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EPRI National Cost Estimate for Retrofit of U.S. Power Plants with Closed-Cycle Cooling

Technical Brief — *Clean Water Act Fish Protection Issues*

Summary

EPRI's retrofit cost study indicates that the potential cost of closed-cycle cooling retrofits, based on capital costs and costs associated with lost revenue from outage time to install the towers and associated structures, plant inefficiencies and energy penalties, exceeds $95 billion.

Background

The U.S. Environmental Protection Agency (EPA) is currently developing revised regulations for power plant cooling water intake structures under §316(b) of the Clean Water Act, which requires that *"the location, design, construction and capacity of cooling water intake structures shall reflect the best technology available (BTA) for minimizing adverse environmental impact."* EPA is considering technology-based aquatic life protection performance standards that may require closed-cycle cooling as BTA for existing thermoelectric facilities.

In once-through systems, cooling water is withdrawn from waters of the U.S., passed once through the power plant condenser cooling system and then returned to the source waterbody. Wet closed-cycle cooling systems differ in that the heated cooling water is not returned to the waterbody but is conveyed to a tower that utilizes evaporative cooling. Mechanical towers are the most common form of closed-cycle cooling. Other less commonly used closed-cycle cooling systems include natural draft, dry, and hybrid towers; and cooling ponds, enhanced ponds, and spray canals. Closed-cycle cooling withdraws significantly less water than the once-through approach and, therefore, impinges and entrains fewer aquatic organisms. However, closed-cycle cooling consumes more water than once-through cooling and introduces other environmental and social impacts (e.g., noise, salt drift, icing, fogging, and visible vapor plumes).

EPRI has carried out a study to estimate the national cost of retrofitting existing once-through cooled facilities with closed-cycle cooling systems at 428 power facilities potentially subject to a retrofit requirement (based on their use of greater than 50 million gallons per day of once-through cooling water). These facilities generate approximately 312,000 MW of electricity, including 60,000 MW from 39 nuclear facilities and 252,000 MW from 389 fossil facilities. Detailed information on EPRI's approach and cost estimate results is contained in *Closed-Cycle Retrofit Study: Capital and Performance Cost Estimates* (EPRI Technical Report 1022491).

Approach

While closed-cycle cooling is commonly used at new facilities, the retrofit of existing facilities that use once-through cooling to closed-cycle cooling can be challenging or impractical for a variety of site-specific reasons, such as space constraints, layout of existing site infrastructure, economic factors and environmental issues. Thus, the initial step in this EPRI project was to assemble all available independent retrofit cost information to establish a probable range of costs. Independent retrofit cost estimates for 82 facilities were obtained from individual utilities, and, as expected, showed a general trend of increasing costs with increasing plant once-through cooling water flow, but very large cost differences exist for any given flow.

Based on discussions with plant personnel and architect-engineering firms and the application of professional judgment, EPRI then developed a list of eleven factors which were believed to be the important influences that determine the site-specific degree of retrofit difficulty. A model was developed using the 82 site-specific retrofit cost estimates and facility flow to establish cost estimates for the various degrees of retrofit difficulty (easy, average, difficult and more difficult for fossil facilities and difficult and more difficult for nuclear facilities). Additional information to evaluate these eleven factors for individual facilities was solicited from the entire population of potentially affected facilities. Adequate information was obtained from 125 facilities to con-

duct a site-specific degree of difficulty analysis to estimate the capital cost (cost of equipment, materials and construction to build cooling towers and connecting pipes). The proportional allocations of the degree of difficulty for the 125 facilities were then used to estimate the national capital cost of retrofits. In this analysis, EPRI assumes the use of wet mechanical draft cooling towers since they are most commonly used. Only one natural draft tower has been constructed in the last two decades. If natural draft towers are constructed, capital cost would increase while lost revenue for operating power would be reduced. EPRI also estimated three additional retrofit costs as a result of lost revenue due to the:

1. Extended outage necessary for tower installation at some facilities
2. Heat rate penalty for most facilities resulting from reduced cooling efficiency
3. Increased operating power requirements for mechanical cooling towers (fans and pumps)

Closed-cycle cooling costs not estimated in this study include costs of permitting, financing, labor and chemical O&M, replacement power for facilities prematurely retired for economic or other reasons, electric system upgrades due to premature retirements and lost generation due to the use of power for the cooling tower and heat rate penalty, and the social and environmental costs of cooling tower operation.

The capital costs were aggregated and extrapolated along with estimates of lost revenue due to extended outage time, operating energy requirements for the cooling tower and the heat rate penalty to provide an estimated national total net present value and annualized costs assuming retrofit of all 428 facilities.

Results

Retrofit Capital Costs: EPRI estimates a net present value of $62 billion ($19.6 and $42.4 billion for nuclear and fossil facilities, respectively) in capital costs to retrofit the 428 once-through cooled facilities. While uncertainties in the estimated capital cost exist, analyses that compared the EPRI correlation-based estimates to facility-specific independent cost estimates found them to be within ±10%, indicating the methodology is reasonably robust for the purpose of estimating the national capital cost.

Extended Outage Revenue Loss: In most cases, cooling tower construction can be completed while the facility continues to operate and generate electric power and the final tie-in of the closed-cycle cooling system can take place during a normal scheduled maintenance outage. For other facilities an extended outage may be required. Some reasons for an extended outage include: 1) re-location of existing infrastructure necessary for electric power generation, 2) water pressure concerns due to site elevations may require replacing or re-enforcing water tunnels and 3) baseloaded facilities with a relatively long remaining life (e.g., nuclear plants) may re-optimize the cooling system to improve energy efficiency. Based on predicted outage times for nuclear and fossil facilities, the estimated national cost of extended outages is a net present value of $17.3 billion ($8.3 billion for nuclear facilities and $9.0 billion for fossil facilities).

Cost (Billions)	Nuclear	Fossil	Total
Net Present Value*	$31.9	$63.3	$95.2
Annualized Cost	$2.3	$4.7	$7.0

* Assumes a 30 year system life

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Heat Rate Penalty: Reduced condenser cooling efficiency from a closed-cycle system compared to once-through cooling will result in an overall net reduction in electricity production output for most facilities. Conversion of a once-through cooling system to a closed-cycle cooling system using a wet cooling tower frequently results in an increase in the achievable turbine backpressure for most of the year and a corresponding loss of plant efficiency and output for most facilities. In most circumstances, EPRI estimates an output penalty of about 1.2% for the hottest 10% of the year and 0.9% for the remainder of the year. Assuming a generation cost of $35/MWh, lost revenues from this heat rate penalty are estimated at $527 million/yr for fossil facilities and $182 million for nuclear facilities, for a combined total of $709 million/yr. This equates to a net present value of $8.8 billion.

Energy Penalty: Closed-cycle cooling retrofits will cause a net generation decrease since some of the facility generation output must be used to operate fans and additional water pumps for the closed-cycle cooling system. EPRI estimates that the sum of the additional pumping and fan power results in an energy penalty that ranges from 0.9 to 1.7% of plant output; with a mid-range value of 1.3% (or 13 MW for a 1,000 MW plant). Assuming a generation cost of $35/MWh, the estimated cost of the combined energy requirements is $568 million ($427 million for fossil and $141 million for nuclear) which equates to a net present value of $7.1 billion.

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