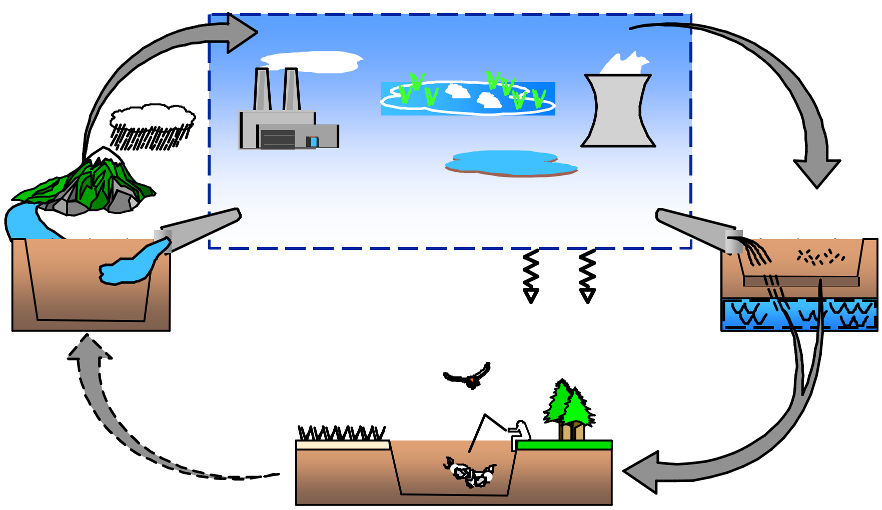
Water & Sustainability (Volume 4): U.S. Electricity Consumption for Water Supply & Treatment - The Next Half Century

Technical Report



Water & Sustainability (Volume 4): U.S. Electricity Consumption for Water Supply & Treatment—The Next Half Century

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Topical Report, March 2002

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REPORT SUMMARY

The fast growing demand for clean, fresh water—coupled with the need to protect and enhance the environment—has made many areas of the United States and the rest of the world vulnerable to water shortages for various human uses. As they interact with the electricity industry, these uses encompass agricultural irrigation, thermoelectric generation, municipal water/wastewater treatment and distribution, and industrial processes. The dependency of electricity supply and demand on water availability can impede societal and economic sustainability, adversely affect the future growth of electric demand, cause shortages in current electric supplies, and impact electric grid topology planning.

Background

Unlike gradually developing environmental concerns, such as climate change where long lead-times allow coping strategies to be developed from evolving scientific and technical innovations, water (and energy) shortages can occur relatively suddenly and cripple local and national economies. EPRI perceived a critical need to better understand and manage the interrelationship of water and energy, to improve environmentally sustainable economic development.

Objectives

- To determine if there will be sufficient electricity available for providing fresh water and treating wastewater to satisfy the country's agricultural, power production, industrial, and drinking water needs.
- To determine typical electricity consumption per unit of water supply and treatment for end-use sectors and thermoelectric generation.
- To project future growth patterns of electric consumption associated with water supply and treatment over the next half century.

Approach

The project team combined two decades of expertise in electricity, environmental, and water management efforts to develop a four-volume series of Water & Sustainability documents to meet the project objectives. This volume is *Water & Sustainability: U.S. Electricity Consumption for Water Supply & Treatment—The Next Half Century (Volume 4)*. The other volumes are *Water & Sustainability: Research Plan (Volume 1, EPRI report 1006784), Water & Sustainability: An Assessment of Water Demand, Supply, and Quality in the U.S.—The Next Half Century (Volume 2, 1006785), and Water & Sustainability: U.S. Water Consumption for Power Production—The Next Half Century (Volume 3, 1006786).*

Results

This screening study's results included

- For the first time, unit energy (electric) requirements have been estimated for all end-use sectors and for thermal power generation, with respect to water supply and treatment.
- Generally, electricity demand associated with water supply and treatment for various end-use sectors will likely track Bureau of Census population growth projections of 50% by the year 2050. The only exceptions are irrigation pumping and industrial (excluding mining) uses, both of which will triple over that period. Thermal power generation electricity requirements associated with water use will remain relatively flat.
- Some 4% of the nation's electricity use goes towards moving (80%) and treating water/wastewater. Approximately 80% of municipal water processing and distribution costs are for electricity. Electricity availability, while critical for water supply and wastewater processing, is not a major impediment to economic development. However, water is a key constraint on such development and will strongly affect the overall demand for electricity from human activities that depend on water availability.
- Groundwater supply of water from public sources requires about 30% more electricity on a unit basis than supply from surface water. The difference is due primarily to a higher requirement for raw water pumping for groundwater systems.

EPRI Perspective

Given EPRI's Electricity Technology Roadmap projections of some 7000 GW of additional electric generation needs by the year 2050, it is imperative that any critical resource availability on which this projection rests be evaluated and addressed. This Water & Sustainability effort did find that electricity availability is not a constraint on water supply and treatment capabilities; rather, it is electricity supply and demand that depend on water availability.

Keywords

Water management
Sustainability
Electricity generation
Electricity demand
Electric grid

ABSTRACT

The use of electricity for public and private supply of water and for wastewater treatment is an important factor in economic growth and sustainability in the United States. As the economy grows, all sectors increase their demand for fresh water and generate additional quantities of wastewater that must be treated before discharge.

This report estimates, for the first time, *unit electricity requirements* for the supply of fresh water and the treatment of wastewater across the U.S. economy. These unit electricity requirements are then used to project total electricity requirements for selected sectors of the economy. Sectors included in this analysis include:

- Public water supply agencies
- Publicly owned wastewater treatment facilities and privately operated wastewater treatment facilities
- Self-supply of water to the domestic, commercial, industrial, mining, irrigation, livestock, and thermal power generation sectors

Issues regarding changes in unit electricity consumption and aggregate electricity requirements for each sector are also identified and their impact on future projections are assessed.

Projected future electricity requirements for water supply and wastewater treatment are expected to represent less than 4 percent of the total projected annual electricity sales to all sectors over the period 2000 to 2050.

The amount of electricity required to meet the cooling water needs of thermal plants over the period 2000 through 2020 is estimated to represent less than 0.5 percent of the total generation of these types of plants.

Overall electricity demand, associated with water supply and treatment for various end-use sectors, will likely track Bureau of Census population growth projections of 50% over the period 2000 through 2050, with the exception of irrigation pumping and industrial (excluding mining) uses, both of which will triple over that period. Thermal power generation electricity requirements associated with water use will remain relatively flat.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1
INTRODUCTION AND SUMMARY

Introduction

The use of electricity for public and private supply of water and for wastewater treatment is an important factor in economic growth and sustainability in the United States. As the economy grows, all sectors increase their demand for fresh water and generate additional quantities of wastewater that must be treated before discharge.

This report estimates unit electricity requirements for the supply of fresh water and the treatment of wastewater across the U.S. economy. These unit electricity requirements are then used to project total electricity requirements for selected sectors of the economy. Sectors included in this analysis include:

- Public water supply agencies
- Publicly owned wastewater treatment facilities and privately operated wastewater treatment facilities
- Self-supply of water to the domestic, commercial, industrial, mining, irrigation, livestock, and thermal power generation sectors

The main question addressed by the study is: "Will there be sufficient electricity available to satisfy the country's need for fresh water." In order to make this assessment, unit electricity requirements for water supply and wastewater treatment were estimated. These were used in conjunction with projections of water consumption requirements for various economic sectors to develop aggregate electricity requirements for the period 2000 through 2020, with an extrapolation to the year 2050. Where possible, projections were carried out for each of the nine geographical areas defined by the U.S. Census Bureau.

The projections of electricity requirements for water delivery and wastewater treatment were also compared to a national forecast of electricity consumption by sector through the year 2020 [1] to determine whether the estimates were reasonable. Further, issues and caveats regarding the forecast estimates were identified, and to the extent possible their impact on the estimates was qualified and quantified.

Summary of Results

The key contributions of this study include:

- For the first time, *unit energy (electric) requirements* have been estimated for all end-use sectors and for thermal power generation, with respect to *water supply and treatment*.
- Generally, electricity demand associated with water supply and treatment for various end-use sectors, will likely track Bureau of Census population growth projections of 50% by the year 2050, with the exception of irrigation pumping and industrial (excluding mining) uses, both of which will triple over that period. Thermal power generation electricity requirements associated with water use will remain relatively flat.
- Some 4% of the nation's electricity use goes towards moving (80%) and treating water/wastewater. Approximately 80% of municipal water processing and distribution costs are for electricity. Electricity availability, while critical for water supply and wastewater processing, is not a major impediment to economic development. However, water is a key constraint on such development, and will strongly affect the overall demand for electricity from human activities – which depend on water availability.
- Groundwater supply of water from public sources requires about 30% more electricity on a unit basis than supply from surface water. The difference is due primarily to a higher requirement for raw water pumping for groundwater systems.
- Of the end-use sectors, the industrial sector uses the most self-supplied percentage (80%); the mining subsector uses nearly 100% self-supplied water.
- Factors that could increase unit energy (electric) consumption for public supply/treatment agencies include
  - -- The age of the water delivery system: as systems age friction in piping increases and efficiency of pumping systems decreases, resulting in an increase in electricity requirements for pumping
  - -- Implementation of voluntary or mandatory restrictions on water consumption (including application of home appliance and plumbing fixture water consumption standards): water conservation programs will should reduce the overall amount of electricity required, but may actually result in an increase in unit electricity consumption as economies of scale may be lost or systems operate at below optimum levels
  - -- Requirements for improved treatment: as standards and requirements for drinking water quality increase, more rigorous treatment will be required. Regardless of the type of enhanced treatment employed, more rigorous treatment will result in increased pumping energy requirements
  - -- The additional water pumping associated with advanced wastewater treatment results in 3 times the electricity use of a conventional trickling filter approach. In fact, this difference leads to the expectation of a 20% increase in electricity use by public supply agencies from 2000 to 2005; the projection for the next 45 years after that is only another 20%, since major treatment approach changeovers will have been completed in the first five year period.

- Factors that could decrease unit energy (electric) consumption for public supply/treatment agencies include
  - -- Economies of scale: a trend to larger systems from smaller systems will provide economies of scale of operation, resulting in reduced unit electricity consumption
  - -- Replacement of older equipment with more energy efficient pumps, drives, and water processing equipment
- Conclusions about privately operated wastewater treatment works include
  - -- The average size of privately owned wastewater treatment facilities will fall into the smallest size range of publicly owned treatment works.
  - -- Wastewater treatment facilities associated with industrial plants are designed to deal with specific contaminants generated by the facilities – for instance, wastewater treatment plants associated with food processing and pulp and paper facilities are designed to deal with higher loadings/concentrations of BOD and COD than municipal facilities. Municipal wastewater treatment facilities are typically designed to handle domestic wastes, in terms of both volume and concentration of waste.
  - -- Given the smaller size and potentially higher loadings, the unit electricity consumption of these types of facilities will tend to be higher than for POTWs. A reasonable estimate of unit electricity consumption would be about 2,500 kWh/million gallons (0.661 kWh/cubic meter).
  - -- Since discharges from these facilities are typically to surface water, it is likely that more aggressive wastewater treatment will be required over the next 20 years – this is likely to increase unit electricity consumption over the period by perhaps 5 to 10 percent.
  - -- It is expected that more privately operated wastewater treatment facilities will be constructed over the next 20 years. These facilities would provide either full treatment followed by discharge to surface water, or pretreatment to reduce concentrations to significantly reduced levels before discharge to POTWs. In the latter case, the industrial facilities may be currently discharging untreated wastewater directly to a POTW for treatment. As municipally owned wastewater treatment facilities are starting to reach their treatment limits, it is often less expensive for industrials to engage in pretreatment rather than to pay the increasing surcharges imposed on their higher concentration discharges. Hence, the total amount of electricity required to process wastewater in privately operated facilities is expected to increase over the 50 year horizon.

Table 1-1 summarizes the unit energy (electricity) consumption for sectoral and thermal power generation water movement and treatment. Table 1-2 summarizes the results of this analysis for sectoral electricity requirements for public and self-supply of fresh water and wastewater treatment. These electricity requirements do not take into account the source of the electricity for each of the sectors, which will be a combination of purchased electricity and self-generated electricity. Therefore, these projections overestimate the amount of electricity required from public utilities to meet requirements for fresh water and wastewater treatment.

Table 1-1
Summary of Unit Energy (Electric) Consumption for Water Supply and Wastewater Treatment

Sector	Surface Water	Ground Water	Wastewater
kWh/Million gallons			
Domestic	-NA-	700	-NA-
Commercial	300	700	2500
Industrial	300	750	2500
Mining	300	750	2500
Irrigation	300	700	-NA-
Livestock	300	700	-NA-
Power Generation	300	800	-NA-
Public Supply (includes wide area distribution)	1406	1824	-NA-
Publicly Owned Treatment Works (typical)	trickling filter activated sludge advanced wastewater treatment advanced treatment with nitrification		955 1,322 1,541 1,911
kWh/cubic meter			
Domestic	-NA-	0.185	-NA-
Commercial	0.079	0.185	0.661
Industrial	0.079	0.198	0.661
Mining	0.079	0.198	0.661
Irrigation	0.079	0.185	-NA-
Livestock	0.079	0.185	-NA-
Power Generation	0.079	0.211	-NA-
Public Supply (includes wide area distribution)	0.371	0.482	-NA-
Publicly Owned Treatment Works (typical)	trickling filter activated sludge advanced wastewater treatment advanced treatment with nitrification		0.252 0.349 0.407 0.505

Table 1-2
Summary of Electricity Consumption Projections for Water Supply and Wastewater Treatment

Year	2000	2005	2010	2015	2020	2050	Approx. % Increase 2000-2050
Public Supply and Treatment – Million kWh							
Public Water Supply	30,632	31,910	33,240	34,648	36,079	45,660	50
POTWs	21,006	24,512	24,895	25,277	26,039	29,820	50
Private Supply and Treatment – Million kWh							
Domestic Supply	894	930	965	1,001	1,038	1,274	50
Commercial Supply	476	499	525	553	581	780	50
Industrial Supply	3,341	3,793	4,236	4,731	5,284	10,255	200
Mining Supply	490	509	528	548	569	713	50
Irrigation Supply	23,607	25,639	27,909	30,453	33,314	60,646	150
Livestock Supply	992	1,047	1,095	1,144	1,192	1,510	50
Privately Operated Wastewater Treatment (see note)	42,012	49,025	49,790	50,555	52,078	59,641	50
Total Electricity	123,450	137,864	143,182	148,910	156,174	210,299	100

Note: It was not possible to make electricity consumption projections for privately operated wastewater treatment facilities (see Chapter 3). The figure shown here is a surrogate representing twice the electricity consumption of POTWs. This estimate was used because there are about 50 percent more privately operated wastewater treatment facilities in the U.S. as POTWs, and their unit electricity consumption is estimated to be about 50 percent greater than that of POTWs because of loss of economies of scale and different treatment regimens.

Table 1-3 summarizes a U.S. Department of Energy (USDOE) forecast [1] of electricity sales by sector through the year 2020. The USDOE forecast was extrapolated using the final five year (2015 – 2020) growth rate to the year 2050. As a comparison, the projected electricity requirements for water supply and wastewater treatment represent ***less than 4 percent*** of the total projected electricity sales to all sectors. Since the electricity requirements shown in Table 1-2 include both purchased and self-generated electricity, on a percentage basis the projected purchased electricity requirement for water supply and wastewater treatment will be substantially less than 4 percent of total electricity sales. Given this relatively small portion of total electricity requirements, it is not expected that changes in the supply or availability of electricity will have a major impact on water production and demand.

Table 1-3
Forecast Total Electricity Consumption for all Sectors

Year	2000	2005	2010	2015	2020	2050	Approx. % Increase 2000-2050
Million kWh							
Residential	1,184,516	1,281,269	1,378,904	1,464,345	1,562,615	2,307,302	100
Commercial	1,096,484	1,189,062	1,277,113	1,343,749	1,370,502	1,542,583	50
Industrial	1,058,701	1,148,552	1,217,122	1,302,949	1,377,577	1,924,188	100
Transportation	20,742	4,529	36,328	43,822	49,269	99,503	400
Total Electricity	3,360,443	3,623,411	3,909,467	4,154,866	4,359,964	5,821,547	100

Source: USDOE, EIA [1]

As noted earlier, these projections were developed by first determining unit electricity consumption figures for each of the sectors—the number of kilowatt-hours required to deliver or treat a unit volume (common units are either a million gallons or a cubic meter) of water. The technologies employed in these areas are relatively mature. Improvements to existing technologies or radically new technologies that would significantly impact the unit are not expected. Some marginal improvements in efficiency through more energy efficient pumps and motor drives may be achieved, but many systems have already been upgraded and the impact of those upgrades is reflected in the unit electricity consumption figures used here.

Thermal generation of electricity is another consumer of electricity to satisfy water supply requirements. Large quantities of cooling water must be pumped continuously for once-through cooling of thermal generation equipment. Generators relying on recirculated water (through cooling towers) for cooling require smaller amounts of make-up water (to make up for evaporative losses), but may still be significant consumers of electricity.

It should be noted that electricity consumption for internal use in power generation is not included in electricity consumption forecasts. On the supply side, reporting is generally based on gross generation of electricity, consumption for internal use, and net generation for sale (the difference between the first two items). The use of electricity by electric utilities for water pumping and/or wastewater treatment will generally be accounted for in the second of the three categories.

The amount of electricity required to meet the cooling water needs of thermal plants over the period 2000 through 2020 is estimated to represent less than 0.5 percent of the total generation of these types of plants. At the same time, the electricity requirements for providing cooling water from its source to thermal power plants is expected to decline on an absolute basis. This is primarily due to a shift away from once-through cooling, with high water requirements, to cooling using recycled water (e.g. wet cooling towers) and the expected increased use of dry cooling towers, where no water is lost from the system. These latter types of cooling systems require significantly less water than once-through cooling, because of their drastically lower make-up water need. They therefore consume much less electricity for pumping of make-up water. However, total power plant electricity consumption for cooling tower technology is similar to once-through cooling requirements, with pumping for water recirculation through the cooling tower approximately equal to the difference in make-up water requirements.

References

Annual Energy Outlook, 2000, U.S. Department of Energy, Energy Information Agency, Washington DC: 2000. Appendix A. This document can be downloaded from the forecast sections of the EIA website at http://www.eia.doe.gov.

2
ELECTRICITY REQUIREMENTS FOR DELIVERY OF WATER BY PUBLIC SUPPLY AGENCIES

This chapter describes the methodology used to estimate and project electricity requirements for the delivery of fresh water by public water supply agencies to end consumers in all sectors.

This chapter describes the methodology used to estimate and project electricity requirements for the delivery of water by water supply agencies. A brief process description of the types of treatment used is provided for background and context. The future projections of electricity for public water supply agency are also provided in this chapter.

Fresh Water Treatment Process Descriptions and Unit Electricity Requirements

Fresh water is derived from two main sources in the United States. The first is surface water: lakes, rivers or other bodies of water. The second is groundwater or wells. While some fresh water is derived from desalinization of sea water, this is an extremely small portion of the total and is not considered further here.

Surface Water Treatment Process Description

In a typical sequence of operations for surface water treatment, the following steps are followed (refer to Figure 2-1). Raw water is first screened to remove gross debris and contaminants. The water is then pre-oxidized using chlorine or ozone treatment to kill any disease-carrying organisms and to remove taste or odor causing substances. Alum and/or polymeric materials are added to the water to aid in the flocculation and coagulation of finer particles. The flocculation step serves to agglomerate finer particles that can then be settled out or removed in the sedimentation and filtration steps. A second disinfection step kills any remaining disease-causing organisms and leaves a disinfectant residue that is carried into the distribution system to prevent the growth of any organisms. The clearwell storage allows contact time for disinfection and provides surge capacity for the distribution system to meet system demand. The treated water is then distributed to consumers by high pressure pumping. Sludges and other impurities removed from the fresh water are concentrated and disposed of.

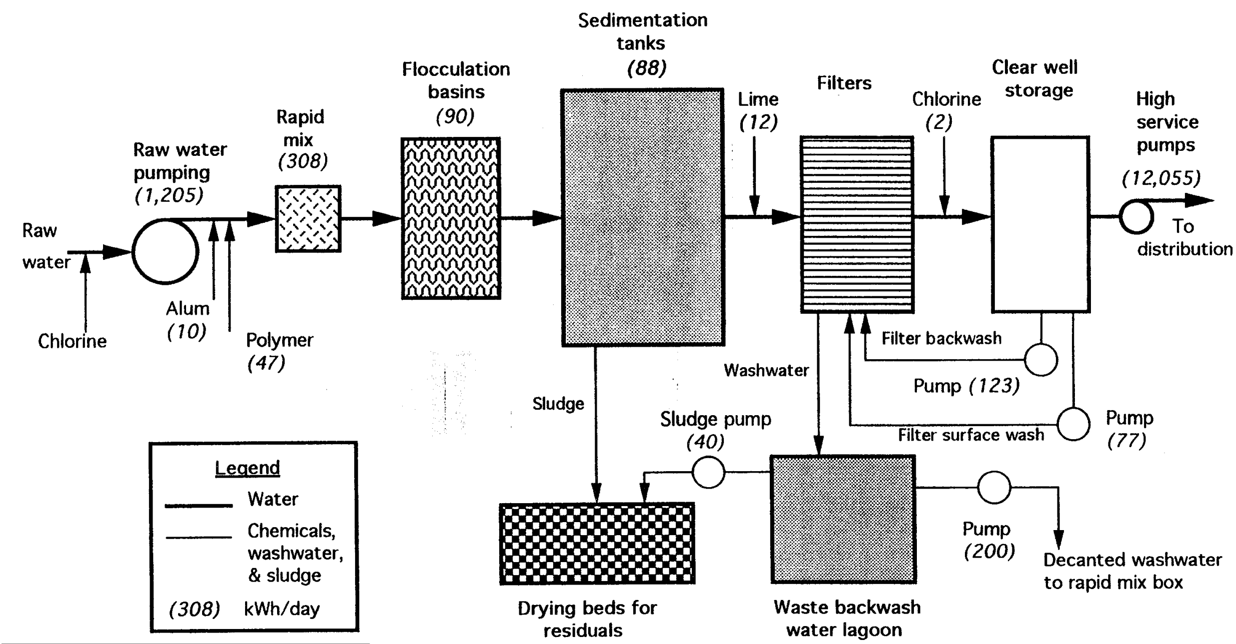

Figure 2-1
Representative Surface Water Treatment Plant Process (with Typical Daily Electricity Consumption for a 10 Million Gallon/Day Facility)

Source: EPRI [1]

Surface Water Treatment Unit Electricity Consumption

Along with the process sequence shown in Figure 2-1 are daily electricity requirements for each process step. These figures are representative of a 10 million gallon per day (MM gal/day) (37,850 cubic meter per day (m^3/d)) surface water treatment facility. Such a facility would have an estimated total electricity consumption of about 14,057 kWh per day, which is equivalent to a unit energy consumption of 1,406 kWh per million gallons (mg) (0.371 kWh per cubic meter). Table 2-1 shows how unit energy consumption varies with the size of the treatment plant. Variations are driven primarily by economies of scale, particularly from the smallest size facilities. It should be noted that regardless of size, the predominant use of electricity is for treated water pumping to the distribution system—this represents about 80 to 85 percent of the total electricity consumption for surface water treatment.

Groundwater Treatment Process Description

The process sequence for groundwater supply by public water supply agencies is much less severe than for surface water. The sequence consists of well pumping to the surface. The water is chlorinated for disinfection and removal of odor and taste. The treated water is then pumped directly to the distribution system or alternatively to aboveground or ground level storage tanks before distribution.

Table 2-1
Unit Electricity Consumption for Surface Water Treatment Plants

Treatment Plant Size	Unit Electricity Consumption
1 MM gal/day (3,785 m^3/d)	1,483 kWh/MM gal (0.392 kWh/m^3)
5 MM gal/day (18,925 m^3/d)	1,418 kWh/MM gal (0.375 kWh/m^3)
10 MM gal/day (37,850 m^3/d)	1,406 kWh/MM gal (0.371 kWh/m^3)
20 MM gal/day (75,700 m^3/d)	1,409 kWh/MM gal (0.372 kWh/m^3)
50 MM gal/day (189,250 m^3/d)	1,408 kWh/MM gal (0.372 kWh/m^3)
100 MM gal/day (378,500 m^3/d)	1,407 kWh/MM gal (0.372 kWh/m^3)

Source: EPRI [1]

Groundwater Treatment Unit Electricity Consumption

Unit electricity consumption for supply from groundwater is estimated at 1,824 kWh/million gallons (0.482 kWh/m^3) [1], some 30% greater than for surface water. This appears to be independent of the size of the pumping and treatment facility. The predominant consumer of electricity is pumping. About one-third of the electricity is used for well pumping, while the most of the balance is used for booster pumping into the distribution system. Less than 0.5 percent of the electricity is used for chlorination of the water.

Projected Electricity Requirements for Fresh Water Supply by Public Agencies

Methodology

The unit electricity consumption estimates for surface water and groundwater supply of fresh water were used along with a 1999 inventory of public water supply systems to estimate baseline electricity consumption for the United States. The inventory is maintained by the U.S. Environmental Protection Agency (USEPA) in the Safe Drinking Water Information System [2]. The inventory characterizes approximately 30,000 public water supply systems in the United States by source of water (ground or surface water), size. Water systems are further characterized as community water systems and transient and non-transient non-community water systems[1] and by the population served.

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[1] All public water systems have at least 15 service connections or serve at least 25 people per day for 60 days per year. Community water systems are public water systems serving the same population throughout the year; most residences in cities and towns are served by community water systems. Non-community water systems are public water systems that do not serve the same population year round. A non-transient non-community water system serves the same people more than six months per year, but not year round (e.g. a school with its own water supply).

Based on the size of the system and the source of raw water, a unit energy consumption figure was assigned to each. Further, per capita daily water consumption estimates were assigned to each of the systems. For community water systems, a per capita consumption of 200 gallons per day (757 liter per day) was assumed; for non-community systems a lower figure of 150 gallons per day was assumed [1].

System by system baseline daily and annual electricity consumption estimates were generated and summed for each of the nine U.S. census regions. These baseline regional electricity consumption estimates were used to develop projections out to the year 2050 using the U.S. Department of Commerce (USDOC) Census Bureau projections of population growth by region. The assumption is that the aggregate supply of fresh water and therefore the electricity consumption to provide that supply will follow the general trend in population growth. Population growth projections and compound annual growth rates derived from these data are shown in the Appendix.

Sensitivity analyses were conducted to assess the impact on electricity consumption of changes in per capita water consumption and variations in unit electricity consumption for the various types of systems.

Public Water System Inventory

The summary inventory and characteristics of public water systems for 1999 is shown in Tables 2-2 and 2-3. Table 2-2 enumerates the inventory by type (community and non-community system), by source of water (ground or surface), and by population served. Table 2-3 breaks the inventory of public water systems down by size of population served.

Electricity Consumption Projections

The baseline regional electricity consumption projections for supply of fresh water by public water supply agencies is shown graphically in Figure 2-2 and in tabular form in the Appendix. Electricity consumption is estimated at about 30 billion kWh for the year 2000. This is expected to reach about 36 billion kWh by the year 2020 and 46 billion kWh by 2050.

Sensitivity analyses were conducted to determine the impact on projected electricity consumption of downward and upward variations in unit electricity consumption and per capita water consumption. The results of these cases are illustrated in Figures 2-3 through 2-6. Results are presented in tabular form in the Appendix.

Figure 2-7 presents a summary of the projections on a national basis showing how the baseline case is bounded by the sensitivity cases. In the year 2000, the national baseline electricity consumption is estimated at 30 billion kWh and is bounded by a sensitivity of about ±. 22 percent of the baseline case.

A transient non-community water system serves the public but not the same individuals for more than six months; for example, a rest area or campground can be considered a transient water system.

The projection out to the year 2020 shows a baseline national energy consumption projection of about 36 billion kWh, bounded by a similar sensitivity of about ± 22 percent of the baseline case.

Table 2-2
Summary Data of Public Water Systems -- 1999

Public Water Systems	Primary Water Source			Population Served	
	Source	**Number**	**Percent**	**Million**	**Percent**
Community	Surface	10,728	20	167	66
	Ground	43,195	80	86	34
	Total	53,923	100	253	100
Non-Community	Surface	2,671	2	2	8
	Ground	111,140	98	21	92
	Total	113,811	100	23	100
Total	Surface	13,399	8	169	61
	Ground	154,335	92	107	39
	Total	167,734	100	276	100

Source: USEPA Office of Wastewater Management [4]

Table 2-3
Size Distribution of Public Water Systems -- 1999

		Population Size Range					
		< 500	**501 – 3,300**	**3,301 – 10,000**	**10,001 – 100,000**	**> 100,000**	**Totals**
Community Water Systems	**Number of Systems**	31,904	14,040	4,355	3,276	347	53,923
	Population Served (millions)	5.2	19.8	23.4	91.0	112.4	253.8
	Percent of Population served	2.0	8.0	10.0	36.0	44.0	100.0
Non-Community Water Systems	**Number of Systems**	107,923	5,509	253	114	12	113,811
	Population Served (millions)	9.9	5.4	1.4	3.6	2.8	23.1
	Percent of Population served	43.0	23.0	6.0	16.0	12.0	100.0

Source: USEPA Office of Wastewater Management [4]

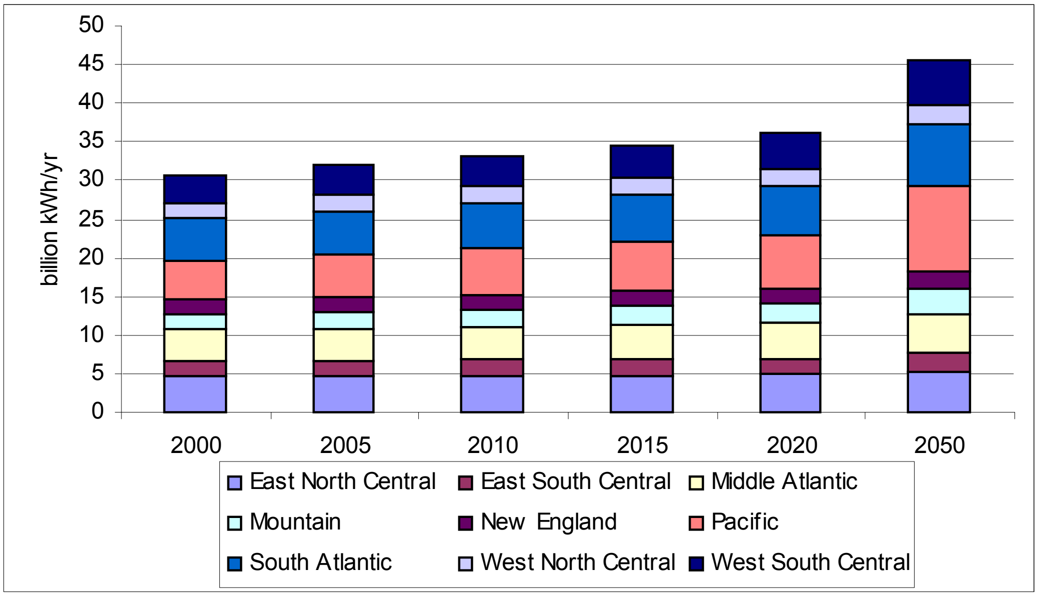

Figure 2-2
Baseline Regional Energy Consumption Projection for Water Supply by Public Water Supply Agencies

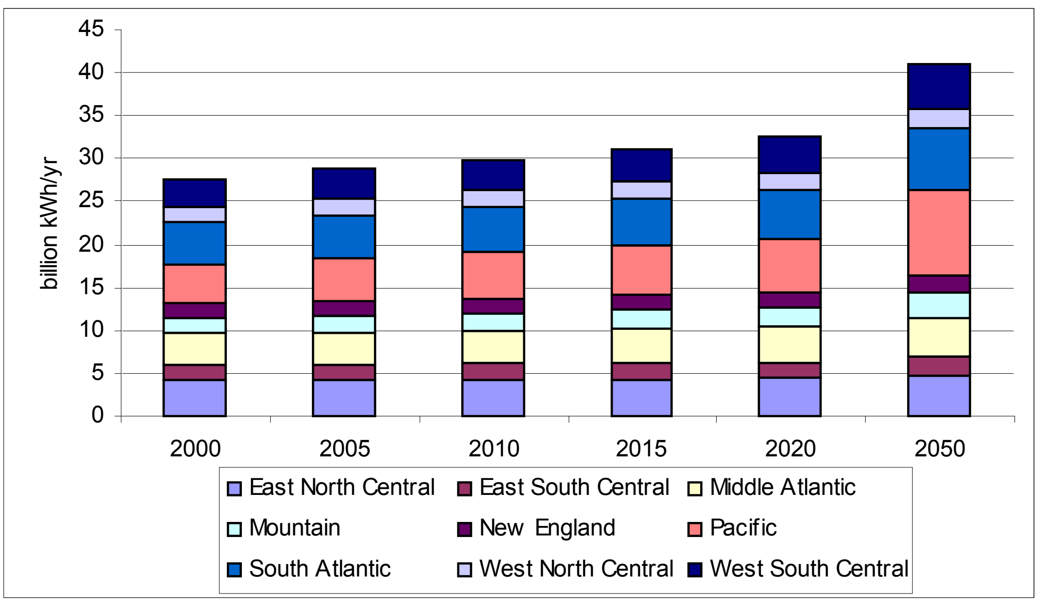

Figure 2-3
Regional Energy Consumption Projections for Water Supply by Public Water Supply Agencies–Reduced Unit Energy Consumption

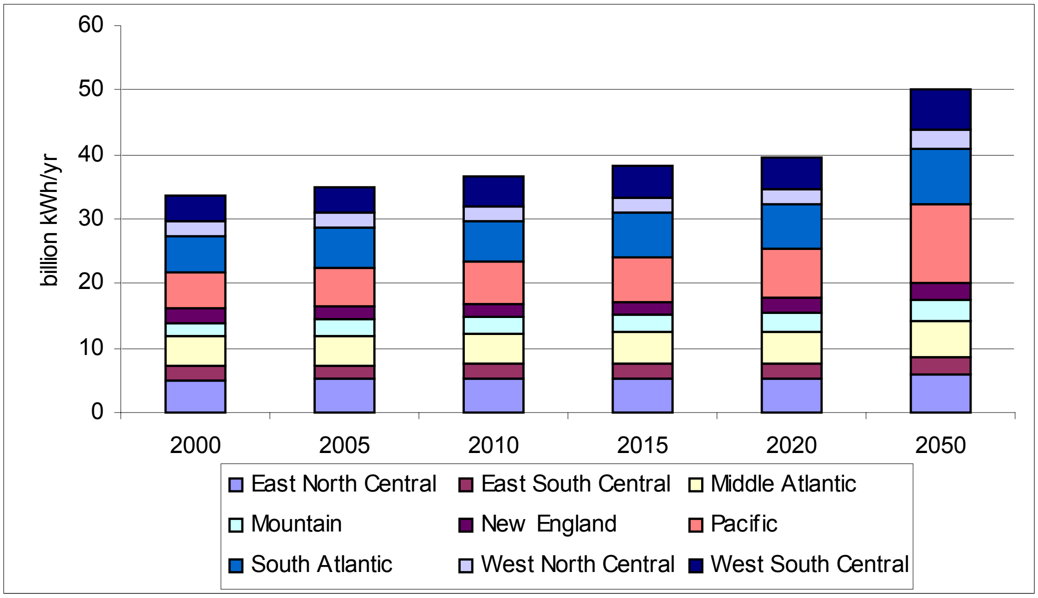

Figure 2-4
Regional Energy Consumption Projections for Water Supply by Public Water Supply Agencies–Increased Unit Energy Consumption

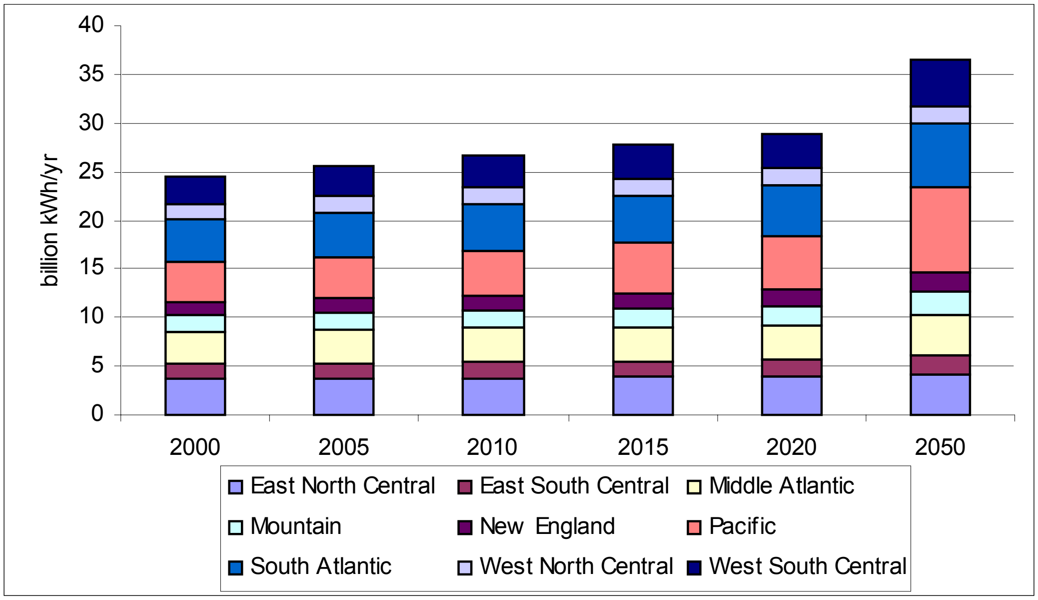

Figure 2-5
Regional Energy Consumption Projections for Water Supply by Public Water Supply Agencies–Reduced Per Capita Water Consumption

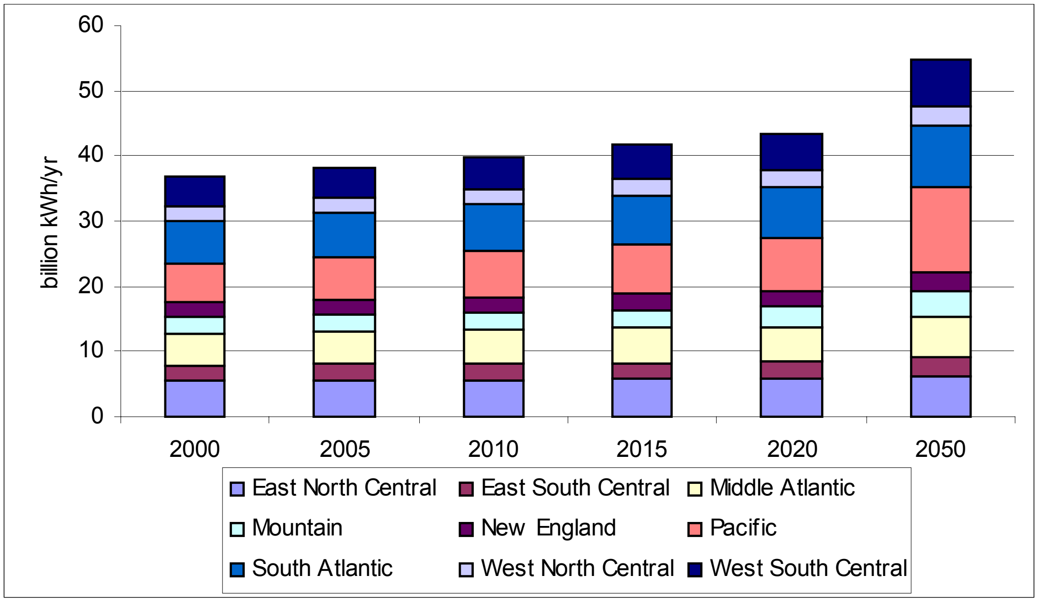

Figure 2-6
Regional Energy Consumption Projections for Water Supply by Public Water Supply Agencies–Increased Per Capita Water Consumption

Issues Related to Trends in Electricity Use for Supply of Fresh Water from Public Supply Agencies

Trends in Unit Electricity Consumption

Unit electricity consumption in water supply is driven upward and downward by a number of factors. Factors that would tend to increase the unit electricity consumption for water supply include:

- The age of the water delivery system: as systems age friction in piping increases, resulting in an increase in electricity requirements for pumping
- Implementation of voluntary or mandatory restrictions on water consumption (including application of home appliance and plumbing fixture water consumption standards): water conservation programs will should reduce the overall amount of electricity required, but may actually result in an increase in unit electricity consumption as economies of scale may be lost or systems operate at below optimum levels
- Requirements for improved treatment: as standards and requirements for drinking water quality increase, treatment that is more rigorous will be required. Regardless of the type of enhanced treatment employed, increased process will result in increased pumping energy requirements.

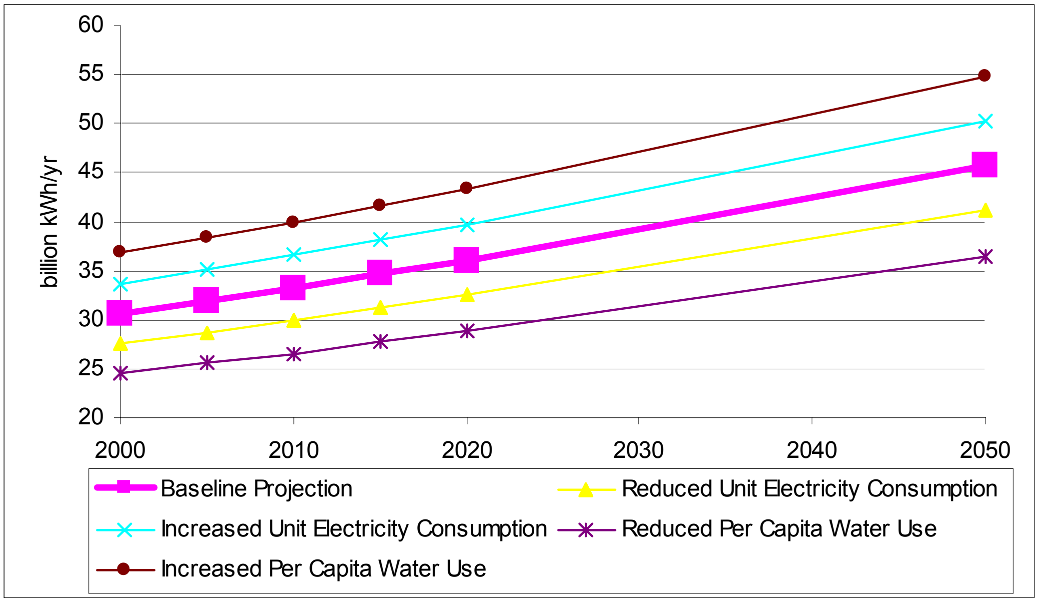

Figure 2-7
National Energy Consumption Projections for Water Supply by Public Water Supply Agencies–Baseline and Sensitivity Cases

Factors that would tend to decrease the unit electricity consumption for water supply include:

- Economies of scale: a trend to larger systems from smaller systems will provide economies of scale of operation, resulting in reduced unit electricity consumption
- Replacement of older equipment with more energy efficient pumps, drives, and water processing equipment

It is difficult to estimate the combined impact of all or some of these issues on unit and total electricity consumption. Currently, there are over 150,000 public water supply systems in the United States, and it is safe to say to few or none operate identically. As the population grows, additional systems will be added. Given the diversity of water supply systems, it is difficult to predict how electricity consumption will react to the net aggregate impact of these factors and issues. For the purpose of this exercise, it is probably adequate to note that unit electricity consumption will most likely remain close to present levels or increase slightly over the next 20 years. The slight increase would most likely be due to increased inefficiencies related to aging of existing equipment and the need for more aggressive water treatment to remove contaminants to ensure a safe supply of drinking water. Further, the use of chlorine for disinfection has become a subject of controversy, because of concerns of dioxin formation. The use of chlorine may be reduced in favor of ozonation or UV treatment.

Power Quality Issues—Reliability of Supply

Most water processing facilities have backup power in case of electricity interruptions. Most of this is in the form of conventional diesel generator sets. Backup power is required to maintain the security of system operations, given that water systems typically have little storage capacity compared to demand. At least one public agency (Orange County, California) is known to bypass electricity as a prime mover entirely in at least a portion of their operation—natural gas engine driven pumps are employed. This trend is apparently not widespread in the industry [5], with emissions being one major issue.

Other Issues and Observations

Electricity is probably the most costly input to fresh water treatment. Despite this it is interesting to note that few of the persons contacted in the preparation of this assessment who are associated with public supply agencies were able to provide information on the unit or total energy consumption of their facilities.

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5. Personal communication, Howard Johnson, Water Production Supervisor, Orange County City Water, Orange County, CA.

3
ELECTRICITY REQUIREMENTS FOR WASTEWATER TREATMENT BY POTWS AND PRIVATE FACILITIES

This chapter describes the methodology used to estimate and project electricity requirements for the treatment of wastewater by publicly owned treatment works (POTWs) to end consumers in all sectors. A brief process description of the types of treatment used is provided for background and context. The future projections of electricity for POTW use based on a baseline estimate are also provided in this chapter.

Wastewater Treatment Process Descriptions and Unit Electricity Requirements

There are many strategies and process sequences available for treatment of wastewater in the United States. Given that there are over 15,000 publicly owned wastewater treatment facilities (POTWs) in the United States, it is impossible to capture those variations in the estimation of unit electricity consumption. Instead, four representative types of facilities will be used to characterize the larger population, with unit electricity consumption estimates for each of these types provided over a range of sizes. The four types of treatment facilities to be included in this analysis are:

- Trickling Filter
- Activated Sludge
- Advanced Wastewater Treatment
- Advanced Wastewater Treatment with Nitrification

These four types of systems were chosen as being the most important wastewater treatment facilities, comprising a significant portion of the overall population of POTWs. All are based on biological and chemical treatment of the wastewater. The sections below provide an overview of the sequence of operations of each of these processes.

Trickling Filter Wastewater Treatment

In the typical process sequence for a trickling filter wastewater treatment plant (see Figure 3-1), influent wastewater is screened to remove gross material carried in the stream. Finer particles are then removed with an aerated grit removal system. The wastewater is held in a settling vessel to remove other particulates before it is biologically treated in the trickling filter system. The trickling filter itself is a substrate over which the organic wastewater is passed. The trickling filter substrate supports the growth of bacteria that aerobically consume the organic material. A secondary settling step removes other particulate matter. The treated wastewater is then disinfected by chlorination before discharge. The remaining sludges may be further treated biologically to remove organic materials, then are thickened. A further anaerobic digestion step removes remaining organics, and the sludge is then dewatered mechanically and disposed of by incineration or by being sent to landfill.

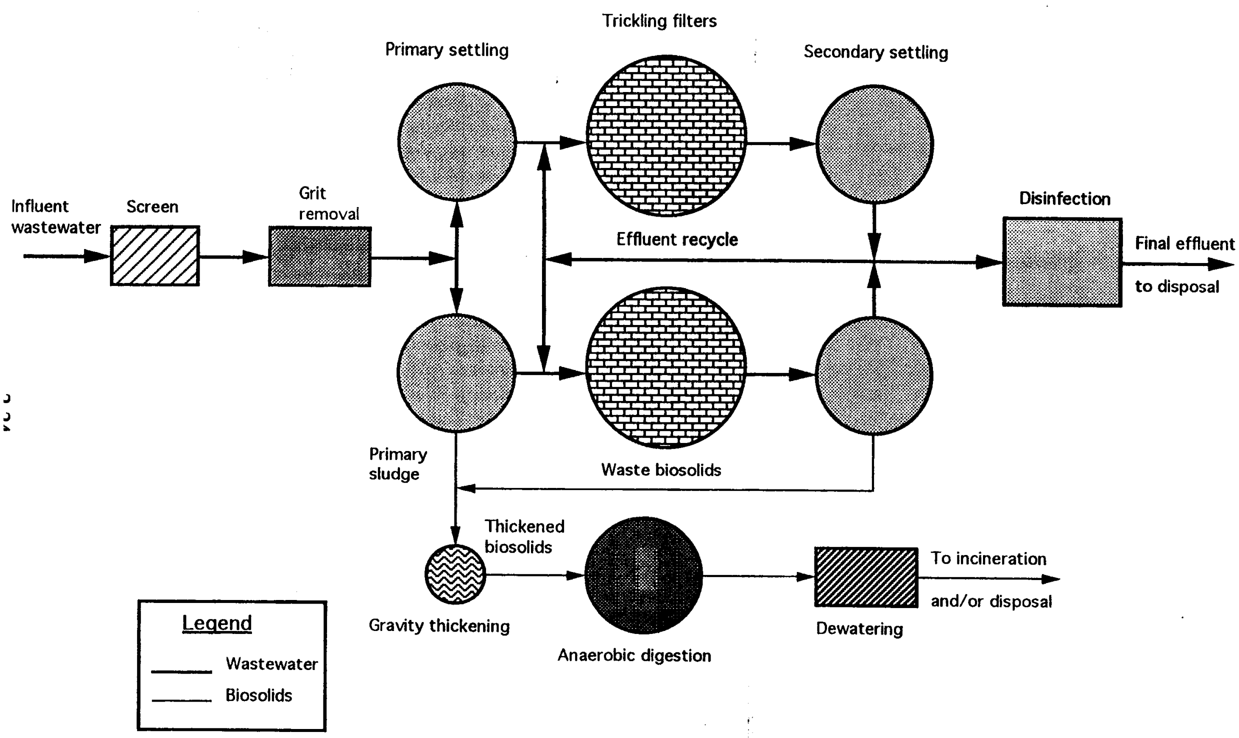

Figure 3-1
Representative Trickling Filter Wastewater Treatment Process

Source: EPRI [1]

Activated Sludge Wastewater Treatment

As with the previous system, incoming wastewater to the activated sludge process is first screened to remove gross contaminants, and then passes through a grit removal system to remove smaller particulate matter (refer to Figure 3-2). A primary settling chamber is used to remove smaller particulate and suspended matter and the effluent is then digested aerobically in an aeration tank. After sufficient residence time for digestion has passed, the wastewater stream is pumped to a secondary settling tank, for removal of digested material. After secondary settling, the treated wastewater is disinfected with chlorine and discharged. The sludge from primary settling is similarly aerobically digested, then pumped to a settling tank to separate the liquid from the solid stream. The solids are thickened and then anaerobically digested for removal of remaining organic materials. The waste sludge is then dewatered and disposed of in landfill or by incineration.

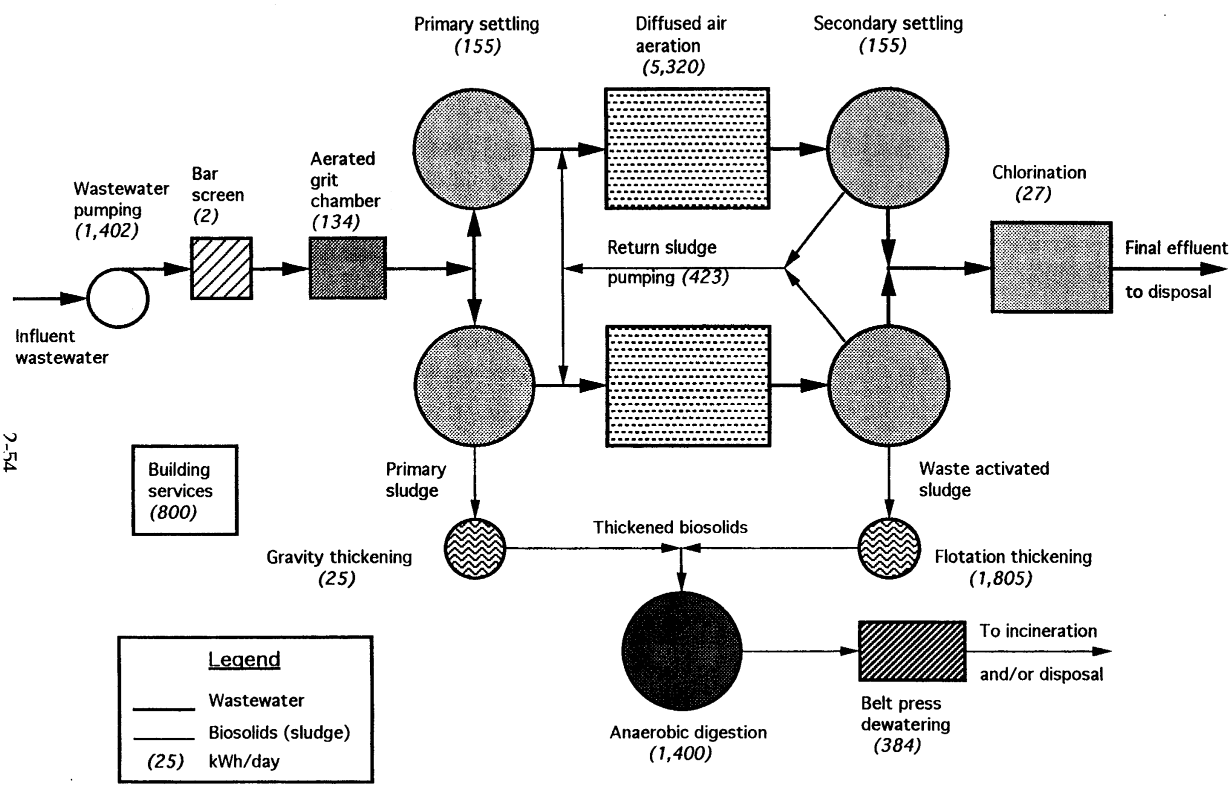

Figure 3-2
Representative Activated Sludge Wastewater Treatment Process Sequence (with Typical Daily Electricity Consumption for a 10 Million Gallons/Day Facility)

Source: EPRI [1]

Advanced Wastewater Treatment

The advanced wastewater treatment process (see Figure 3-3) is similar to the activated sludge process, but includes additional treatment in the form of filtration prior to discharge of the biologically treated waste stream. These types of systems are more effective in removing nitrogen, phosphorus, and suspended solids by filtration. The front part of the process is similar to the activated sludge process. Incoming effluent is screened and grit is removed. After settling to remove suspended solids, the wastewater is aerobically digested in an activated sludge process. If nitrogen removal is required, bacteria specific for nitrification are used in this step. After secondary settling chemicals are injected into the waste stream to aid in agglomeration of remaining solids, which are removed in the subsequent filtration step. After disinfection, the treated water is discharged. The sludges are thickened, anaerobically digested, dewatered and disposed of in landfill or by incineration.

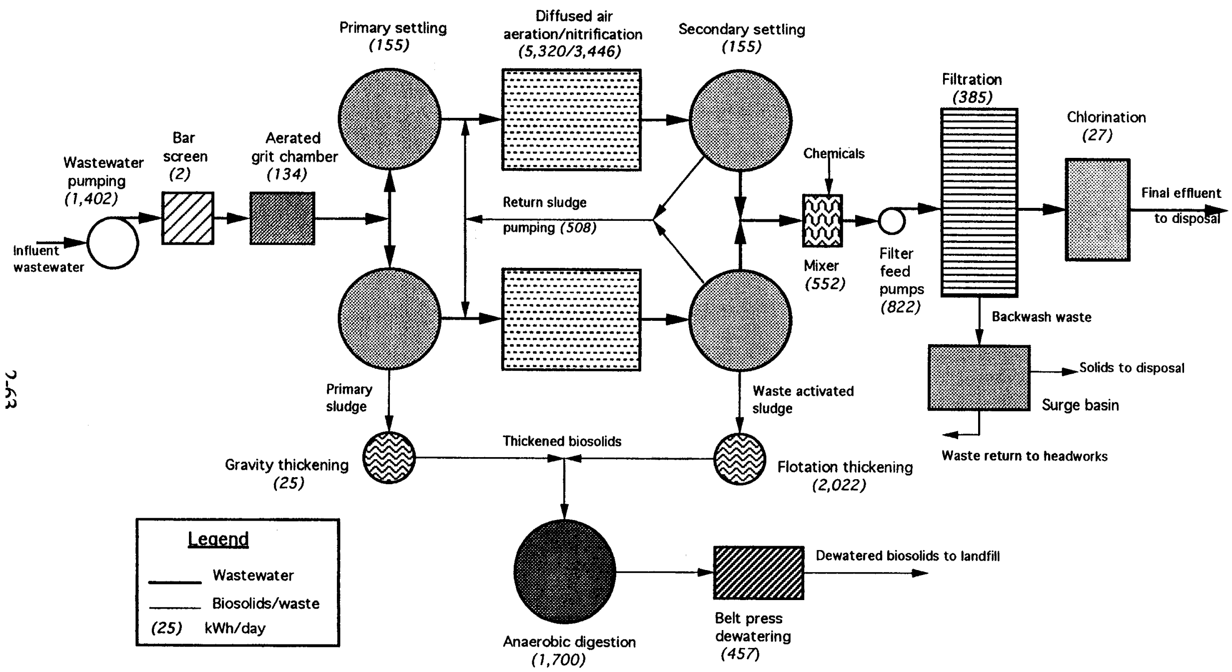

Figure 3-3
Representative Advanced Wastewater Treatment Process Sequence (with Typical Daily Electricity Consumption's for a 10 Million Gallons/Day Facility)

Source: EPRI [1]

Unit Electricity Consumption for POTWs

Unit electricity consumption for the four processes are shown in Table 3-1, broken down by size of the treatment facility. Variation in unit electricity consumption with size is illustrated in Figure 3-4. As would be expected, the unit electricity consumption decreases with the size of the plant due to economies of scale. As also would be expected, unit electricity consumption is higher as the degree of treatment and complexity of the process increases – advanced wastewater treatment with nitrification is 3 times as energy intensive (due to additional pumping requirements) than the relatively simple trickling filter treatment.

Table 3-1
Unit Electricity Consumption for Wastewater Treatment by Size of Plant

Treatment Plant Size million gallons/day (cubic meters per day)	Unit Electricity Consumption kWh/million gallons (kWh/cubic meter)			
	Trickling Filter	Activated Sludge	Advanced Wastewater Treatment	Advanced Wastewater Treatment Nitrification
1 MM gal/day (3,785 m^3/d)	1,811 (0.479)	2,236 (0.591)	2,596 (0.686)	2,951 (0.780)
5 MM gal/day (18,925 m^3/d)	978 (0.258)	1,369 (0.362)	1,573 (0.416)	1,926 (0.509)
10 MM gal/day (37,850 m^3/d)	852 (0.225)	1,203 (0.318)	1,408 (0.372)	1,791 (0.473)
20 MM gal/day (75,700 m^3/d)	750 (0.198)	1,114 (0.294)	1,303 (0.344)	1,676 (0.443)
50 MM gal/day (189,250 m^3/d)	687 (0.182)	1,051 (0.278)	1,216 (0.321)	1,588 (0.423)
100 MM gal/day (378,500 m^3/d)	673 (0.177)	1,028 (0.272)	1,188 (0.314)	1,558 (0.412)

Source: EPRI [1]

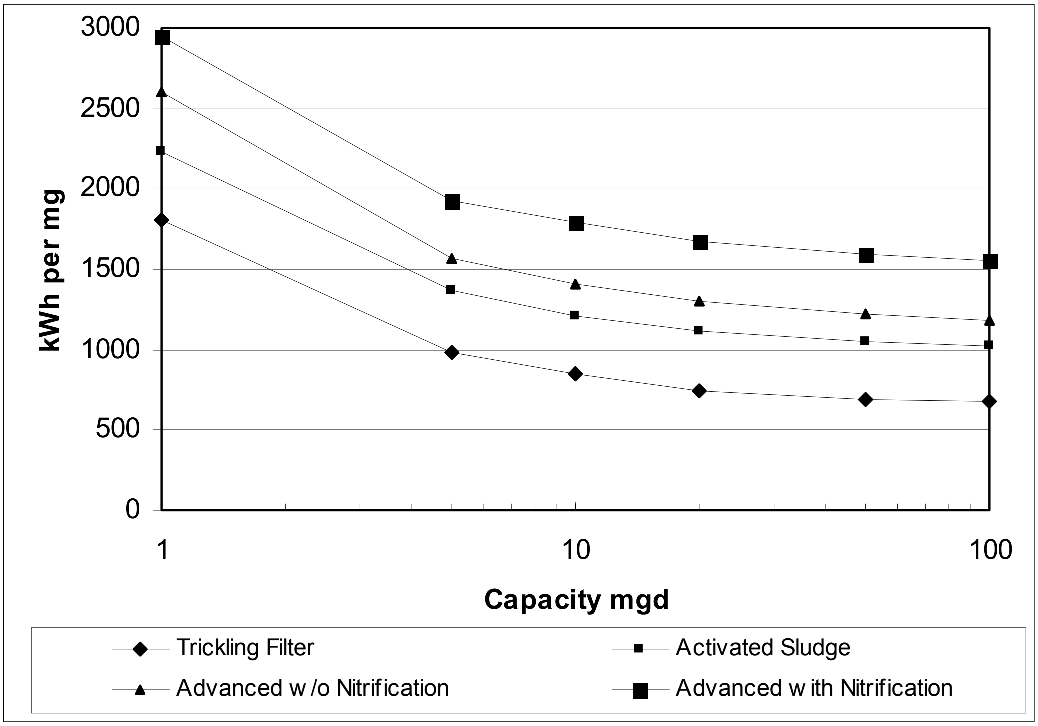

Figure 3-4
Variations in Unit Electricity Consumption with Size for Representative Wastewater Treatment Processes

Source: EPRI [1]

Projected Electricity Requirements for Wastewater Treatment by POTWs

Methodology

The unit electricity consumption estimates for the representative types of treatment processes were used along with a 1996 inventory of publicly owned treatment works (POTWs) to estimate baseline energy consumption for the United States. The inventory is maintained by the U.S. Environmental Protection Agency (USEPA) and forms the basis for the Clean Water Needs Survey, reported on a regular basis to Congress [2]. The underlying data for the survey characterizes approximately 15,000 POTWs currently in operation, and defines the need for an additional 2,500 facilities to meet future needs.

Unit electricity requirements (kWh per million gallons) for the generic systems above were aggregated over the range of capacities to yield a single value for national use projections:

- 955 kWh/million gallons (0.252 kWh/m^3) for trickling filter systems
- 1,322 kWh/million gallons (0.349 kWh/m^3) for activated sludge

- 1,541 kWh/million gallons (0.407 kWh/m^3) for advanced wastewater treatment without nitrification
- 1,911 kWh/million gallons (0.505 kWh/m^3) for advanced wastewater treatment with nitrification

The value used for a level of treatment less than secondary[2] was taken at about 50 percent of the value for activated sludge treatment (661 kWh/million gallons). For secondary treatment, a weighted unit value was used assuming 70 percent of capacity was activated sludge and 30 percent was trickling filters; the weighted value is 1,212 kWh/million gallons. For advanced wastewater treatment, it was assumed 50 percent of the capacity included nitrification. The weighted values are 1,578 and 1,726 kWh/million gallons, respectively. For no discharge and other, 400 kWh/million gallons was assumed. No allowance for onsite generation of electricity from biogas was included.

POTW Inventory

The summary inventory and characteristics of POTWs is shown in Tables 3-2 and 3-3. Table 3-2 lists the number of facilities by flow range and aggregate flow, while Table 3-3 shows the number of facilities by level of treatment and aggregate design flow. For comparison, data for 1998 and 1996, the last two surveys are presented, to illustrate how the POTW inventory has been changing over time. As can be seen, there has been a substantial increase in both the number of facilities and the aggregate flow. Further, there has been a trend toward larger facilities, and toward facilities with more aggressive levels of wastewater treatment. Indeed, the number of facilities providing less than secondary levels of treatment in 1996 was one-tenth the number in the previous survey.

[2] Primary treatment is designed to remove large solids (e.g., rags and debris) and smaller inorganic grit and is the first stage of each of the four representative processes (screening and settling). Secondary treatment removes organic contaminants using microorganisms to consume biodegradable organics (e.g., activated sludge or trickling filters). Advanced treatment systems go beyond secondary treatment to include nitrification (to convert ammonia to nitrates), denitrification (to convert nitrates to nitrogen), physical-chemical treatment (to remove dissolved metals and organics), and/or disinfection (to kill any remaining pathogens).

Table 3-2
Number of Wastewater Facilities by Flow Range

Flow Range million gallons/day (m^3/day)	1988		1996	
	Number of facilities	Total design capacity MM gal/day (m^3/day)	Number of facilities	Aggregate flow MM gal/day (m^3/day)
0.01 – 0.10 (37.85 – 378.5)	5,983	259 (980,315)	6,444	287 (1,086295)
0.11 – 1.00 (378.6 – 3,785)	6,589	2,307 (8,731,995)	6,476	2,323 (8,792,555)
1.01 – 10.0 (3,786 – 37,850)	2,427	7,178 (27,168,730)	2,573	7,780 (29,447,300)
10.1 – 100.0 (37,851 – 378,500)			466	11,666 (44,155,810)
10.1 and over (37,851 and over)	466	18,992 (71,884,720)		
100.1 and over (378,500 and over)			47	10,119 (38,300,415)
Unknown	146	---	38	---
Total	15,591	28,736 (108,765,760)	16,024	32,175 (121,782,375)

Source: USEPA [2]

Table 3-3
Number of Wastewater Treatment Facilities by Level of Treatment

Level of Treatment	1988		1996	
	Number of facilities	Total design capacity MM gal/day (m^3/day)	Number of facilities	Total design capacity MM gal/day (m^3/day)
Less than secondary	1,789	5,030 (19,038,550)	176	3,054 (11,559,390)
Secondary	8,536	16,097 (60,927,145)	9,388	17,734 (67,123,190)
Greater than secondary	3,412	15,488 (58,622,080)	4,428	20,016 (75,760,560)
No discharge	1,854	1,034 (3,913,690)	2,032	1,421 (5,378,465)
Total	15,591	37,649 (142,501,465)	16,024	42,225 (159,821,625)

Source: USEPA [2]

Electricity Consumption Projections for POTWs

The baseline electricity consumption projection for wastewater treatment by POTWs is shown in graphically in Figure 3-5; data are provided in tabular form in the Appendix. Electricity consumption for the baseline case is estimated at about 21 billion kWh for the year 2000. This is expected to increase to about 26 billion kWh by 2020 and 30 billion kWh by 2050.

Sensitivity analyses were conducted to determine the impact on projected electricity consumption of upward variations in unit energy consumption, representing the need for increased processing. Results of the sensitivity analyses are illustrated in Figures 3-6 and 3-7, and are provided in tabular form in the Appendix.

Figure 3-10 presents a summary of the projections on a national basis, showing how the baseline case compares to the case where unit electricity consumption increases further by 2.5 and 5 percent reflecting the need for more aggressive water treatment.

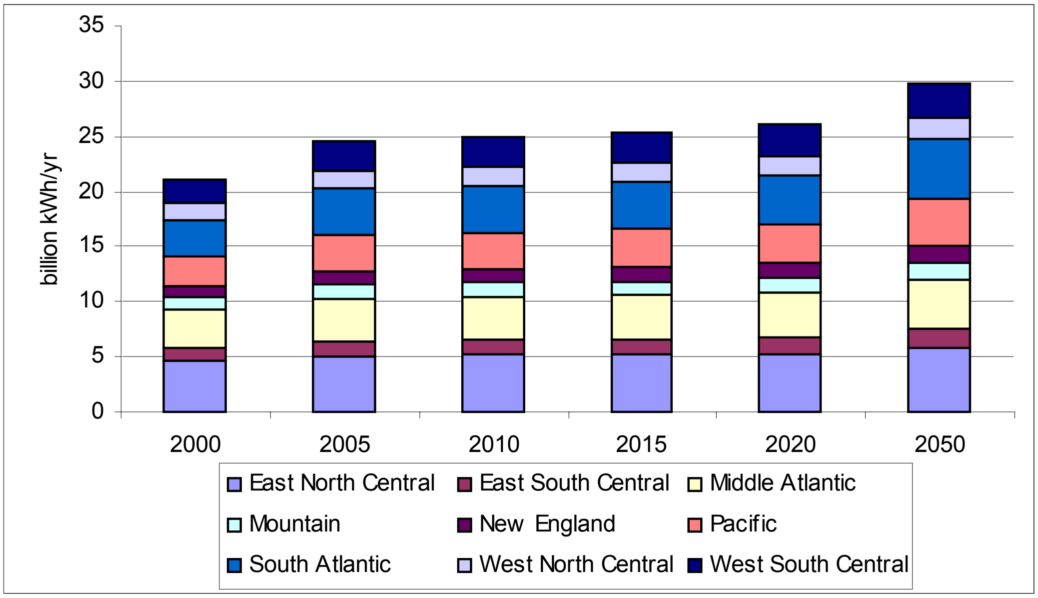

Figure 3-5
Baseline Regional Energy Consumption Projections for Wastewater Treatment by POTWs

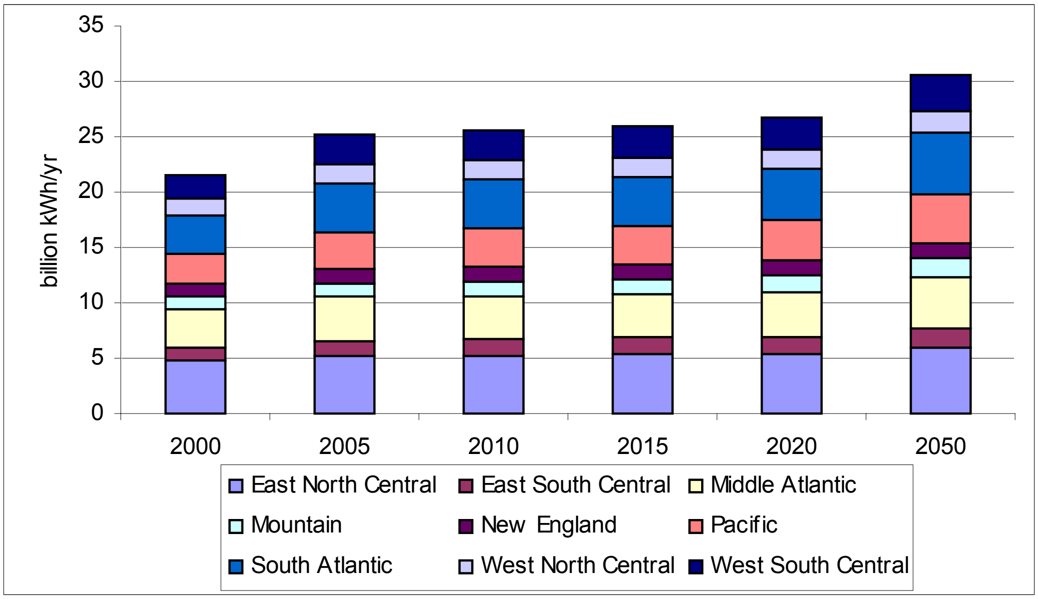

Figure 3-6
Regional Energy Consumption Projections for Wastewater Treatment by POTWs—2.5 Percent Increase in Unit Electricity Consumption

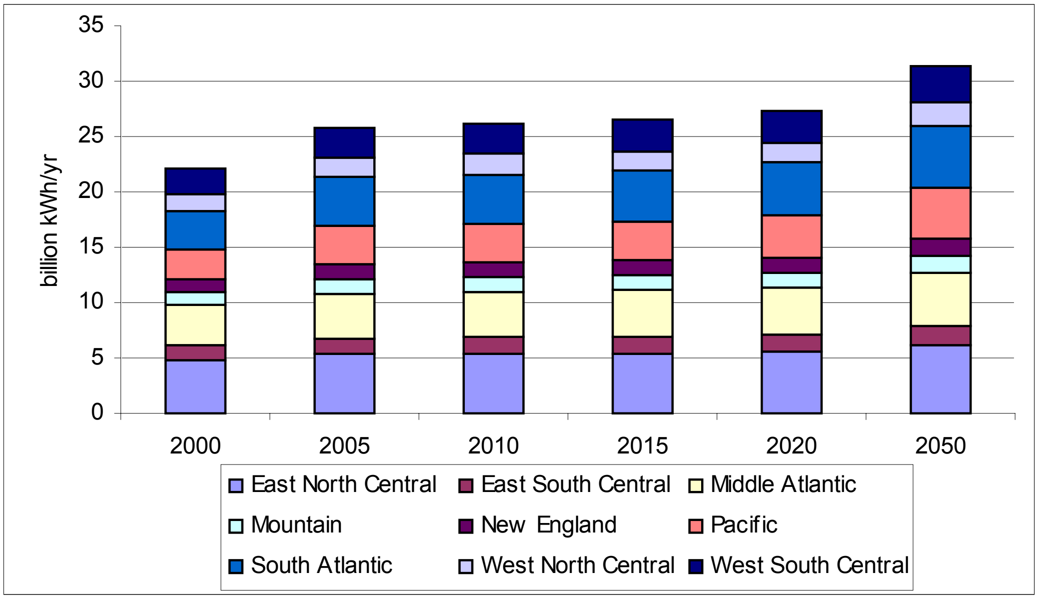

Figure 3-7
Regional Energy Consumption Projections for Wastewater Treatment by POTWs—5 Percent Increase in Unit Electricity Consumption

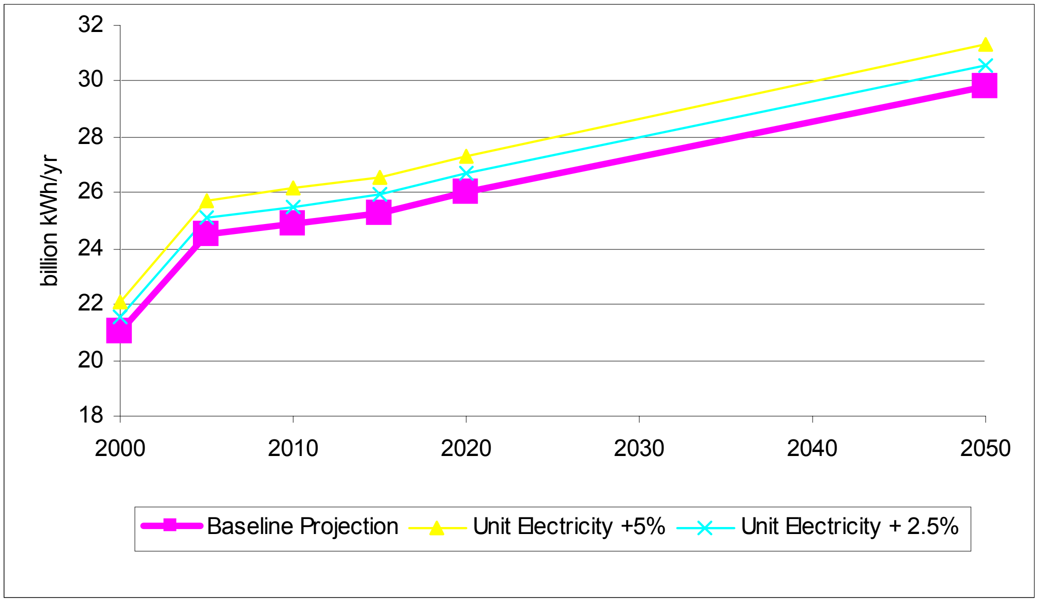

Figure 3-8
National Energy Consumption Projections Wastewater Treatment by POTWs–Baseline and Sensitivity Cases

Issues Related to Trends in Electricity Use for Wastewater Treatment by POTWs

Trends in Unit Electricity Consumption

Unit electricity consumption in wastewater treatment is driven upward and downward by a number of factors. Factors that would tend to increase the unit electricity consumption:

- The age of the wastewater treatment system: as systems age friction in piping increases, and other equipment is subject to age-related inefficiencies, resulting in an increase in electricity requirements
- Requirements for more aggressive and effective treatment: as standards and requirements for wastewater discharges increase (reducing the amount of contaminants allowed to be discharged), treatment that is more rigorous will be required. Regardless of the type of enhanced treatment employed, increased pumping will be required, resulting in increased unit electricity requirements.

Factors that would tend to decrease the unit electricity consumption for water supply include:

- Economies of scale: a trend to larger systems from smaller systems will provide economies of scale of operation, resulting in reduced unit electricity consumption
- Replacement of older equipment with more energy efficient pumps, drives, and water processing equipment

The major driver of unit energy consumption will be the degree of treatment required. As noted above, there has been a trend to more aggressive treatment, with upgrades or replacements of older systems not affording this higher level of treatment. This trend is seen in comparing the estimated unit electricity consumption in 1988 to that estimated for 2000: the baseline unit energy consumption was estimated to increase at an average compound rate of about 0.8 percent per year. The trend in unit electricity consumption is expected to continue upward, as treatment that is more aggressive may be mandated. Another driver, as in the case of fresh water supply, may be the trend to reduce the use of chlorine for disinfection because of concerns of dioxin formation. Ozonation or UV treatment may be used in place of chlorination, increasing unit electricity consumption.

Given the large number of POTWs (over 15,000) and the variation in the equipment and processes employed, it is difficult to generalize. However, given the trend toward more aggressive treatment, unit electricity consumption for wastewater treatment will most likely continue to experience a small upward trend in the future.

Power Quality Issues—Reliability of Supply

Most POTWs have backup power in case of electricity interruptions. Most of this is in the form of conventional diesel generator sets. Backup power is required to maintain the security of system operations, given that these systems typically have little storage capacity compared to demand.

Electricity Use in Privately Operated Wastewater Treatment Works

Along with the approximately 16,000 publicly owned wastewater treatment plants in the United States, there are approximately 23,000 additional treatment facilities that are privately owned and operated, according to the United States Geological Survey (USGS). These are generally captive facilities associated with industrial plants and commercial operations [3]. Robust detailed statistics on the number, type, and aggregate flows of these treatment facilities are not available through published sources making it difficult to characterize these facilities[3]. However, the following general comments can be made:

- The average size of privately owned wastewater treatment facilities will fall into the smallest size range of POTWs.
- Wastewater treatment facilities associated with industrial plants are designed to deal with specific contaminants generated by the facilities – for instance, wastewater treatment plants associated with food processing and pulp and paper facilities are designed to deal with higher loadings/concentrations of BOD and COD than municipal facilities. Municipal wastewater treatment facilities are typically designed to handle domestic wastes, in terms of both volume and concentration of waste.
- Given the smaller size and potentially higher loadings, the unit electricity consumption of these types of facilities will tend to be higher than for POTWs. A reasonable estimate of unit electricity consumption would be about 2,500 kWh/million gallons (0.661 kWh/cubic meter).
- Since discharges from these facilities are typically to surface water, it is likely that more aggressive wastewater treatment will be required over the next 20 years – this is likely to increase unit electricity consumption over the period by perhaps 5 to 10 percent.
- It is expected that more privately operated wastewater treatment facilities will be constructed over the next 20 years. These facilities would provide either full treatment followed by discharge to surface water, or pretreatment to reduce concentrations to significantly reduced levels before discharge to POTWs. In the latter case, the industrial facilities may be currently discharging untreated wastewater directly to a POTW for treatment. As

[3] The USEPA has an online database of wastewater treatment facilities, which is developed from discharge permits (the Environmental Data Warehouse, at http://www.epa/gov/enviro. The database includes information about the maximum daily average allowable discharge from each facility, the 4-digit SIC code associated with the operation of the facility, and other characterizing information. For the purposes of this analysis, however, the database is incomplete: many facilities do not have an SIC code associated with them, and flow rates are not listed for many other facilities. Further, the flow rates are maximum average allowable discharges, and these may be significantly higher than actual flows. The data also do not indicate the type and level of treatment afforded. The database includes a total of about 16,000 records for which non-zero maximum average daily flows are recorded, and for which an SIC code is associated with a facility. Of these 16,000 records, about 6,300 are for POTWs, and the balance are privately operated—or at least are not associated with SIC Code 4952: Sewerage Systems. These numbers of facilities are significantly lower than the population of systems identified by the USGS. Given the poor quality of the data set, it was decided not to try to use it to make projections of total energy use by sector for wastewater treatment in captive facilities.

municipally owned wastewater treatment facilities are starting to reach their treatment limits, it is often less expensive for industrials to engage in pretreatment rather than to pay the increasing surcharges imposed on their higher concentration discharges. Further, USEPA programs (e.g., the National Pretreatment Program) recognize the need for industrial and other sector pretreatment to reduce the burden on POTWs on handling industrial wastes, which may contain toxic or otherwise hazardous materials or materials that might interfere with the biological processes in place at the POTWs. [4] In some cases, particularly in the paper industry, notable efforts have been made to reduce both water consumption and wastewater discharges, through the practice of reclaiming and reusing water internally. Finally, the issue of run-off water containing animal wastes (livestock and poultry) has led to initiatives to collect and treat this waste. These factors will contribute to the expected increase in the unit electricity consumption to process wastewater as noted above, and will contribute to the total volume of processed waste. Hence, the total amount of electricity required to process wastewater in privately operated facilities is expected to increase over the 20 and 50 year horizons.

- These smaller facilities would tend to be less impacted by power quality issues, particularly interruptions, than POTWs. This would be the case where the operations that generate the wastewater are interrupted simultaneously with the treatment facility. However, if the treatment processes depend on aeration or mechanical processes to aid digestion of wastes, sustained loss of power can result in subsequent problems with the biological processes.

References

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4

ELECTRICITY REQUIREMENTS FOR SUPPLY OF WATER BY END-USERS

As noted earlier in this report, fresh water is supplied by public water supply agencies with distribution to end-users, and by end-users themselves. Electricity consumption estimates associated with public supply of freshwater were covered in Chapter 2. Here, the unit and total electricity estimates associated with the supply of water by the entities for their own consumption will be covered. The following sectors will be covered here:

- Domestic (residential)
- Commercial
- Industrial and mining
- Irrigation and livestock
- Thermal power generation

These sectors account for a total of about 334 billion gallons per day of water consumption from all sources. Table 4-1 shows the breakdown of water consumption by sector and source (public supply and self supply) for 1995. The domestic and commercial sectors rely most heavily on public water supply sources. The industrial, mining, agricultural, and thermal power generation sectors rely significantly more on water that they provide for themselves.

Domestic Sector

Characterization of Sector

According to the U.S. Geological Survey (USGS), the domestic sector consumed about 26 billion gallons of water per day (98 million cubic feet) in 1995. Of this, about 85 percent were from public water supply agencies, and the balance was supplied by the end-user. Of the self-supplied water, most is from groundwater (wells). A regional breakdown of water consumption by source is shown in Table 4-2.

Residential wellwater pumping systems are simple, consisting of the well pump, which lifts water and pressurizes it, and a storage tank, in which the pressurized water is stored for distribution to the house. For typical homes, the pump size ranges from about ½ hp to 2 hp. Multi-family dwellings have similar types of systems, with larger pumps up to about 10 hp depending on the volume of the water lifted.

Table 4-1
Supply of Fresh Water by Source 1995

Sector	Public Supply	Self-Supply	Total Water Supply
Million gallons per day			
Domestic	22,509	3,374	25,883
Commercial	6,630	2,895	9,524
Industrial	4,737	20,717	25,454
Mining	-	2,754	2,754
Irrigation	-	133,575	133,575
Livestock	-	5,477	5,477
Power Generation	98	131,771	131,771
Total U.S.	33,974	300,562	334,437
Cubic meters per day			
Domestic	85,196,565	12,770,590	97,967,155
Commercial	25,093,415	10,956,061	36,049,476
Industrial	17,928,410	78,415,359	96,343,769
Mining	-	10,424,269	10,424,269
Irrigation	-	505,580,618	505,580,618
Livestock	-	20,728,931	20,728,931
Power Generation	371,309	498,751,343	499,122,651
Total U.S.	128,589,698	1,137,627,170	1,266,216,868

Source: USGS [1]

Table 4-2
Supply of Fresh Water to the Domestic Sector 1995

Region	Self-Supplied			Public Supply	Grand Total
	Ground	Surface	Total		
Million gallons/day					
East North Central	668	3	671	2,571	3,242
East South Central	172	3	175	1,221	1,396
Middle Atlantic	411	-	411	2,907	3,318
Mountain	202	3	206	2,113	2,319
New England	180	1	181	739	920
Pacific	305	21	326	4,736	5,062
South Atlantic	889	1	890	3,680	4,570
West North Central	278	-	278	1,190	1,468
West South Central	237	-	237	3,352	3,589
Total U.S.	3,343	31	3,374	22,509	25,883
Cubic meters/day					
East North Central	2,528,380	10,977	2,539,357	9,731,235	12,270,592
East South Central	651,020	9,463	660,483	4,621,485	5,281,968
Middle Atlantic	1,555,635	-	1,555,635	11,002,995	12,558,630
Mountain	766,084	12,869	778,953	7,997,705	8,776,658
New England	682,436	3,407	685,842	2,797,115	3,482,957
Pacific	1,153,290	78,728	1,232,018	17,925,760	19,157,778
South Atlantic	3,364,865	3,028	3,367,893	13,928,800	17,296,693
West North Central	1,053,366	-	1,053,366	4,504,150	5,557,516
West South Central	897,045	-	897,045	12,687,320	13,584,365
Total U.S.	12,652,120	118,471	12,770,590	85,196,565	97,967,155

Source: USGS [1]

Unit Electricity Consumption

Unit electricity consumption for these types of systems will vary with the depth of the well, the pressure and flow rate of the output water, and the efficiency of the pump system. For the purposes of this analysis, a unit electricity consumption of about 700 kWh per million gallons (0.185 kWh/m^3) is assumed. This figure is based on the electricity requirements for municipal groundwater system well pumping (605 kWh/million gallon—0.161 kWh/m^3), with allowance for the significantly reduced scale of residential pumping and for the additional energy for pressurization of the residential distribution system.

Electricity Consumption Projection

Using regional population growth projections as the basis, Figure 4-1 shows the estimated regional growth in electricity consumption for residential self-supply of water for the period 2000 through 2020, with an extrapolation through 2050. These data are presented in tabular form in the Appendix. As can be seen, the total electricity consumption for domestic water self-supply is estimated at 894million kWh for 2000, growing to 1.038 billion kWh by 2020.

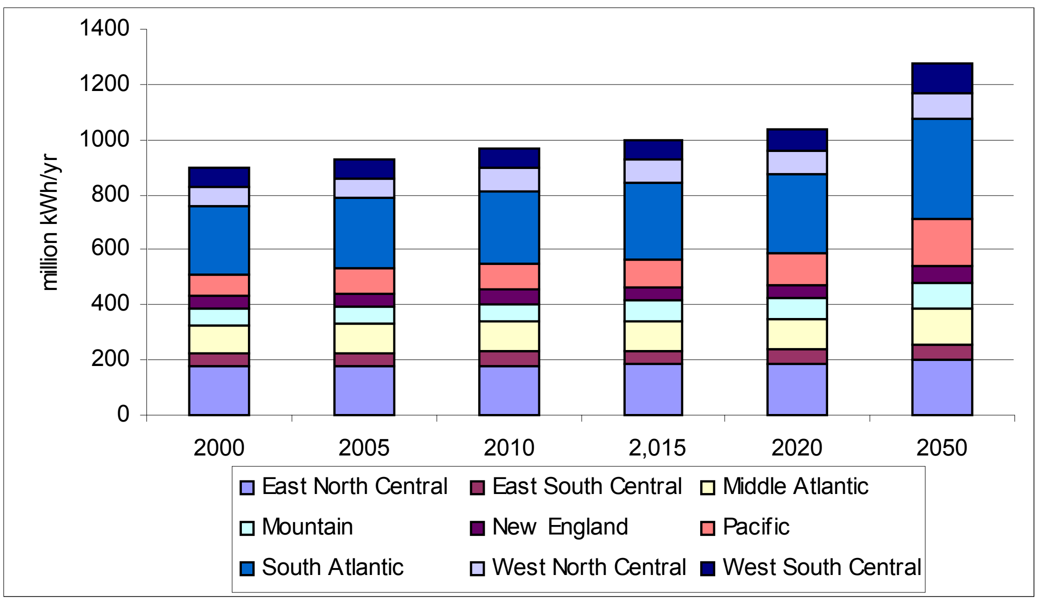

Figure 4-1
Baseline Regional Energy Consumption Projection for the Domestic Sector

These technologies are relatively mature and no significant improvements in unit electricity consumption are expected over the time horizon for these projections. Marginal improvements may be achieved with increased pump efficiencies.

The estimates shown here are based on the assumption that the same proportion of water derived from public and self-supply will be maintained over the forecast period, and that with self-supply, the same proportion of water derived from ground and surface water sources will also be maintained. Changes in the way water is supplied to domestic sector regionally and nationally will affect the total electricity consumption, but the unit electricity consumption estimates will not be affected.

Commercial Sector

Characterization of Sector

The use of water by the commercial sector is estimated at about 9.5 billion gallons per day, according to the USGS [1]. Of this, about 6.6 billion gallons per day is drawn from public supply sources and the balance of 2.9 billion gallons per day is self-supplied. Of this, nearly 2 billion gallons per day is derived from surface water, and the balance from ground water. Table 4-3 shows the breakdown of water supply by source by region for the commercial sector.

Groundwater supply systems for the commercial sector are similar to those employed in the domestic sector, differing primarily in the size of the pumps and storage systems used. These systems consist of a well pump, which lifts water and pressurizes it, and a storage tank in which the pressurized water is stored for distribution. Larger commercial facilities may also employ additional pumping to ensure adequate flow and pressure at the point of water discharge. These pumps are relatively small compared with the well pump.

Surface water supply is carried out by low head pumping from nearby bodies of water. Water may be stored in above-ground tanks (gravity flow to the point of use) or ground-level or below-ground tanks (where additional pumping may be employed to ensure adequate flow and pressure at the point of water use). Pump size depends on distance from the point of water supply to water use.

Unit Electricity Consumption

For groundwater pumping, unit electricity consumption will vary with the depth of the well, the pressure and flow rate of the output water, and the efficiency of the pump system. For the purposes of this analysis, unit electricity consumption for groundwater pumping of 700 kWh per million gallons (0.185 kWh/m^3) is assumed. This figure is based on the unit electricity requirement for municipal groundwater system well pumping (605 kWh/million gallon—0.161 kWh/m^3) with allowance for the reduced scale of commercial pumping and for the additional energy requirements for system pressurization and/or distribution pumping

For surface water supply, unit electricity consumption will vary with the distance between point of supply and point of use, the pressure and flow rate of the output water, and the efficiency of the pumping system. For the purposes of this analysis, unit electricity consumption for surface water supply of 300 kWh/million gallons (0.079 kWh/m^3) is assumed. This figure is based on the unit electricity consumption for municipal surface water pumping of 278 kWh/million gallons (0.073 kWh/m^3), with an upward adjustment based on the reduced scale of commercial pumping, the need for distribution pumping within the facility, and the energy requirements for treating (e.g., softening, chlorination) the water prior to use.

Table 4-3
Supply of Fresh Water to the Commercial Sector 1995

Region	Self-Supplied			Public Supply	Grand Total
	Ground	Surface	Total		
Million gallons/day					
East North Central	122	202	324	1,278	1,602
East South Central	33	32	65	392	457
Middle Atlantic	169	80	249	806	1,055
Mountain	68	314	382	605	987
New England	70	37	107	351	458
Pacific	161	1,062	1,223	1,304	2,527
South Atlantic	178	50	228	1,072	1,300
West North Central	88	50	139	409	548
West South Central	50	128	178	413	591
Total U.S.	940	1,955	2,895	6,630	9,524
Cubic meters/day					
East North Central	461,770	764,570	1,226,340	4,837,230	6,063,570
East South Central	124,527	121,120	245,647	1,483,720	1,729,367
Middle Atlantic	639,665	303,557	943,222	3,050,710	3,993,932
Mountain	258,516	1,188,869	1,447,384	2,289,925	3,737,309
New England	264,572	140,802	405,374	1,327,400	1,732,773
Pacific	610,899	4,019,292	4,630,191	4,935,640	9,565,831
South Atlantic	672,973	188,115	861,088	4,057,520	4,918,608
West North Central	334,594	189,629	524,223	1,548,065	2,072,288
West South Central	189,250	483,345	672,595	1,563,205	2,235,800
Total U.S.	3,556,765	7,399,297	10,956,061	25,093,415	36,049,476

Source: USGS [1]

Electricity Consumption Projection

Using EPRI's growth projections for the commercial sector [2] as the basis (growth rates are shown in the Appendix), Figure 4-2 shows the estimated regional growth in electricity consumption for the self-supply of water to the commercial sector for the period 2000 through 2010, with extrapolations to 2020 and 2050. These data are presented in tabular form in the Appendix. Total electricity consumption for the year 2000 for self-supply of water to the commercial sector is estimated at 476 million kWh/year. This is projected to grow to 580 million kWh/year by the year 2020. Extrapolation to 2050 yields estimated annual energy consumption of 780 million kWh/year.

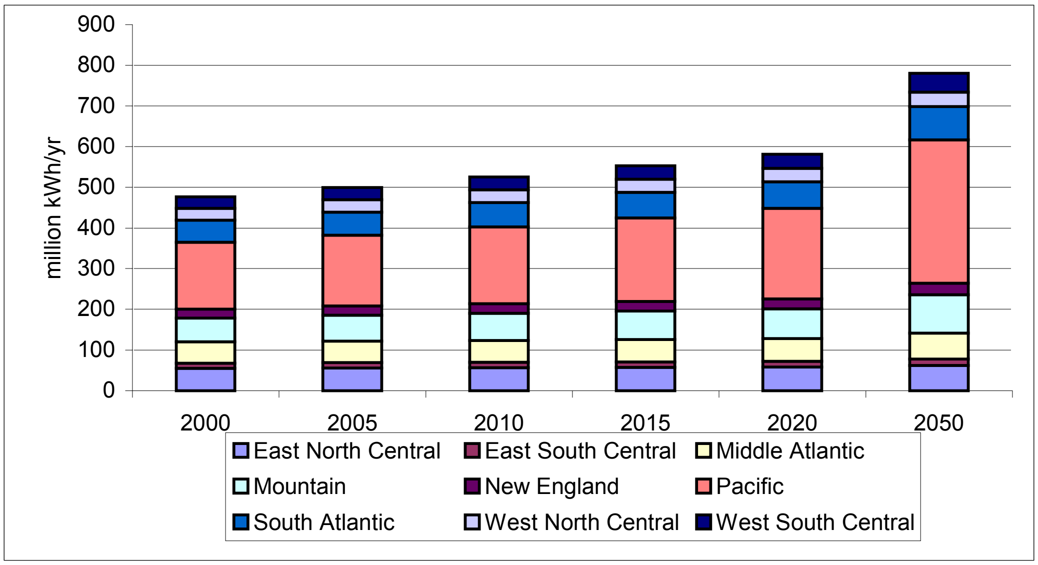

Figure 4-2
Baseline Regional Energy Consumption Projection for the Commercial Sector

As with the domestic sector, the technologies used to supply water from surface or ground sources is relatively mature and no significant improvements in unit electricity consumption is expected over the time horizon for these projections. Marginal improvements may be achieved with increased pump efficiencies and the use of variable speed drives.

The estimates shown here are based on the assumption that the same proportion of water derived from public and self-supply will be maintained over the forecast period, and that with self-supply, the same proportion of water derived from ground and surface water sources will also be maintained. Changes in the way water is supplied to the commercial sector regionally and nationally will affect the total electricity consumption, but the unit electricity consumption estimates will not be affected.

Self-supply of water to the commercial sector is highly dependent on the availability of electricity to operate pumps. Any prolonged power interruption will severely impact access to water for this sector, after storage vessels are drawn down and cannot be replenished. At the same time, most establishments in this sector would be unable to operate any of their operations without electricity. For such commercial facilities as offices and retail outlets, the availability of water is not critical except for sanitary purposes, and sufficient water storage capacity is generally available to meet the needs during short power interruptions. For restaurants, other food service facilities, and supermarkets and groceries, water supply is more important and prolonged power interruptions can result in loss of water supply. Larger commercial facilities, such as shopping malls, often have back-up power supplies in the form of diesel generators, and it is assumed that motive power for water supply would be supplied by these types of systems.

Industrial and Mining

Characterization of Sectors

The USGS [1] estimates that the industrial sector consumes about 25 billion gallons of water per day. Of this, about 80 percent are self-supplied with the balance from public water supply sources. Of the self-supplied water, about 4 billion gallons per day comes from groundwater and the balance from surface water.[4] A regional breakdown of water consumption by source is shown in Table 4-4.

The USGS estimates that the mining sector consumes about 2.7 billion gallons per day, all of which is self-supplied. A little over one-third of the water consumed is from groundwater pumping, while the balance is drawn from surface water. A regional breakdown of water consumption by source is shown in Table 4-5.

Groundwater supply systems for these sectors consist of a well pump, which lifts water. The water is generally stored in a tank for distribution to the point of use. Additional distribution pumping is required to ensure adequate flow and pressure at the point of water discharge and to overcome frictional losses in the distribution system. Well pump size will depend on the depth of the well and the discharge pressure and volume.

Surface water supply is carried out by low head pumping from nearby bodies of water. Water may be stored in above ground tanks (gravity flow to the point of use) or ground-level or below-ground tanks (where additional pumping may be employed to ensure adequate flow and pressure at the point of water use). Pump size depends on distance from the point of water supply to water use.

[4] It is not unusual for industrial plants to have multiple sources of water, and use the multiple sources simultaneously. The author is aware of at least one plant that uses municipally supplied water, water drawn from wells within the plant boundaries, and water drawn from a large lake by pipeline from a distance of about 2 miles.

Table 4-4
Supply of Fresh Water to the Industrial Sector 1995

Region	Self-Supplied			Public Supply	Grand Total
	Ground	Surface	Total		
Million gallons/day					
East North Central	694	4,882	5,576	1,019	6,595
East South Central	360	1,873	2,233	560	2,793
Middle Atlantic	317	1,820	2,137	640	2,777
Mountain	216	165	381	129	510
New England	55	105	159	175	334
Pacific	691	910	1,601	703	2,303
South Atlantic	813	3,189	4,002	697	4,698
West North Central	237	302	538	332	871
West South Central	694	3,397	4,091	482	4,573
Total U.S.	4,076	16,642	20,717	4,737	25,454
Cubic meters/day					
East North Central	2,626,790	18,478,370	21,105,160	3,856,915	24,962,075
East South Central	1,362,600	7,089,305	8,451,905	2,119,600	10,571,505
Middle Atlantic	1,199,845	6,888,700	8,088,545	2,422,400	10,510,945
Mountain	818,696	623,011	1,441,707	489,401	1,931,107
New England	207,040	395,533	602,572	661,240	1,263,812
Pacific	2,614,678	3,444,350	6,059,028	2,659,341	8,718,369
South Atlantic	3,075,313	12,070,365	15,145,678	2,637,010	17,782,687
West North Central	895,910	1,141,178	2,037,087	1,258,134	3,295,221
West South Central	2,626,033	12,857,645	15,483,678	1,824,370	17,308,048
Total U.S.	15,426,903	62,988,456	78,415,359	17,928,410	96,343,769

Source: USGS [1]

Table 4-5
Supply of Fresh Water to the Mining Industry 1995

Region	Self-Supplied			Public Supply	Grand Total
	Ground	Surface	Total		
Million gallons/day					
East North Central	78	271	349	-	349
East South Central	18	31	49	-	49
Middle Atlantic	224	177	401	-	401
Mountain	361	258	619	-	619
New England	3	23	26	-	26
Pacific	19	128	146	-	146
South Atlantic	179	204	383	-	383
West North Central	47	516	563	-	563
West South Central	134	85	218	-	218
Total U.S.	1,061	1,693	2,754	-	2,754
Cubic meters/day					
East North Central	293,338	1,026,871	1,320,208	-	1,320,208
East South Central	66,995	116,957	183,951	-	183,951
Middle Atlantic	849,354	669,945	1,519,299	-	1,519,299
Mountain	1,366,385	976,530	2,342,915	-	2,342,915
New England	10,977	88,191	99,167	-	99,167
Pacific	70,023	483,723	553,746	-	553,746
South Atlantic	676,758	772,140	1,448,898	-	1,448,898
West North Central	176,760	1,953,060	2,129,820	-	2,129,820
West South Central	506,433	319,833	826,266	-	826,266
Total U.S.	4,017,021	6,407,248	10,424,269	-	10,424,269

Source: USGS [1]

Unit Electricity Consumption

For groundwater pumping, unit electricity consumption will vary with the depth of the well, the pressure and flow rate of the output water, and the efficiency of the pump system. For the purposes of this analysis, a unit electricity consumption for groundwater pumping of 750 kWh per million gallons (0.198 kWh/m^3) is assumed for both the industrial and mining sectors . This figure is based on the unit electricity requirement for municipal groundwater system well pumping (605 kWh/million gallon—0.161 kWh/m^3) with allowance for the reduced scale of pumping and for the additional energy requirements (associated with frictional losses and/or higher pressures) for distribution pumping.

For surface water supply, unit electricity consumption will vary with the distance between point of supply and point of use, the pressure and flow rate of the output water, and the efficiency of the pumping system. For the purposes of this analysis, a unit electricity consumption for surface water supply of 300 kWh/million gallons (0.079 kWh/m^3) is assumed. This figure is based on the unit electricity consumption for municipal surface water pumping of 278 kWh/million gallons (0.073 kWh/m^3), with an upward adjustment based on the reduced scale of pumping, the need for distribution pumping within the facility, and the energy requirements for treating the water prior to use.

Electricity Consumption Projections

Using EPRI's growth projections for the industrial and mining sectors [3] as the basis (growth rates are shown in the Appendix), Figure 4-3 shows the estimated regional growth in electricity consumption for the self-supply of water to the industrial sector for the period 2000 through 2010, with extrapolations to 2020 and 2050 and Figure 4-4 shows the projection for the mining sector. These data are also presented in tabular form in the Appendix. Total electricity consumption for the year 2000 for self-supply of water to industry is estimated at 3.3 billion kWh/year, which is projected to grow to 5.2 billion kWh/year by 2020. Extrapolation to 2050 yields estimated annual energy consumption of 10.2 billion kWh/year.

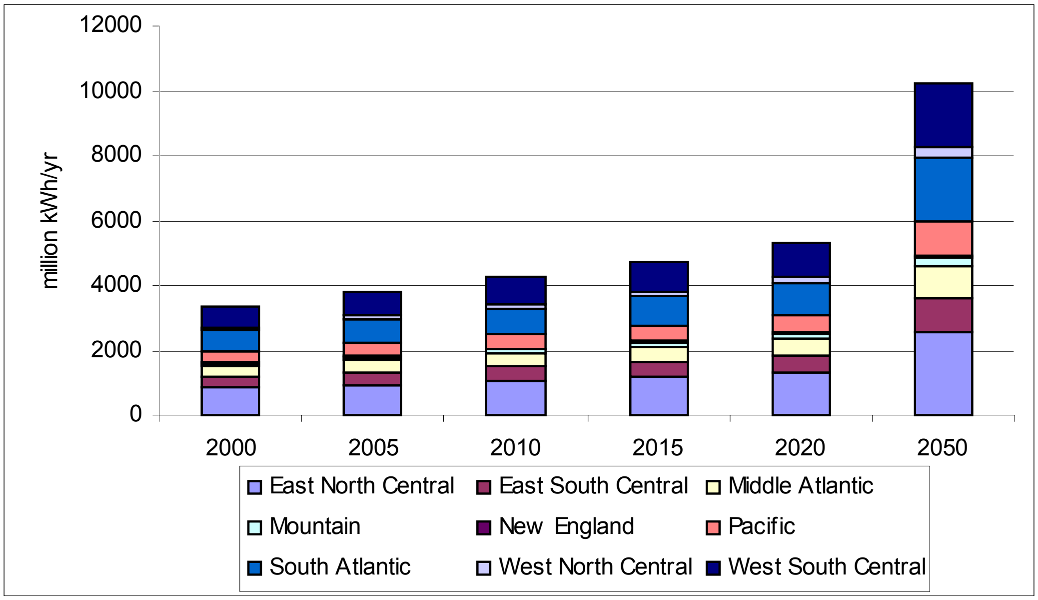

Figure 4-3
Baseline Regional Energy Consumption Projection for the Industrial Sector

Total electricity consumption for self-supply of water to the mining industry for the year 2000 is estimated at 490 million kWh/year, which is projected to grow to 569 million kWh/year by 2020. Extrapolation to 2050 yields estimated annual energy consumption of 713 million kWh/year.

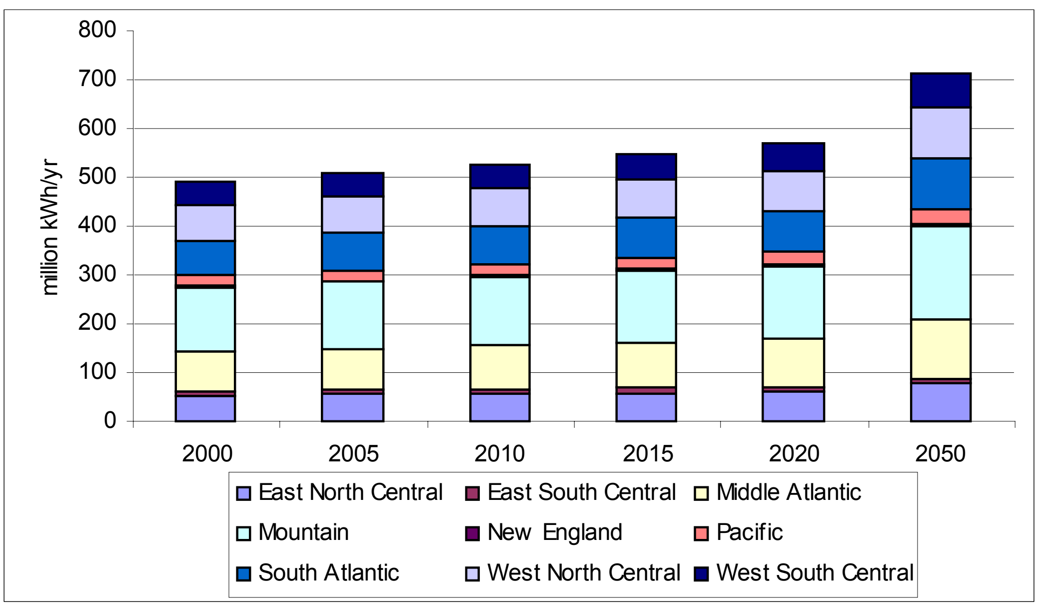

Figure 4-4
Baseline Regional Energy Consumption Projection for the Mining Sector

The technologies used to supply water from surface or ground sources is relatively mature and no significant improvements in unit electricity consumption is expected over the time horizon for these projections. Marginal improvements may be achieved with increased pump efficiencies and the use of variable speed drives in the industrial and mining sectors.

The estimates shown here are based on the assumption that the same proportion of water derived from public and self-supply will be maintained over the forecast period, and that with self-supply, the same proportion of water derived from ground and surface water sources will also be maintained. Changes in the way water is supplied to the commercial sector regionally and nationally will affect the total electricity consumption, but the unit electricity consumption estimates will not be affected.

An issue that needs to be explored and resolved is the source of the electricity used for water pumping in the industrial and mining sectors. The figures shown here are gross electricity consumption figures and do not take into account the source of electricity. The industrial and mining sectors are large consumers of self-generated electric power. A single facility may cover all or part of its electricity requirements from the distribution grid, with the balance from self-generation. Statistics indicating the historical and projected share of electricity consumption by this sector from purchased power and self-generation are not generally available, although EPRI's Energy Market Profiles: Industrial does provide breakdowns by 2-digit SIC code for 1998. Lacking refined information, the figures shown here are most likely larger than the amount of electricity required from utility generation alone. Further, mines are often located in remote locations, not always accessible to the electricity transmission and distribution system. A significant portion of the electricity consumed by the mining sector is self-generated, but precise figures are not available. Therefore, the projected electricity consumption figures for the industry and mining shown here represent electricity from all sources—purchased and self-generated.

Facilities in these industries having their own supply of electric power outside of the public utility distribution system are less affected by utility power interruptions than those depending solely on the utility grid. Unscheduled loss of electric power can cause havoc in most industrial plants, not only with water supply but also with manufacturing processes.

Irrigation and Livestock

Characterization of Sector

The USGS [1] estimates that about 133 billion gallons of water per day is used for irrigation, making this the single largest domestic consumer. All of the water is self-supplied, with about two-thirds from surface water and the balance from groundwater. A regional breakdown of water consumption by source for irrigation is shown in Table 4-6.

The USGS estimates that about 5.5 billion gallons of water per day is consumed by the livestock sector, all of which is self-supplied. About 60 percent of the water is from surface water, while the balance is drawn from groundwater. A regional breakdown of water consumption by source is shown in Table 4-7.

Table 4-6
Supply of Fresh Water for Irrigation 1995

Region	Self-Supplied			Public Supply	Grand Total
	Ground	Surface	Total		
Million gallons/day					
East North Central	521	200	721	-	721
East South Central	1,701	211	1,912	-	1,912
Middle Atlantic	56	115	171	-	171
Mountain	9,247	45,460	54,707	-	54,707
New England	48	101	149	-	149
Pacific	12,670	29,520	42,190	-	42,190
South Atlantic	2,310	2,314	4,624	-	4,624
West North Central	9,764	2,315	12,079	-	12,079
West South Central	12,701	4,322	17,023	-	17,023
Total U.S.	49,018	84,557	133,575	-	133,575
Cubic meters/day					
East North Central	1,971,985	755,108	2,727,093	-	2,727,093
East South Central	6,439,799	798,635	7,238,434	-	7,238,434
Middle Atlantic	212,717	434,140	646,857	-	646,857
Mountain	34,999,895	172,066,100	207,065,995	-	207,065,995
New England	181,680	383,042	564,722	-	564,722
Pacific	47,956,329	111,731,308	159,687,636	-	159,687,636
South Atlantic	8,741,836	8,758,490	17,500,326	-	17,500,326
West North Central	36,956,740	8,760,761	45,717,501	-	45,717,501
West South Central	48,073,285	16,358,770	64,432,055	-	64,432,055
Total U.S.	185,534,266	320,046,353	505,580,618	-	505,580,618

Source: USGS [1]

Table 4-7
Supply of Fresh Water for Livestock 1995

Region	Self-Supplied			Public Supply	Grand Total
	Ground	Surface	Total		
Million gallons/day					
East North Central	182	54	235	-	235
East South Central	422	185	607	-	607
Middle Atlantic	72	19	91	-	91
Mountain	133	1,633	1,765	-	1,765
New England	9	14	23	-	23
Pacific	269	259	528	-	528
South Atlantic	200	318	518	-	518
West North Central	395	174	569	-	569
West South Central	572	568	1,140	-	1,140
Total U.S.	2,254	3,223	5,477	-	5,477
Cubic meters/day					
East North Central	687,356	202,876	890,232	-	890,232
East South Central	1,598,406	700,225	2,298,631	-	2,298,631
Middle Atlantic	270,628	72,294	342,921	-	342,921
Mountain	501,891	6,179,770	6,681,661	-	6,681,661
New England	35,579	51,855	87,434	-	87,434
Pacific	1,018,165	980,315	1,998,480	-	1,998,480
South Atlantic	758,136	1,203,252	1,961,387	-	1,961,387
West North Central	1,495,075	658,212	2,153,287	-	2,153,287
West South Central	2,165,020	2,149,880	4,314,900	-	4,314,900
Total U.S.	8,530,255	12,198,677	20,728,931	-	20,728,931

Source: USGS [1]

Groundwater supply systems for these sectors consist of a well pump, which lifts water. The water may be stored in a tank for later distribution to the point of use, or distributed immediately. Well pump size will depend on the depth of the well and the discharge pressure and volume.

Surface water supply is carried out by low head pumping from nearby bodies of water. Water is generally distributed immediately by gravity flow. Pump size depends on distance from the point of water supply to water use.

Unit Electricity Consumption

For groundwater pumping, unit electricity consumption will vary with the depth of the well, the pressure and flow rate of the output water, and the efficiency of the pump system. For the purposes of this analysis, a unit electricity consumption for groundwater pumping of 700 kWh per million gallons (0.185 kWh/m^3) is assumed for both irrigation and livestock . This figure is based on the unit electricity requirement for municipal groundwater system well pumping (605 kWh/million gallon—0.161 kWh/m^3) with allowance for the reduced scale of pumping and for the additional energy requirements for distribution pumping.

For surface water supply, unit electricity consumption will vary with the distance between point of supply and point of use, the pressure and flow rate of the output water, and the efficiency of the pumping system. For the purposes of this analysis, a unit electricity consumption for surface water supply of 300 kWh/million gallons (0.079 kWh/m^3) is assumed. This figure is based on the unit electricity consumption for municipal surface water pumping of 278 kWh/million gallons (0.073 kWh/m^3), with an upward adjustment based on the reduced scale of pumping.

Electricity Consumption Projections

Trends in the amount of farmland under irrigation were used as the basis in formulating the growth projection for electricity consumption for irrigation pumping. Regional growth rates were developed from historical data compiled by the United States Department of Agriculture (USDA) [4]. Regional growth rate projects are provided in the Appendix.

Figure 4-5 shows estimated regional growth in electricity consumption for the self-supply of water for irrigation for the period 2000 through 2010, with extrapolations to 2020 and 2050 and Figure 4-6 shows the projection for livestock. These data are also presented in tabular form in the Appendix. Total electricity consumption for the year 2000 for self-supply of water for irrigation is estimated at 23.6 billion kWh/year, which is projected to grow to 33.3 billion kWh/year by 2020. Extrapolation to 2050 yields estimated annual energy consumption of 60.6 billion kWh/year.

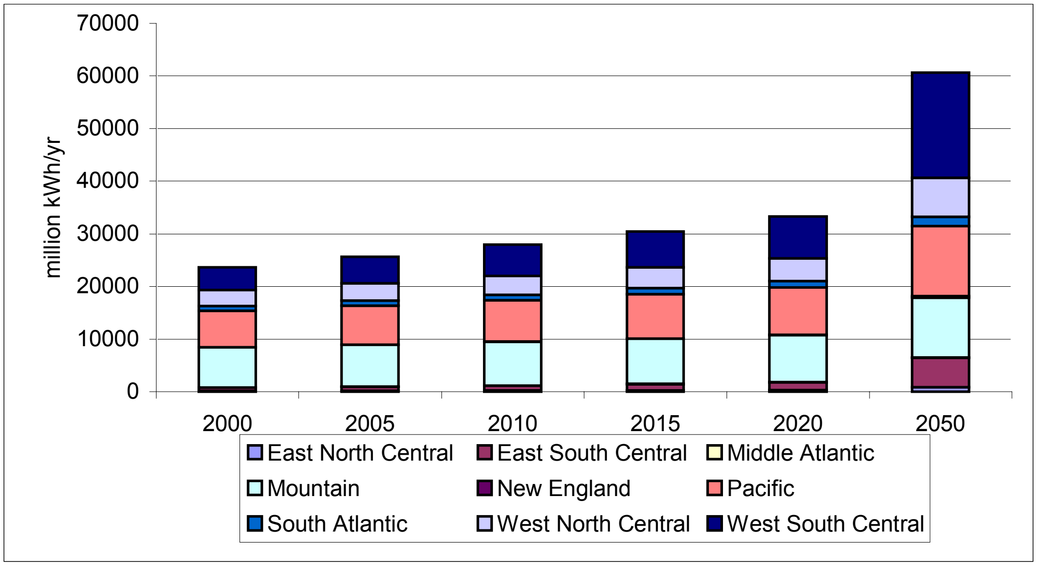

Figure 4-5
Baseline Regional Energy Consumption Projection for Irrigation

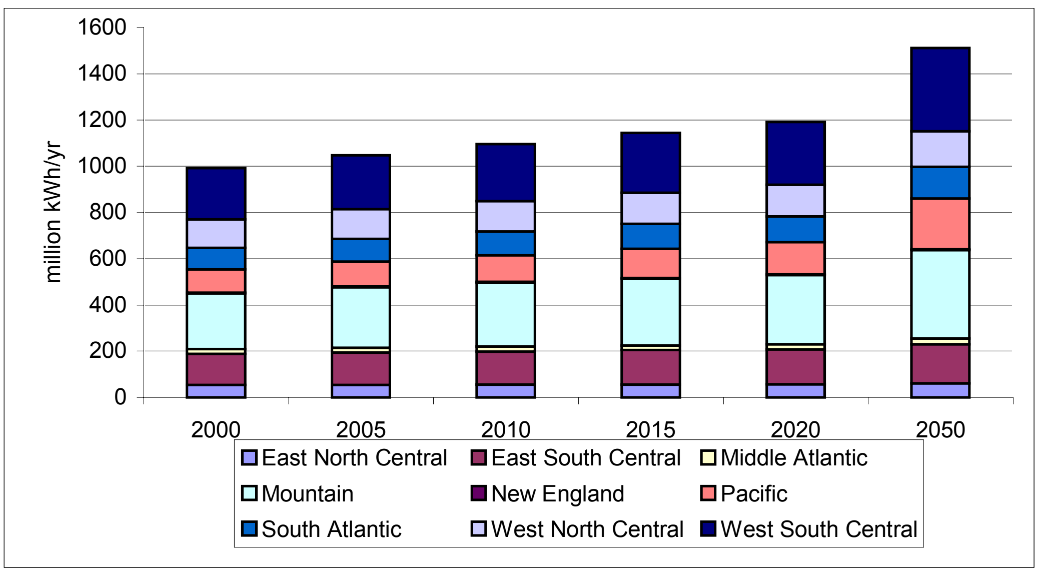

Figure 4-6
Baseline Regional Energy Consumption Projection for Livestock

A suitable metric for projection of water use for livestock was difficult to devise. Livestock are used for meat production (red meat and poultry slaughter), and for provision of other products (milk, eggs). The statistics kept for these two very different dispositions were impossible to combine to form a single meaningful metric, nor was it was possible to segregate water consumption for these different uses. It was decided to use population growth projections as the basis for projections in this sector, since the growth and consumption of livestock products is tied to the population.

Using population growth as the basis for the projection, the total electricity consumption for self-supply of water for livestock for the year 2000 is estimated at 992 million kWh/year, which is projected to grow to 1.2 billion kWh/year by 2020. Extrapolation to 2050 yields estimated annual energy consumption of 1.5 billion kWh/year.

The technologies used to supply water from surface or ground sources are relatively mature and no significant improvements in unit electricity consumption are expected over the time horizon for these projections. Marginal improvements may be achieved with increased pump efficiencies and the use of variable speed drives in the industrial and mining sectors.

Water conservation efforts are continuing in the agricultural sector, with a decrease in the amount of water being used for irrigation and livestock use. While this while impact aggregate electricity consumption, it should have little impact on the unit electricity consumption estimates. Other factors that could impact total electricity requirements for irrigation and livestock are precipitation, changes in diet among the population (shifts between red meat and poultry, eggs, and dairy products—this could also impact the types of crops grown for animal feed and hence the water requirements for those crops), and changes in water requirements of crops due to genetic manipulation.

An issue that needs to be explored is the source of the electricity used for water pumping in the agricultural and livestock sectors. The figures shown here are gross electricity consumption figures and do not take into account the source of electricity. Because not all farmland can take electricity from the distribution grid, this sector sometimes uses small generators at remote locations for motive power for pumps. Statistics indicating the historical and projected share of electricity consumption by this sector from purchased power and self-generation were not available. Hence, the figures shown here are most likely larger than the amount of electricity required from utility generation alone.

Power Generation

Characterization of Sector

The USGS [1] estimates that about 131 billion gallons of water per day is used for thermal power production, making this the second largest domestic consumer after irrigation. The water is predominantly self-supplied, with most from surface water sources. A regional breakdown of water consumption by source for thermal power generation is shown in Table 4-8.

Groundwater supply systems for these sectors consist of a well pump, which lifts water. The water is generally stored in a tank for distribution to the point of use. Additional distribution pumping is required to ensure adequate flow and pressure at the point of water discharge and to overcome frictional losses in the distribution system. Well pump size will depend on the depth of the well and the discharge pressure and volume.

Table 4-8
Supply of Fresh Water for Thermal Power Generation 1995

Region	Self-Supplied			Public Supply	Grand Total
	Ground	Surface	Total		
Million gallons/day					
East North Central	50	45,140	45,190	5	45,195
East South Central	86	17,120	17,206	3	17,209
Middle Atlantic	8	13,068	13,076	27	13,103
Mountain	81	469	550	16	565
New England	48	1,620	1,668	2	1,670
Pacific	75	612	687	6	694
South Atlantic	68	22,087	22,155	5	22,160
West North Central	49	14,221	14,269	4	14,274
West South Central	99	16,871	16,970	30	17,000
Total U.S.	563	131,208	131,771	98	131,869
Cubic meters/day					
East North Central	188,493	170,854,900	171,043,393	20,061	171,063,454
East South Central	325,510	64,799,200	65,124,710	10,220	65,134,930
Middle Atlantic	30,659	49,462,380	49,493,039	100,681	49,593,720
Mountain	305,071	1,775,165	2,080,236	59,046	2,139,282
New England	182,059	6,131,700	6,313,759	8,327	6,322,086
Pacific	285,011	2,316,420	2,601,431	23,467	2,624,898
South Atlantic	256,623	83,598,160	83,854,783	19,682	83,874,465
West North Central	183,573	53,826,107	54,009,679	15,519	54,025,198
West South Central	373,580	63,856,735	64,230,315	114,307	64,344,622
Total U.S.	2,130,577	496,620,766	498,751,343	371,309	499,122,651

Source: USGS [1]

Surface water supply is carried out by low head pumping from nearby bodies of water. Water may be stored in above ground tanks (gravity flow to the point of use) or ground-level or below-ground tanks (where additional pumping may be employed to ensure adequate flow and pressure at the point of water use). Pump size depends on distance from the point of water supply to water use.

Unit Electricity Consumption

For groundwater pumping, unit electricity consumption will vary with the depth of the well, the pressure and flow rate of the output water, and the efficiency of the pump system. For the purposes of this analysis, a unit electricity consumption for groundwater pumping of 800 kWh per million gallons (0.211 kWh/m^3) is assumed. This figure is based on the unit electricity requirement for municipal groundwater system well pumping (605 kWh/million gallon—0.161 kWh/m^3) with allowance for the reduced scale of pumping and for the additional energy requirements for distribution pumping.

For surface water supply, unit electricity consumption will vary with the distance between point of supply and point of use, the pressure and flow rate of the output water, and the efficiency of the pumping system. For the purposes of this analysis, a unit electricity consumption for surface water supply of 300 kWh/million gallons (0.040 kWh/m^3) is assumed. This figure is based on the unit electricity consumption for municipal surface water pumping of 278 kWh/million gallons (0.073 kWh/m^3), with an upward adjustment based on the reduced scale of pumping, the need for distribution pumping within the facility, and the energy requirements for treating the water prior to use.

Electricity Consumption Projection

The estimate of the amount of electricity required for delivery of water is based on United States Department of Energy projections of generation by type of generating facility and estimates of make-up water requirements for cooling by the various types of generators. DOE thermal generation estimates by thermal generation are summarized in Table A-22 in the Appendix, by DOE generating region. These generation figures include only generation by biomass, coal, nuclear, municipal solid waste, other fossil generation, and combined cycle plants; these types of plants use cooling water. A map of generating regions is provided in Figure A-1 in the Appendix. Estimates of unit water use for various types of generator were developed by BKI [5] in a parallel effort to this project. These figures are summarized in Table 4-9.

Table 4-9
Average Water Requirements for Thermal Power Plant Cooling.

Cooling Type	Fuel Type	Gal/MWh	m^3/MWh
Cooling Pond make-up water	Fossil	450	1.7
	Nuclear	800	3.0
Dry Cooling Tower	all	----	----
Once-Through Cooling	Fossil	35,000	132.5
	Nuclear	42,500	160.8
	Combined Cycle	13,750	52.0
Wet Cooling Tower make-up water	Fossil	550	2.1
	Nuclear	950	3.6
	Combined Cycle	230	0.9
	Gas Combined Cycle	250	0.9

Source: BKI [5]

Figure 4-7 shows the amount of electricity required to meet the cooling water needs of these plants over the period 2000 through 2020. This represents less than 0.5 percent of the total generation of these types of plants.

As can be seen in Figure 4-7, the electricity requirements for cooling water pumping is expected to decline. This is primarily due to a shift away from once-through cooling, with high water requirements, to cooling using recycled water (e.g. wet cooling towers) and the expected increased use of dry cooling towers, where no water is lost from the system.

The technologies used to supply water from surface or ground sources are relatively mature and no significant improvements in unit electricity consumption are expected over the time horizon for these projections. Marginal improvements may be achieved with increased pump efficiencies and the use of variable speed drives in the industrial and mining sectors. Other new initiatives, such as the reduction in once-through cooling and the increased use of dry cooling towers (as opposed to evaporative or wet cooling towers) in power plants would tend to reduce the amount of water that would be pumped for make-up purposes. However, this should have little impact on the unit electricity requirements for water pumping from groundwater or surface water sources.

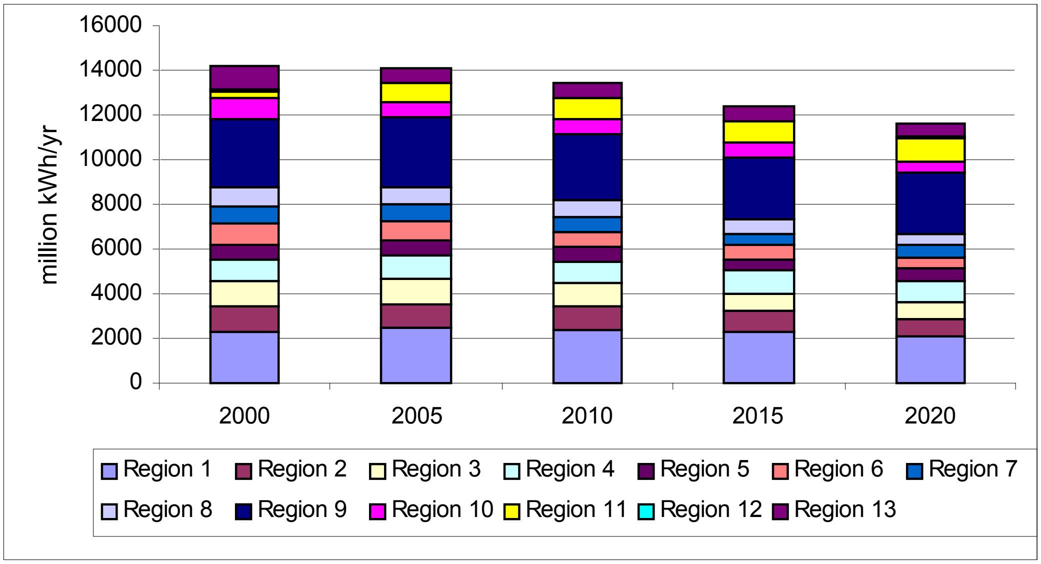

Figure 4-7
Baseline Regional Energy Consumption Projection for Thermal Power Generation

It should be noted that electricity consumption for internal use in power generation is not included in electricity consumption forecasts. On the supply side, reporting is generally based on gross generation of electricity, consumption for internal use, and net generation for sale (the difference between the first two items). The use of electricity by electric utilities for water pumping and/or wastewater treatment will generally be accounted for in the second of the three categories.

References

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A
SUPPORTING DATA

This Appendix contains supporting data and tables for the analyses presented in the main sections of this report.

Population Growth Projections

U.S. Census Bureau population growth projections used in the electricity consumption projections are provided in Tables A-1 and A-2. Table A-1 shows how population will grow in absolute terms by region. Table A-2 shows compound annual growth rates by region.

Table A-1
Population Growth Projections by Region

Population in millions	1995	2000	2005	2010	2015	2020	2025	2050
United States	262.76	274.63	285.98	297.72	310.13	322.74	335.05	406.92
East North Central	43.46	44.42	45.15	45.76	46.41	47.06	47.68	50.86
East South Central	16.07	16.92	17.60	18.12	18.59	19.00	19.35	21.16
Middle Atlantic	38.15	38.53	38.92	39.52	40.29	41.16	42.07	46.91
Mountain	15.65	17.73	19.25	20.22	21.12	22.05	22.96	28.13
New England	13.31	13.58	13.84	14.17	14.55	14.94	15.32	17.39
Pacific	41.95	43.69	46.35	50.29	54.77	59.42	64.14	94.02
South Atlantic	47.00	50.15	52.92	55.46	57.97	60.41	62.68	75.33
West North Central	18.35	19.08	19.67	20.15	20.62	21.05	21.43	23.46
West South Central	28.83	30.55	32.26	34.02	35.83	37.65	39.43	49.67

Source: U.S. Census Bureau [1]

Table A-2
Compound Annual Population Growth Rates by Region

	1995 to 2000	2000 to 2005	2005 to 2010	2010 to 2015	2015 to 2020	2020 to 2025	Projected through 2050
United States	0.89%	0.81%	0.81%	0.82%	0.80%	0.75%	0.78%
East North Central	0.44%	0.33%	0.27%	0.28%	0.28%	0.26%	0.26%
East South Central	1.04%	0.80%	0.58%	0.51%	0.44%	0.36%	0.36%
Middle Atlantic	0.19%	0.21%	0.30%	0.39%	0.43%	0.44%	0.44%
Mountain	2.53%	1.66%	0.99%	0.88%	0.86%	0.81%	0.81%
New England	0.40%	0.38%	0.47%	0.52%	0.53%	0.51%	0.51%
Pacific	0.81%	1.19%	1.64%	1.72%	1.64%	1.54%	1.54%
South Atlantic	1.31%	1.08%	0.94%	0.89%	0.83%	0.74%	0.74%
West North Central	0.79%	0.61%	0.48%	0.46%	0.42%	0.36%	0.36%
West South Central	1.17%	1.10%	1.07%	1.04%	0.99%	0.93%	0.93%

Source: U.S. Census Bureau [1]

Electricity Consumption for Fresh Water Supply by Public Water Supply Agencies

Table A-3
Baseline Regional Energy Consumption Projection for Water Supply by Public Water Supply Agencies

Billion kWh per year by Region	2000	2005	2010	2015	2020	2050
East North Central	4.60	4.68	4.74	4.81	4.88	5.27
East South Central	1.92	1.99	2.05	2.11	2.15	2.40
Middle Atlantic	4.19	4.23	4.30	4.38	4.48	5.10
Mountain	2.02	2.19	2.30	2.41	2.51	3.21
New England	1.85	1.89	1.93	1.98	2.04	2.37
Pacific	5.05	5.36	5.82	6.34	6.87	10.88
South Atlantic	5.38	5.68	5.95	6.22	6.49	8.09
West North Central	1.96	2.02	2.07	2.11	2.16	2.41
West South Central	3.65	3.86	4.07	4.29	4.50	5.94
Total U.S.	30.63	31.91	33.24	34.65	36.08	45.66

Table A-4
Regional Energy Consumption Projection for Water Supply by Public Water Supply Agencies–Reduced Unit Energy Consumption

Billion kWh per year by Region	2000	2005	2010	2015	2020	2050
East North Central	4.14	4.21	4.27	4.33	4.39	4.74
East South Central	1.72	1.79	1.85	1.89	1.94	2.16
Middle Atlantic	3.77	3.81	3.87	3.94	4.03	4.59
Mountain	1.82	1.97	2.07	2.17	2.26	2.88
New England	1.67	1.70	1.74	1.78	1.83	2.13
Pacific	4.55	4.83	5.24	5.70	6.19	9.79
South Atlantic	4.85	5.11	5.36	5.60	5.84	7.28
West North Central	1.76	1.82	1.86	1.90	1.94	2.17
West South Central	3.29	3.47	3.66	3.86	4.05	5.35
Total U.S.	27.57	28.72	29.92	31.18	32.47	41.09

Table A-5
Regional Energy Consumption Projection for Water Supply by Public Water Supply Agencies–Increased Unit Energy Consumption

Billion kWh per year by Region	2000	2005	2010	2015	2020	2050
East North Central	5.06	5.15	5.22	5.29	5.37	5.80
East South Central	2.11	2.19	2.26	2.32	2.37	2.64
Middle Atlantic	4.61	4.66	4.73	4.82	4.92	5.61
Mountain	2.22	2.41	2.53	2.65	2.76	3.53
New England	2.04	2.08	2.13	2.18	2.24	2.61
Pacific	5.56	5.90	6.40	6.97	7.56	11.97
South Atlantic	5.92	6.25	6.55	6.85	7.14	8.90
West North Central	2.15	2.22	2.27	2.33	2.37	2.65
West South Central	4.02	4.25	4.48	4.72	4.95	6.54
Total U.S.	33.69	35.10	36.56	38.11	39.69	50.23

Table A-6
Regional Energy Consumption Projection for Water Supply by Public Water Supply Agencies–Reduced Per Capita Water Consumption

Billion kWh per year by Region	2000	2005	2010	2015	2020	2050
East North Central	3.68	3.74	3.79	3.85	3.90	4.22
East South Central	1.53	1.60	1.64	1.68	1.72	1.92
Middle Atlantic	3.35	3.39	3.44	3.50	3.58	4.08
Mountain	1.62	1.75	1.84	1.93	2.01	2.56
New England	1.48	1.51	1.55	1.59	1.63	1.90
Pacific	4.04	4.29	4.65	5.07	5.50	8.70
South Atlantic	4.31	4.55	4.76	4.98	5.19	6.47
West North Central	1.57	1.61	1.65	1.69	1.73	1.92
West South Central	2.92	3.09	3.26	3.43	3.60	4.75
Total U.S.	24.51	25.53	26.59	27.72	28.86	36.53

Table A-7
Regional Energy Consumption Projection for Water Supply by Public Water Supply Agencies–Increased Per Capita Water Consumption

Billion kWh per year by Region	2000	2005	2010	2015	2020	2050
East North Central	5.52	5.62	5.69	5.77	5.85	6.33
East South Central	2.30	2.39	2.46	2.53	2.58	2.88
Middle Atlantic	5.03	5.08	5.16	5.26	5.37	6.12
Mountain	2.42	2.63	2.77	2.89	3.02	3.85
New England	2.22	2.26	2.32	2.38	2.44	2.84
Pacific	6.07	6.44	6.98	7.60	8.25	13.05
South Atlantic	6.46	6.82	7.15	7.47	7.78	9.71
West North Central	2.35	2.42	2.48	2.54	2.59	2.89
West South Central	4.39	4.63	4.88	5.14	5.40	7.13
Total U.S.	36.76	38.29	39.89	41.58	43.30	54.79

Electricity Consumption for Wastewater Treatment by POTWs

Table A-8
Baseline Regional Energy Consumption Projection for Wastewater Treatment by POTWs

Billion kWh per year by Region	2000	2005	2010	2015	2020	2050
East North Central	4.66	5.06	5.14	5.22	5.31	5.88
East South Central	1.21	1.41	1.43	1.46	1.50	1.72
Middle Atlantic	3.42	3.76	3.82	3.88	3.96	4.42
Mountain	1.08	1.29	1.31	1.33	1.38	1.60
New England	1.09	1.24	1.26	1.28	1.31	1.45
Pacific	2.62	3.27	3.32	3.37	3.54	4.32
South Atlantic	3.36	4.23	4.30	4.37	4.55	5.38
West North Central	1.51	1.65	1.67	1.70	1.73	1.92
West South Central	2.06	2.60	2.64	2.68	2.75	3.14
Total U.S.	21.01	24.51	24.89	25.28	26.04	29.82

Table A-9
Regional Energy Consumption Projection for Wastewater Treatment by POTWs—2.5 Percent Increase in Unit Electricity Consumption

Billion kWh per year by Region	2000	2005	2010	2015	2020	2050
East North Central	4.77	5.18	5.26	5.35	5.44	6.02
East South Central	1.24	1.45	1.47	1.49	1.54	1.76
Middle Atlantic	3.50	3.86	3.92	3.98	4.06	4.53
Mountain	1.11	1.33	1.35	1.37	1.41	1.64
New England	1.12	1.28	1.30	1.32	1.34	1.49
Pacific	2.68	3.35	3.40	3.45	3.63	4.43
South Atlantic	3.44	4.34	4.41	4.48	4.66	5.52
West North Central	1.55	1.69	1.72	1.74	1.77	1.97
West South Central	2.11	2.66	2.70	2.74	2.82	3.22
Total U.S.	21.53	25.13	25.52	25.91	26.69	30.57

Table A-10
Regional Energy Consumption Projection for Wastewater Treatment by POTWs – 5 Percent Increase in Unit Electricity Consumption

Billion kWh per year by Region	2000	2005	2010	2015	2020	2050
East North Central	4.89	5.31	5.39	5.48	5.58	6.17
East South Central	1.27	1.48	1.51	1.53	1.57	1.80
Middle Atlantic	3.59	3.95	4.01	4.07	4.16	4.64
Mountain	1.14	1.36	1.38	1.40	1.45	1.68
New England	1.15	1.31	1.33	1.35	1.37	1.52
Pacific	2.75	3.43	3.48	3.54	3.72	4.54
South Atlantic	3.52	4.45	4.52	4.58	4.78	5.65
West North Central	1.59	1.73	1.76	1.78	1.82	2.01
West South Central	2.17	2.73	2.77	2.81	2.89	3.30
Total U.S.	22.06	25.74	26.14	26.54	27.34	31.31

Electricity Consumption for Water Supply by End-Users

Domestic Sector

Table A-11
Baseline Regional Energy Consumption Projection for Water Supply by the Domestic Sector

Million kWh per year by Region	2000	2005	2010	2015	2020	2050
East North Central	174	177	180	182	185	200
East South Central	46	48	50	51	52	58
Middle Atlantic	106	107	109	111	113	129
Mountain	59	64	67	70	73	93
New England	47	48	49	50	52	60
Pacific	81	86	93	102	110	174
South Atlantic	242	256	268	280	292	364
West North Central	74	76	78	80	82	91
West South Central	64	68	71	75	79	104
Total U.S.	894	930	965	1,001	1,038	1,274

Commercial Sector

Table A-12
Commercial Sector Growth Projections

Commercial Floor Space (million square feet)	1995	2000	2005	2010	2015	2020	2025	2050
United States	71,101	76,963	81,730	86,410	91,358	96,589	102,120	134,904
Average Annual Growth Rate		**1995 to 2000**	**2000 to 2005**	**2005 to 2010**	**2010 to 2015**	**2015 to 2020**	**2020 to 2025**	**Projected through 2050**
United States		1.60%	1.21%	1.12%	1.12%	1.12%	1.12%	1.12%

Source: EPRI [2]

Table A-13
Baseline Regional Energy Consumption Projection for Water Supply by the Commercial Sector

Million kWh per year by Region	2000	2005	2010	2015	2020	2050
East North Central	54	55	56	57	58	62
East South Central	13	13	13	14	14	16
Middle Atlantic	52	53	54	55	56	64
Mountain	59	64	67	70	73	93
New England	22	23	23	24	25	29
Pacific	164	174	189	206	223	353
South Atlantic	54	57	60	63	65	82
West North Central	29	30	31	32	32	36
West South Central	28	30	32	33	35	46
Total U.S.	476	499	525	553	581	780

Industrial and Mining Sectors

Table A-14
Industrial Sector Growth Projections

Industrial Value Added (billion 1993 dollars)	1995	2000	2005	2010	2015	2020	2025	2050
United States	1,452	1,651	1,874	2,093	2,338	2,611	2,916	5,659
Average Annual Growth Rate		**1995 to 2000**	**2000 to 2005**	**2005 to 2010**	**2010 to 2015**	**2015 to 2020**	**2020 to 2025**	**Projected through 2050**
United States		2.61%	2.57%	2.23%	2.23%	2.23%	2.23%	2.23%

Source: EPRI [3]

Table A-15
Baseline Regional Energy Consumption Projection for Water Supply by the Industrial Sector

Million kWh per year by Region	2000	2005	2010	2015	2020	2050
East North Central	824	935	1,045	1,167	1,303	2,529
East South Central	345	392	438	489	546	1,060
Middle Atlantic	325	369	412	461	514	999
Mountain	88	100	111	124	139	270
New England	30	34	38	43	48	92
Pacific	328	373	416	465	519	1,008
South Atlantic	650	738	824	920	1,028	1,995
West North Central	111	126	141	158	176	341
West South Central	639	725	810	905	1,011	1,961
Total U.S.	3,341	3,793	4,236	4,731	5,284	10,255

Table A-16
Mining Sector Growth Projections

Mining Value Added (billion 1993 dollars)	1995	2000	2005	2010	2015	2020	2025	2050
United States	96	98	102	106	110	114	119	149
Average Annual Growth Rate		**1995 to 2000**	**2000 to 2005**	**2005 to 2010**	**2010 to 2015**	**2015 to 2020**	**2020 to 2025**	**Projected through 2050**
United States		0.58%	0.76%	0.75%	0.75%	0.75%	0.75%	0.75%

Source: EPRI [3]

Table A-17
Baseline Regional Energy Consumption Projection for Water Supply by the Mining Sector

Million kWh per year by Region	2000	2005	2010	2015	2020	2050
East North Central	52	54	57	59	61	76
East South Central	8	9	9	9	10	12
Middle Atlantic	83	86	90	93	97	121
Mountain	131	136	141	146	152	190
New England	3	4	4	4	4	5
Pacific	20	20	21	22	23	29
South Atlantic	73	76	79	82	85	107
West North Central	71	74	77	80	83	104
West South Central	47	49	51	53	55	69
Total U.S.	490	509	528	548	569	713

Irrigation and Livestock

Table A-18
Areas Under Irrigation by Region

Thousand Acres	1997	2000	2005	2010	2015	2020	2025	2050
United States	54,998	57,973	63,403	69,499	76,360	84,105	92,873	158,940
East North Central	1,369	1,500	1,746	2,033	2,367	2,755	3,208	6,862
East South Central	1,257	1,441	1,810	2,273	2,854	3,585	4,502	14,063
Middle Atlantic	198	207	222	238	255	274	294	418
Mountain	14,433	14,785	15,390	16,020	16,676	17,359	18,069	22,084
New England	63	71	87	107	131	160	196	540
Pacific	12,447	12,948	13,827	14,766	15,769	16,840	17,984	24,980
South Atlantic	3,083	3,217	3,453	3,706	3,978	4,270	4,583	6,529
West North Central	11,557	12,197	13,344	14,598	15,971	17,473	19,115	29,957
West South Central	10,591	11,608	13,525	15,757	18,359	21,390	24,922	53,507

Source: U.S. Department of Agriculture [4]

Table A-19
Compound Annual Irrigation Growth Rates by Region

	1997 to 2000	2000 to 2005	2005 to 2010	2010 to 2015	2015 to 2020	2020 to 2025	Projected through 2050
United States	1.72%	1.72%	1.72%	1.72%	1.72%	1.72%	1.72%
East North Central	3.09%	3.09%	3.09%	3.09%	3.09%	3.09%	3.09%
East South Central	4.66%	4.66%	4.66%	4.66%	4.66%	4.66%	4.66%
Middle Atlantic	1.42%	1.42%	1.42%	1.42%	1.42%	1.42%	1.42%
Mountain	0.81%	0.81%	0.81%	0.81%	0.81%	0.81%	0.81%
New England	4.14%	4.14%	4.14%	4.14%	4.14%	4.14%	4.14%
Pacific	1.32%	1.32%	1.32%	1.32%	1.32%	1.32%	1.32%
South Atlantic	1.43%	1.43%	1.43%	1.43%	1.43%	1.43%	1.43%
West North Central	1.81%	1.81%	1.81%	1.81%	1.81%	1.81%	1.81%
West South Central	3.10%	3.10%	3.10%	3.10%	3.10%	3.10%	3.10%

Source: U.S. Department of Agriculture [4]

Table A-20
Baseline Regional Energy Consumption Projection for Water Supply for Irrigation

Million kWh per year by Region	2000	2005	2010	2015	2020	2050
East North Central	180	210	245	285	331	825
East South Central	575	722	907	1,139	1,430	5,611
Middle Atlantic	29	31	33	36	38	58
Mountain	7,641	7,954	8,279	8,618	8,971	11,413
New England	29	35	43	53	64	217
Pacific	6,909	7,378	7,879	8,415	8,986	13,330
South Atlantic	905	972	1,043	1,120	1,202	1,838
West North Central	3,007	3,289	3,598	3,937	4,307	7,384
West South Central	4,332	5,048	5,881	6,852	7,983	19,970
Total U.S.	23,607	25,639	27,909	30,453	33,314	60,646

Table A-21
Baseline Regional Energy Consumption Projection for Water Supply for Livestock

Million kWh per year by Region	2000	2005	2010	2015	2020	2050
East North Central	53	54	55	56	57	61
East South Central	135	140	145	148	152	169
Middle Atlantic	21	21	21	21	22	25
Mountain	241	262	275	287	300	382
New England	4	4	4	4	4	5
Pacific	101	107	116	127	138	218
South Atlantic	92	97	101	106	111	138
West North Central	125	129	132	135	138	153
West South Central	221	233	246	259	272	359
Total U.S.	992	1,047	1,095	1,144	1,192	1,510

Thermal Power Generation

Table A-22
Projected Thermal Electricity Generation

Million kWh per year by DOE Region	2000	2005	2010	2015	2020
Region 1	538,398	586,890	614,832	632,654	648,644
Region 2	245,170	251,010	255,480	265,520	280,917
Region 3	223,129	249,910	265,623	265,209	276,798
Region 4	235,939	265,738	279,698	296,679	312,152
Region 5	155,253	168,863	178,832	184,424	190,974
Region 6	93,733	85,829	84,528	97,124	97,356
Region 7	82,627	91,397	83,911	92,156	92,961
Region 8	149,231	161,209	179,880	200,948	216,173
Region 9	600,590	662,575	707,346	728,856	756,565
Region 10	301,274	310,671	327,082	338,388	345,545
Region 11	101,413	154,119	166,847	174,515	187,461
Region 12	123,758	150,342	153,749	153,951	158,136
Region 13	149,189	131,727	164,367	192,511	213,432
Total U.S.	2,999,703	3,270,279	3,462,176	3,622,935	3,777,115

For generation from biomass, coal, combined cycle, municipal solid waste (MSW), nuclear, and other fossil fuel generation only.

Table A-23
Estimated Cooling Water Use for Thermal Generation

Billion Gallons per Day by DOE Region	2000	2005	2010	2015	2020
Region 1	21	22	22	21	20
Region 2	10	10	9	8	7
Region 3	10	10	9	7	7
Region 4	9	9	9	9	9
Region 5	6	6	6	5	5
Region 6	8	8	7	5	5
Region 7	8	7	6	5	5
Region 8	8	7	7	5	5
Region 9	27	28	27	26	25
Region 10	9	7	6	6	5
Region 11	3	7	8	9	10
Region 12	1	0	0	0	0
Region 13	10	6	6	6	6
Total U.S.	129	129	123	113	106

For generation from biomass, coal, combined cycle, municipal solid waste (MSW), nuclear, and other fossil fuel generation only. Water requirements represent total volume of water throughput for once-through cooling systems or total volume of water for make-up for recirculated cooling systems.

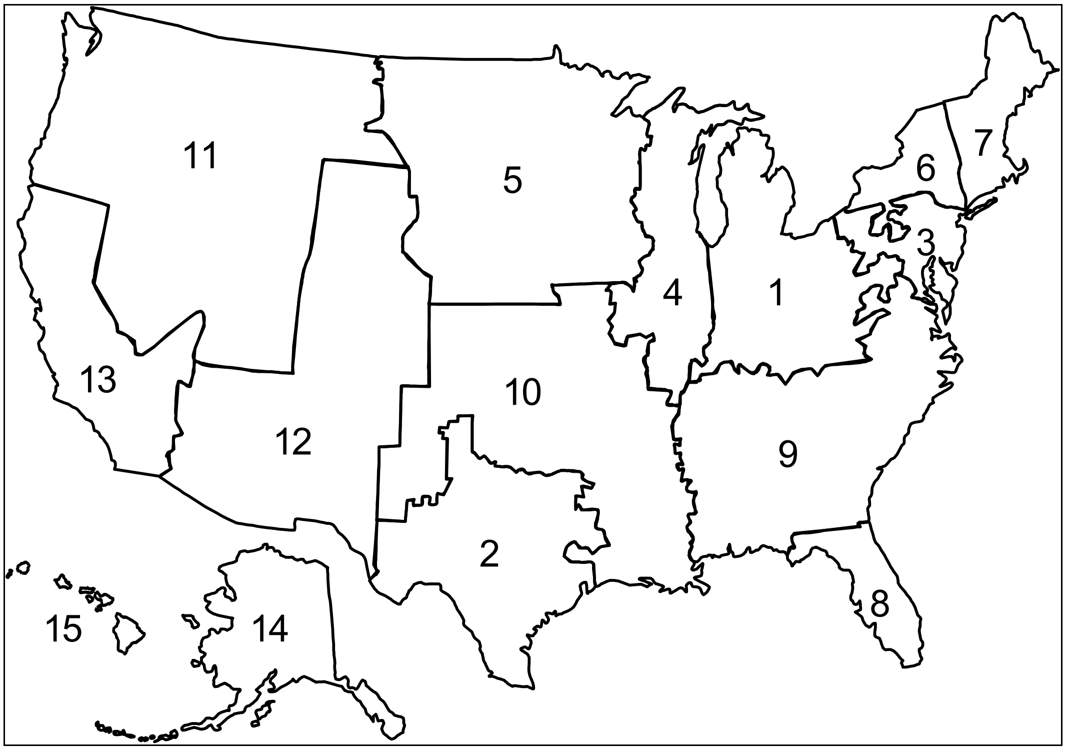

Figure A-1
DOE Generation Regions

Table A-24
Baseline Regional Energy Consumption Projection for Make-up and Once Through Cooling Water Supply for Thermal Power Generation

Million kWh per year by DOE Region	2000	2005	2010	2015	2020
Region 1	2,322	2,437	2,404	2,326	2,138
Region 2	1,133	1,110	1,003	893	742
Region 3	1,095	1,117	1,024	810	763
Region 4	960	1,031	999	976	940
Region 5	686	672	654	566	546
Region 6	926	839	712	601	519
Region 7	823	779	646	526	523
Region 8	854	800	716	591	519
Region 9	3,007	3,098	2,988	2,824	2,696
Region 10	961	729	673	605	514
Region 11	281	774	903	972	1,080
Region 12	63	34	33	31	27
Region 13	1,044	672	664	708	642
Total U.S.	14,155	14,092	13,418	12,426	11,648

For generation from biomass, coal, combined cycle, municipal solid waste (MSW), nuclear, and other fossil fuel generation only.

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