The installation of closed cooling systems at the four Hudson River Plants covered by this study would result in:

- a large capital investment over the next few years;
- a substantial loss of capacity and a large energy production cost penalty during the tying in of the new systems, particularly at the nuclear stations;
- a permanent loss of net generating capacity ranging from 121 MW during winter months to 184 MW during the peak temperature period; and
- the need to generate approximately 580,000 MWh per year from other sources.

The total present value of the capital and operating costs of installing closed cooling system at the four Hudson River Plants is estimated to range from approximately $850,000,000 to $1,230,000,000, depending on plant operating lives (see Table 4 - 5). Note that this amount could increase further by approximately $600,000,000 if the Indian Point Plants were to be required to shutdown throughout the construction period. These amounts represent the value of the total additional resources which would have to be dedicated to produce the same amount of electric power and provide the same amount of capacity with the closed cooling systems as the plants would provide with their current once through systems. This is an extremely high cost for the years that any benefits would accrue, particularly for the nuclear plants.

Table 4 – 5 Costs (Millions Of 1999 Dollars) Of Wet/Dry Cooling Towers Considered For The Hudson River Plants

Cost Component	Bowline Point	Indian Point 2	Indian Point 3	Roseton	Total
Initial Costs (non-escalated value in year of occurrence)					
Construction	113	161	202	113	589
Interest During Construction	6	10	9	6	31
Energy & Capacity Loss During Construction	1	91	95	1	188
Initial Annual Costs					
Operation & Maintenance	0.7	1.0	1.1	0.7	3.5
Energy & Capacity Loss	3	11	8	3	25
Taxes, Insurance, and Capitalized Replacements.	6	8	2	3	19
Total Life Cycle Costs (Present value in 1999)*					
For end of life (EOL) at 40 years after startup	138 for EOL at 2012	270 for EOL at 2013	310 for EOL at 2016	132 for EOL at 2014	851
For end of life (EOL) at 50 years after startup	183 for EOL at 2022	364 for EOL at 2023	366 for EOL at 2026	162 for EOL at 2024	1075
For end of life (EOL) at 60 years after startup	213 for EOL at 2032	432 for EOL at 2033	404 for EOL at 2036	184 for EOL at 2034	1233
Average Annual Life Cycle Costs					
For end of life at 40 years after startup	29 for EOL at 2012	54 for EOL at 2013	39 for EOL at 2016	23 for EOL at 2014	145
For end of life at 50 years after startup	19 for EOL at 2022	35 for EOL at 2023	26 for EOL at 2026	16 for EOL at 2024	96
For end of life at 60 years after startup	16 for EOL at 2032	31 for EOL at 2033	20 for EOL at 2036	13 for EOL at 2034	80

* costs incurred for each year of life are discounted by interest rate per year back to 1999 and summed; discounted costs of losses of capacity and energy during construction are then added

5. Environmental Impacts

5.1 General

The primary beneficial environmental effect of installation of cooling towers at the existing Hudson River Plants would be the reduction of the amount of water taken from the Hudson River by about 97% of the current values, producing a similar reduction in the amount of aquatic biota entrainment. The reduction in mortality would be less than 97% since unlike the case with the closed cooling systems, not all entrained organisms are killed in the once through systems. Any reductions in impacts due to the lower withdrawals, would not be accomplished without significant economic penalty described in previous sections. For assessment purposes, wet/dry towers were evaluated.

As noted in the economic analysis in Section 4, the plants will experience a substantial derating due to increased turbine backpressure and auxiliary loads. This will reduce the output of the plants without reducing fuel consumption, emissions or other related impacts at the Hudson River Plants. The generation lost from the Hudson River plants, amounting to nearly 600,000 MWh per year, will have to be made up at other plants with the attendant impacts occurring at these plants. To make up for the lost capacity of the Hudson River Plants will require 184 MW of additional capacity. If newly constructed plants are used to provide this capacity, impacts can include land and habitat disturbance, visual impacts, and the other effects of construction of a medium sized power plant.

Among the other drawbacks of cooling towers is the fact that most of the cooling is produced by evaporation of the water circulating in the tower. On an annual basis the Bowline Point, Indian Point and Roseton plants operating at projected capacity factors will evaporate on the order of 15 billion gallons of river water annually. The maximum evaporation rates of up to 21 million pounds per hour will occur during the warmest periods, which are often the times of the lowest fresh water flows. This maximum evaporation rate can equal approximately 4% of the minimum summer fresh water flow rate in the Hudson River.

In addition, drift, small airborne droplets of cooling water, are continuously emitted into the ambient air. These droplets contain salts and chemicals that are present in the cooling tower water. Chemical constituents in the Hudson River intake water are carried through and concentrated in the cooling tower and a portion of them are dispersed into the ambient air with the drift. The drift rate in modern, well designed and maintained, cooling towers is on the order of 0.001 to 0.002 percent of the total flow rate. Even these low rates may lead to deposits of salts that were judged marginally detrimental to some tree species occurring in the vicinity the Hudson River Plants. Based on work done by the Boyce Thompson Institute on salt damage to foliage [Reference 11] and the serious potential for occurrences of 14 day droughts, it was judged that areas with salt deposition rates of more than 100 kg per month in summer or autumn would experience damage to these species, with more severe damage occurring at higher deposition rates. In recent years the presence of wooly adelgids has placed increased stress on the eastern hemlock population, so that the salt deposits may be more deleterious than previous studies indicated.

Some icing and fogging may occur downwind of the cooling towers during certain unusual atmospheric conditions.

Cooling towers generate noise from their fans as well as from the water that splashes through the tower. To reduce the noise emitted by the tower, low speed quiet fans are used and the towers are equipped with inlet air baffles and splash shields. The claimed effect of these provisions is that the noise level at 400 feet from the towers is expected not to exceed 50 dBA. More typically, noise levels of 65 dBA are achieved with low speed fans and high quality fan drives. The results of previous studies indicate that the noise levels from the cooling towers will probably be acceptable.. The more typical levels will produce measurably higher night time noise levels around the Indian Point Units, possibly to the level of significant nuisance in a few residential areas. The offsite noise levels from towers at Roseton and Bowline are expected be well below current levels from other sources.

Blowdown discharge contains concentrated levels of salts and chemicals present in the makeup water as well as chemicals added to prevent fouling. The temperature of the blowdown will generally be 10 to 30 F higher than the river water to which it is returned. The discharge flow rates will be about 1 to 3% of the flow circulated through the towers.

Sludge develops in the basin from silt and heavier suspended solids in the makeup. The sludge must be properly managed and the cost of testing, removal, and proper disposal could be substantial.

In order to install cooling towers at Indian Point, large tracts of land will have to be cleared of vegetation. At the Indian Point sites, large quantities of rock will have to be excavated, most of which will have to be disposed of off site. The site clearing, excavation and transportation of surplus material and its disposal will have an adverse effect on the environment and will impact the vicinity with significant increases in noise, vehicular traffic, dust, and the potential spillage of earth and rock on the roads.

5.2 Environmental Impacts at Bowline Point

The cooling towers for Bowline Point Units 1 & 2 would occupy an area of approximately 6 acres adjacent to the Hudson River. This area is currently covered with a second growth mixed hardwood forest which is in the transition phase between late pioneer and mature species and shows some indications of being wetlands. The immediate site and the surrounding area will be entirely cleared for ease of construction and to allow maximum airflow to the towers.

The tower location is visible and the pair of 432 foot long and 50 foot high (60 feet to the top of the fan stacks) towers at the river's edge will add to the aesthetic impact of the plant. The view from the river of the second pair of towers, some 400 hundred feet further inland, will be largely obscured.

Assuming a tower drift rate of 0.002%, which is reportedly readily achievable from well designed and maintained towers, salt deposition rates can exceed 20,000 kg per month during the summer low fresh water flow months. Earlier studies of the potential effects of salt deposition from mechanical draft cooling towers on Bowline area vegetation concluded that the annual deposition rates at all points off site were below those that would cause any significant damage
The noise produced by cooling towers from splashing of the water and from the fans and gear boxes should not increase sound levels in nearby residential areas noticeably, with moderate noise abatement features included in the design. Elaborate noise abatement measures included in the cost estimate should eliminate noise impact from operation of the cooling towers.

The construction of the closed cooling system will require approximately two years. During this time there will be an increase in traffic through the town center due to the flow of heavy equipment, materials, and workmen to the site.

5.3 Environmental Impacts at Indian Point 2

The cooling towers for Indian Point 2 would occupy an area of approximately 15 acres comprising a long narrow strip along the Hudson River. This area is currently covered with a mature hardwood forest. The site will be entirely cleared for ease of construction and to allow maximum airflow to the towers.

The tower location is highly visible river frontage and the four 432 foot long and 50 foot high towers (60 feet to the top of the fan stacks) at the river's edge will add substantially to the aesthetic impact of the plant. Views from the Hudson River, from scenic overlooks on area highways, and from Palisades Interstate State Park on the Western shore would be significantly impacted. Nearly all of the forested shoreline from the plant security fence to Lent's cove would be replaced by the towers. The construction of the towers will preclude any potential access to the river for recreational or commercial purposes.

In considering salt deposition damage, the effects of towers at both Indian Point Units 2 and 3 should be considered together since the areas of deposition will overlap to a great degree. Assuming a tower drift rate of 0.002%, which is reportedly readily achievable from well designed and maintained towers salt deposition rates can exceed 15,000 kg per month from each plant during the summer and fall low fresh water flow months . It appears that the flowering dogwoods and white ash trees in an area of about ten square kilometers will experience some damage during droughts Canadian hemlocks, which comprise a significant portion of the forest in this area [Reference 12], may experience substantial, and perhaps fatal, deleterious effects during these drought periods. The area which may experience substantial damage includes most of Buchanan and Verplanck to near Montrose Point, and may include some of the park land on the west side of the river. Some additional areas in Peekskill and its immediate environs may be similarly affected [References 2 and 3].

As with salt deposition, noise from the towers at both Indian Point Units should be considered jointly. In the immediate vicinity of the units the nearer towers will provide the dominant portion of the sound energy and the fact that there are a second set of towers in the general area should not have a significant effect. At large distances, the presence of two sets of towers can be expected to add about 3 dBA to the noise level from a single unit's cooling towers. The combined noise levels from the two sets of towers is expected to produce sound power levels (SPL) of no more than 48 dBA outside the site except on the river itself, within less than 3000 feet of the towers. The contribution from the towers, when combined with other noise sources will lead to additional areas having SPLs greater than 48 or even 50 dBA. This will represent a violation of Buchanan noise ordinances. Perhaps more relevant than the absolute sound pressure levels is the L_{dn}. L_{dn} is a measurement of the impact of noise over both day and night. Night noises are weighed more heavily than daytime noises, reflecting their relative effect on people's quality of life. Thus, a noise level which remains constant for both day and night, such as that the towers will produce, has an L_{dn} approximately 6 dB higher than its SPL, and the constant noise level of 48 dBA is equivalent to an L_{dn} of 54 dB. This contribution to the ambient L_{dn} will result in several residential areas increasing to the 55 to 60 L_{dn} level, a point at which residents can be expected to complain and seek redress in significant numbers. If the more elaborate noise abatement measures included in the cost estimate are as effective as the manufacturer claims, there will be essentially no noise impact from operation of the cooling towers.

The construction of the closed cooling system will require approximately three years. During this time there will be a substantial increase in traffic through the town particularly along Route 9 and Bleakley Avenue due to the flow of heavy equipment, materials, and workmen to the site. For example, approximately 3,000 truckloads of excavated material would be removed from the site. The increase in traffic is expected to raise the L_{dn} levels from the marginal to the probably objectionable level in these areas. Pollutants from truck exhausts are expected to be quite noticeable. During the early construction phase, the excavation can be expected to be audible beyond the plant boundary.

5.4 Environmental Impacts at Indian Point 3

The cooling towers at Indian Point 3 will be located at two adjacent sites. One along the river's edge about 350 feet south of the unit's turbine building and the second approximately 400 feet due east and inland from the first. The installation of the cooling towers will displace warehouse and other support facilities and a large parking area. These facilities will have to be relocated on the site with probable destruction of the mature mixed hardwood forest occupying most of the site. In addition, a gas pipeline will have to be relocated with similar consequences as well as disturbance of the shoreline and riverbed in the vicinity of the existing and relocated pipeline.

The towers can be expected to have a substantial aesthetic impact, particularly the 430 foot long by fifty foot high (sixty foot to the tops of the fan stacks) tower immediately along the river. The intrusiveness of the riverside tower is amplified because it will be placed on a combined filled and excavated site 45 feet above the river's edge. Views from the Hudson River, from scenic overlooks on area highways and from Palisades Interstate State Park on the Western shore would be significantly impacted.

The effects of salt deposition from the combined drift of towers at IP 2 and IP 3 are discussed above in Section 5.3. The noise levels from cooling towers at IP 3 are expected to be below 45 dBA at all residential and recreational areas. The IP 3 cooling towers will be a minor contributor to potentially unacceptable noise levels at the Bleakley Avenue area. The additional traffic from construction vehicles can be expected to be a major noise source during daytime hours for much of the three year construction period. For example, on the order of 9,000 truckloads of excavated materials may have to removed from the site.

5.5 Environmental Impacts at Roseton

The cooling towers for the Roseton Power Plant would occupy an area of approximately 6 acres between the units and the Hudson River. This area is currently essentially vacant. The towers would be visible from the river and the opposite shore. However, for the most part, the towers would block the view of the power plants and related facilities rather than of natural features.

Assuming a tower drift rate of 0.002%, which is reportedly readily achievable from well designed and maintained towers, salt deposition rates can exceed 11,000 kg per month during summer drought months. Based on a review of results for the study of the Roseton Plant performed in the late 1970s, it appears that several thousand flowering dogwoods and white ash trees will experience some damage during droughts which can be expected to occur at least twice in the next twenty years. Any Canadian hemlock trees in the immediate vicinity the towers may experience some damage from salt deposition during drought conditions.

The noise produced by cooling towers from splashing of the water and from the fans and gear boxes should not increase sound levels in nearby residential areas noticeably. Noise abatement measures included in the cost estimate should essentially eliminate any noise impact from operation of the cooling towers.

The construction of the closed cooling system will require approximately two years. During this time there will a substantial increase in traffic along Route 9W due to the flow of heavy equipment, materials, and workmen to the site. The increase in noise and the pollutants from truck exhausts will be quite noticeable along Post Road and River Road.

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