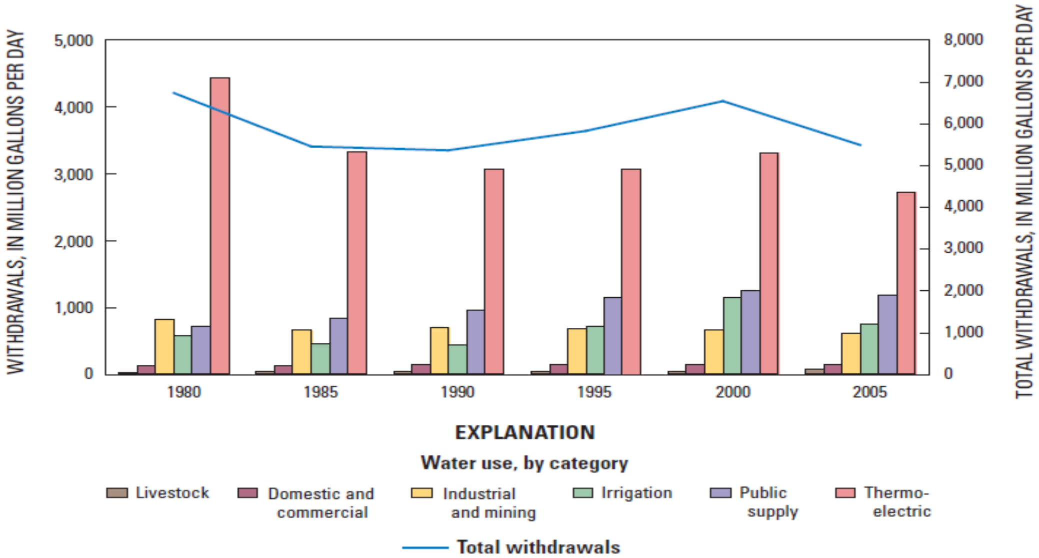
Abstract

Water scarcity is a problem of increasing concern for the state of Georgia. For the last three decades the state has experienced droughts that have reached extreme conditions on many occasions. Georgia released a comprehensive water plan in 2008 that outlined historical and projected water use for various sectors of the economy. Water use for energy generation has the largest by volume consumptive use of water in the state. The report outlined plans for future energy generating facilities in order to meet the projected demand increase for electricity due to population growth over the next 30 years. The planned technologies for these power plants relied mostly on conventional fossil fuel generators with tower cooling systems. From a water consumption standpoint these facilities are highly inefficient compared to currently available technologies. Though a quantitative analysis of the median water consumption rates of alternative fuel sources and cooling technologies and a qualitative analysis of the feasibility of these alternatives from a geographical perspective, it was determined that concentrated solar power and adoption of dry cooling technology for conventional combustion generators provided the greatest water savings (96-99% on average) relative to other generation technologies. It was also concluded that the choice in cooling technology had nearly as much impact on water consumption by a power plant as did the choice of a fuel source.

For the last five years Georgia has seen increases in the areas affected by extreme drought conditions, starting in 2007 with a major drought that garnered national media attention. However, droughts have posed a threat to Georgians for over 30 years. These climactic changes have created greater hardship due to legal conflicts with neighboring Florida and Alabama over the two major river basins located in the state. Additionally, the metropolitan Atlanta area has seen a large population increase in the last decade, which has increased demand for water (U.S. Census, 2010). Throughout the droughts and interstate conflicts, Georgia attempted to mitigate some of this water scarcity through legislation, interstate compacts, and conservation measures. Despite these attempts, the most recent dry period resulted with over half the state declared to be in extreme drought in 2012.

Georgia has not seen any major shifts in the allocation of water resources in the last 20-30 years. As depicted in Figure 1, since 1985, thermoelectric power has been by far the largest water use in the state. The changes in irrigation withdrawals are consistent with variances in hydrological conditions, increasing during drier years (1980 and 2000) and decreasing during normal or wetter years, and therefore do not indicate a larger economic trend toward or away from certain industries and water uses (Fanning, 2009).

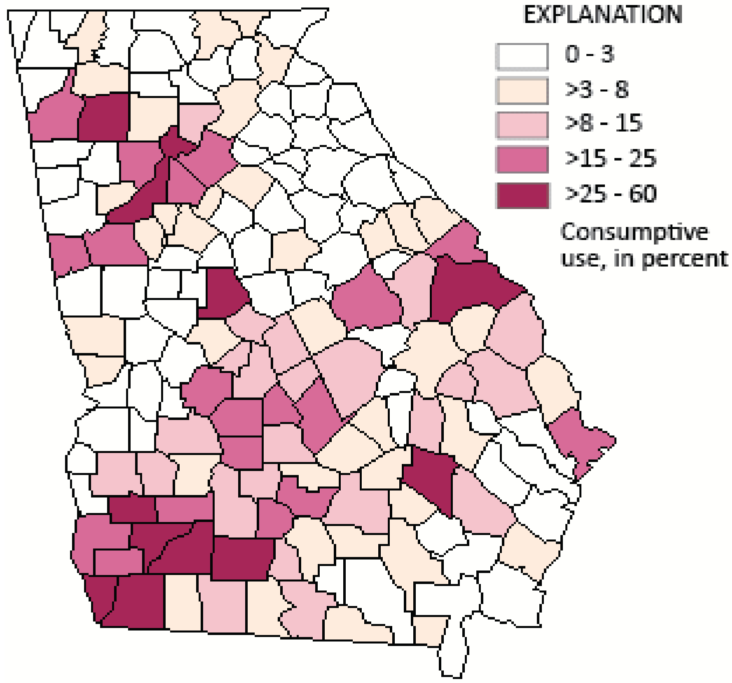
Figure 1. Trends in total water use by category, Georgia 1980-2005



Source: Fanning, 2009. Georgia Environmental Protection Division

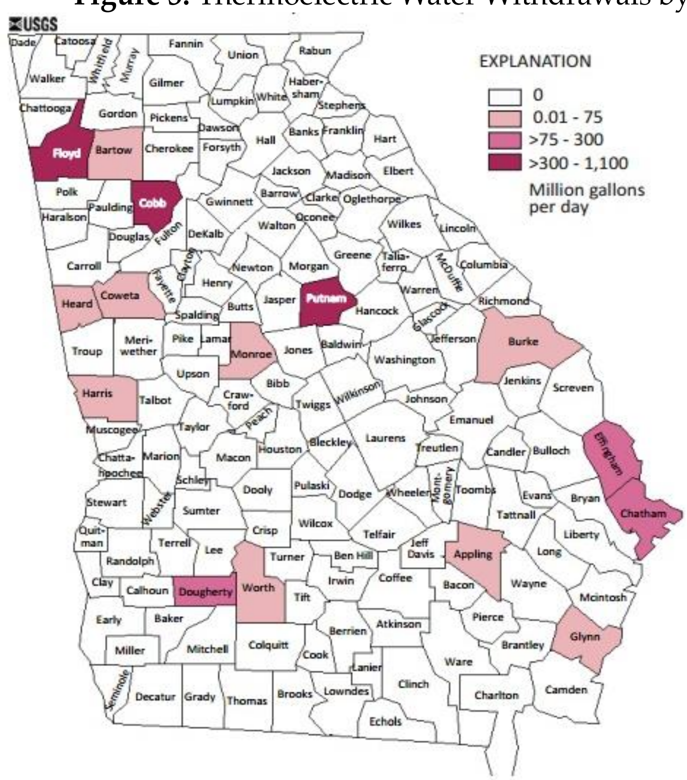
In the United States, approximately eighty-nine percent of electricity is generated in thermoelectric power plants. Another nine percent comes from hydroelectric generation and the remaining two percent comes from wind and solar energy. In Georgia the energy generation portfolio is similar to the national figures. Ninety-five percent of the state's electricity comes from thermoelectric sources (coal, gas, nuclear) and the remaining five percent from hydroelectric generation (Energy Information Administration, 2012). Additionally, Georgia is ranked ninth highest in the nation in both electricity generation and consumption. One of the costs not adequately accounted for in our power supply portfolio is the water use of these power plants. Figures 2 and 3 illustrate the withdrawals for thermoelectric power in Georgia and the level of consumptive water use in different counties.

Figure 2. Consumptive Water Use by County



Source: U.S. Geological Survey 2009

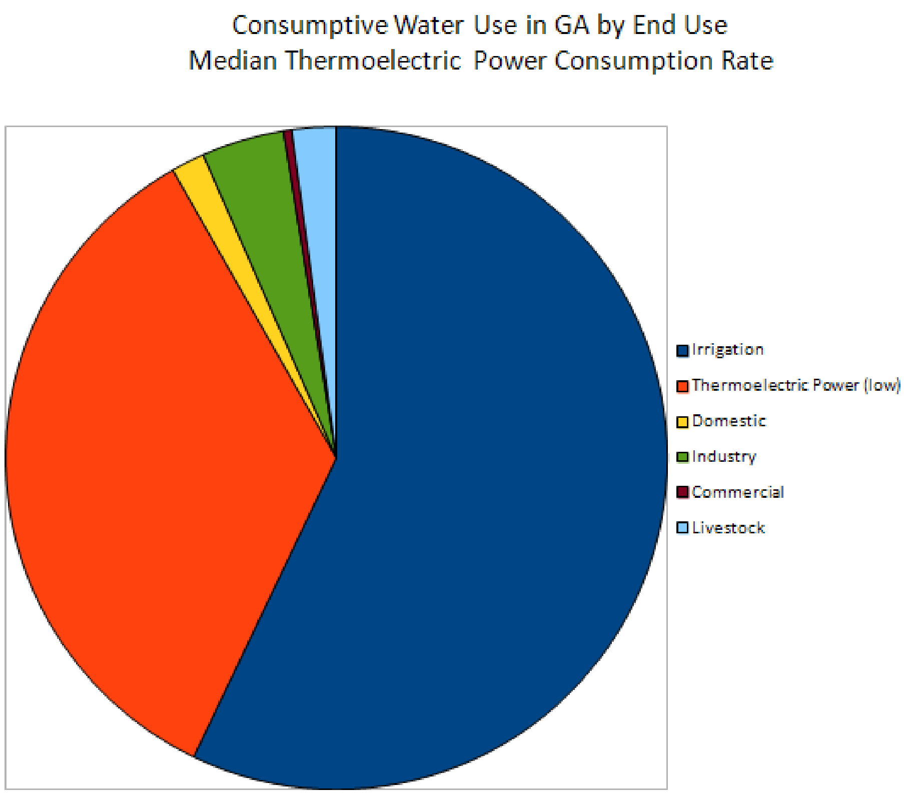
Figure 3. Thermoelectric Water Withdrawals by County



Source: U.S. Geological Survey 2009

Differentiated from aggregate water withdrawals, this paper will focus on the water use that is evaporated, transpired or otherwise removed from the immediate water environment. The maps above illustrate that there is a great deal of overlap between the counties with the highest withdrawals for thermoelectric power and those with the highest consumptive water uses. In Georgia consumptive water use accounts for approximately 24% of total water disposition with the breakdown of use by category illustrated in the figures below.

Figure 4. Areas Represent a Percent of the Total Water Consumption in Georgia[a]



Note: [a] The median thermoelectric water use rate was used due to the variability in cooling technologies which can have dramatically different water consumption rates from 0-70%.

Thermoelectric power is responsible for 35-50% of consumptive water use in Georgia which is the largest share of any of the categories. Though irrigation and livestock have a larger water consumption factor of 100%, compared to the 18% and 35% factors used for thermoelectric power in constructing the figures above, the total volume of water withdrawn by power plants far outpaces agricultural withdrawals (USGS 2009).

The nature of electricity production and distribution under the grid system warrants oversight and control by the government. Because much of Georgia remains rural, and urban sprawl fuels the growth of suburban neighborhoods, the demand for electricity follows this growth. Providing reliable service to these neighborhoods incurs a significant cost that may or may not be profitable for the utility company. Thus, to encourage the electric companies to provide service and to ensure that citizens have power, Georgia has given Georgia Power and a handful of electric membership corporations (EMCs) monopolistic control over the state's electricity market. Currently there are 11 new power generation facilities planned to come online in the next 5-10 years in order to keep up with increasing electricity demand (Davis and Horrie, 2010). Most are slated to use conventional, fossil fuel technologies, and this paper will explore opportunities for water conservation through alternative fuel or cooling technology adoption.

The opportunity costs of water conservation during periods of drought will have differing impact on water consumers in various sectors (power generation, industry, agriculture, and residential users). Without a conservation strategy, prices will necessarily rise as demand for an increasingly scarce resource grows. In fact, according to a recent study by the Environmental Finance Center at the University of North Carolina, Georgia's water utilities are already under financial stress. The 2012 report revealed that many water suppliers are not covering their operating expenses, making it difficult update aging infrastructure or finance necessary expansion (EFC, 2012). The proposed power plants fall under five different regional water planning councils (depicted in table 1) and reports released by these individual authorities in 2010 projected significant increases in municipal water demand over the next 40 years with moderate to severe water shortages resulting.

Table 1. Proposed Power Plant Location and Projected Regional Water Demand

River Basin Commission	Power Plants	Municipal Demand Increase 2010-2050	Water shortage
Upper Ocmulgee Watershed	Oglethorpe Power	11%	20 million gallons per day
Upper Oconee Watershed	Paul Creek Energy Center, LLC and Plant Washington	41.8%	42 million gallons per day
Lower Flint Watershed	Plant Mitchell, Bainbridge Power, and Longleaf Energy Station	44.4%	400 million gallons per day
Savannah Watershed	Warren County Biomass Energy Facility and Plant Vogtle Units 2 & 3	10.9%	19 million gallons per day
Chattahoochee Watershed	Units 1-3 of Plant McDonough	29%	0-90 million gallons per day[a]

Sources: GAEPD Lower Flint, Middle Chattahoochee, Upper Oconee, Upper Ocmulgee, and Savannah Regional Water Plans
Note: [a] Different agriculture use scenarios result in this range of shortages

These shortages could have very negative effects on economic viability of these regions by constraining residential growth, agriculture and industry. Because thermoelectric power consumes such a large percentage of Georgia's water resources, there is great potential for conservation which will be discussed in the following sections.

Methodology

A combination of sources was used to inform the statistical analysis of projected water use scenarios for the different power generating facilities. Basic information about each of the 11 planned facilities (see table1 below) was taken from Georgia's State Water Plan, which was compiled by the Environmental Protection Division of the Georgia Department of Natural Resources and adopted by the Georgia General Assembly in 2008 (EPD, 2009).

Table 2. Planned Energy Utility Facilities in Georgia

Plant Name	Capacity (MW)	Fuel Source/ Prime Mover	Cooling Type[a]	County	Planned Year of Operation
Plant Mitchell	96	Biomass/Steam Turbine	OT	Dougherty	2013 (delayed)
McDonough Units 4&5	1682	Natural Gas/Steam Turbine	CT	Cobb	2012 (delayed)
McDonough Unit 6	841	Natural Gas/Steam Turbine	CT	Cobb	2013 (delayed)
Vogtle Unit 3	1102	Nuclear/Steam Turbine	CT	Burke	2016
Vogtle Unit 4	1102	Nuclear/Steam Turbine	CT	Burke	2017
Bainbridge Power	170	No. 2 Fuel Oil/Simple Cycle	N/A	Decatur	b/w 2010 and 2015
Paul Creek Energy Center, LLC	225	Natural Gas/Simple Cycle	N/A	Washington	b/w 2015 and 2020
Plant Washington	850	Coal/Steam Turbine	CT	Washington	b/w 2010 and 2015
Longleaf Energy Station	1,200	Coal/Steam Turbine	CT2	Early	b/w 2015 and 20203
Oglethorpe Power – Monroe County4	1,200	Natural Gas/Combined-Cycle	CT	Monroe	b/w 2015 and 2020
Warren County Biomass Energy Facility	100	Biomass/Steam Turbine	CT	Warren	20155
Total			**8,568 MW**		

Source: Georgia Environmental Protection Division, 2009.
Note: [a] Cooling Type Abbreviations = OT: Once-through (single pass), CT :Cooling Tower (re-circulated)

To determine the water demand coefficient for different electricity generating technologies, data from a study done by the National Renewable Energy Laboratory was compiled in a spreadsheet with the capacity (MW/hour) of each of the planned power plants and various water demand scenarios were calculated across nine different fuel sources, with different cooling processes and technologies under each source (Macknick et al, 2011). The following tables detail these factors.

Table 3. Consumption Factors for Renewable Technologies and Cooling Technology

Fuel Type	Cooling	Technology	Median	Max	Min
PV	n/a	Utility Scale PV	26	33	0
Wind	n/a	Wind Turbine	0	1	0
Concentrated Solar Power	Tower	Through	865	1057	725
		Power Tower	786	860	740
		Fresnel	1000	1000	1000
	Dry	Through	78	79	43
		Power Tower	26	26	26
	Hybrid	Through	338	345	105
		Power Tower	170	250	90
	n/a	Stirling	5	6	4
Biopower	Tower	Steam	553	965	480
		Biogas	235	235	235
	Once through	Steam	300	300	30
	Pond	Steam	390	480	300
	Dry	Biogas	35	35	35
Geothermal	Tower	Dry Steam	176	1796	1796
		Flash (freshwater)	10	19	5
		Flash (geothermal fluid)	2583	3100	2067
		Binary	3600	3963	1700
		EGS	4784	5147	2885
	Dry	Flash (freshwater)	0	0	0
		Binary	135	270	0
		EGS	850	1778	300
	Hybrid	Binary	221	368	74
		EGS	1406	1999	813
Hydropower	n/a	agg. in-stream res.	4491	18000	1425

Source: Macknick, et.al., National Renewable Energy Laboratory, 2011.

Table 4. Consumption Factors for Thermoelectric Power Fuel Types and Cooling Technology

Nuclear	Tower	Generic	672	845	581
	Once through	Generic	269	40	100
	Pond	Generic	610	720	560
Natural Gas	Tower	Combined cycle	198	300	130
		Steam	826	1170	662
		Combined cycle w/ CCS	378	378	378
	Once through	Combined cycle	100	100	20
		Steam	240	291	95
	Pond	Combined cycle	240	240	240
	Dry	Combined cycle	2	4	0
	Inlet	Steam	340	600	80
Coal	Tower	Generic	687	1100	480
		Subcritical	471	664	394
		Supercritical	493	594	458
		IGCC	372	439	318
		Subcritical w/ CCS	942	942	942
		Supercritical w/ CCS	846	846	846
		IGCC w/ CCS	540	558	522
	Once through	Generic	250	317	100
		Subcritical	113	138	72
		Supercritical	103	124	64
	Pond	Generic	545	700	300
		Subcritical	779	804	737
		Supercritical	42	64	4

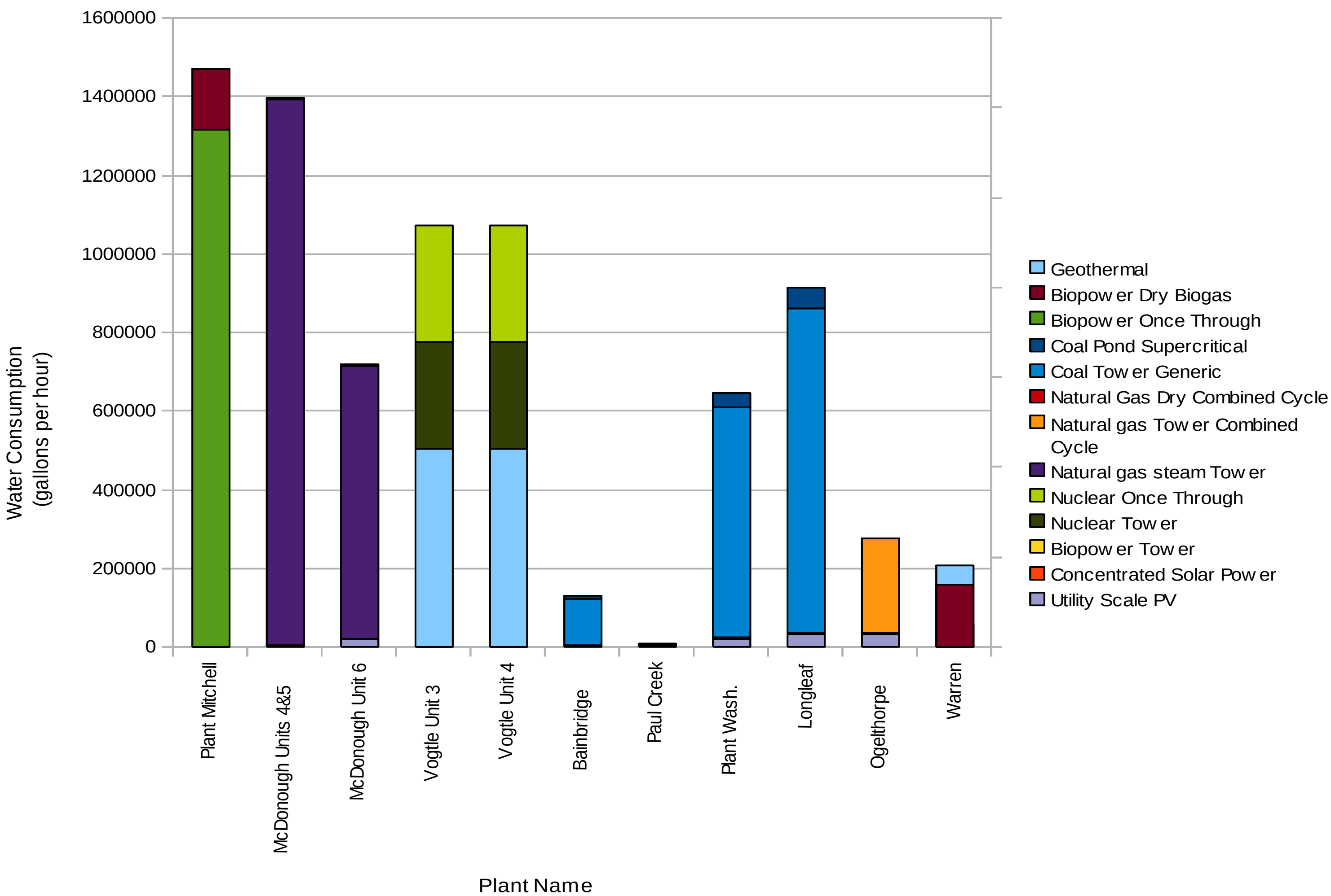
Source: Macknick, et.al., National Renewable Energy Laboratory, 2011.

These results were then analyzed based on the feasibility of different alternative energy technologies based on geographic location (county). The data regarding renewable energy potential was also taken from the National Renewable Energy Laboratory, which published data regarding wind, biomass, and various solar energy generation potential at the state and county level. One the potential of different energy sources was determined, the water demand scenarios for different cooling processes and technologies within that energy source were analyzed to determine the best available technology in terms of lowest water consumption. For each planned facility the water consumption of the current planned technology was calculated and then feasible water saving alternatives were identified both in alternative fuel sources and the current technology if different cooling technologies were to be employed.

Results

There are many opportunities for water conservation through changes in the planned technology across the 11 facilities. The greatest opportunities for savings occur at the the plants with the highest capacity, which include Units 4 & 5 at Plant McDonough, Units 2 & 3 at Plant Vogtle, Plant Long Leaf and Plant Oglethorpe, which all have generating capacities exceeding 1,000 MW. The greatest possible water savings (calculated by dividing the feasible technology with the lowest water use by the current planned technology's water use) averaged to a 99% savings at each of these facilities. The graph below illustrates the water consumption requirements of different fuel and cooling technologies applied to the conditions of each planned power plant.

Figure 6. Graph of Water Consumption of Fuel and Cooling Technology Alternatives for Planned Power Facilities in Georgia



Some of the water saving alternatives are very difficult to see on the graph because their use is so much lower than the current technologies. Utility scale solar photovoltaic (PV) electricity generation is one of these options. The solar PV potential for the entire state of Georgia is between 5 and 5.5 on a scale of 3 (low potential) to 6.5 (high potential). For most facilities, concentrated solar power (CSP) which uses long, curved mirrors across a large land area to focus light on a pipe filled with a heat transfer liquid. This heated liquid is used to make steam and drive a turbine to generate electricity (DOE, 2010) was the alternative with the lowest water consumption. The exceptions to this were Units 4, 5 & 6 at plant McDonough, Paul Creek, and Oglethorpe, all of which would reap the greatest savings from using a combined cycle (generating steam and electricity) natural gas generator with dry cooling as opposed to a purely steam facility with tower cooling.

In a typical thermoelectric power plant, heat is removed from the cycle with a condenser. In order to remove the heat, cooling water is used. The two major types of cooling for power production are once-through cooling and closed-loop cooling; a minor type is termed dry cooling (Torcellini, 2003). Dry cooling is typically more water efficient, because dry cooling uses little or no water and needs less maintenance than cooling towers that require water. The cooling water (and related heat) is then discharged in to a river, a reservoir, or an ocean. However in some places this practice is being replaced by a process of evaporating a portion of the cooling tower which aims to minimize the environmental impacts from quickly dumping large amounts of heated water back into the stream. This results in significant consumptive use of water. For all of the planned facilities using coal, natural gas, and biomass a significant savings (96% on average), could be achieved through the adoption of dry cooling.

Biomass as a fuel source also yielded potential as a water saving technology with an average of 94% reduction in water consumption over current planned technologies at each of the facilities. However, there are significant barriers in technology, logistics, and policy to bring an electrical utility-scale biomass facility online. Plant Mitchell in Dougherty County has been trying to convert its coal fired facility into a biomass plant for the last five years, and has run into regulatory challenges as well as transportation issues in getting a steady supply of biomass feedstocks to the plant in a cost effective manner (PRN Newswire, 2011). Additionally, the consumptive water use requirements in this analysis only account for electricity generation, and do not take into consideration the water required for production of biomass feedstocks, which could be a potentially significant net consumptive use. Though natural gas and coal also have high water use requirements for production, unlike biomass these fuel sources are not produced in Georgia, and therefore would not have an impact on the water resources of the state (Stone, 2010).

Geothermal was only a feasible option at Plant Vogtle and Plant Warren because the geological conditions in Burke and Warren counties were the only places among all the locations of the planned power plants that had even a slight potential for geothermal energy. The savings could be significant, 99% reduction in water consumption, but given that the potential at these sites was only one ranking above “least favorable” it may not be a reliable alternative.

Hydropower is a very attractive option for Plant McDonough, Plant Vogtle, Plant Bainbridge, and Plant Long Leaf, all of which have untapped dam potential of 50-100 MW (NREL, 2013). Water flowing through the turbines and into the river is not considered consumptive because it is still immediately available for other uses. Increased surface area of the reservoir, when compared to the free flowing stream, does result in additional water evaporation from the surface, but the rate of evaporation would be dependent on a number or variables, so for this analysis consumptive use is assumed to be zero. Therefore, opting for a hydroelectric dam over a fossil fuel powered facility would result in a 100% water savings.

Finally, wind power is not included in this analysis, not because it does not result in water savings (like hydro power is estimated to be near 100%), but because none of the planned facilities are located in regions of Georgia that have potential for wind energy generation.

Conclusions

Based on this analysis of the water consumption rates of various fuels, technologies and cooling processes it can be concluded that the choice of cooling process has almost as much impact on the water use of planned power plants in Georgia as a choice in fuel source. The difference between the water consumption of a fossil fuel generator with dry cooling verses a concentrated solar or solar PV facility was not significant. Furthermore, in some cases the solar facility consumed more water. Moving forward, the next step would be to complete a cost benefit analysis for each of the feasible alternatives identified for each planned power plant. Considerations would need to be made for the environmental impacts of these plants, particularly since the fuel choices will have very different impacts, because of their emissions systems. Additionally, the potential for electricity rate changes in order to construct these facilities and operational life would need to be included in this analysis in order to give a more complete assessment of alternative means of electricity generation for future Georgia power plants.

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