Testimony

Hearing of the Subcommittee on Energy and Environment
Committee on Science and Technology

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Bryan J. Hannegan
Vice President, Environment and Generation
The Electric Power Research Institute

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Thank you, Chairman Baird, Ranking Member Inglis, and Members of the Subcommittee. I am Bryan Hannegan, Vice President – Environment and Generation, at the Electric Power Research Institute (EPRI). EPRI conducts research and development on technology, operations and the environment for the global electric power industry. As an independent, non-profit Institute, EPRI brings together its members, scientists and engineers, along with experts from academia, industry and other centers of research to:

- collaborate in solving challenges in electricity generation, delivery and use;
- provide technological, policy and economic analyses to drive long-range research and development planning; and
- support multi-discipline research in emerging technologies and issues.

EPRI's members represent more than 90 percent of the electricity generated in the United States, and international participation extends to 40 countries. EPRI has major offices and laboratories in Palo Alto, California; Charlotte, North Carolina; Knoxville, Tennessee, and Lenox, Massachusetts.

EPRI appreciates the opportunity to provide testimony to the Subcommittee on the subject of "Technology Research and Development Efforts Related to the Energy and Water Linkage". In my testimony today, I would like to highlight the following key points:

- While thermoelectric power plant cooling accounts for approximately 40% of freshwater withdrawals in the U.S., it accounts for only 3% of total consumption.

- Water use for power generation has declined steadily per unit of power produced; however more significant growth in power demand has led to a total increase in water use by the electric power sector over the past 5 decades.

- The largest users of water are nuclear and coal-based power plants; however renewable energy resources such as concentrated solar and biomass can also use significant water resources on a life-cycle basis.

- Advanced cooling technologies, such as dry cooling and use of degraded waters, can reduce water use in power plants but come at a significant increased cost using existing technologies available today.

- EPRI, working with DOE and others, has identified a $40 million, 10-year research program focused on reducing the cost of existing cooling options, and developing new technology options and decision support tools to reduce the demand for fresh water resources in the coming decades.

- These research efforts are urgently needed to mitigate the expected shortfall in water needs for thermoelectric cooling as a result of future electricity demand growth, competing demand for water resources by other economic sectors, and new water demands from low-carbon generation sources such as nuclear, biomass, and CO_2 capture and storage.

I. Fresh Water Use at Thermoelectric Power Plants

The major use of water for thermoelectric plants is condensing of steam. These plants convert heat energy (as steam) to electric energy. The source of the heat energy may be nuclear, coal, gas, oil, biofuel, solar or geothermal. The heat source boils water and the resulting steam is driven through a turbine which turns a generator. The steam exits the turbine into the condenser where it must be condensed and cooled in order to be pumped backed to the boiler and converted to steam to complete the overall cycle.

According to the most recent available survey of water withdrawals by the USGS (Figure 1), thermoelectric power plant cooling accounts for approximately 40% of freshwater withdrawals in the U.S. Agricultural irrigation accounts for approximately the same amount. Most of the water withdrawn by thermoelectric generation is discharged back into the receiving water body. On the other hand, thermoelectric power plants account for approximately three percent of total freshwater consumption in the U.S (Figure 2). The USGS stopped reporting water consumption values after the 1995 survey; water use numbers were reported for 2000 but have not changed substantially. In arid regions of the US, power companies employ significant use of cooling towers, non-traditional water sources, water recycling within the power plant and use of evaporation ponds. In these instances the total amount of freshwater withdrawn by power plants is likely to be significantly less that in other regions.

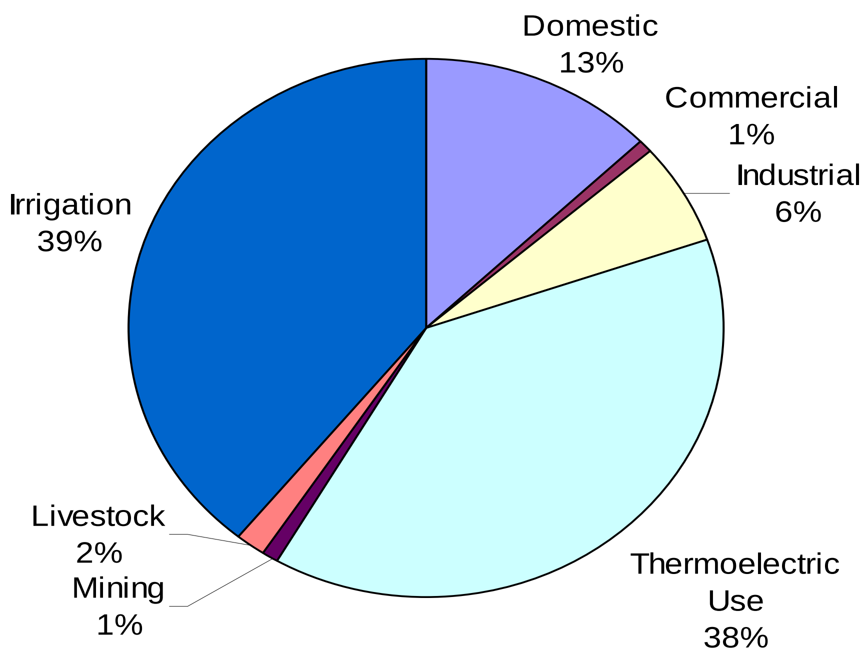

Figure 1 – 1995 Fresh Water Withdrawal by Type (USGS)

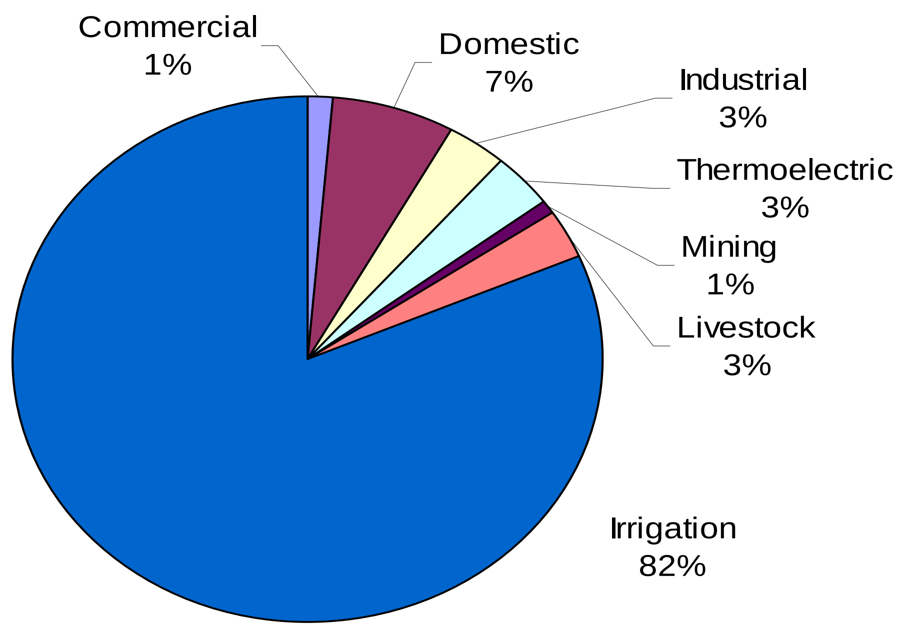

Figure 2 – 1995 Fresh Water Consumption (USGS)

The use of recirculating systems (e.g., cooling towers) and freshwater conservation measures, such as substitution of sewage treatment effluent for freshwater in the arid parts of the country, has been driven by limited water availability. In other parts of the country, the main driving factor for recirculating systems has been water intake and discharge regulations (e.g., fish protection and thermal discharge requirements).

These measures have enabled the electric power industry to reduce its water withdrawals per unit of electric power generated by a factor of three (Table 1). However, the electric industry increased its output of electric power by a factor of 15 over the same period. The net result was a 5-fold increase in water withdrawals by the electric power industry since 1950, most of which occurred before 1980. Total water withdrawal by the industry has actually declined since 1980.

	1950	**1960**	**1970**	**1980**	**1990**	**2000**
Withdrawals (billion gal)	14,500	36,500	62,100	77,000	71,000	71,000
Power Generated (billion MWh)	0.23	0.61	1.28	2.00	2.68	3.45
Water Withdrawal Efficiency (gal/MWh)	63,000	60,000	49,000	39,000	27,000	21,000

Table 1—Water Withdrawals, Power Generated and Improvement in Water Withdrawal Efficiency, 1950-2000

Power plant water use is often measured as the amount of water withdrawal per unit of electric energy generated. The lower this number, the more efficient is the plant's use of water. Power plant water use varies with type of generation (Figure 3). The efficiencies shown in the figure are representative of the type of generation. In reality, there is considerable variability depending not only on the type of generation but also on numerous other factors. For example, with respect to coal plants with wet cooling towers, a survey conducted by EPRI showed that cooling water withdrawal ranged from 500 to 700 gallons/megawatt-hour.

Note that a coal plant uses water not only for cooling but also for flue gas scrubbing and ash handling. A combined cycle gas plant, which uses the exhaust of a gas turbine to drive a single steam cycle, is significantly more water efficient than a single steam cycle plant. A renewable energy plant may or may not have significant cooling requirements. While a wind energy or solar photovoltaic plant uses little water, a solar thermal or biofuel plant is conceptually no different than a fossil or nuclear steam plant and needs significant amounts of water for cooling. With respect to biofuel, there can also be significant water demand associated with fuel production. Although Figure 3 does not show water demands by geothermal electricity production, its water needs are conceptually no different than those of nuclear and coal plants. In fact, geothermal electricity production requires more cooling water since its thermal efficiency (ratio of electricity output to thermal energy input) is relatively low compared to other electric generation technologies.

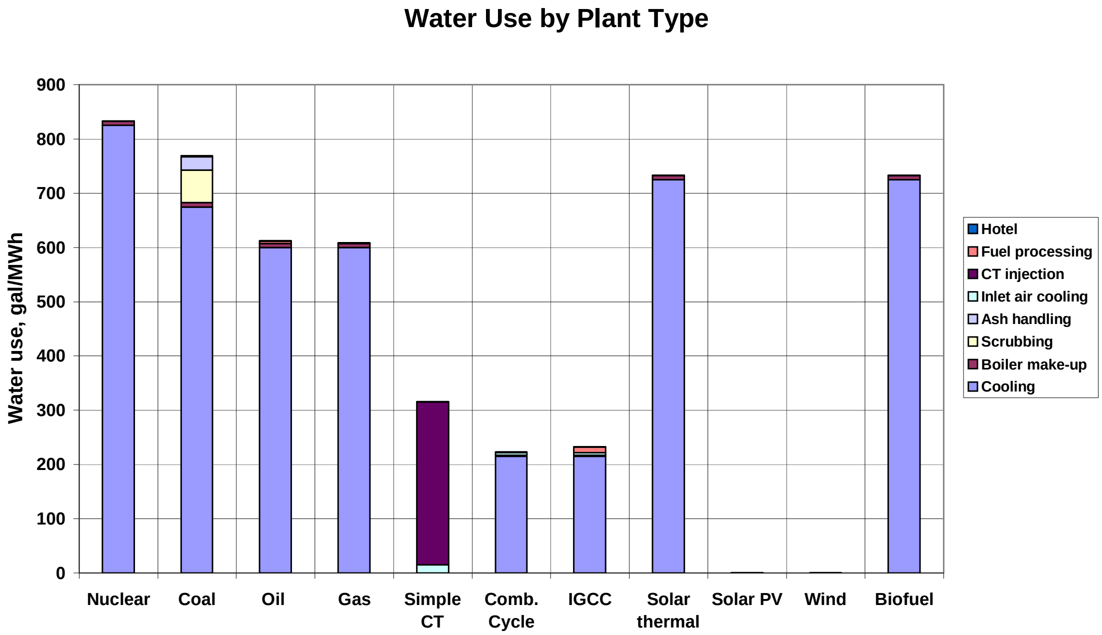

Figure 3 – Water Use by Power Plant Type

Under severe drought conditions or heat waves, the generating capacity of operating power plants is more likely to be limited by an inability to meet thermal discharge permits than by the quantity of available water. When thermal discharge limitations occur it is possible for the appropriate regulatory agency to grant the plant a waiver to continue operating. However, when there is inadequate water to operate the plant at full capacity, the only options are either to reduce power plant generation or completely shut down the plant. Over the last several years, there have been isolated incidents in the U.S. of plants having to reduce power or shut down because of limited available water. In France, in 2003, there was a major multi-week heat wave that resulted in a regional impact consisting of a 7-15% loss of nuclear generation capacity for five weeks, a loss of 20% of hydro generation capacity, large scale load shedding, purchase of large amounts of electricity on the wholesale power market, and sharp increases in electricity prices on the spot market.

II. Existing Cooling Technologies in Use Today

Historically, condensing and cooling of the steam has been provided by once-through cooling systems (Figure 5) in which cool water from a river, lake, ocean or a pond is pumped to the condenser where it condenses the steam from the turbine. After exiting the condenser, the heated cooling water is discharged back into the receiving water body.

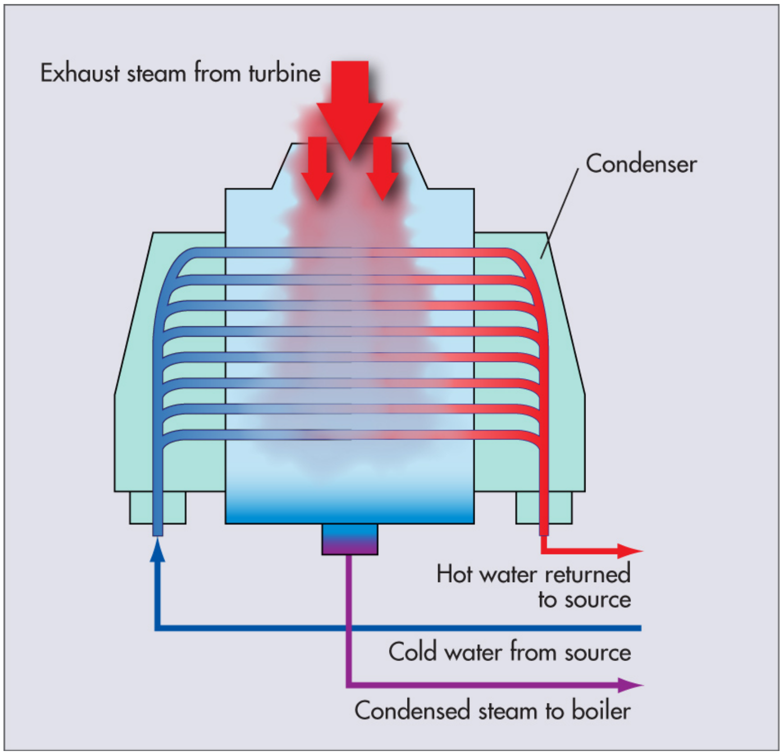

Figure 5 – Schematic of Once-Through Cooling

To minimize the impacts on fish and address thermal discharges, new electric power generation plants typically use recirculating cooling water systems (Figure 6). In a recirculating cooling water system, the cooling water is cooled either in a cooling tower or cooling pond and then recycled back to the condenser.

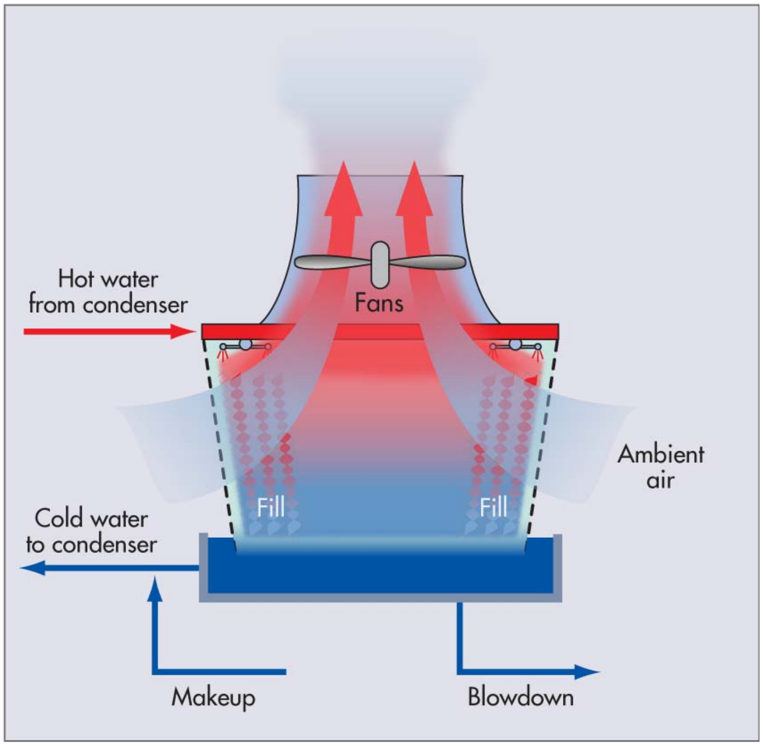

Figure 6 – Schematic of Wet Cooling Tower for Recirculating Cooling

If a recirculating cooling water system was completely closed, the salt concentration in the water would build up to a point where the condenser tubes would collect saline scale (affecting performance) and corrosion would be excessive. For this reason, it is necessary for a percentage of the recycling water be released during each cycle. This water is called blowdown. To makeup for the blowdown and cooling water that is lost to evaporation and drift of the cooling tower exhaust, the recycling system must continuously withdraw water. This water is called makeup.

Figure 7 shows a schematic of typical water use in a 500MW thermal plant with a recirculating cooling system (wet cooling tower). The cooling tower is the largest water consumer in the plant, and in this example, requires 9537 gal/min (gpm) of fresh water when running at full load. This makeup is required to replace the water lost to evaporation and drift (about 2/3 of the total) and blowdown (about 1/3).

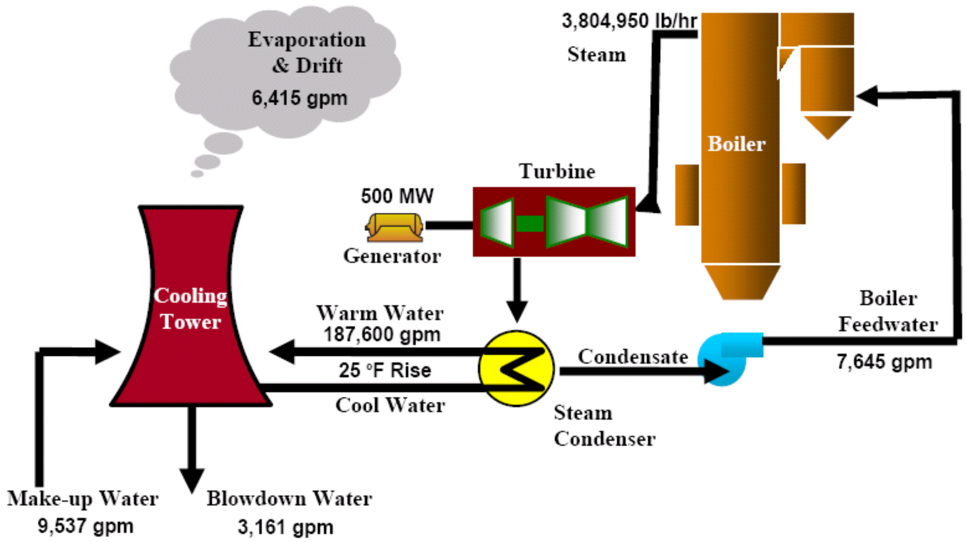

Figure 7 – Typical Water Requirements for 500 MW Thermal Plant with Cooling Towers

There are four major strategies for reducing fresh water use in thermoelectric generation, all of which are being applied to some extent today:

1. **Dry/hybrid cooling** substitutes air for water as the cooling medium.
2. **Non-traditional water sources** substitute degraded waters such as sewage treatment effluent, agricultural runoff, produced water associated with the extraction of oil and gas, mine water, saline groundwater, and stormwater for freshwater.
3. **Water recycle strategies** will treat waste streams within the plant and reuse the water; e.g., remove salts from cooling tower blowdown and recycle as makeup.
4. **Increased thermal conversion efficiency** through use of the waste heat of one plant process to drive another. For example, combined heat and power applications use the waste heat from the electric generation process to satisfy space heating needs, reducing the overall fuel and water use required while providing the same level of energy services.

The advantages and limitations of each of these technologies depend on local conditions and fuel costs; hence there is no universal optimal approach. The objective of EPRI's advanced cooling research program is to optimize the various technologies in terms of technological and economic performance with the goal of minimizing both overall costs and environmental impact.

III. Future Impacts on Water Use in the Electric Power Industry

Water availability is expected to become a major issue for the electric utility industry over the next decade and beyond. Siting of new plants is already constrained by access to cooling water, especially fresh water. Electric power is frequently assigned the lowest priority for water allocation after residential, commercial industrial and agricultural uses. Given limited supplies of fresh water and increasing demands, it is critical to examine options for reducing this anticipated demand as electricity is needed to drive the US economy. This demand must be viewed in light of anticipated changes in climate and new technologies expected to enter the marketplace.

CO_2 Policy and New Generation – With the expectation that the United States will soon have some form of regulation for carbon dioxide and other greenhouse gases, utilities are already anticipating and planning for the changes that will need to occur. Many of these changes will impact water requirements, and new generation will need to be responsive to public and regulatory pressures.

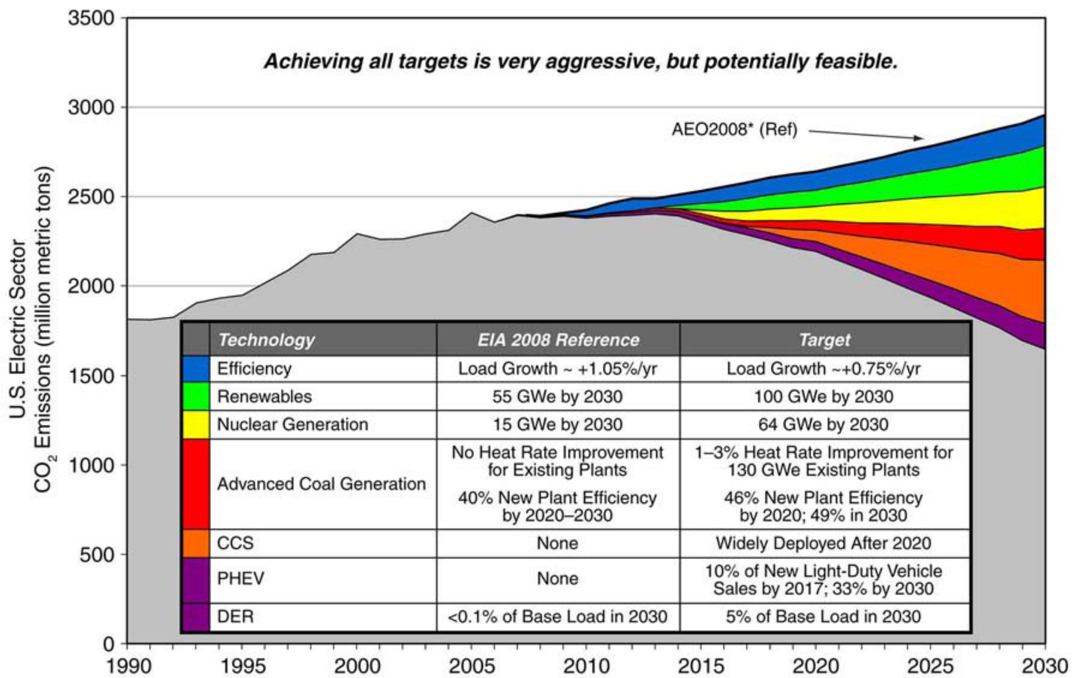

Figure 8 – The EPRI PRISM--Potential U.S. Electric Sector CO_2 Reductions

EPRI's PRISM analysis (Figure 8) examines the potential for CO_2 reductions under varying assumptions of conservation, energy efficiency and new technologies entering the marketplace over the next 20 years. These technologies, if implemented, would have water resource impacts which are briefly described below.

More Nuclear, More Biomass, and More Solar – Figure 8 shows EPRI's assumed increases in power generation from nuclear, biomass and solar generating stations from the PRISM analysis. Each of these technologies has potential water impacts. Current nuclear power plant designs use slightly more cooling water than their fossil-fueled equivalents. This is due to the lower peak steam temperature and pressure that nuclear units can achieve and the subsequent impact on efficiency. It is also much more difficult and expensive to use some of the water conserving technologies (such as dry cooling) because of the containment and safety issues inherent to nuclear plants.

Dedicated biomass generation is growing as an electric power source and has no net carbon emissions. These plants have similar water requirements to other fossil-fueled plants while in operation. However, from a life cycle perspective, water is likely required to cultivate the fuel and should be taken into consideration when examining future water use and consumption. Solar power can be generated by photovoltaic systems, which have little water requirement aside from cleaning the panels, or solar thermal. Solar thermal plants operate much the same as traditional thermal power plants, where solar radiation is used in place of fuel to boil a working fluid, which is then used to turn a turbine and condensed and cooled with a cooling system. Water requirements for solar thermal plants are similar to other thermal plants.

Carbon Capture and Storage – The application of carbon capture and storage (CCS) for fossil power plants will entail additional water requirements and could ultimately lead to doubling of the water requirement for such plants. Figure 9 shows data from a DOE-NETL study that compares water use among different technologies, including coal with CCS. EPRI studies show very similar results: an ultra-supercritical pulverized coal (USC) plant with carbon capture would incur a 38% increase in water consumption compared to one without CCS. When the decrease in net power is factored into the calculation (due to the parasitic load of the carbon capture equipment), a facility with a CCS system will use more than twice as much water compared to a facility without CCS.

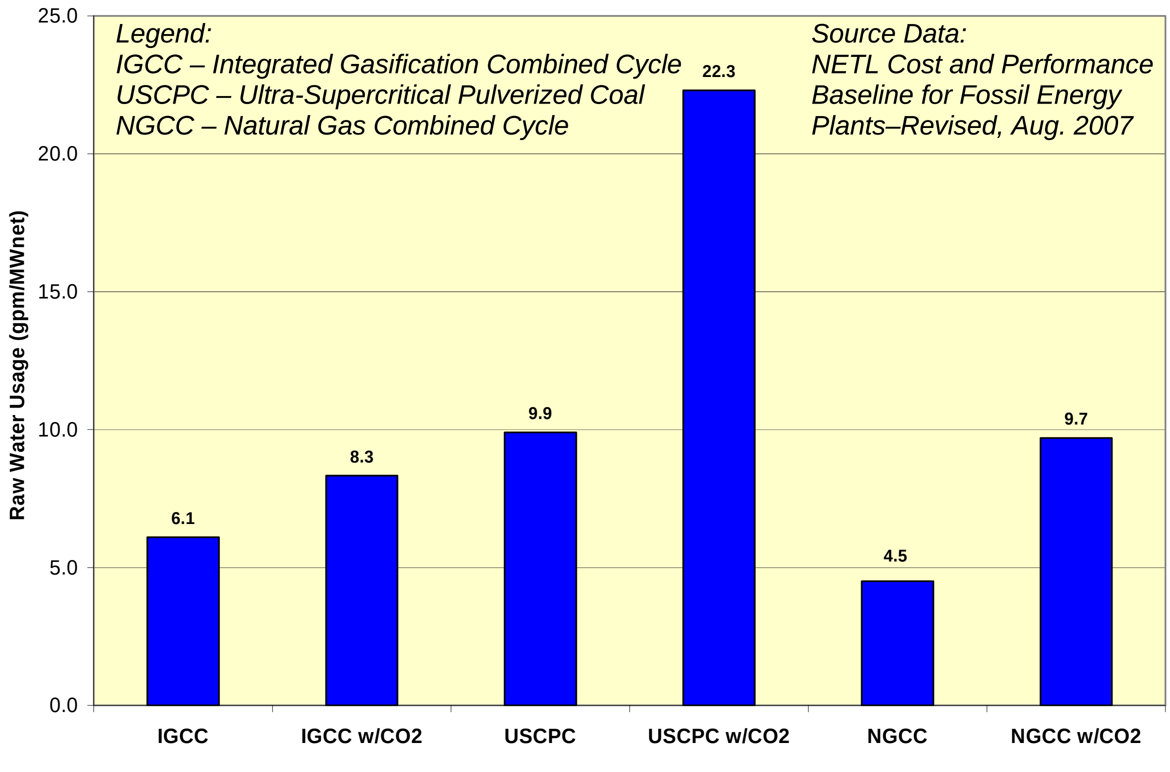

Figure 9 – Advanced Coal Power Plant Water Use (DOE - NETL Study)

Shift of Other Carbon Emitters to Electricity – EPRI's PRISM study and other analyses of greenhouse gas reductions predict that other sectors of the economy will switch to electric technologies in response to CO_2 emission constraints as the reductions in the electric sector would be more cost-effective in many cases. Examples include:

- Industrial – change to electric motors, eliminate package boilers, etc.
- Agricultural – electric motors for water pumps and other stationary equipment
- Residential – switching to electric water heating, cooking, etc.
- Transportation – increased use of electric and plug-in hybrid vehicles

Some of this new electric load will be met with renewable energy sources that may not require water, but some portion of this increased demand for electricity will require access to water including those with advanced water conserving technologies.

Change of Existing Once-Through Cooling to Cooling Towers – As current once through cooled plants are retired, new electric generating facilities will likely employ cooling towers (primarily for fish protection). While the use of cooling towers reduces water withdrawal by 95% or more, it also doubles water consumption (through evaporative losses). Unless power companies have cost-effective options to reduce water use, there will be an increasing demand for fresh water for cooling. Many new plants are already being challenged on water use grounds.

Potential Increase in Climate Change Impacts and Drought – A recent study performed by the University of California-Santa Barbara Bren School of Environmental Science for the California Energy Commission predicts that climate change would potentially reduce the snow pack in the Sierra Nevada Mountains and the runoff from snow melt would be shorter and stronger. While it is often difficult to use climate model precipitation data and predict localized impacts, changes in the global climate will have impacts on water resource distribution and availability, and precipitation patterns. These changes could require additional storage capacity, additional treatment to address water quality degradation, and lower water volumes with higher variability. All of these potential changes would have dramatic effects on operation of thermal power plants.

New Regulations – There are several pending regulations that will govern how water is used in current and future thermal generation power plants. Each of these regulations will provide additional limits that must be met, and could have a significant impact on water withdrawals and water consumption.

- Pursuant to Section 316(b) of the Clean Water Act, EPA is developing new regulations to address fish entrainment and impingement losses at Cooling Water Intake Structures (CWIS) for once-through cooled plants. New plants must already meet fish protection equivalent to wet cooling towers. EPA is still drafting regulations for retrofitting CWIS for existing once through cooled plants. These requirements, while still under development, could potentially require retrofit of cooling towers on many once through cooled power plants.

- EPA is considering development of new Effluent Guidelines for the utility industry. These new regulations could potentially require significant change in how water is managed and treated within power plants including the potential to reduce overall water discharges.

- The California State Water Resources Board is going one step further and considering regulations that would require all ocean-cooled power plants in the state to retrofit cooling towers.

IV. Opportunities to Reduce Water Needs in the Electric Sector

EPRI conducts and plans research to allow the power industry to address risks associated with growing limitations on water availability. The objectives are two fold: (1) to reduce energy and costs associated with increasing water use efficiency while reducing overall water use and (2) to develop integrated risk analysis tools that can be used for planning water use among various stakeholders. The former consists of studies to improve existing water conserving technologies, demonstration of emerging technologies, and development of new technologies. Research plans also call for fundamental strategic studies of heat transfer, fluid flow and desalination to make major technological breakthroughs with respect to air cooling and water treatment. The second objective is to create and test integrated risk analysis tools for community and regional water resource planning and management. Reports resulting from completed EPRI research are listed in Appendix A.

Another important facet of the EPRI program is collaboration with government agencies and other research organizations. EPRI has been working closely with the Energy-Water Nexus (EWN), a group of national energy laboratories, to further the understanding of the many facets of the overall energy-water sustainability issue. EPRI belongs to the EWN Executive Advisory Committee and has contributed to the Report to Congress and Research Roadmap that EWN has produced for USDOE. EPRI has also provided assistance to GAO as they review the issue of energy-water sustainability. EPRI is an active member of the Federal Advisory Committee on Water Information (ACWI), a FACA committee chaired by USDOI. EPRI co-chairs, with U.S. Forest Service, the Energy-Water Sustainability Subcommittee of ACWI. Other organizations that EPRI has collaborated with on the issue include: American Society of Mechanical Engineering, Water Environment Research Foundation, WateReuse Research Foundation, California Energy Commission, and Water Research Foundation. A listing of government funding that EPRI has received is included in Appendix B.

There are many opportunities for reducing fresh water use in the electric sector and the following sections pinpoints some of the additional research needs. Many of these needs have been outlined in a recent DOE Roadmap report which was completed with input from EPRI and others.

Degraded Water Sources – EPRI has extensively studied the use of degraded water sources, including many joint studies with DOE and the CA Energy Commission. These studies have evaluated degraded water sources from the standpoint of quantity, quality, variability, treatment options and cost, transportation options and cost, and wastewater disposal issues. Many power plants have been operating for years on degraded water sources, particularly treated sewerage effluent. This degraded water source has been the most attractive source because of its year round availability, proximity to power plants, inexpensive price, relatively low cost treatment and minimal impacts to power plant operation. Even this water source is being protected in some areas of the country for use in irrigation and groundwater recharge, limiting its use for power plant cooling.

Additional degraded water sources that are being considered include:

- Brackish water from coastal areas
- High salinity groundwater
- Mine water and produced water from oil and gas wells
- Agricultural runoff
- Stormwater

Each of these sources will cost more than traditional surface or groundwater sources, with the highest costs usually a result of treating the water and transporting it to the power plant. Additional costs can come from materials of construction, chemicals to prevent scaling, fouling and corrosion, storage or backup water system costs, and wastewater treatment and disposal.

Degraded water sources typically contain suspended or dissolved solids. Suspended solids can usually be filtered or removed in clarifiers, but dissolved solids are more difficult to remove. These dissolved solids can lead to scaling and corrosion of power plant equipment, and the suspended and dissolved solids can lead to fouling. In addition, nutrients and minerals in degraded water sources can lead to biological growth that creates additional fouling issues. All of these treatments have to be incorporated to prevent operational and maintenance issues within the power plant and add to the cost of using degraded water sources.

EPRI has identified many research needs for improving the use of degraded water sources. Some of the research that EPRI has identified includes:

- Better and cheaper treatment options
- Wastewater disposal options (salts)
- Coatings to prevent scaling, fouling and corrosion
- Technologies that can better accommodate degraded water sources (like Wet Surface Air Coolers)
- Long term experience and guidelines on using degraded water sources (example: brackish and salt water cooling towers)

Dry Cooling – Dry cooling works like the radiator on an automobile, where heat is rejected to the atmosphere by passing air over a heat exchanger, usually by using fans. There are generally two types of dry cooling. Air-cooled condensers (ACCs) are used to condense and cool the steam directly from the turbine (Figure 10). The steam is ducted to the ACC in large piping. With indirect dry cooling, the steam is cooled in a traditional condenser using a recirculating water loop. The warm water is then pumped to an air-cooled heat exchanger, where it is cooled and returned to the condenser.

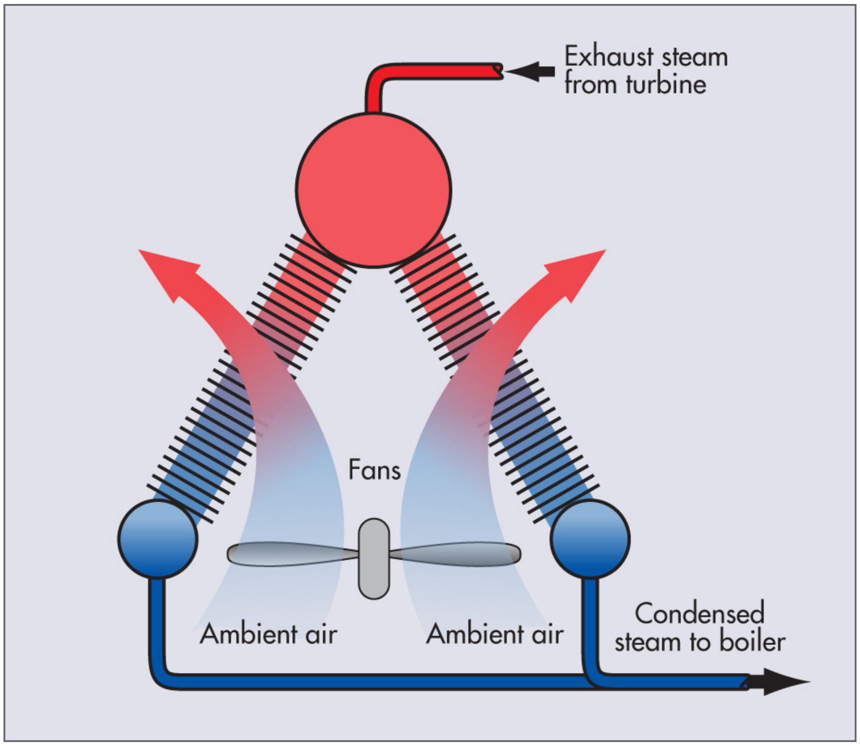

Figure 10 – Schematic of Air Cooled Condenser

While dry cooling can virtually eliminate the water required to cool power plants, it does have drawbacks.

- Cost - The capital cost for dry cooling systems is significantly higher, typically over 10% higher than wet cooling systems (Figure 11), because they require the manufacture of large finned-tube heat exchangers, large fans and drive motors, and large steel structures to provide ground clearance for proper air circulation. There are also higher operating costs associated with dry cooling. The fans needed for air circulation are much larger and more numerous than those required for a wet tower. This increases the parasitic load on the unit, and reduces the net power available from the plant. Dry cooling cools water to the *dry-bulb* temperature, which means that the water returned to the plant will be warmer than it would be with a wet cooling tower (which cools to the *wet-bulb* temperature) or once through cooling (which cools to the local surface water temperature). This higher temperature has the effect of reducing unit efficiency, which can mean up to and over a 10% efficiency penalty on the hottest days.

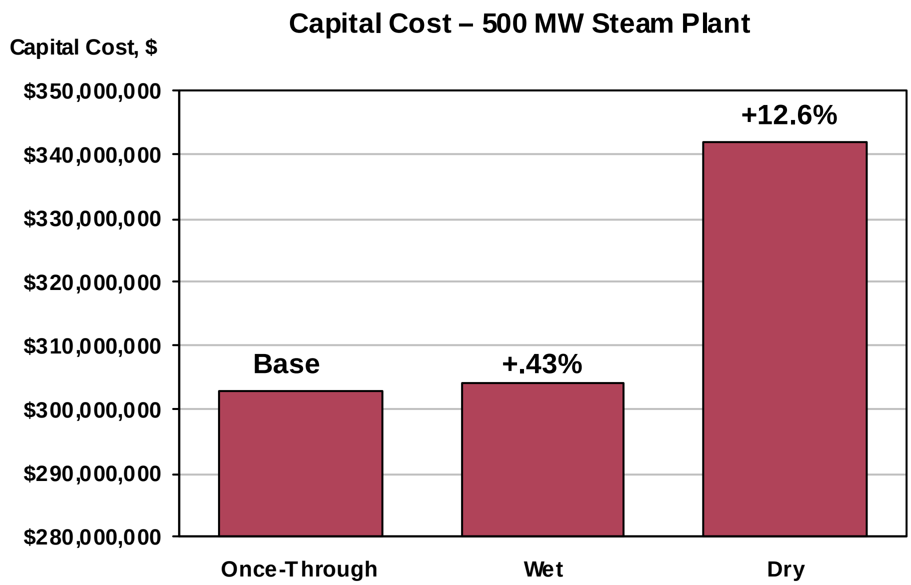

Figure 11 – Comparison of Costs for Cooling Systems

- Size – Dry cooling systems are significantly larger than traditional cooling towers and they require additional land space to build.

- Noise – The large number of cooling fans can create issues with noise for neighbors. This can be alleviated with the purchase of low-speed, low-noise fans, but this type of fan adds significantly to the cost.

- Wind Effects – Many utilities have experienced wind impacts on their air cooled condensers. These wind impacts have caused sudden drops in load, and in extreme cases, unit trips. High winds, especially gusty winds, can cause stalling of the air flow in leading edge fans, which causes a sudden drop in the cooling capacity. This creates higher backpressure for the steam turbine which cam lead to blade damage. If the control system is fast enough, it will be able to reduce steam flow (reducing load) and protect the turbine. If the backpressure rises too rapidly, and the control system cannot close the steam valves fast enough to protect the turbine, the unit will trip in order to protect the turbine from major damage.

EPRI has sponsored a great deal of research into addressing these issues for dry cooling. We have already investigated the wind effects and have developed a simple wind screen that should eliminate most of the wind issues. Additional research is needed to field test and demonstrate the technology and move it to commercial application. EPRI also believes that further improvements in efficiency of dry cooling could be made by improving the heat transfer characteristics of the condensing steam and the finned tubes. Significant improvements in finned tubes in recent years have resulted in better heat transfer and lower manufacturing costs, but there is still room for improvement in this area.

Hybrid Cooling – Hybrid cooling systems (Figure 12) provide a combination of a wet cooling tower and a dry cooling tower. This arrangement allows most of the heat to be rejected to the atmosphere on the cooler days, and still have high efficiency during hot days, with the wet tower taking part of the cooling load when the temperatures are higher. This system is becoming more popular because the tower sizes can be minimized to reduce additional costs, and performance is better than air-cooling only.

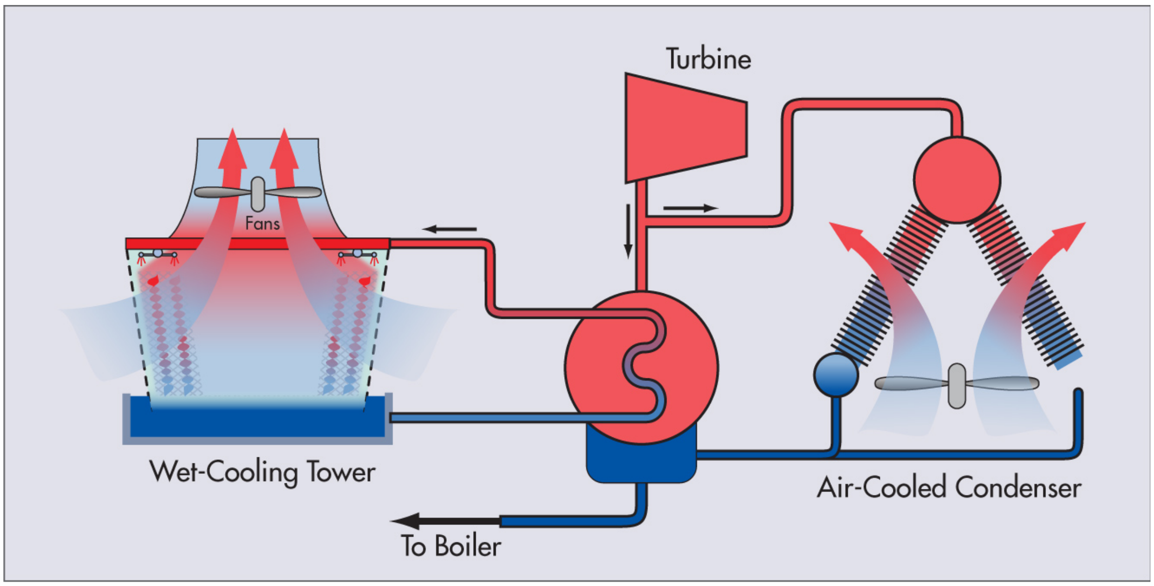

Figure 12 – Schematic of a Hybrid Cooling System

EPRI is just beginning a research program to assess the state of the art for hybrid towers. There are many ways to optimize such a system, depending on the goals of the plant design and the available water sources. The guidelines EPRI will be developing will assist plant designers with this optimization process.

There may also be a research need in helping plant operators decide when to use the wet cooling portion of the hybrid system. When operators are faced with a limited water source, and the need to preserve water for the hottest operating days of the year, some sort of forecasting and optimization tool would be useful in deciding when to use the wet cooling towers for maximum benefit (efficiency, power demand and power price).

Combined Cycles/Bottoming Cycles – Natural gas combined cycle (NGCC) power plants are common in the United States and are the predominant type of plant constructed in the last 10-15 years. NGCC plants have many benefits that make them the logical choice. The combined cycle provides for much higher efficiencies that, in return, reduces the fuel costs. This also has the effect of lowering the carbon emissions for each unit of power generated.

NGCC plants (Figure 13) also can provide a large water conservation benefit. Since roughly 2/3 of the power is produced by the combustion turbines, which do not require cooling water, the cooling water consumption is reduced by an equivalent amount. In addition, the 1/3 of the power produced by the steam generator/turbine can be cooled by ACCs, further reducing the water usage. The ACC will be smaller, since it is only cooling one third of the total plant, and any efficiency penalties on hot days would only be incurred on that one third of the capacity.

Figure 13 – NGCC Plant with Air Cooled Condenser (Structure to Left)

Bottoming cycles (Figure 14) are another way to increase the efficiency of a traditional steam plant. Such cycles were investigated by EPRI and Electricite de France (EdF) in the 1980’s, and these cycles are being examined again in light of upcoming water constraints. Increasing the power output from thermal plants would provide for decreased water consumption per unit power generated. These systems, for now, appear very costly, and managing the working fluids (ammonia or supercritical CO_2) poses a potential safety risk. However, additional research into combined cycle options, including bottoming cycles, may lead to economical systems to improve power plant efficiency, reducing both emissions (including carbon) and water utilization.

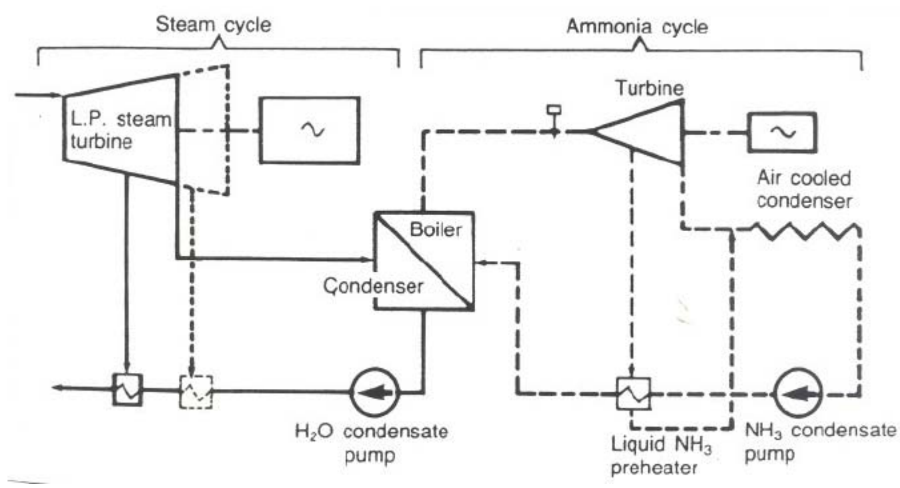

Figure 14 – Schematic of Ammonia Bottoming Cycle

Water Recapture and Water Reuse – There is a significant amount of water lost through power plant stacks (flue gas from fossil fuels) and cooling tower plumes. DOE-NETL has been sponsoring work to develop the Air-2-Air ™ system (Figure 15) for capturing moisture in cooling tower plumes. Water loss could potentially be reduced by 15-30%.

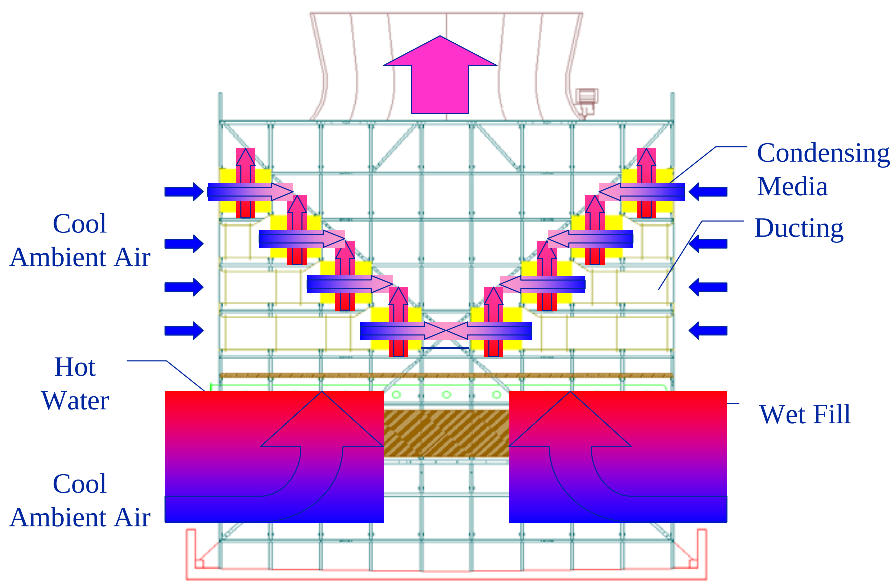

Figure 15 – Schematic of Air-2-Air ™ System

The Energy and Environmental Research Center at the University of North Dakota is pilot testing a desiccant system to recover water from flue gas. Lehigh University has also received DOE funding to develop condensing heat exchangers that will condense water from flue gas. KEMA, in the Netherlands, is developing a membrane system to extract water from flue gas. All of these technologies hold promise to replace part of the water requirements for power generation, but need additional research before they can be considered commercially available or economical.

Power plants in operation today already employ many practices to reuse water within the plant. Water is typically "cascaded" from one use to another, depending on the quality of water that is needed for each process. Some examples include:

- Fresh water that is treated and used for boiler feedwater
- Wastewater from the water treatment system is used as makeup in the Flue Gas Desulfurization (FGD) system
- Boiler blowdown is used as makeup in cooling water system
- Cooling tower blowdown is used as makeup in the FGD system
- FGD blowdown is used for ash sluicing
- Ash pond runoff is used for fly ash wetting (dust control)

By tightening the water balance in the plant, many utilities have already mastered the art of water reuse. Investments in research for more efficient and lower cost wastewater treatment systems would allow for even greater recycling and reuse. EPRI is sponsoring research in many areas of wastewater treatment, zero liquid discharge and water management toward this goal.

Role of Renewable Resources – Renewable energy from wind, solar photovoltaic, geothermal (with brine water cooling), hydroelectric, marine and hydrokinetic sources all require little to no water consumption. To the extent that these technologies can economically penetrate the generation mix, water use can be reduced. EPRI has an extensive research program into renewable energy sources, and is supporting the commercialization of new and better technologies to reduce the cost of these resources and reduce their environmental impacts.

Advanced Desalination Techniques – Sandia National Labs has had an extensive membrane and desalination program that has provided improvements in membrane technologies for reverse osmosis and other issues like salt management. As degraded water sources are used to replace potable water sources, economical desalination technologies will help reduce the costs of water treatment in the electric industry as well. Additional research into better membranes and new desalination concepts will have a dual effect. By reducing the cost of desalination, the use of degraded water sources in power plants becomes more economical. In addition, better technologies will reduce the amount of electricity required and the cost of desalination to meet growing population demands for fresh water. This research could have major impacts on society as a whole in future years. Additional research is also needed to address salt management, especially in inland areas where ocean disposal is not an option.

EPRI is also investigating a new forward osmosis technology that, if feasible, would be a breakthrough in desalination, and wastewater treatment and reuse. These "breakthrough" technologies could have a major impact on how we develop new water sources for everyone, not just the utility sector.

V. Research Needs

Most of the technologies described above are still in the development stage or have limits on where they can economically be applied. Additional work will be needed to develop viable options and provide solutions to water conservation needs in the electric sector. None of these water conserving options are universally applicable. Each has its advantages based on such factors as fuel type, plant design, local water sources, meteorological conditions and other factors. All of the alternative options for water conservation are more expensive than using traditional cooling towers and once through cooling using fresh water sources. However, these economics are based on the current price of raw water, and that price is expected to increase dramatically, especially over the typical 50-60 year life of a new power plant. In order to protect the capital investment that is made when building a new plant, power companies must be assured of a constant water source for the duration. The utility industry, and ultimately the ratepayers, will benefit from a "toolbox" of potential solutions to allow for a best-fit solution to each plant for water conservation.

In order to reduce these costs and have a variety of options to choose from in a water constrained world of the future, extensive research is needed. These research plans have been developed in cooperation between the federal government (primarily DOE and the national labs) and EPRI.

- **Engineering and Economic Analysis:** Although the choice among various water-use technologies depends on a variety of plant-specific considerations—including climate and the cost of available water—clear guidelines for the economic and operational consequences of alternative water conservation technologies are not available. Thus there is a need to develop an analytical framework to help guide plant decisions in the selection of equipment and approaches for addressing water needs.

  Previous EPRI research has laid the groundwork for such a framework by comparing the economics of various cooling technologies in particular circumstances for fossil plants. EPRI is planning additional research that will develop a decision framework for utility planners to readily compare costs and performance of alternative air and water cooling systems for thermoelectric plants. Follow-on work will adapt the framework for analysis of other water-conserving technologies.

- **Improving Dry and Hybrid Cooling:** Although there are currently several power plants that use dry cooling, most are gas-fired, combined-cycle units. There is only limited experience with dry cooling on a large scale and under baseload operations. In addition to the guidelines EPRI will be developing for designing and operating these systems, there is additional need for basic research to improve them. The greatest research need is to reduce capital and operating cost of these systems. Research will include both large-scale field verification testing of

- **Reducing Water Losses from Cooling Towers:** One of the most promising ways to reduce water consumption from existing systems is to capture the evaporative losses from cooling towers, which could produce savings up to $1.2 million annually for a 350-MW plant. A number of new options are currently being explored. The Air to Air heat exchanger described earlier could recapture about 15–30% of water exiting the cooling tower. This technology is being prepared for full-scale field testing. EPRI is also proposing additional research into optimization of water use in existing cooling towers. While these reductions are likely to be small, the cumulative effect over entire plants could be quite significant. In addition, efficiency gains in plant operations can have a similar effect in providing additional power to the grid for the same cooling water load.

- **Use of Degraded Water:** To reduce the demand for fresh water, plants in some regions are considering the use of nontraditional sources of degraded water, such as treated municipal effluent, contaminated groundwater, and agricultural irrigation return water. A major obstacle, however, is the cost of treating degraded water before it can be used in a power plant. In addition to the technology research needs identified before, additional research is needed to develop a better inventory of potential sources and explore the feasibility of matching these sources with cost-effective pretreatment technologies.

- **Water Resources Management and Forecasting:** Episodic droughts and water shortages are an increasing problem in all regions of the U.S. An example of needed research in this arena is comparing the performance of available climate models to improve the forecasting of droughts. Additional research would also provide better decision-support tools, development of effective strategies for coping with water shortages, and integrated predictions of climate change impacts by incorporating output from climate models into watershed models to assess future water availability.

EPRI has estimated the total cost of such a research program as ~$40 million over a 10-year period. The potential benefits of using the technologies developed as part of such a program would be substantial at the plant level through improved efficiency of plant operation and significant reductions in water use. The technical potential exists to increase water use efficiency and water conservation in thermoelectric generation. Realizing this potential and the associated cost savings will require a sustained research program dedicated to water sustainability. Such a program could create a portfolio of new technologies and practices that utilities could apply in site-specific ways to achieve substantial benefits.

EPRI, the electric sector, DOE, the California Energy Commission and others have invested in decades of research to bring us to this point, and we are continuing to invest in the next generation of water conserving technologies. This research investment today will have a tremendous payoff for the industry and the country in the future.

Appendix A – List of Resources Available Through EPRI

See Attached List

Appendix B – Government Funding of EPRI Research on Water Sustainability and Advanced Cooling Technologies

1. Use of Produced Water in Recirculating Cooling Systems at Power Generating Facilities. NETL/USDOE. $735,000.
2. Technical Support for National Energy-Water Report to Congress. Sandia/USDOE. $50,000.
3. Water/Energy Sustainable Residential Development. WERF/USEPA. $850,000.
4. Ohio River Basin Regional Water Quality Trading Program. USEPA. $995,000.
5. Alternative Cooling. California Energy Commission. $320,000.
6. El Dorado Spray Enhanced Cooling. California Energy Commission. $252,000.
7. U.S. Wave Energy Resource Assessment. USDOE. $500,000.
8. Eel Downstream Passage. USDOE. $50,000.
9. Lab Evaluation of Cylindrical Wedge Wire Screens. USEPA. $150,000.
10. Field Evaluation of Wedge Wire Screens. USEPA. $300,000.
11. Field Evaluation of Strobe Lights for Fish Protection. USEPA $200,000.
12. Engineering Design of Advance Hydropower Turbine USDOE. $600,000.
13. Turbine Design Support. New York State ERDA. $250,000.
14. California Hydropower Sedimentation Assessment. California Energy Commission. $50,000
15. Hydrokinetic Turbine Testing. USDOE. Proposal under review.
16. River In-steam Resource Assessment. USDOE. Proposal under review.
17. Live Cycle Cost Assessment of Wave and Hydrokinetic Power Plants. Proposal under review.