

# ENERGY USE AT WISCONSIN'S DRINKING WATER UTILITIES



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## **EXECUTIVE SUMMARY**

### **BACKGROUND**

For drinking water utilities, energy costs typically range from 20 to 60 percent of a utility's annual operating budget and, in the next five to ten years, new federal and state regulations may require the installation of more energy intensive treatment processes like ozonation, membrane filtration, and ultraviolet irradiation. As a result, utilities are interested in reducing their energy costs through the adoption of energy-efficient designs and technologies. The State of Wisconsin is also interested in reducing energy consumption at drinking water utilities in an effort to meet the objectives of the state's Focus on Energy program.

Nationwide, three percent of the total electricity generated by the electric power industry is consumed by publicly owned water and wastewater industries (Burton 1996). In 1996, an estimated 78 million kWh/day of electricity was used for water supply and treatment in the United States. By 2016, that number is expected to increase to 100 million kWh/day. According to Burton's 1996 report, the total energy used by a typical surface water treatment plant was approximately 1.4 kWh per 1000 gallons of water produced. The same report indicated that a typical groundwater utility used 1.8 kWh per 1000 gallons of water produced.

Most of the energy consumed in a drinking water supply system is associated with pumping water. For a typical surface water system, 85% of energy costs are from pumping raw or treated water and 9% are from pumping concentrated waste streams. For groundwater systems, almost all energy costs are for pumping except where ion exchange and physical/chemical treatment is required.

### **OBJECTIVE**

Wisconsin Focus on Energy began to include drinking water utilities in its energy reduction program in the Year 2002. In order to quantify the statewide energy savings obtained from this program, there was a need to quantify the status quo of energy consumption at Wisconsin's drinking water utilities. This report was written to meet this need and to provide a literature review of energy saving measures that water utilities can use.

## RESULTS

Wisconsin's drinking water utilities consumed over 300 million kWh/year of energy for water production. The state's largest utilities, those in Class AB, consumed about 75% of this total. The median values for normalized energy use, normalized energy expenditures, electric rate, and percent water loss for each of the classes are listed in Table ES.1. Class AB had the lowest resulting median values for each of these categories.

Although some differences in median values are evident in Table ES.1, the key difference was in the variability of the reported values. The range of values reported by Class AB utilities was much smaller than the range of values reported by Class C utilities. Class D utilities exhibited the widest variability. This may be a result of poorer data quality with the smaller utilities and the Wisconsin Public Service Commission is encouraged to determine if this is the case.

In Class AB, seven of the ten utilities at or below the 10<sup>th</sup> percentile of kWh/1000 gallons of water pumped from 1997-2000 were utilities that purchased water. Six of the 21 utilities achieving the lowest energy use in Class C were also water purchasers. Similar trends were seen for energy expenditures per gallon of water produced. Therefore, to continue developing future lists of model utilities having the lowest energy use, those utilities that purchase water need to be removed from the database. Class AB utilities that consistently used the least amount of energy per gallon of water produced were Eau Claire, Racine, Sheboygan, Two Rivers, Waterloo, and Watertown. An in depth analysis of these utilities is encouraged to determine the reasons for

Table ES.1.

Comparison of median values between classes.

Class	kWh/1000 gal	\$/1000 gal	\$/kWh	% Water Loss
AB	1.51	0.053	0.084	9.6
C	1.85	0.065	0.113	11.7
D	1.89	0.075	0.151	12.6

their low energy use. Such an analysis can help other utilities develop alternative strategies for reducing energy use.

Geographic location appeared to be a significant factor for those Class AB and Class C utilities that used the most energy. All of the utilities that reported high energy use were groundwater utilities, with the exception of two utilities (Glendale and Fox Point) that purchase water from the North Shore Water Commission. Most of the high energy users were in Brown, Waukesha, and Walworth Counties. These counties are all in areas of significant water table drawdown in the deep sandstone aquifer. A significant number of high energy users also appear in the southwestern part of Wisconsin, from Trempealeau County to Grant County. There may be little that these utilities can do to significantly reduce energy consumption unless alternative water supplies are used, more stringent water conservation measures are employed, or regional policies are implemented to reverse the drawdown trend. Such measures may not be economically justifiable and need to be reviewed on a case-by-case basis.

Energy use and energy expenditures were not related to water loss in any of the three classes. However, on a statewide basis, about 38 million kWh/year of energy was used to produce lost water at an annual energy cost of approximately \$2 million. Class AB utilities accounted for about 70% of the energy used to produce lost water. Although the state may economically benefit from a reduction in water loss, it is not clear whether each utility can justify a reduction in water loss because it may cost more money to reduce water loss than would be saved. The state may need to consider an incentive program of some type to get individual utilities to reduce water loss.

Differences in groundwater and surface water utilities were observed both in energy use and expenditures. Groundwater utilities used approximately 1.3% more energy per gallon of water produced than surface water utilities. However, approximately 4.3% of Wisconsin's utilities are producing 41% of the state's drinking water from a surface water source. Therefore, changes in energy use at this small number of utilities affects a large number of consumers.

New technologies were seen to have effects on energy use and expenditures for surface water utilities. Ozone disinfection and membrane filtration increased both energy use and energy expenditures at those utilities that implemented these technologies between 1997 and 2001. The estimated annual increases in energy use and expenditures for ozone implementation were 0.12 to 0.55 kWh/1000 gallons pumped and \$0.007 to \$0.025/1000 gallons pumped, respectively.

The estimated annual increases in energy use and expenditures for implementation of microfiltration were 0.0 to 0.7 kWh/1000 gallons pumped and \$0.005 to \$0.040/1000 gallons pumped, respectively. No estimates could be made regarding ultrafiltration since not enough data was available. The surface water utilities implementing these new processes should continue to be monitored to see if energy use and expenditures continue to increase relative to groundwater utilities in the near future.

Overall, the most energy and money can be saved by reducing energy use in Class AB because Class AB utilities used the most energy, treated the most water, and served the largest number of consumers. Even though Class AB utilities are using the least amount of energy per 1000 gallons of water pumped, this class has the most potential for energy savings. Utilities at or below the 10<sup>th</sup> percentile and at or above the 90<sup>th</sup> percentile for energy use, energy expenditure, and water loss should be evaluated further to determine what in these specific utilities is placing them in the aforementioned percentiles. This analysis should help utilities in the high percentiles lower their energy use and costs while still providing a quality product to the residents of Wisconsin.

# CHAPTER 1

## INTRODUCTION

### BACKGROUND

For drinking water utilities, energy costs typically range from 20 to 60 percent of a utility's annual operating budget and, in the next five to ten years, new federal and state regulations may require the installation of more energy intensive treatment processes like ozonation, membrane filtration, and ultraviolet irradiation. As a result, utilities are interested in reducing their energy costs through the adoption of energy-efficient designs and technologies. The State of Wisconsin is also interested in reducing energy consumption at drinking water utilities in an effort to meet the objectives of the state's Focus on Energy program.

Nationwide, three percent of the total electricity generated by the electric power industry is consumed by publicly owned water and wastewater industries (Burton 1996). Pumps, fans, blowers, mixers, centrifuges, ozone generators, and UV disinfection equipment use most of the power. In 1996, publicly owned treatment works served 71% of the United States population.

For small utilities, it may not be economical to spend a few thousand dollars to study energy conservation when the facility's total energy costs are only a few thousand dollars per year. Large utilities, on the other hand, may be willing to spend a considerable amount to reduce their electric bill by 1 or 2 percent. Despite the economic advantages of lowering the electric bill, other utility objectives must take precedence over energy savings. They include:

- Meeting daily consumer demands.
- Providing emergency demands for items like fire protection and water delivery during power outages.
- Maintaining water quality.
- Minimizing capital costs.

In many cases, the cost savings achieved by reducing energy use are not justified (Walski 1993). A detailed engineering economic analysis of each energy saving option is required to identify which options are the most cost effective to implement. Present worth and payback period

analysis are two economic analysis methods that may be used in the savings determination (Walski 1993, Arora and LeChevallier 1998).

In 1996, an estimated 78 million kWh/day of electricity was used for water supply and treatment in the United States. By 2016, that number is expected to increase to 100 million kWh/day due to increases in water demand and the use of new energy-intensive technologies such as ozone, membranes, and ultraviolet irradiation. Table 1.1 provides a summary of energy consuming processes that may be used in a drinking water treatment facility (Burton 1996).

Most of the energy consumed in a drinking water supply system is associated with pumping water. Pumping is used to deliver raw water to the treatment plant, to deliver treated water to customers, and to backwash filters.

Table 1.1.

Summary of energy consuming processes used in drinking water treatment (Burton 1996).

Electrotechnologies	Process or Operation												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Well pumps	X									X			
Water pumps	X									X			
Traveling screens		X											
Blowers/fans					X		X						
Agitators/mixers			X	X	X		X	X	X			X	
Clarifier drives					X	X					X		
Sludge pumps					X	X	X				X	X	X
Process water pumps					X	X	X	X					X
Compressors							X						
Chemical pumps			X		X	X		X				X	
Chemical mixers			X		X	X						X	
Conveyors		X					X						
Centrifuges											X		X
Belt filter press													X
Vacuum pumps						X							X
Hydraulic drives													X
Evaporators									X				X
Drainage Pumps	X			X	X				X	X			
Cranes/hoists	X	X							X	X			
Ozone generators							X						

Process #	Process Name
1	Raw Water Pumping
2	Screens
3	Rapid Mixers
4	Flocculation
5	Sedimentation
6	Filtration & Backwash
7	Chemical Treatment
8	Ozonation
9	Disinfection
10	Distribution Pumping
11	Sludge Thickening
12	Sludge Conditioning
13	Sludge Dewatering

*Note: Publication of this table in the final report is contingent upon receipt of copyright approval.*

For a typical surface water system, 85% of energy costs are from pumping raw or treated water and 9% are from pumping concentrated waste streams. Table 1.2 shows the approximate energy requirements (kWh/day) for various treatment processes within surface water treatment plants ranging from 1 mgd to 100 mgd in size. For all size categories in this table, the total energy requirement is approximately 1.4 to 1.5 kWh per 1000 gallons of water produced.

For groundwater systems, almost all energy costs are for pumping except where ion exchange and physical/chemical treatment is required. Table 1.3 shows the approximate energy requirements for various treatment processes within groundwater treatment facilities ranging from 1 mgd to 20 mgd in size. For all size categories in this table, the total energy requirement is approximately 1.8 kWh per 1000 gallons of water produced.

Energy costs associated with ozone disinfection, UV radiation, and membrane treatment are not included in Tables 1.2 and 1.3, but certainly could consume relatively large amounts of energy.

Opportunities for energy savings are possible from demand side management . This includes reducing energy costs by shifting power consumption from on-peak to off-peak hours. Adding storage for off peak/emergency pumping and/or pumping capacity may reduce peak pumping. Efficient pumping programs can save energy by reducing both peak demand and total energy use.

Other energy savings opportunities within the water treatment plant include (Burton 1996):

- Using premium efficiency motors with adjustable speed drives.
- Using effective instrumentation and control.
- Managing operations by the efficient use of available storage and high-efficiency pumping units.
- Operating emergency generators for peak-clipping when no or little storage is available.
- Optimizing ozone generation.

Various utilities have used manual, automatic, and operator knowledge based economic dispatch systems to control energy use. Supervisory control and data acquisition (SCADA) systems have been used by water utilities to monitor and automatically control water distribution

Table 1.2.

Electricity requirements for surface water treatment plants (Burton 1996).

Item/Plant Production	1 MGD	5 MGD	10 MGD	20 MGD	50 MGD	100 MGD
Raw Water Pumping	121	602	1205	2410	6027	12055
Rapid Mixing	41	176	308	616	1540	3080
Flocculation	10	51	90	181	452	904
Sedimentation	14	44	88	175	438	876
Alum Feed System	9	10	10	20	40	80
Polymer Feed System	47	47	47	47	47	47
Lime Feed System	9	11	12	13	15	16
Filter Surface Wash Pumps	8	40	77	153	383	767
Backwash Water Pumps	13	62	123	246	657	1288
Treated Water Pumping	1205	6027	12055	24110	60273	120548
Chlorination	2	2	2	2	4	8
Residuals Pumping	4	20	40	80	200	400
Thickened Solids Pumping	N/A	N/A	N/A	123	308	616
<b>Total (kWh/day)</b>	<b>1483</b>	<b>7092</b>	<b>14057</b>	<b>28176</b>	<b>70384</b>	<b>140685</b>

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Table 1.3.

Electricity requirements for groundwater treatment plants (Burton 1996).

Item/Plant Production	1 MGD	5 MGD	10 MGD	20 MGD
Well Pumping	605	3025	6050	12100
Chlorination	9	45	93	186
Booster Pumping	1210	6050	12100	24200
<b>Total (kWh/day)</b>	<b>1824</b>	<b>9120</b>	<b>18243</b>	<b>36486</b>

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systems for over 25 years. Most utilities with design flows greater than 20 mgd have SCADA systems. There are two levels of economic control: manual economic remote control and automatic economic set point remote control. The use of manual and automatic levels of control may reduce electricity costs by 5 to 25%. Through the use of storage and scheduled pumping, 70% reductions in peak energy costs and 83% reductions in peak demand costs have been reported. Many utilities use manual controls, but several use SCADA for automatic set point control. Both methods rely on human experience and are not resilient to changes in operating conditions because they are reactive rather than predictive (EMA Services and T/Systems 1996).

## **OBJECTIVE**

Wisconsin Focus on Energy began to include drinking water utilities in its energy reduction program in the Year 2002. In order to quantify the statewide energy savings obtained from this program, there was a need to quantify the status quo of energy consumption at Wisconsin's drinking water utilities. This report was written to meet this need and to provide a review of energy saving measures that water utilities can use.

## **ORGANIZATION OF REPORT**

Chapters 2 and 3 of this report focus on the methods and results, respectively, of research designed to evaluate energy consumption at Wisconsin's drinking water utilities. Chapter 4 summarizes information obtained from the open literature, focusing on steps that drinking water utilities can take to reduce energy consumption and to reduce energy costs.



## CHAPTER 2

### STUDY METHODS

Data related to energy use by drinking water utilities was provided by the Wisconsin Public Service Commission for the years 1997 to 2000 and for all utilities in Classes AB, C, and D. For each utility, the data included gallons pumped, kWh used, cost of energy, and gallons lost. From this data, normalized energy consumption (in kWh/1000 gallons pumped), normalized energy expenditures (in \$/1000 gallons pumped), energy rates (in \$/kWh), and normalized water loss (in gallons lost/gallons pumped) were estimated for each utility and each year.

Within each class, the results were examined to determine their dependence on system size, whether or not the system purchased water, and whether the system used surface water or groundwater. To evaluate system size, all years were combined for each utility and the data were ranked on gallons pumped for the entire four-year period. Class AB utilities were divided into three size categories:

1. those that pumped more than 5 billion gallons of water from 1997 through 2000,
2. those that pumped between 1 and 5 billion gallons of water from 1997 through 2000, and
3. those that pumped less than 1 billion gallons of water from 1997 through 2000.

Class C utilities were divided into four size ranges:

1. those that pumped more than 0.6 billion gallons of water from 1997 through 2000,
2. those that pumped between 0.4 and 0.6 billion gallons of water from 1997 through 2000,
3. those that pumped between 0.2 and 0.4 billion gallons of water from 1997 through 2000,  
and
4. those that pumped less than 0.2 billion gallons of water from 1997 through 2000.

Finally, Class D utilities were divided into five size ranges:

1. those that pumped more than 0.20 billion gallons of water from 1997 through 2000,

2. those that pumped between 0.15 and 0.20 billion gallons of water from 1997 through 2000,
3. those that pumped between 0.10 and 0.15 billion gallons of water from 1997 through 2000,
4. those that pumped between 0.05 and 0.10 billion gallons of water from 1997 through 2000, and
5. those that pumped less than 0.05 billion gallons of water from 1997 through 2000.

For each category, probability tables were created using Microsoft Excel 2000. The probability tables were constructed by ranking the data from small to large, assigning each value a rank ( $i$ ) and calculating the plotting position of the probability scale as  $p = i/(n+1)$  where  $n$  = the total number of observations. The plotting position multiplied by 100 shows the percentile. For example, if a point is in the 99<sup>th</sup> percentile it means that only 1% of the total data points are higher than this specific point. The probability tables were used to read any percentile of specific interest. In this research, the higher and lower percentiles were of the most interest because they identify the utilities that consumed the higher and lower energy compared to others.

Box plots were created for each category using Statistica software. These plots show the median (50<sup>th</sup> percentile), the 25<sup>th</sup> and 75<sup>th</sup> percentiles (lower and upper values in the box), and the minimum and maximum value. The difference between the 75<sup>th</sup> percentile and the 25<sup>th</sup> percentile is also known as the interquartile range and represents the middle 50% of utilities in the category. Circles in the box plots represent data that were deemed to be “outliers.” Outliers were data points that were outside a range of  $\pm 1.5$  times the box height. Stars in the box plots represent data that were named as “extremes”. Extremes were data points that were outside a range of  $\pm 3.0$  times the box height. The concept of outliers and extremes is also explained by the following:

Outlier data points:

Data points  $> 75^{\text{th}}$  percentile +  $1.5(75^{\text{th}}$  percentile –  $25^{\text{th}}$  percentile)

Data points  $< 25^{\text{th}}$  percentile –  $1.5(75^{\text{th}}$  percentile –  $25^{\text{th}}$  percentile)

Extreme data points:

Data points  $> 75^{\text{th}}$  percentile +  $3.0(75^{\text{th}}$  percentile –  $25^{\text{th}}$  percentile)

Data points  $< 25^{\text{th}}$  percentile –  $3.0(75^{\text{th}}$  percentile –  $25^{\text{th}}$  percentile)

The outlier and extreme data points are statistical terms and do not imply that the use of energy was “extreme”.



## CHAPTER 3 RESULTS

### BACKGROUND

There were 581 drinking water utilities that submitted an annual report to the Wisconsin Public Service Commission (PSC) each year from 1997 to 2001. As noted earlier, the PSC divides these utilities into three classes based on the number of customers served. Class AB utilities serve more than 4,000 customers, Class C utilities serve between 1,000 and 4,000 customers, and Class D utilities serve less than 4,000 customers.

Figure 3.1a shows the distribution of utilities by class in the Year 2000. This figure shows that the majority of the utilities in the database were Class D utilities. There were 2.5 and 4.8 times as many utilities in this class as there were in Class C and Class AB, respectively. Figure 3.1b shows the average fraction of total energy consumed by each class for all years from 1997 through 2000. Class AB utilities consumed the largest portion of energy used by the Wisconsin drinking water industry, nearly 75% of the total. This means that 13.1% of the utilities in the state were using 74.1% of the total energy consumed in Wisconsin's drinking water industry. Based on the percentage of energy used, cutting energy use in Class AB utilities would have more of a statewide effect than cutting energy use in Class C and Class D utilities.

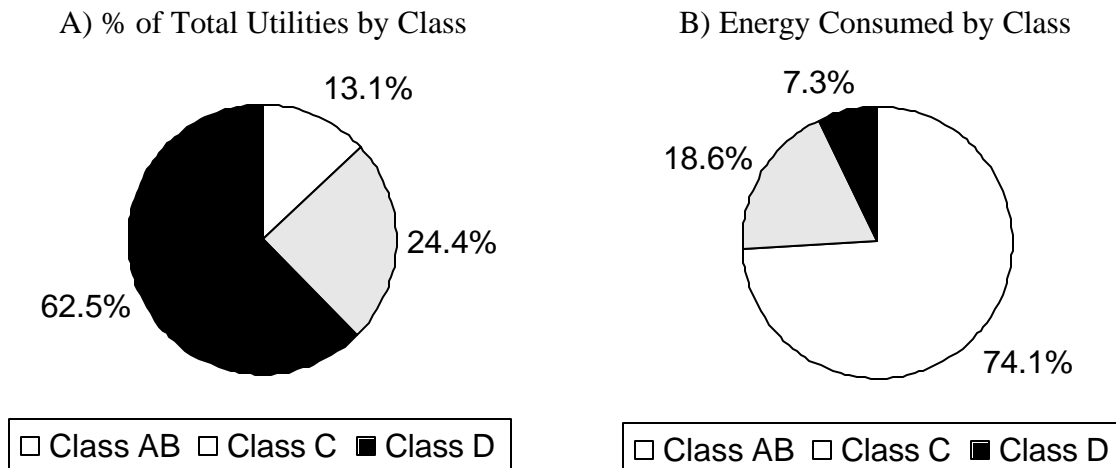


Figure 3.1. Number of utilities and energy consumption among water utility classifications.

Figure 3.2 shows the yearly energy use (in millions of kWh/yr) by class from 1997 through 2000. Class AB utilities had an average annual increase of 0.43% in energy consumption while Class C and Class D had average annual decreases of 0.33% and 0.09%, respectively, in energy consumption. Figure 3.3 shows the water production (in billions of gallons/yr) and Figure 3.4 shows the normalized energy use (in kWh per 1000 gallons of water produced). From 1997 through 2000, Class AB had an average annual increase in water production of 0.62%. Class C and Class D had average annual decreases in water production of 0.47% and 0.14%, respectively. The normalized energy use decreased by 0.25% per year for Class AB and increased by 0.16% and 0.09% per year for Classes C and D, respectively. Class AB had an overall decrease in normalized energy use with both an increase in energy use and an increase in water production, whereas Classes C and D showed opposite trends. From 1997 through 2000, Class C utilities consistently used the most energy on a normalized basis while Class D utilities consistently consumed the least.

If these trends continue until the year 2020, energy consumption will increase to about 290 million kWh for Class AB and will decrease to approximately 60 and 26 million kWh, respectively, for Classes C and D. Annual water production will increase to approximately 190 billion gallons for Class AB and decrease to approximately 31 and 14 billion gallons,

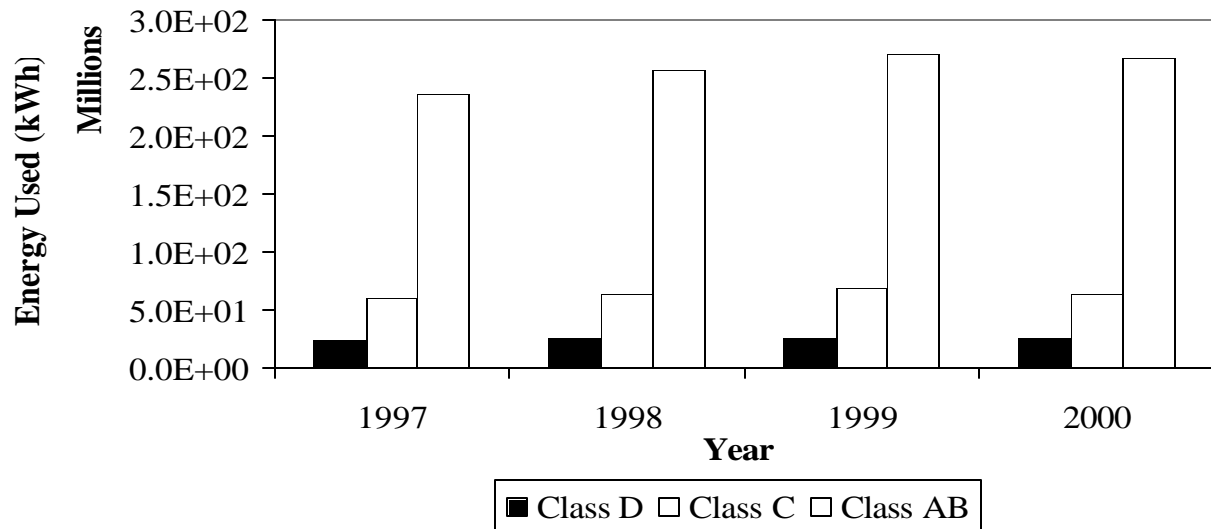


Figure 3.2. Yearly consumption of energy by class from 1997 through 2000.

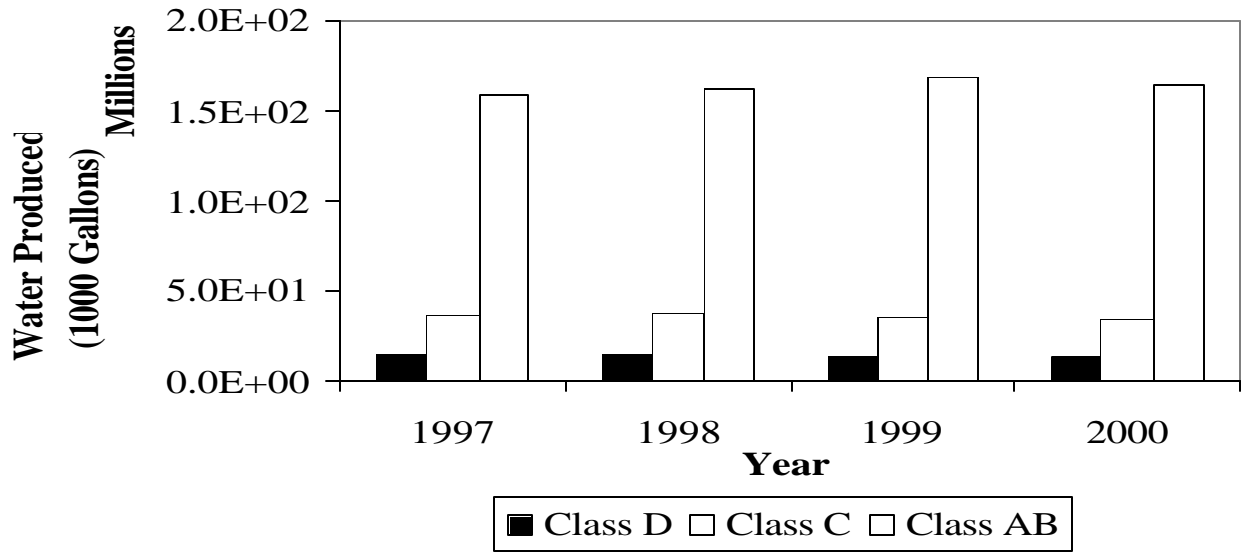


Figure 3.3. Yearly production of water by class from 1997 through 2000.

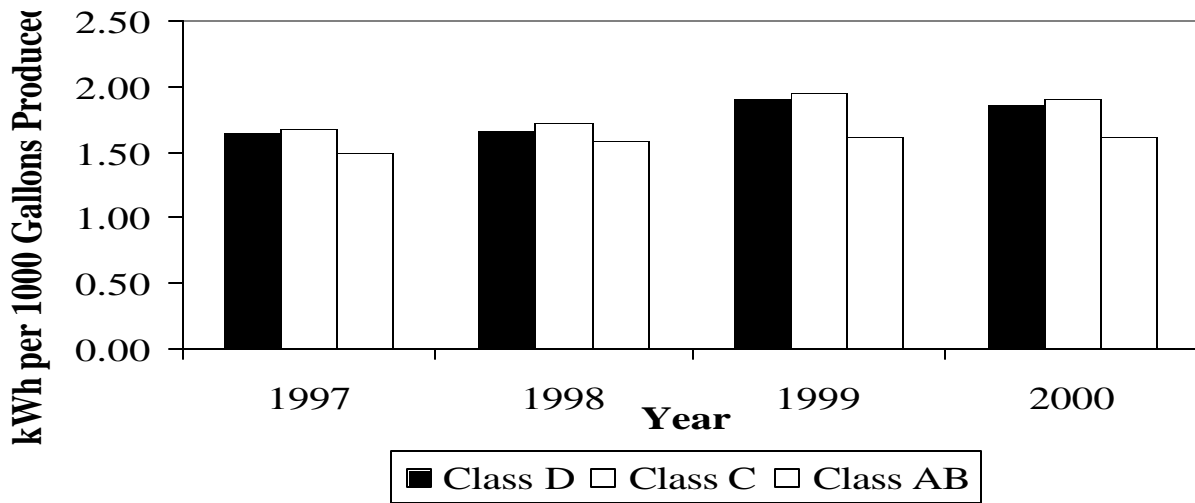


Figure 3.4. Normalized energy use by class from 1997 through 2000.

respectively, for Classes C and D. Normalized energy use will decrease to 1.5 kWh per 1000 gallons of water produced for Class AB and increase to approximately 2.0 and 1.9, respectively, for Classes C and D.

Further classifications can be made based on the source of water, either groundwater or surface water. The source of water can have an effect on energy consumption by a utility. For example, groundwater is generally of higher quality than surface water and usually requires less treatment and may have lower energy requirements for treatment. On the other hand, a groundwater system that pumps from a deep aquifer may have increased energy requirements due to the need for large pumps. Therefore, energy consumption is highly site specific, but some general observations may be made regarding the influence of source water on energy consumption.

Figure 3.5 shows the percentage of utilities in each class using surface water. For Class AB, 25% use surface water as their water source while the remaining 75% use groundwater. For Classes C and D, nearly 100% of the utilities use groundwater as their water source. Figures 3.6, 3.7, and 3.8 show comparisons between groundwater and surface water utilities in regards to energy use (millions of kWh/yr), water production (billions of gallons/yr), and normalized energy use (kWh per 1000 gallons of water pumped) from 1997 through 2000. On average,

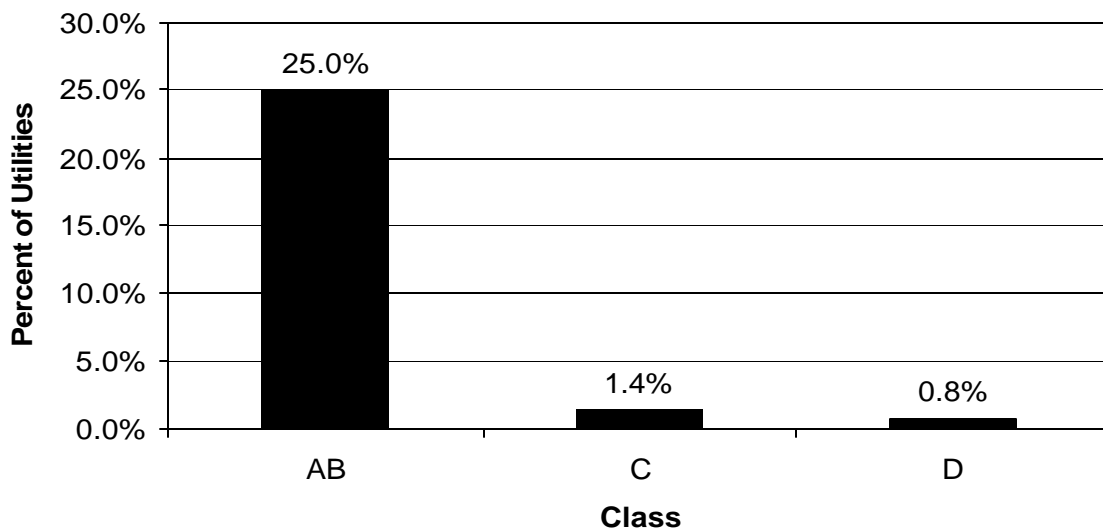


Figure 3.5. Percent of utilities by class using surface water.

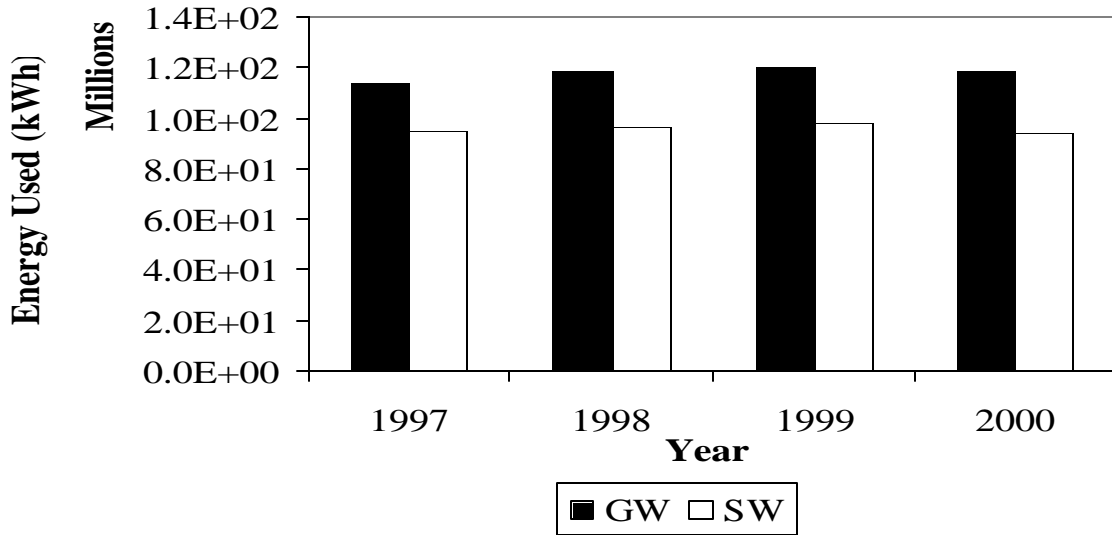


Figure 3.6. Energy use comparison between groundwater and surface water utilities.

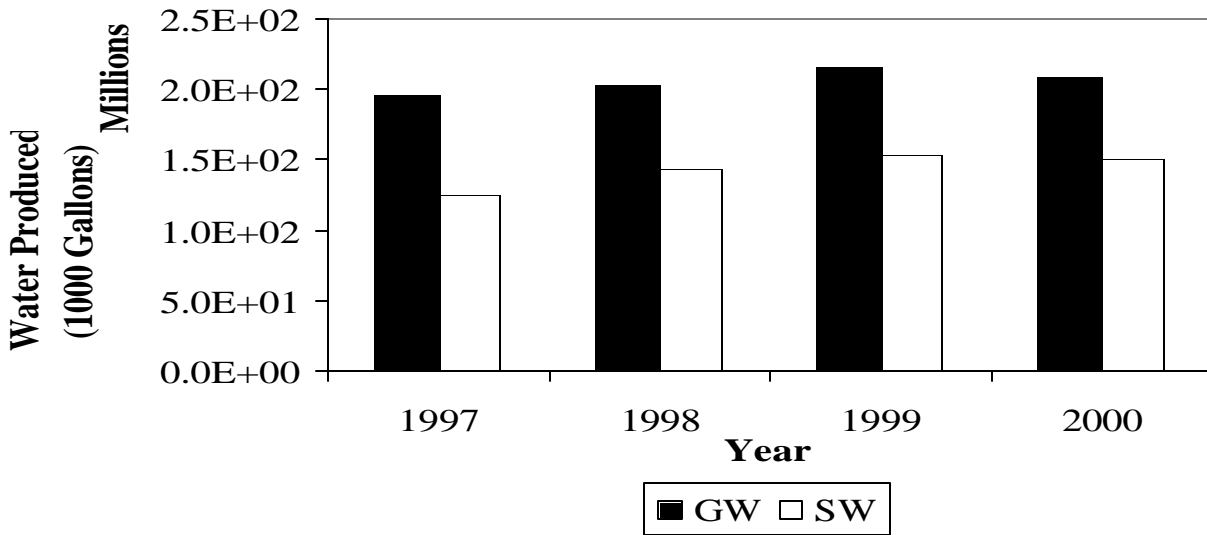


Figure 3.7. Water production comparison between groundwater and surface water utilities.

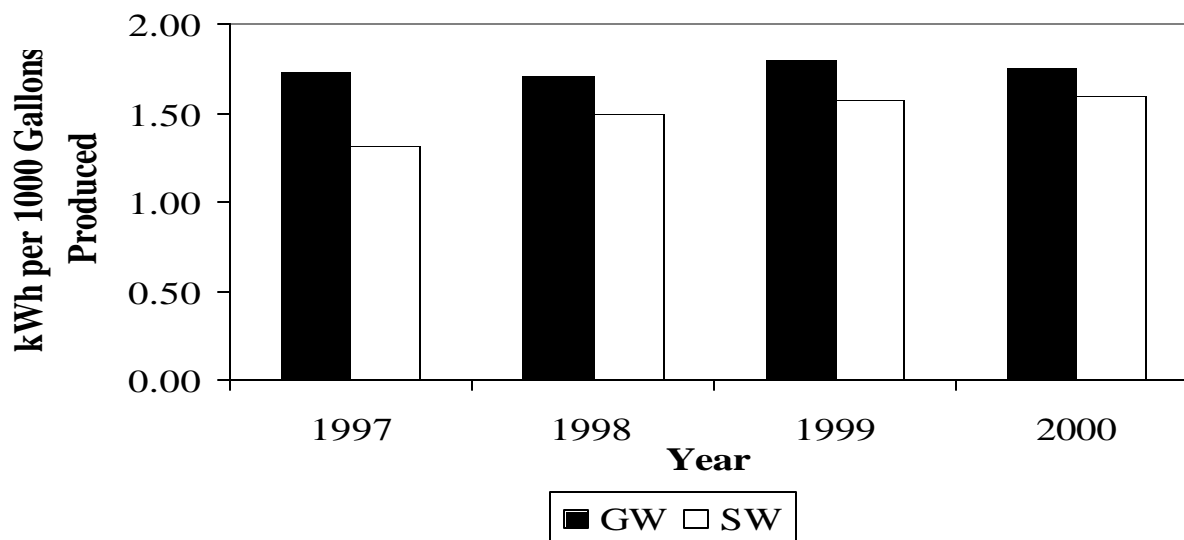


Figure 3.8. Comparison of groundwater and surface water utilities for normalized energy use.

groundwater utilities produced 59% of the water in the state, whereas surface water utilities produced 41% of the drinking water in the state. This means that 4.3% of the state’s utilities produced 41% of Wisconsin’s drinking water from a surface water source. Groundwater utilities had an average increase in energy use of 1.6% per year and surface water utilities had an average decrease in energy use by 0.32% per year (see Figure 3.6). Water production in both groundwater and surface water utilities increased by 2.1% and 6.5%, respectively, per year. Normalized energy use also increased in both groundwater and surface water utilities by 0.50% and 6.8%, respectively.

The drinking water utilities comprising Class AB consume more energy than Classes C and D combined. Class AB also contains most of the surface water utilities in the state. These surface water utilities either have already implemented or will be implementing energy intensive processes like ozone disinfection and membrane filtration into their treatment schemes. Therefore, the focus should begin on Class AB utilities since the greatest opportunities for energy savings exists here.

## CLASS AB UTILITIES

### *Energy Use*

As noted in Chapter 2, energy use was normalized as the total kWh of energy consumed per 1000 gallons of water pumped over a one-year period. A high value of normalized energy consumption at a utility may indicate the use of inefficient pumping or treatment systems, the use of an energy intensive treatment process such as ozonation or membrane filtration, or the need for relatively large pumping requirements due to the presence of extensive pipelines or deep groundwater wells.

Figure 3.9 shows the energy used by Class AB utilities from 1997 through 2000. The left column of the chart shows the results for all utilities in Class AB while the other columns show results for three different utility size categories within Class AB. For example, the right column shows results for those Class AB utilities that pumped more than 5 billion gallons from 1997

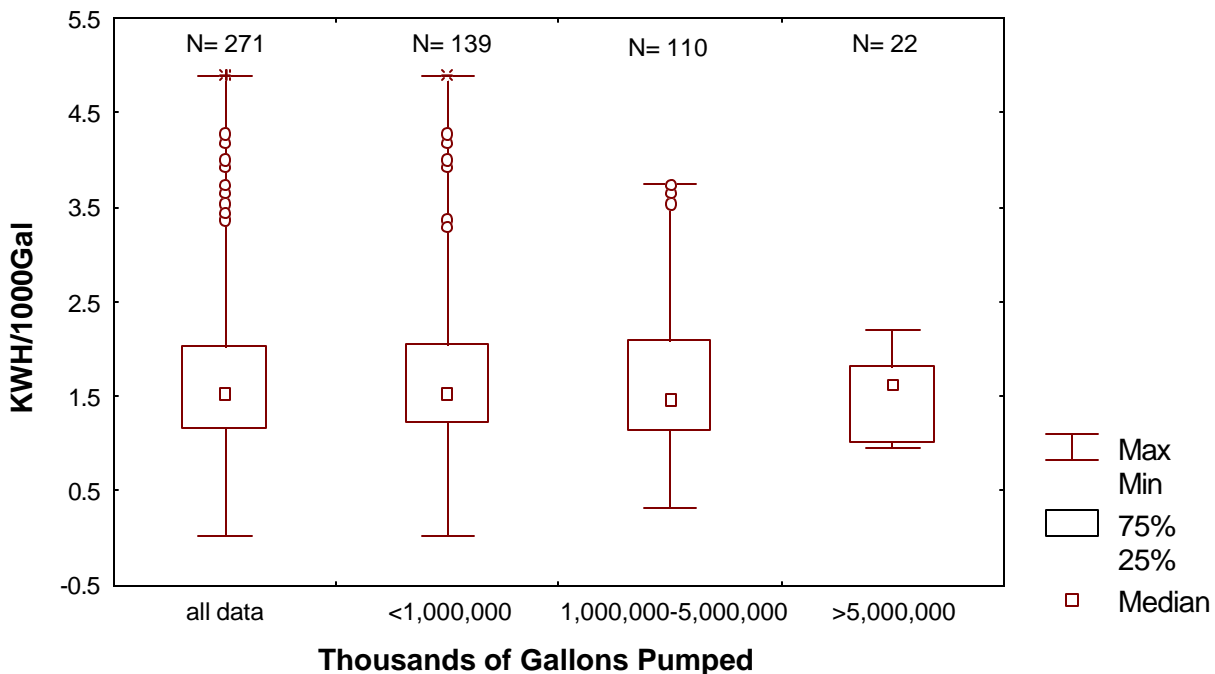


Figure 3.9. Effect of water production rate on energy used per 1000 gallons pumped for Class AB utilities.

through 2000. The number at the top of each column shows the number of utilities represented by the column.

As shown by the left column of Figure 3.9, the median value for energy use by all 271 Class AB utilities was around 1.5 kWh/1000 gallons pumped. The range from the 25<sup>th</sup> percentile to the 75<sup>th</sup> percentile is called the interquartile range and represents the middle 50% of the utilities in Class AB. Therefore, for the left column of Figure 3.9, the interquartile range of 1.2 to 2.0 kWh/1000 gallons pumped represents the energy used by the “typical” utility in Class AB. Although the typical Class AB utility was within this range, values for all Class AB utilities ranged from 0.0 to 4.9 kWh/1000 gallons pumped.

To determine if the observed results were a function of system size, the Class AB utilities were split into three groups based on total water production from 1997 through 2000. The second through fourth columns of Figure 3.9 show box plots for these three groups. As shown in Figure 3.9, the median and interquartile range for energy use were relatively independent of water production in Class AB. However, the overall range of energy use was significantly influenced by utility size, with the smaller Class AB utilities exhibiting the widest range of energy consumption and the largest Class AB utilities exhibiting the smallest range of energy consumption. It is possible that data quality improves with increasing utility size and the PSC is encouraged to contact those utilities that report energy use outside of the typical range to determine if data quality is an issue for the smaller utilities.

As noted earlier, the amount of energy consumption may be influenced by the source of water used by the utility. For example, utilities using groundwater versus surface water may consume less energy due to reduced treatment demand but may need more energy due to greater source water pumping requirements. Also, utilities purchasing water from another utility may have significantly lower energy consumption since the water has already been treated and pumped prior to the point of purchase.

An analysis of the Class AB data reveals that the 10<sup>th</sup> percentile energy use was 0.83 kWh/1000 gallons pumped. An examination of those utilities that used less energy than 0.83 kWh/1000 gallons pumped is worthwhile because it may reveal those utilities that can be used as models by other utilities that are interested in reducing energy consumption. Those utilities that used less than 0.83 kWh/1000 gallons pumped are shown in Table 3.1. Nearly all of the utilities ranked in the lowest 10% of utilities for energy use are those that purchased water from another

Table 3.1.

Alphabetical list of Class AB utilities that used less than 0.83 kWh/1000 gallons.

Utility	Years Achieved
Brown Deer	1997 through 2000
Glendale	1997 and 1998
Grand Chute	1997 through 2000
Greendale	1997, 1998, and 2000
Sheboygan Falls	1997
South Milwaukee	1999
Stoughton	1998
Two Rivers	1997 through 2000
Wauwatosa	1997 through 2000
West Allis	1997 through 2000

utility (see Table 3.2). The only exceptions to this were South Milwaukee, Stoughton, and Two Rivers. South Milwaukee and Stoughton used less than 0.83 kWh/1000 gallons pumped in only one year out of the four years surveyed. Therefore, these utilities did not achieve this low level of energy use on a routine basis. With the exception of Two Rivers, every utility that used less than 0.83 kWh/1000 gallons pumped in three or more years was a utility that purchased their water from another utility.

Utilities that purchased water consumed less energy than those who treated their own water (see Figure 3.10). The median energy consumption for utilities purchasing water was about 0.5 kWh/1000 gallons pumped compared to about 1.5 kWh/1000 gallons pumped for utilities treating water. The interquartile range for utilities that purchased water was 0.4 to 1.6 kWh/1000 gallons. For the utilities that did not purchase water, the interquartile range was 1.3 to 2.0 kWh/1000 gallons. This latter range can be considered typical for those utilities that pump, treat, and distribute their own water.

There were a few utilities that purchased water but consumed relatively large amounts of energy. They include the Glendale Water Utility in 1999 and 2000 and the Menomonee Falls Water Utility in 1997 and 1998. These utilities consumed greater than 3 kWh/1000 gallons in

Table 3.2.

List of Class AB utilities that purchase water.

Utility	Supplier
Brown Deer	Milwaukee Water Works
Glendale	North Shore Water Commission
Grand Chute	Appleton Water Utility
Greendale	Milwaukee Water Works
Menomonee Falls (since 1999)	Milwaukee Water Works
Sheboygan Falls	Sheboygan Water Utility
Wauwatosa	Milwaukee Water Works
West Allis	Milwaukee Water Works
Whitefish Bay	North Shore Water Commission
Wisconsin Gas Water Services - Mequon Utility	Milwaukee Water Works

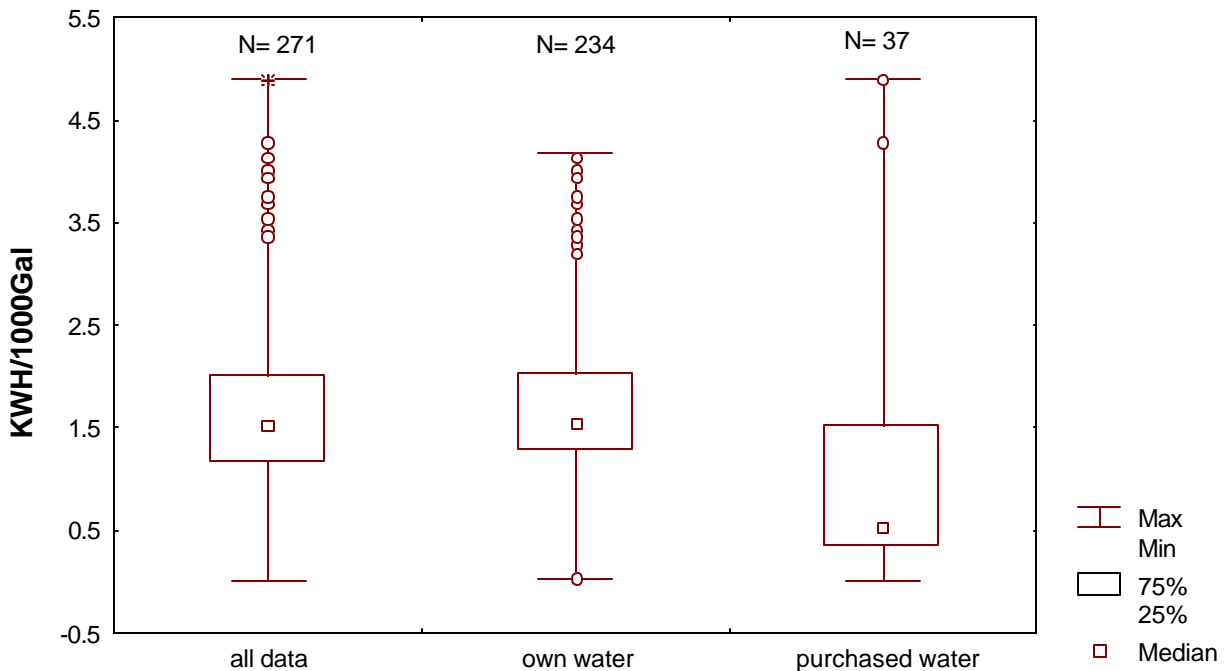


Figure 3.10. Effect of purchasing water on energy used per 1000 gallons pumped for Class AB utilities.

those years. Menomonee Falls used its own source of groundwater back in 1997 and 1998 before purchasing its water from Milwaukee Water Works in 1999 and 2000. It is not clear why Glendale would have consumed such a large amount of energy in recent years.

When the purchasing water utilities were removed from the Class AB database, then the 10<sup>th</sup> percentile energy use was 1.03 kWh/1000 gallons pumped. Those non-purchasing utilities that used less than 1.03 kWh/1000 gallons pumped are shown in Table 3.3. Of the nine utilities listed in Table 3.3, five are surface water utilities (Oshkosh, Racine, Sheboygan, South Milwaukee, and Two Rivers), which indicates that just over half of the Class AB utilities using less than 1.03 kWh/1000 gallons of water pumped were surface water utilities. Oshkosh appeared on the list in 1997 and 1998 but moved off the list after the implementation of ozonation. Racine, Two Rivers, and Waterloo were the only three utilities that achieved this low level of energy use for all four years of this study.

For all Class AB utilities (including those that purchased water from another supplier), the 90<sup>th</sup> percentile energy use was 3.09 kWh/1000 gallons of water pumped. Table 3.4 shows a list of those utilities that used more than 3.09 kWh/1000 gallons pumped at some time during the 1997 through 2000 period studied. All of the utilities in Table 3.4 are groundwater utilities, with

Table 3.3.

Alphabetical list of Class AB utilities that did not purchase water from another utility and used less than 1.03 kWh/1000 gallons.

Utility	Years Achieved
Eau Claire	1997 through 1999
Oshkosh	1997 and 1998
Racine	1997 through 2000
Sheboygan	1999
South Milwaukee	1999 and 2000
Stoughton	1998
Two Rivers	1997 through 2000
Waterloo	1997 through 2000
Watertown	1998 through 2000

Table 3.4.

Alphabetical list of Class AB utilities that used more than 3.09 kWh/1000 gallons.

Utility	Years Achieved
Allouez	1997 through 2000
Ashwaubenon	1997
Brookfield	1997 through 2000
De Pere	1998 through 2000
Glendale	1999 and 2000
Menomonee Falls	1997 and 1998
New Berlin	1997 through 1999
Platteville	1997 through 2000
Waukesha	1997 through 2000
Waupun	1998

the exception of Glendale, which purchases treated surface water from the North Shore Water Commission. It is recommended that the Glendale utility and the Public Service Commission determine whether energy use is being properly reported.

Platteville used more than 3.09 kWh/1000 gallons of water pumped in all four years of the study. This utility has three wells at approximately 1000 feet deep, which is unusually deep when compared with most utilities in Wisconsin (although this is not unusually deep for utilities in southwestern Wisconsin). Brookfield, Menomonee Falls, New Berlin, and Waukesha are all located in Waukesha County, where significant regional-scale drawdown of the groundwater table has occurred. Similar problems have occurred in Brown County, the home of Allouez, Ashwaubenon, and De Pere. There may be little that these utilities can do to significantly reduce energy consumption unless alternative water supplies are used, more stringent water conservation measures are employed, or regional policies are implemented to reverse the drawdown trend. In 1999, Menomonee Falls began using an alternative water supply by purchasing water from the Milwaukee Water Works and energy use at Menomonee Falls dropped below 3.09 kWh/1000 gallons of water pumped after this change. Allouez,

Ashwaubenon, and De Pere are members of the recently formed Central Brown County Water Authority, which is examining alternatives to the current groundwater supply.

Figure 3.11 shows the effect of source water on normalized energy use for those 30 Class AB utilities that did not purchase water. The median values for energy use by groundwater utilities and surface water utilities were 1.7 and 1.4 kWh/1000 gallons pumped, respectively. The difference between these median values was not significant. However, the variability of energy use among groundwater utilities was much larger than observed for surface water utilities. The wider variability for groundwater utilities is consistent with results shown in Figure 3.9 because nearly all of the smaller utilities in Class AB use groundwater.

### *Energy Expenditures*

Energy expenditures were defined as the total amount of money spent on energy per 1000 gallons of water pumped over the period of an entire year. High energy expenditures could be

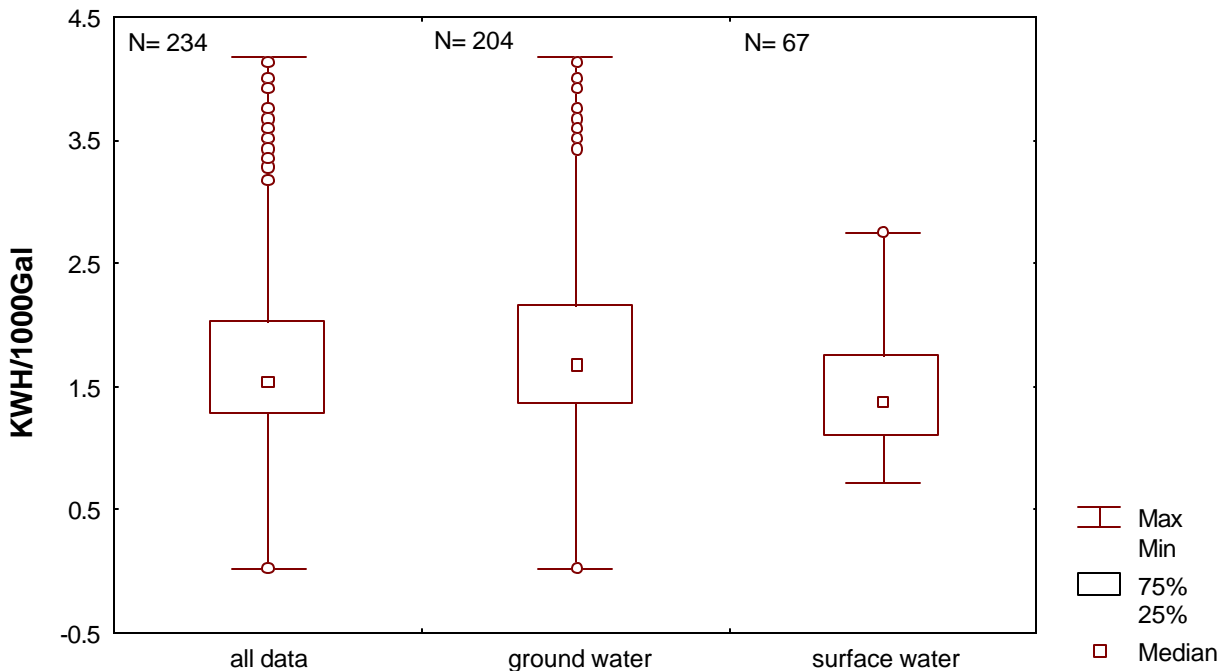


Figure 3.11. Effect of water source on energy used per 1000 gallons pumped for Class AB utilities.

due to high energy consumption, the use of energy during periods of peak energy usage when energy rates are high, or high electric rates negotiated between the water utility and the energy provider.

Figure 3.12 shows the energy expenditures by Class AB utilities from 1997 through 2000. The median value for energy use by Class AB utilities was around \$0.08/1000 gallons, but values ranged from just above \$0.00 to \$0.26/1000 gallons pumped. Expenditures on energy decreased from about \$0.09/1000 gallons to about \$0.05/1000 gallons as the utility size increased from less than 1 billion gallons pumped over the four-year period to greater than 5 billion gallons pumped over the four-year period. As with energy use, the range of energy expenditures was greater for the smaller utilities.

An analysis of the Class AB data reveals that the 10<sup>th</sup> percentile energy expenditure was \$0.045/1000 gallons pumped. An examination of those utilities that used less energy than \$0.045/1000 gallons pumped may reveal those utilities that can be used as models by other utilities that are interested in reducing energy expenditures. Those utilities that used less than

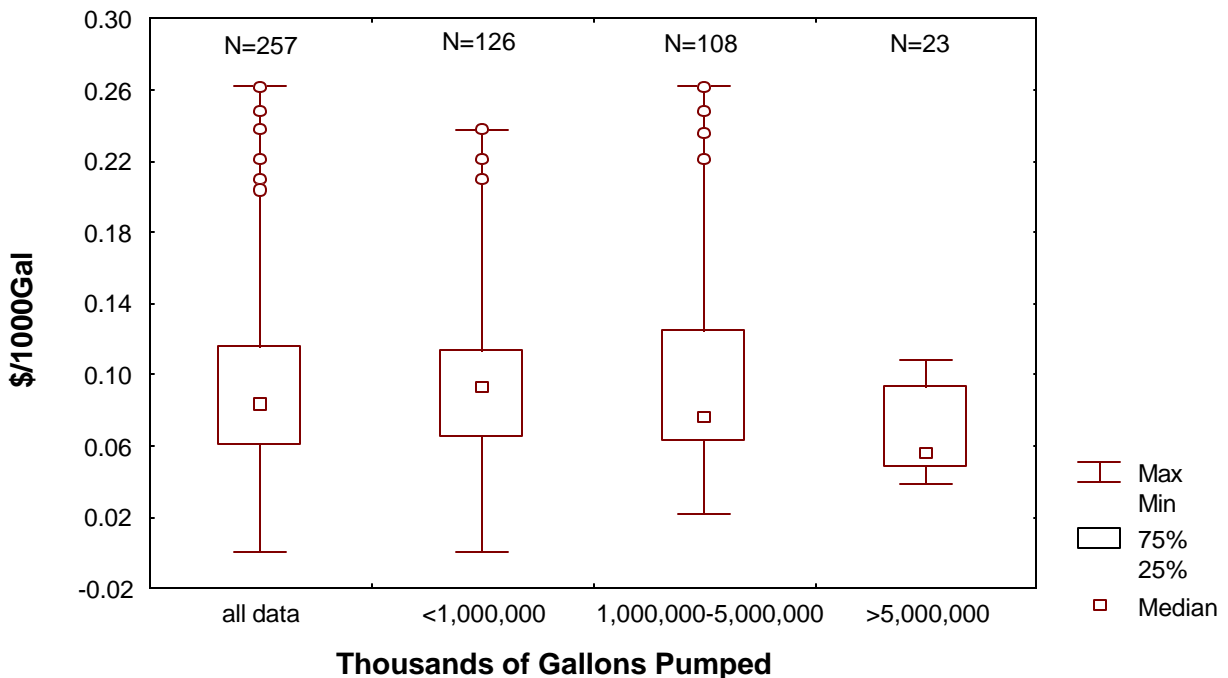


Figure 3.12. Effect of water production rate on cost of energy per 1000 gallons pumped for Class AB utilities.

\$0.045/1000 gallons pumped are shown in Table 3.5. A number of the utilities ranked in the lowest 10% of utilities for energy expenditures are those that purchase water from another utility (see Table 3.2). The exceptions to this are Marinette, Oshkosh, Sheboygan, and South Milwaukee. Four of the eight utilities purchasing water spent less than \$0.045/1000 gallons pumped every year out of the four years surveyed. Of the four utilities that did not purchase water, only Sheboygan appeared on this list for three or more years.

Figure 3.13 indicates that utilities that purchased water spent less on energy than utilities that treated their own water. The median value for energy expenditures was \$0.03/1000 gallons for utilities that purchased water and \$0.08/1000 gallons for utilities that treated their own water.

When the purchasing water utilities are removed from the Class AB database, then the 10<sup>th</sup> percentile energy expenditure was \$0.049/1000 gallons pumped. Those non-purchasing utilities that used less than \$0.049/1000 gallons pumped are shown in Table 3.6. Most of utilities spending less than \$0.049/1000 gallons pumped were surface water utilities with the exceptions of Alliant Energy in Beloit, Stevens Point, and Waterloo.

Table 3.5.

Alphabetical list of Class AB utilities that spent less than \$0.045/1000 gallons on energy.

Utility	Years Achieved
Brown Deer	1997 through 2000
Grand Chute	1997 through 1999
Greendale	1997, 1998, and 2000
Marinette	2000
Oshkosh	1997 and 1998
Sheboygan	1997 through 1999
Sheboygan Falls	1998
South Milwaukee	1999
Wauwatosa	1997 through 2000
West Allis	1997 through 2000
Whitefish Bay	2000
Wisconsin Gas Water Services - Mequon Utility	2000

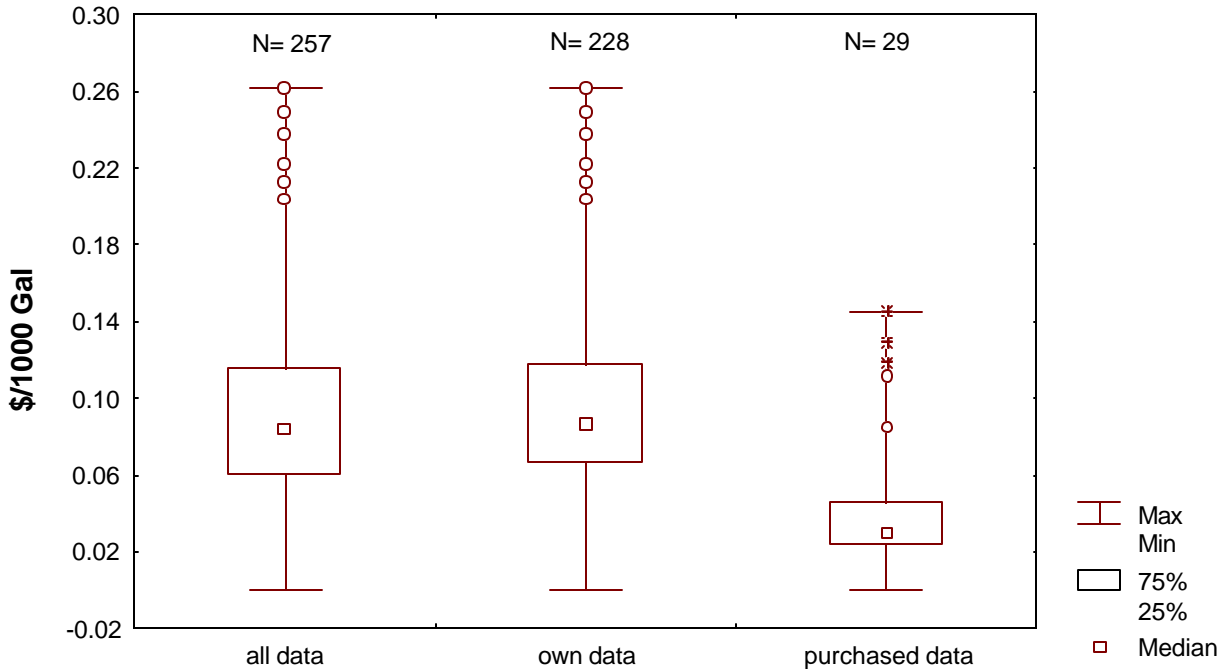


Figure 3.13. Effect of purchasing water on cost of energy used per 1000 gallons pumped for Class AB utilities.

Table 3.6.

Alphabetical list of Class AB utilities that do not purchase water from another utility and spent less than \$0.045/1000 gallons on energy.

Utility	Years Achieved
Alliant Energy in Beloit	2000
Appleton	1997
Green Bay	1998 through 2000
Marinette	2000
Neenah	1997
Oshkosh	1997 through 1999
Racine	1997 through 2000
Sheboygan	1997 through 2000
South Milwaukee	1999
Stevens Point	1997 through 1999
Waterloo	1997 through 1998

For all Class AB utilities (including those that purchase water from another supplier), the 90<sup>th</sup> percentile energy expenditure was \$0.154/1000 gallons of water pumped. Table 3.7 shows a list of those utilities that spent more than \$0.154/1000 gallons pumped at some time during the 1997 through 2000 period studied. All of the utilities in Table 3.7 are groundwater utilities, with the exceptions of Menomonee Falls, which has purchased water from Milwaukee Water Works since 1998, and Port Washington. Seven of the nine utilities listed in Table 3.7 were also listed in the top 10% of energy users. These seven include Allouez, Brookfield, Menomonee Falls, New Berlin, Platteville, Waukesha, and Waupun. A discussion of these utilities and possible reasons for their high energy use was provided in the previous section.

Figure 3.14 indicates the energy expenditures for Class AB utilities based on the water source. Based on median values, utilities using a surface water supply spent about \$0.04/1000 gallons less on energy than utilities using a groundwater supply. The one exception was Port Washington, which spent between \$0.07 and \$0.11/1000 gallons more on energy than other Class AB utilities using surface water as their water source.

Table 3.7.

Alphabetical list of Class AB utilities that spent more than \$0.154/1000 gallons on energy.

Utility	Years Achieved
Allouez	1997 through 2000
Brookfield	1997 through 2000
Fond du Lac	2000
Menomonee Falls	1997 and 1998
New Berlin	1997 through 2000
Platteville	1997 through 2000
Port Washington	1999 and 2000
Waukesha	1997 through 2000
Waupun	2000

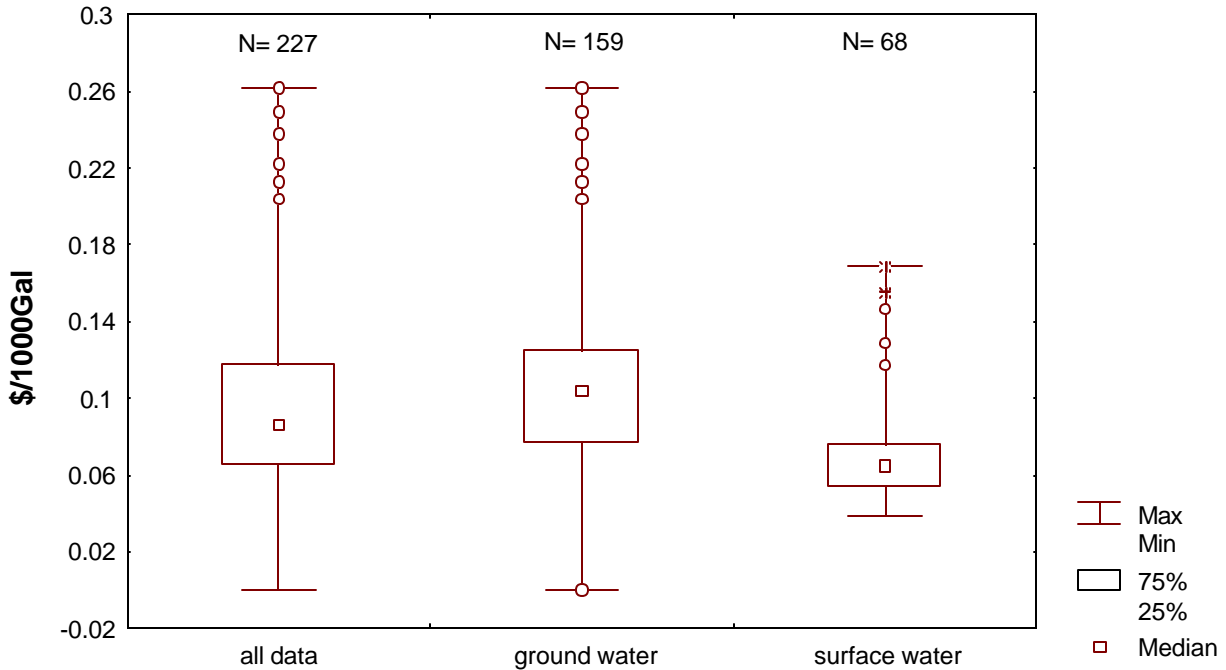


Figure 3.14. Effect of water source on cost of energy used per 1000 gallons pumped for Class AB utilities.

### ***Electric Rates***

The average electric rate charged to each utility was approximated by dividing the total energy expenditures by the total energy consumed over a period of one year. High electric rates could be an indication of pumping during peak electric rates or high electric rates negotiated between the water utility and the energy provider. The median electric rate for all Class AB utilities was around \$0.05/kWh, with values ranging from \$0.01/kWh to \$0.26/kWh. The median value for electric rate was independent of utility size and water source. There were several utilities that had unusually large average electric rates and these utilities are shown in Table 3.8. Greendale, Brown Deer, and Menomonee Falls purchased their water during the years they appeared in this table.

Table 3.8.

Alphabetical list of Class AB utilities that spent more than \$0.081/kWh.

Utility	Years Achieved
Brown Deer	1998 through 2000
Greendale	1998
Menomonee Falls	2000
Stoughton	1998
Two Rivers	1997 through 1999
Watertown	1998 through 2000
Waupun	2000
West Bend	1998 through 2000

### ***Water Loss***

The amount of water unaccounted for was estimated by dividing the volume of water lost by the volume of water pumped as reported in the Public Service Commission annual reports. Water may be lost through leaky pipes, main breaks, fire flows, or meter inaccuracies. Large losses of water through the system may result in higher energy use and expenditures from the pumping of water that is not used for consumptive purposes.

Figure 3.15 shows the ratio of water lost to water pumped for Class AB utilities categorized by the annual volume of water pumped. The median ratio of water lost was independent of utility size in Class AB and was around 0.10 (10%). The range of values was much greater for utilities pumping less than 1 billion gallons over the four-year period (0.00 to 0.43) compared to utilities pumping greater than 5 billion gallons over the four-year period (0.06 to 0.15).

The 10<sup>th</sup> percentile water loss for all Class AB utilities was 4.1% of water pumped. Table 3.9 lists the Class AB utilities that lost less than 4.1% of water pumped during one of the years analyzed. Most of the utilities listed in Table 3.9 were not in the lower or upper 10% of utilities based on energy use or energy expenditures. Those utilities in Table 3.9 that fell within the lowest 10% of energy users are Sheboygan, Stoughton, and Two Rivers. Those utilities that fell

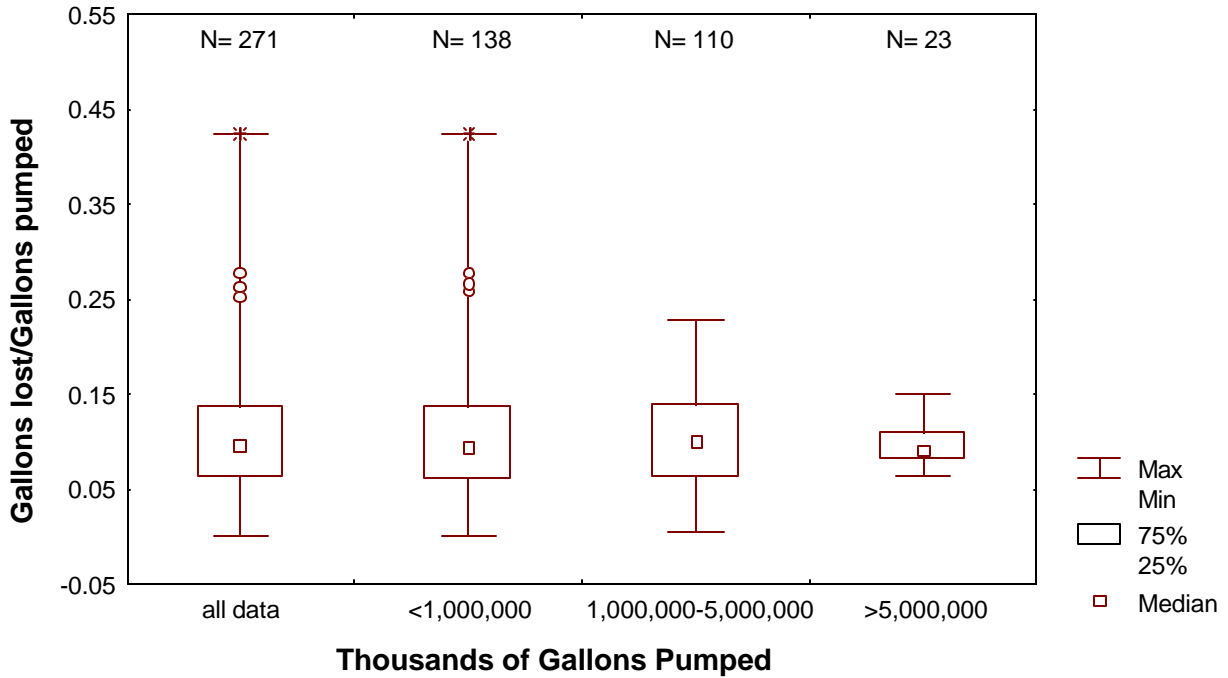


Figure 3.15. Effect of water production rate on water loss for Class AB utilities.

Table 3.9.

Alphabetical list of Class AB utilities that lost less than 4.1% of gallons pumped.

Utility	Years Achieved	Utility	Years Achieved
Alliant Energy in Ripon	2000	Marinette	1997 through 1999
Ashwaubenon	2000	Sheboygan	1998
Brookfield	1997 through 1999	Stoughton	1998 through 2000
Fond du Lac	1999	Two Rivers	1998 through 2000
Glendale	1998	Waterloo	1998 and 2000
Greendale	1997, 1998, and 2000	Waukesha	1998
Kenosha	1998	Waupaca	1998
Manitowoc	1997, 1999, and 2000	Whitefish Bay	1997 and 1999

within the top 10% of utilities for energy use as well as the lowest 10% of utilities for water loss are Ashwaubenon, Brookfield, and Waukesha. Those utilities that fell within the lowest 10% for energy expenditures were Greendale, Marinette, Sheboygan, and Whitefish Bay. Those utilities that fell within the top 10% of utilities for energy expenditures and the lowest 10% for water loss were Brookfield, Fond du Lac, and Waukesha.

The 90<sup>th</sup> percentile water loss for utilities in Class AB was 22.7% of water pumped. Those utilities losing more than 22.7% of water pumped are listed in Table 3.10. None of the utilities listed in Table 3.10 fell below the 10<sup>th</sup> percentile or above the 90<sup>th</sup> percentile for energy use or expenditures.

Based on the analysis of utilities in listed in Tables 3.9 and 3.10, there does not appear to be a relationship between water loss and energy use. Similarly, there appears to be no relationship between water loss and energy expenditures.

Figure 3.16 compares the water loss from utilities purchasing water versus utilities with their own water supply. Based on median values, utilities that purchased water lost about 5% less water than utilities that treated their own water. The range of losses was also lower, from 0% to 16% for those that purchased water and from 0% to 28% for those that did not.

Figure 3.17 shows there was no effect of water source on water loss by those Class AB utilities that did not purchase water.

The amount of money spent on pumping water that was not sold to customers was estimated by multiplying the fraction of water loss by the total energy usage by each utility and

Table 3.10.

Alphabetical list of Class AB utilities that lost more than 22.7% of gallons pumped.

Utility	Years Achieved
Ashland	1999 and 2000
Black River Falls	1999 and 2000
Plymouth	1997
Sturgeon Bay	1997, 1998, and 2000
WI Gas Water Services – Mequon Utility	2000
Wisconsin Rapids	1999

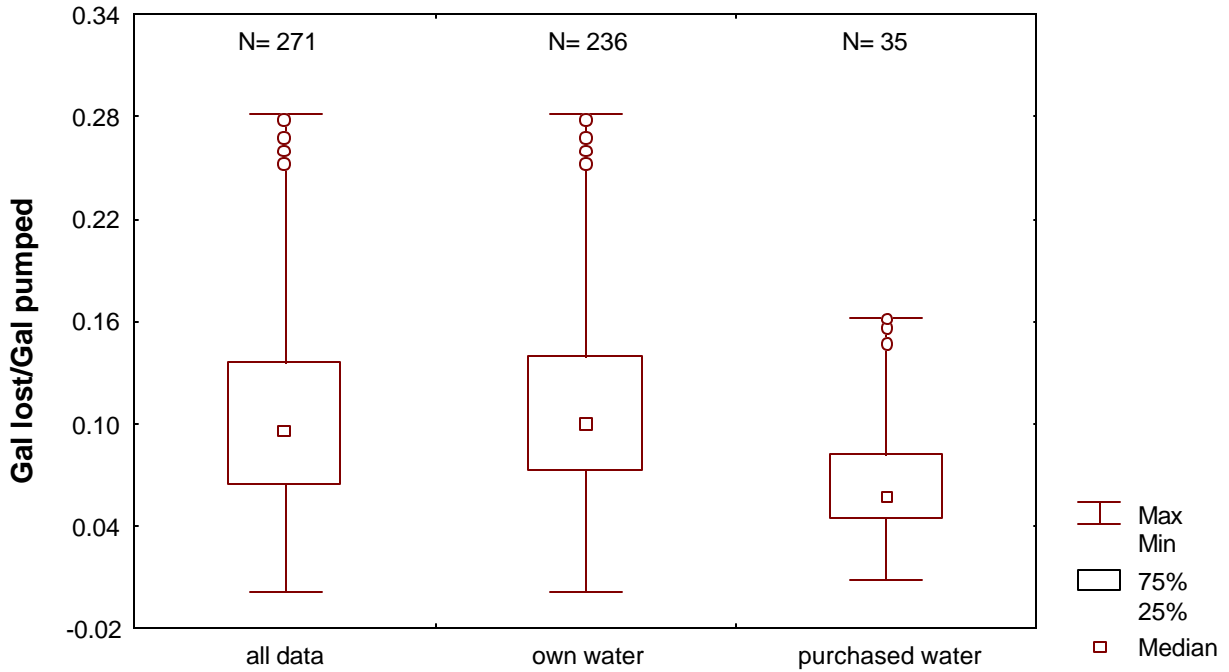


Figure 3.16. Effect of purchasing water on water loss for Class AB utilities.

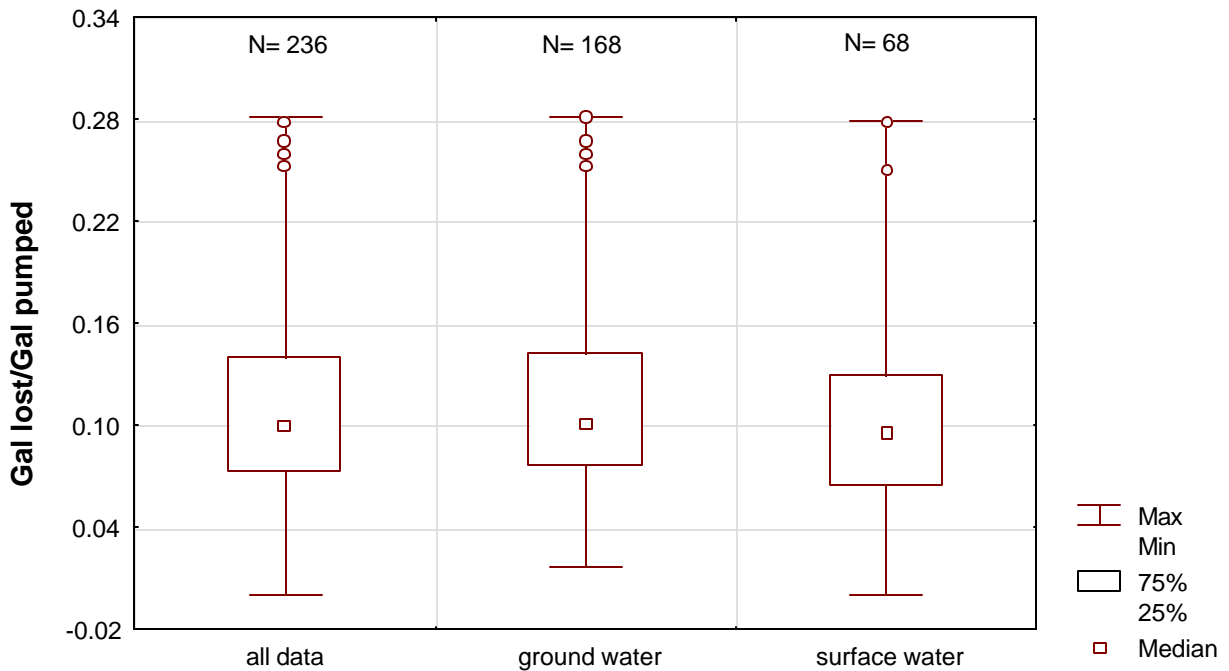


Figure 3.17. Effect of water source on water loss for Class AB utilities.

then multiplying by the average electric rate for that utility. The total energy expenditures on lost water for each class were estimated by summing all the values for each class. Utilities not reporting energy use or energy expenditures were not included in the analysis.

Figures 3.18a and 3.18b show the fraction of total annual energy expenditures on lost water and total annual energy consumption on lost water for the entire Wisconsin water industry. Not surprisingly, Class AB utilities spent the most money and consumed the most energy on water that was lost or not used by consumers. Class AB spent about \$1,300,000 on energy for lost water, about 64% of the total expenditures for the industry. Class AB consumed about 26,000,000 kWh of electricity on lost water, about 69% of the total energy loss for the industry.

***Trends at Utilities Installing Ozone or Membranes***

In order to assess the effect that energy intensive treatment processes have on energy use and energy expenditures, several utilities which have recently installed ozone disinfection or membrane filtration were analyzed. Table 3.11 lists the utilities that were investigated along with the treatment process and year of implementation. The first full year of treatment would occur in the year following the year listed in the table.

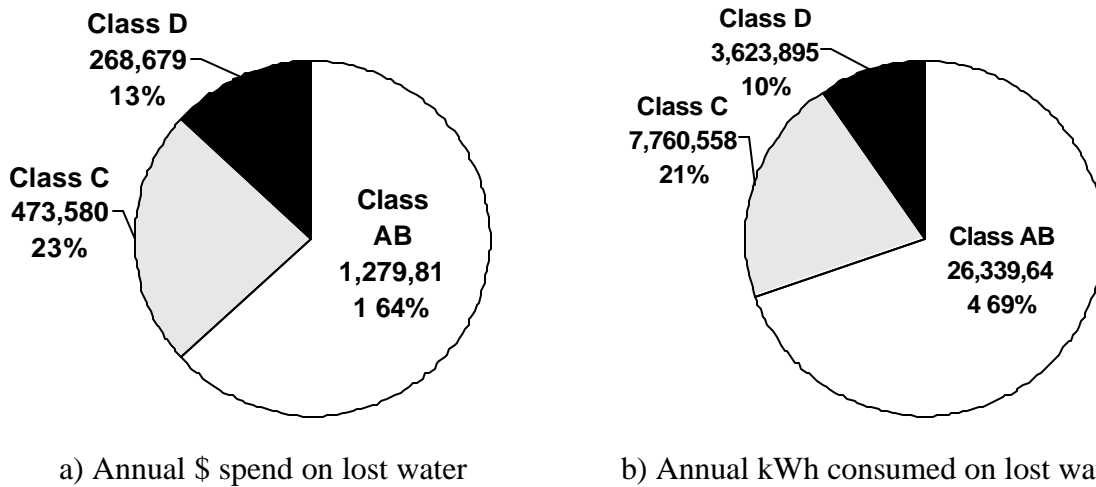


Figure 3.18. Energy consumed to produce lost water and the cost of that energy consumption.

Table 3.11.

List of utilities that have implemented ozone disinfection or membrane filtration since 1997.

Utility	Treatment Process	Year of Implementation
Milwaukee Water Works	Pre-Ozonation	1998
Kenosha Water Utility	Microfiltration	1999
Oshkosh Water Utility	Post-Ozonation	1999
Manitowoc Public Utilities	Microfiltration	2000
Green Bay Water Utility	Pre-Ozonation	2000
Ashland Water Utility	Microfiltration	2001
Appleton Water Utility	Ultrafiltration	2001

Figures 3.19 and 3.20 show the trends in energy use for the water utilities that implemented ozone disinfection or membrane filtration, respectively, since 1997. For the utilities using ozone disinfection, there were increases in energy use upon implementation of the new treatment processes in Milwaukee (1998), Oshkosh (1999), and Green Bay (2000). For the utilities using membrane filtration, Manitowoc observed an increase in energy use in 1999, the year before implementation of microfiltration, and then subsequent increases in the following years. Kenosha observed an increase in energy use in 1998 and 1999, but a decrease in 2000 and 2001. Both Ashland (microfiltration) and Appleton (ultrafiltration) observed increases in energy consumption in 2001 after the new process were implemented.

The changes in energy use relative to the rest of the Class AB utilities, were estimated by observing the change in ranking (or percentile). Figures 3.21 and 3.22 show the trends in ranking of water utilities that implemented ozonation or membrane filtration, respectively, since 1997. The rankings in 2001 were not included since statewide data were not available in time to compile new rankings that included the 2001 data. The trends in ranking follow similar trends observed for energy use. An increase in the rankings was observed upon implementation of an energy intensive process. Significant changes in rankings occurred for the utilities using ozonation, like Milwaukee, which increased from the upper 30<sup>th</sup> percentile to the upper 50<sup>th</sup> percentile after implementing pre-ozonation. For the utilities using membrane filtration, Manitowoc went from the 40<sup>th</sup> percentile to the 70<sup>th</sup> percentile after implementing microfiltration. Kenosha observed an increase in ranking to the 80<sup>th</sup> percentile after

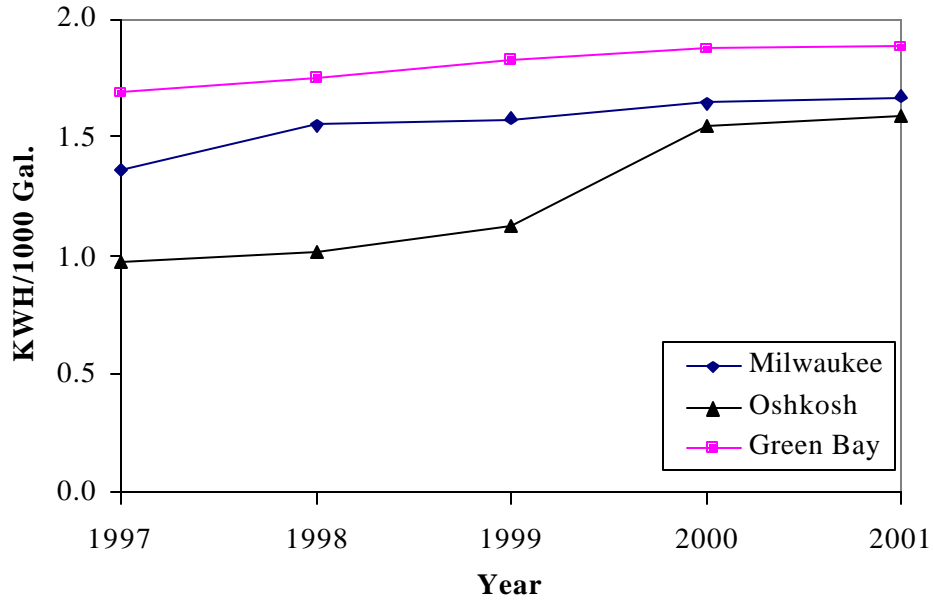


Figure 3.19. Trends in energy use for three water utilities implementing ozonation.

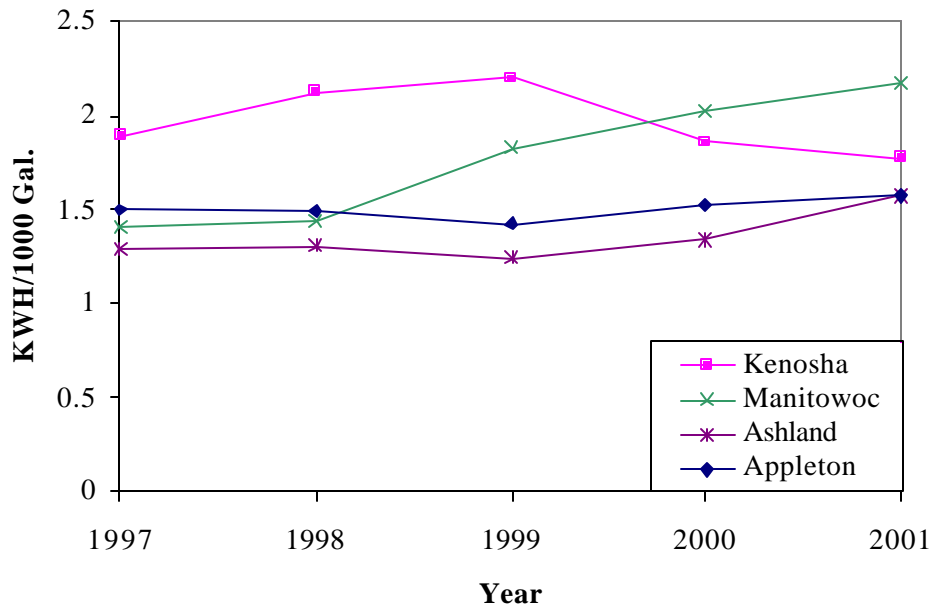


Figure 3.20. Trends in energy use for four water utilities implementing membrane filtration.

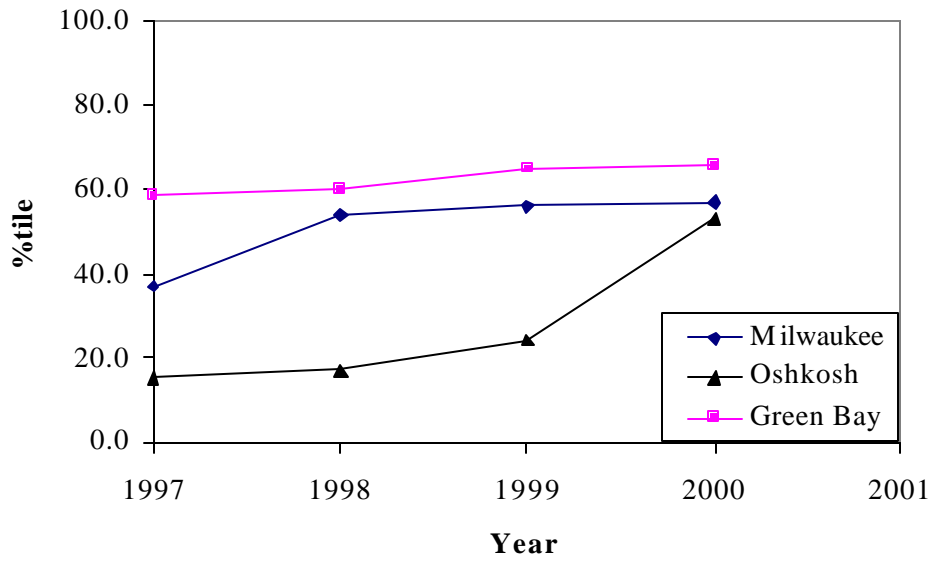


Figure 3.21. Trends in energy use ranking for three water utilities implementing ozonation.

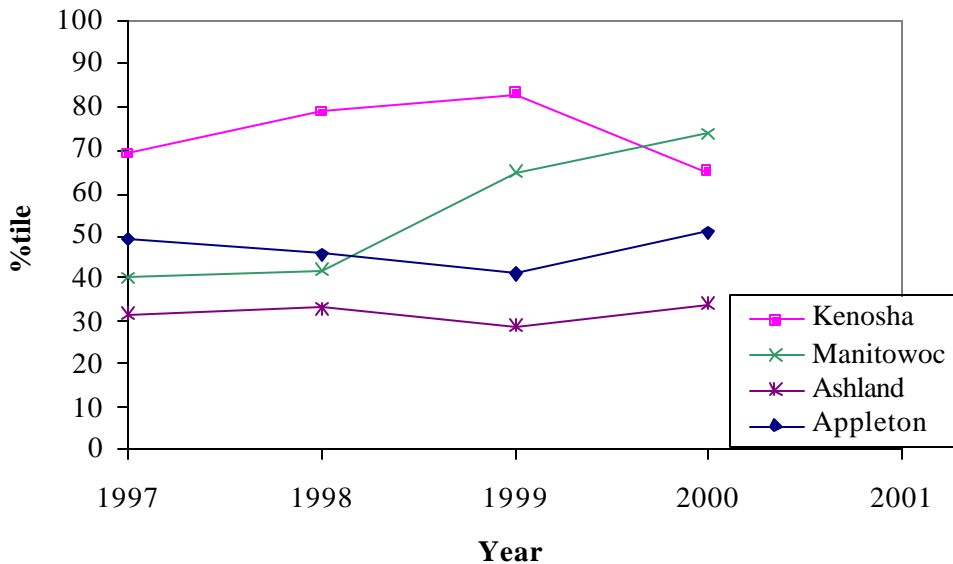


Figure 3.22. Trends in energy use ranking for four water utilities implementing membrane filtration.

implementation of microfiltration, but the ranking decreased to the 65<sup>th</sup> percentile in 2000. Ashland and Appleton just recently started operation of membrane filtration and no ranking data could be compiled.

A similar analysis on energy expenditures was conducted for the same utilities. Figures 3.23 and 3.24 show the trends in energy expenditures of water utilities that implemented ozone disinfection or membrane filtration, respectively. In general, energy expenditures have increased after implementation of both ozone disinfection and membrane filtration. Kenosha observed an increase in energy expenditures in 1998, but levels have remained relatively constant since then. The remaining utilities have seen increases in energy expenditures since implementation.

The changes in energy expenditures relative to the rest of the Class AB utilities were also estimated by observing the change in ranking. Figures 3.25 and 3.26 show the trends in ranking of water utilities which implemented ozone disinfection or membrane filtration, respectively. As with the trends in energy expenditures, the rankings increased after the implementation of ozone disinfection or microfiltration.

In summary, ozone disinfection and membrane filtration increased both energy use and energy expenditures for a water utility. The estimated annual increases in energy use and expenditures for ozone were 0.12 to 0.55 kWh/1000 gallons pumped and \$0.007 to \$0.025/1000 gallons pumped, respectively. The estimated annual increases in energy use and expenditures for microfiltration were 0.0 to 0.7 kWh/1000 gallons pumped and \$0.005 to \$0.04/1000 gallons pumped, respectively. No estimates could be made regarding ultrafiltration since not enough data was available.

## **CLASS C UTILITIES**

### ***Energy Use***

Figure 3.27 shows the effect of water production on energy used by Class C utilities from 1997 to 2000. As noted in Chapter 2, the utilities were divided into several categories based on the gallons of water pumped for the four-year period. The median value for energy use by all Class C utilities (left column of Figure 3.27) was around 1.8 kWh/1000 gallons pumped, but values ranged from about 0 to 12 kWh/1000 gallons pumped. As with the Class AB utilities,

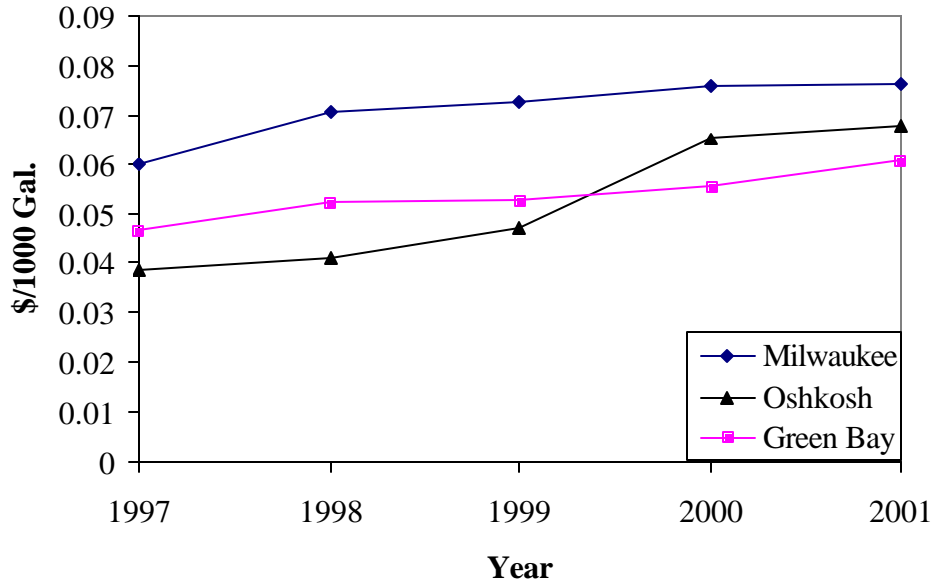


Figure 3.23. Trends in energy expenditures for three water utilities implementing ozonation.

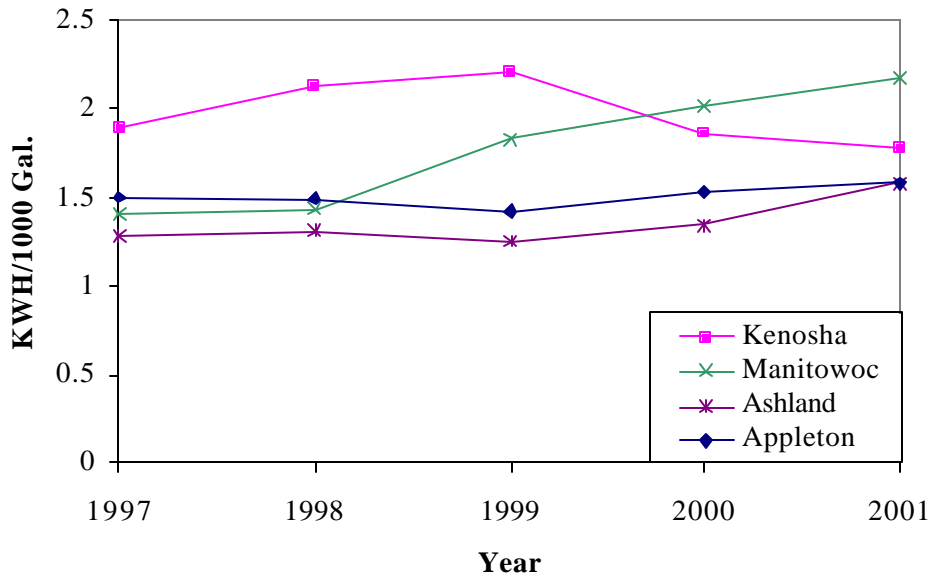


Figure 3.24. Trends in energy expenditures for four water utilities implementing membrane filtration.

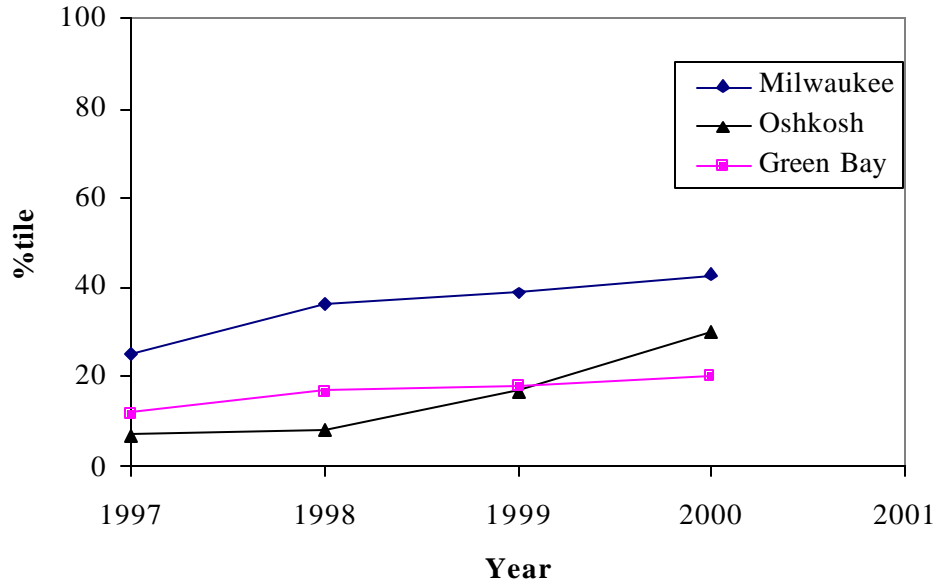


Figure 3.25. Trends in energy expenditure ranking for three water utilities implementing ozonation.

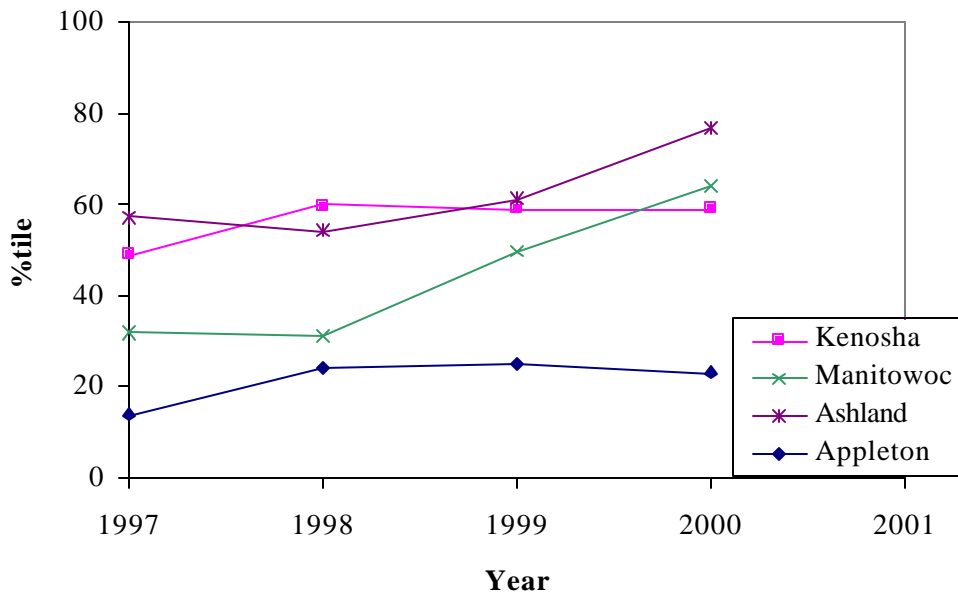


Figure 3.26. Trends in energy expenditure ranking for four water utilities implementing membrane filtration.

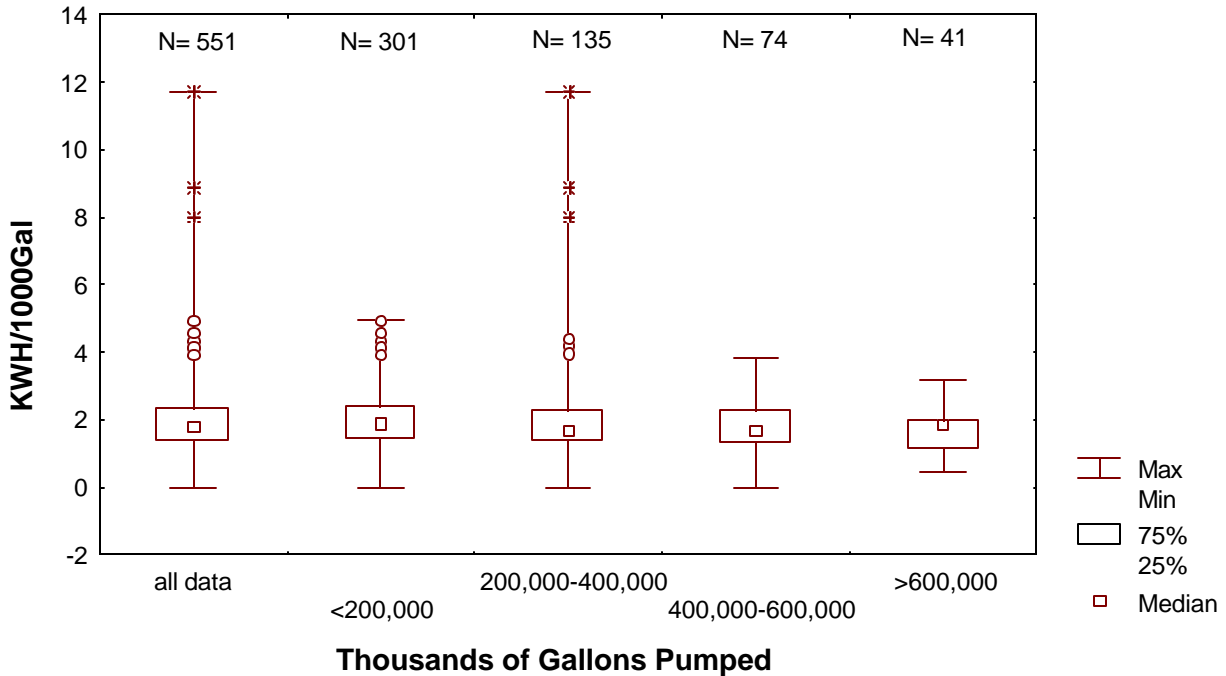


Figure 3.27. Effect of water production rate on energy used per 1000 gallons pumped for Class C utilities.

there was little dependence of median energy use on utility size, but the variability was much greater for smaller utilities in Class C. There was one Class C utility that pumped between 200 and 400 million gallons per year from 1997 to 1999 that had much greater energy use than the other utilities. This was the Fox Point Water Utility, which purchases its water from the North Shore Water Commission.

For all Class C utilities (including those that purchase water from another supplier), the 5<sup>th</sup> percentile energy use was 0.49 kWh/1000 gallons of water pumped. Table 3.12 shows a list of those utilities that used less than 0.49 kWh/1000 gallons of water pumped and those utilities that purchased water are listed in Table 3.13. Each of those utilities listed in Table 3.13 purchased from a utility treating surface water. All of the utilities purchasing water except Fox Point used less energy than 0.49 kWh/1000 gallons of water pumped in at least one year. Few Class C utilities consistently achieved this low level of energy use. Only eight of the twenty utilities listed in Table 3.12 used less than 0.49 kWh/1000 gallons of water pumped in more than one year and three of those eight were water purchasers.

Table 3.12.

Alphabetical list of Class C utilities that used less than 0.49 kWh/1000 gallons.

Utility	Years Achieved
Arcadia	1998
Benton	1998
Black River Falls	1998
Bloomer	1998
Columbus	1998
Crestview	1998
Cumberland	2000
Franklin	1997 and 1998
Germantown	1998 and 2000
Kewaunee	1998
Lodi	1997 and 1998
Muscoda	1998 and 2000
New Holstein	1998
North Park	1998
Pleasant Prairie	1997 through 1999
Rothschild	1998
Shorewood	1998
Spoooner	1998
Sturtevant	1997 and 1998
Whiting	1997 and 1998
Wonewoc	1997 and 1998

Table 3.13.

List of Class C utilities that purchase water.

Utility	Supplier
Crestview Sanitary District	Oak Creek Water and Sewer Utility
Fox Point Water Utility	North Shore Water Commission
Franklin Municipal Water Utility	Oak Creek Water and Sewer Utility
North Park Sanitary District	Crestview San. Distr. and Racine Water Utility
Pleasant Prairie Water Utility	Kenosha Water Utility
Shorewood Municipal Water Utility	Milwaukee Water Works
Sturtevant Water Utility	Racine Water Utility

The 95<sup>th</sup> percentile energy use for all Class C utilities from 1997 through 2000 was 3.49 kWh/1000 gallons of water pumped. Table 3.14 shows a list of those utilities that used more than 3.49 kWh/1000 gallons pumped. All of the utilities in Table 3.14 are groundwater utilities, with the exception of Fox Point, which purchases water from the North Shore Water Commission.

Several geographic clusters are apparent among the utilities listed in Table 3.14. The City of Pewaukee, the Village of Pewaukee, and Sussex are located in Waukesha County, where high drawdown is a likely explanation their high energy use. Lake Como, Pell Lake, and Williams Bay are located in the Lake Geneva region of Walworth County, which is subject to significant drawdown from the Chicago metropolitan area. Cashton, Westby, and Trempealeau are all within 25 miles of La Crosse and, finally, Fennimore is located about 20 miles from Platteville, which was one of the higher energy consumers in Class AB.

Figure 3.28 shows that Class C utilities that purchased water consumed less energy than those that treated their own water, with the exception of Fox Point. The median value for energy use by utilities that purchase water was around 0.5 kWh/1000 gallons pumped, compared to 1.8 kWh/1000 gallons pumped for utilities with their own source of groundwater.

Table 3.14.

Alphabetical list of Class C utilities that used more than 3.49 kWh/1000 gallons.

Utility	Years Achieved
Cashton	1997 through 2000
Fennimore	1997 through 2000
Fox Point	1997 through 1999
Lake Como	1999 and 2000
Pell Lake	1998 and 2000
Pewaukee (City)	1998 and 1999
Pewaukee (Village)	1997, 1999, and 2000
Sussex	1997 through 2000
Trempealeau	1997
Westby	1997 and 2000
Williams Bay	1997 and 1999

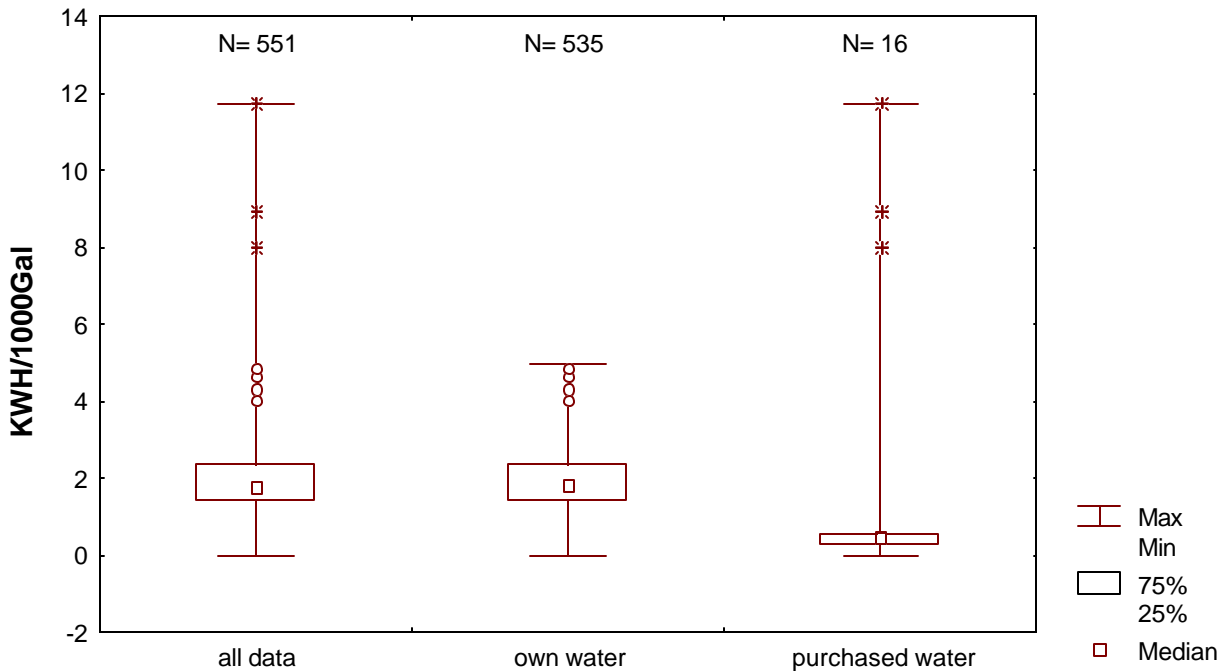


Figure 3.28. Effect of purchasing water on energy used per 1000 gallons pumped for Class C utilities.

## Energy Expenditures

Figure 3.29 shows the energy expenditures by Class C utilities from 1997 to 2000. The median value was around \$0.11/1000 gallons, but values ranged from just above \$0.00 to \$0.38/1000 gallons pumped. Expenditures on energy decreased from about \$0.12/1000 gallons to about \$0.10/1000 gallons as the utility size increased from less than 200 million gallons pumped annually to greater than 600 million gallons pumped annually. The range of values was also greater for the smaller utilities.

For all Class C utilities (including those that purchase water from another supplier), the 5<sup>th</sup> percentile energy expenditure was \$0.053 kWh/1000 gallons of water pumped. Table 3.15 shows a list of those utilities that used less than \$0.053 kWh/1000 gallons of water pumped. All of the utilities in Table 3.15 are groundwater utilities, with the exceptions of those purchasing water (Crestview, Franklin, and Sturtevant). A number of the utilities spending less than the 5<sup>th</sup> percentile on energy also appeared below the 5<sup>th</sup> percentile for energy use. These utilities

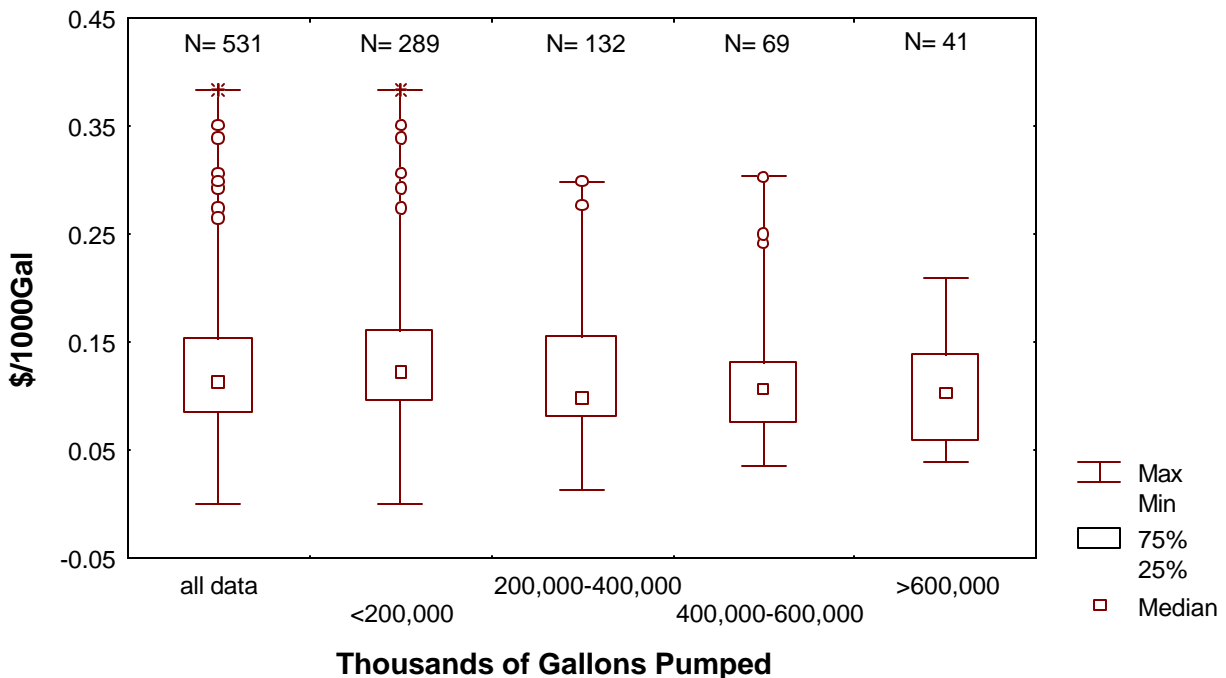


Figure 3.29. Effect of water production rate on cost of energy per 1000 gallons pumped for Class C utilities.

Table 3.15.

Alphabetical list of Class C utilities that spent less than \$0.053/1000 gallons on energy.

Utility	Years Achieved
Black River Falls	1998
Bloomer	2000
Brokaw	1997 through 2000
Crestview	1997 and 1998
Cumberland	1997, 1999, and 2000
Franklin	1997 through 2000
Muscoda	1997 through 2000
Plover	1997
Reedsburg	1997
Rhineland	2000
Sturtevant	1997 and 1998
Whiting	1997 through 1999
Wonewoc	1997

included Black River Falls, Bloomer, Crestview, Cumberland, Franklin, Muscoda, Sturtevant, Whiting, and Wonewoc.

The 95<sup>th</sup> percentile energy expenditure for all Class C utilities from 1997 through 2000 was \$0.227/1000 gallons of water pumped. Table 3.16 shows a list of those utilities that spent more than \$0.227/1000 gallons pumped on energy. All of the utilities in Table 3.16 are groundwater utilities, with the exception of Neillsville. Some of the utilities above the 95<sup>th</sup> percentile in energy expenditure also appeared above the 95<sup>th</sup> percentile for energy use. These utilities include Cashton, Fennimore, Lake Como, Pell Lake, City of Pewaukee, Village of Pewaukee, Sussex, and Williams Bay.

Figure 3.30 indicates that utilities that purchased water spent less on energy than utilities that treated their own water. The median value for energy expenditures was \$0.03/1000 gallons for utilities that purchased water and \$0.12/1000 gallons for utilities that treated their own water.

Table 3.16.

Alphabetical list of Class C utilities that spent more than \$0.227/1000 gallons on energy.

Utility	Years Achieved
Bangor	2000
Cashton	1997 and 2000
Fennimore	1997, 1998, and 2000
Lake Como	1999 and 2000
Mount Horeb	1997
Mukwonago	2000
Neillsville	1997 through 2000
Pell Lake	1998 and 1999 2000
Pewaukee (City)	1998 through 2000
Pewaukee (Village)	1997 through 2000
Sussex	1997, 1998, and 2000
Williams Bay	1997, 1999, and 2000

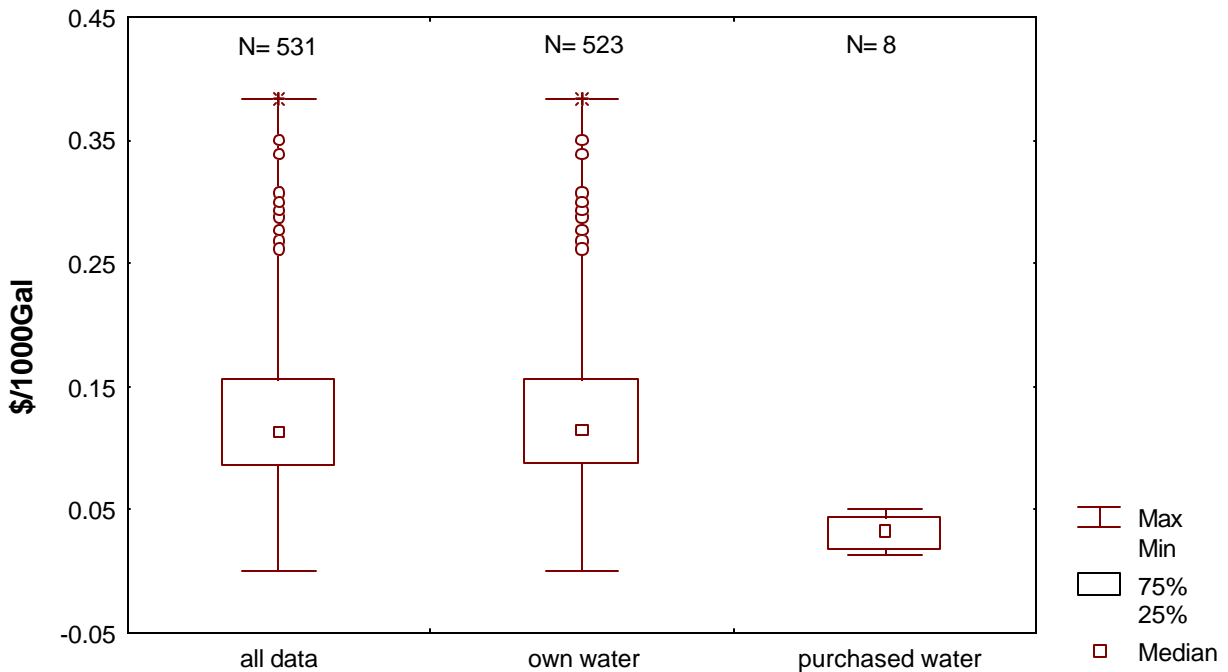


Figure 3.30. Effect of purchasing water on cost of energy used per 1000 gallons pumped for Class C utilities.

### ***Electric Rates***

For all utilities in Class C, the median value for electric rate was around \$0.06/kWh, with values ranging from \$0.01/kWh to \$0.32/kWh. The median value for electric rate was independent of utility size and water source. Table 3.17 lists those utilities at and above the 95<sup>th</sup> percentile for Class C utilities. Several utilities had average electric rates ranging from \$0.75/kWh to \$2215/kWh, but were assumed to be incorrect and were not included in the analysis. Only the Village of Pewaukee appeared at and or above the 95<sup>th</sup> percentile of Class C utilities for energy use, energy expenditures, and electric rates.

### ***Water Loss***

Figure 3.31 shows the fraction of water lost for Class C utilities based on the volume of water pumped to distribution per year. There was no effect of utility size on water loss. The one outlier with about 180% loss is New Lisbon, but this is likely an erroneous value since more water cannot be lost than what is pumped to distribution.

Table 3.17.

Alphabetical list of Class C utilities at or above the 95<sup>th</sup> percentile for electric rates.

Utility	Years Achieved
Black River Falls	1997
Franklin	1997
Germantown	1998 through 2000
Kimberly	1997
Lodi	1997 and 1998
Mondovi	1997 and 2000
North Fond du Lac	1998 through 2000
Pewaukee (Village)	1998
Whitehall	1997
Whiting	1997 and 1998

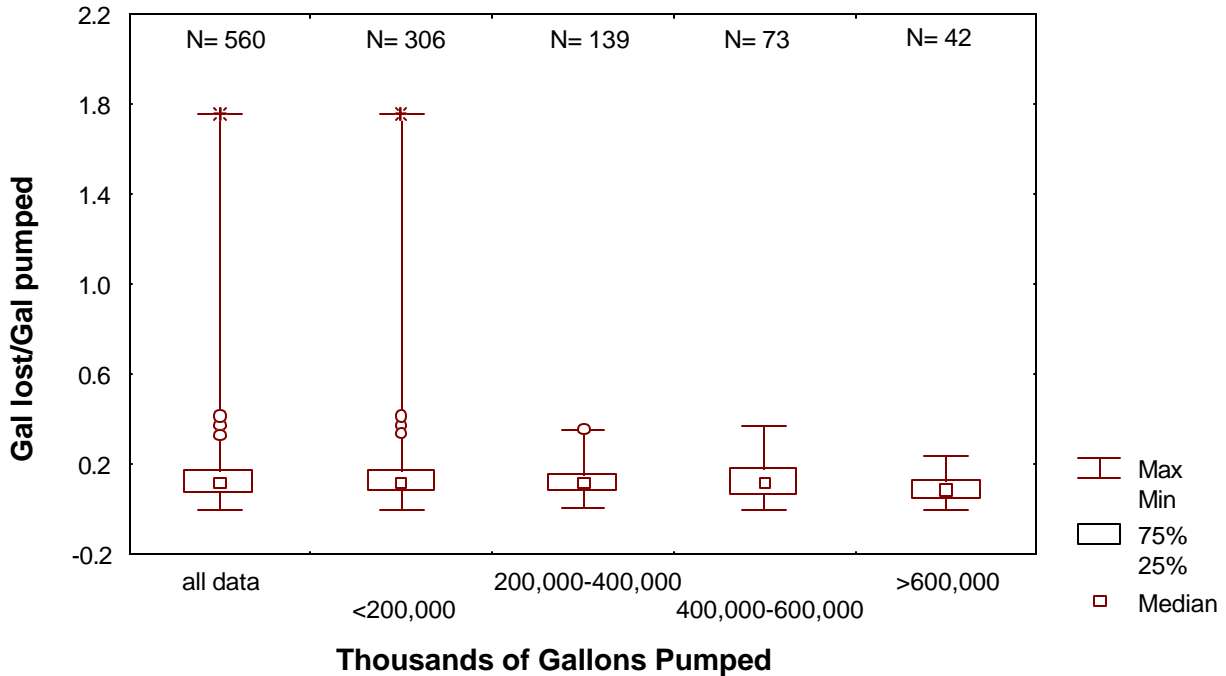


Figure 3.31. Effect of water production rate on water loss for Class C utilities.

The 5<sup>th</sup> percentile water loss for Class C utilities was 2.1% of water pumped for the study period. Those utilities losing 2.1% or less are listed in Table 3.18. Whiting was the only utility listed at or below the 5<sup>th</sup> percentile for energy use, energy expenditures, and water loss among Class C utilities. Meanwhile, Brokaw was listed at or below the 5<sup>th</sup> percentile for both energy expenditures and water loss. Lake Como and Pell Lake had low water loss but had high energy use and energy expenditures while Fox Point and Trempealeau had low water loss and high energy use.

The 95<sup>th</sup> percentile of water loss for Class C utilities was 26.3% and utilities at or above this level are shown in Table 3.19. Of these utilities, Williams Bay was the only utility having high levels of energy use, energy expenditures, and water loss. Although Muscoda and Wonewoc had high water losses, they were both ranked among the lowest in both energy use and energy expenditures for Class C. Overall, there was no trend between water loss and energy use or between water loss and energy expenditures in Class C utilities.

Table 3.18.

Alphabetical list of Class C utilities that lost less than 2.1% of gallons pumped.

Utility	Years Achieved
Belmont	2000
Berlin	1999 and 2000
Brokaw	1997 through 2000
Darboy	1997
East Troy	1998
Fort Atkinson	1998 through 2000
Fox Point	1998 and 2000
Jackson	1997, 1999, and 2000
Kiel	1998
Lake Como	1999
Mosinee	1998 and 1999
Pell Lake	1998 and 1999
Port Edwards	1997
Rhineland	2000
Slinger	1998 and 1999
Sparta	1999
Trempealeau	1998
Whiting	1997

Table 3.19.

Alphabetical list of Class C utilities that lost more than 26.3% of gallons pumped.

Utility	Years Achieved
Argyle	1997
Edgerton	1998 and 1999
Elkhorn	1999
Florence	1999
Mineral Point	1997 and 1998
Mondovi	1997 and 1999
Muscoda	1997 through 1999
Niagara	1997 through 1999
North Fond du Lac	1997 and 1998
Plover	1997
Saukville	1999
Spooner	1999
Verona	1997 and 1998
Williams Bay	2000
Wonewoc	1997 through 2000

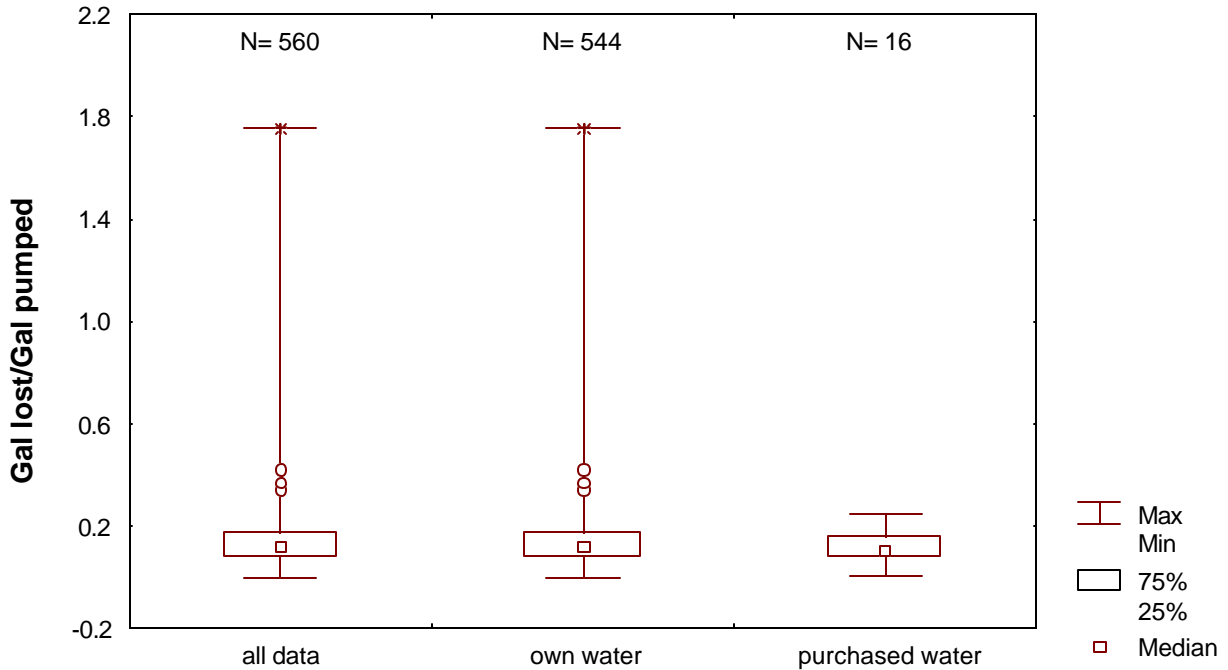


Figure 3.32. Effect of purchasing water on water loss for Class C utilities.

Figure 3.32 shows the fraction of water loss based on the source of water for Class C utilities. Utilities that purchased water had about 10% water loss compared to 12% for utilities using their own source of water. Again, the outlier with 180% water loss should be ignored.

## CLASS D UTILITIES

### *Energy Use*

Figure 3.33 shows the effect of water production on energy used by Class D utilities from 1997 to 2000. As noted in Chapter 2, the utilities were divided into several categories based on the gallons of water pumped for the four-year period. The median value for energy use by all Class D utilities (left column of Figure 3.33) was around 1.9 kWh/1000 gallons pumped, but values ranged from about 0 to 27 kWh/1000 gallons pumped. As with the Class AB and Class C utilities, there was little dependence of median energy use on utility size, but the variability was much greater for smaller utilities in Class D.

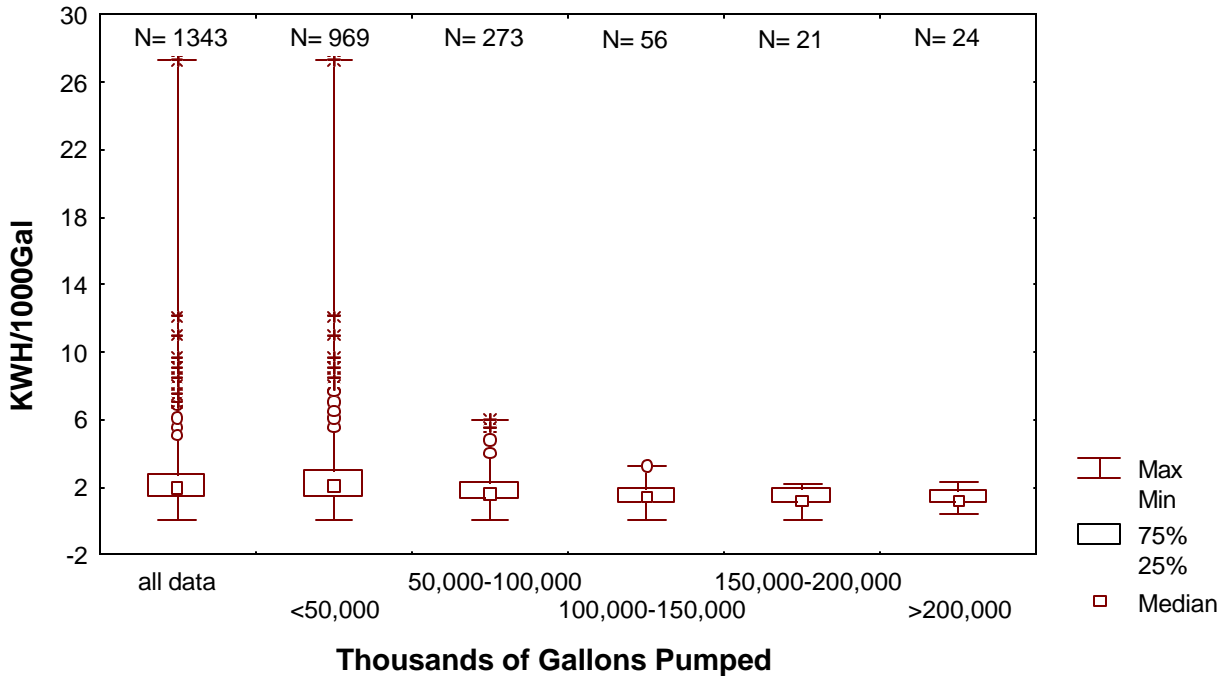


Figure 3.33. Effect of water production rate on energy used per 1000 gallons pumped for Class D utilities.

Table 3.20 shows a list of those Class D utilities that used the least amount of energy per gallon of water produced. This table lists only the top 10 performances in the database, which represent only 0.7% of the total database. Note that this low level of energy use was only achieved in 1998. Table 3.21 shows a list of those utilities that used the highest amount of energy per gallon of water produced. This table includes the highest 13 levels of energy use in the database, representing 1% of the database. Mary Hill Park and Westboro exceeded this level of energy use more than once. The utilities in Table 3.21 are more randomly distributed through Wisconsin, unlike the high energy users in Class AB and Class C.

### ***Energy Expenditures***

Figure 3.34 shows the energy expenditures by Class D utilities from 1997 to 2000. The median value was around \$0.075/1000 gallons, but values ranged from just above \$0.00 to more than \$1.00/1000 gallons pumped. As with Classes AB and C, median energy expenditures per

Table 3.20.

Alphabetical list of the ten Class D utilities that used the least energy per 1000 gallons.

Utility	Years Achieved
Beaver Brook	1998
Dorchester	1998
Embarrass	1998
Fulton	1998
Kronenwetter	1998
Liberty Grove	1998
Lincoln	1998
Manitou Falls	1998
Tony	1998
West Baraboo	1998

Table 3.21.

Alphabetical list of the ten Class D utilities that used the most energy per 1000 gallons.

Utility	Years Achieved
Curtiss	1999
Fairchild	1997
Friesland	1999
Knight	1999
Mary Hill Park	1997 through 2000
Milladore	2000
Mount Sterling	1998
Prentice	1997
Van Woods Estates	1999
Westboro	1998 and 1999

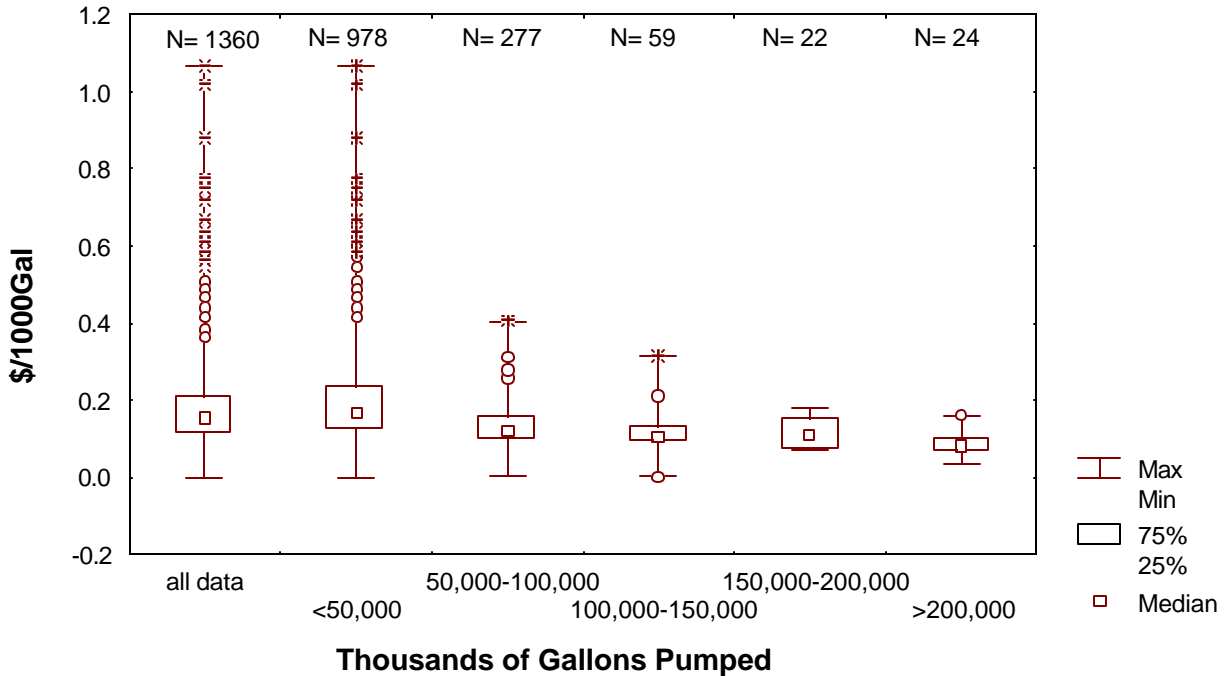


Figure 3.34. Effect of water production rate on cost of energy per 1000 gallons pumped for Class D utilities.

gallon of water produced decreased as the utility size increased. The range of reported values was also greater for the smaller utilities.

Table 3.22 shows a list of those Class D utilities that spent the least amount of money on energy per gallon of water produced. This table lists only the top 14 performances in the database, which represent only 1% of the total database. Golf Hills, Hobart, and Waverly appeared at this level in more than one year. The Lincoln utility was the only utility on this list that also appeared on the list of low energy users (Table 3.20). Table 3.23 shows a list of those utilities that spent the highest amount of money on energy per gallon of water produced. This table includes the highest 14 energy costs in the database, representing 1% of the database. Mary Hill Park and Westboro exceeded this energy cost level more than once. Several of these utilities also appeared on the list of high energy users. These utilities included Knight, Mary Hill Park, Milladore, Van Woods Estates, and Westboro. Interestingly, Manitou Falls appeared on the list of high energy expenses in 1997 but on the list of low energy users in 1998.

Table 3.22.

Alphabetical list of the ten Class D utilities that spent the least on energy per 1000 gallons.

Utility	Years Achieved
Avoca	2000
Barneveld	2000
Genoa City	1997
Golf Hills	1998 through 2000
Hobart	1997 and 1999
Hurley	1998
Lincoln	1998
Somers	1998
Somerset	1999
Waverly	1997 and 1998

Table 3.23.

Alphabetical list of the ten Class D utilities that spent the most on energy per 1000 gallons.

Utility	Years Achieved
Burke	1998
Dodge	1997
East Troy	1999
Knight	1999
Manitou Falls	1997
Mary Hill Park	1997, 1999, and 2000
Milladore	2000
Oliver	1997
Van Woods Estates	1999
Westboro	1997 through 1999

### ***Electric Rates***

For all utilities in Class D, the median value for electric rate was around \$0.15/kWh. The median value for electric rate was independent of utility size. Table 3.24 lists those ten utilities with the highest electric rates in the Class D database. Although this list shows the utilities with the highest expenditures per kilowatt-hour, five of these utilities were listed as having among the lowest energy expenditures per gallon of water pumped. These utilities were Avoca, Barneveld, Genoa City, Golf Hills, and Somerset.

### ***Water Loss***

Figure 3.35 shows the effect of water production on water loss at Class D utilities from 1997 to 2000. The median value for water loss by all Class D utilities (left column of Figure 3.35) was around 12.6%, but reported values ranged from about 0% to 460%. Ignoring the 460% figure as erroneous, the top values of reported water loss were around 100%. There was little

Table 3.24

Alphabetical list of the ten Class D utilities that had the highest electric rates.

Utility	Years Achieved
Avoca	2000
Barneveld	2000
Brockway	1999 and 2000
Elcho	1997
Friesland	1999
Genoa	1997 through 1999
Golf Hills	1998 through 2000
Somerset	1999
Vesper	1998 and 1999
Wauzeka	1998

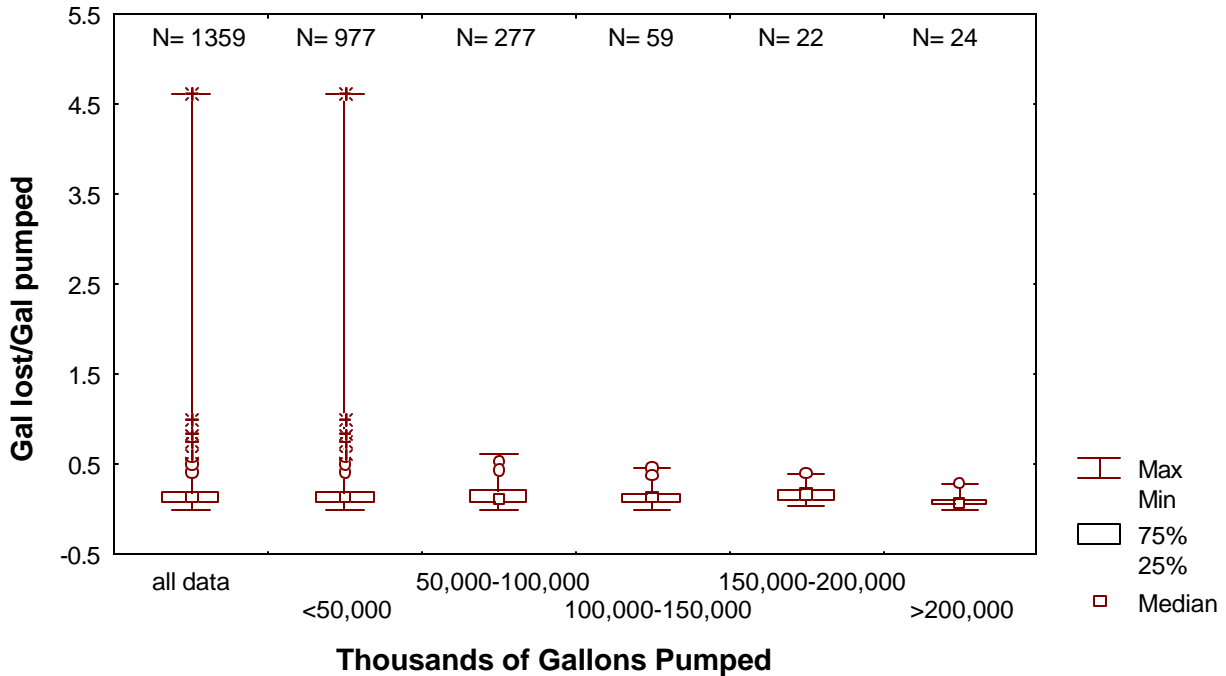


Figure 3.35. Effect of water production rate on water loss for Class D utilities.

dependence of median water loss on utility size, but the variability was much greater for smaller utilities in Class D.

Table 3.25 shows a list of the ten Class D utilities that reported the least amount of water lost. None of the utilities on this list appeared on the lists of top utilities for lowest energy use and lowest energy expenditures. However, Liberty Grove and Manitou Falls appeared on the lists of low energy use and low water loss. Interestingly, Manitou Falls also appeared on the list of highest energy expenditures. Mary Hill Park, Milladore, and Van Woods Estates appeared on the list of low water loss but also appeared on the list of high energy use and on the list of high energy expenditures.

The ten Class D utilities that reported the most amount of water lost appear on Table 3.26. Note that Applewood Hill and Pence appeared at least once Table 3.25 and in Table 3.26. None of the utilities in Table 3.26 appeared on the lists of top utilities for highest energy use and highest energy expenditures. However, Burke appeared on the lists of high energy costs and high water loss. Lincoln appeared on the list of high water loss but also appeared on the list of low energy use and on the list of low energy expenditures.

Table 3.25.

Alphabetical list of the ten Class D utilities with the lowest values of water loss.

Utility	Years Achieved
Applewood Hill	1997
Jamestown	1997 through 1999
Liberty Grove	1997 and 1998
Linden	1998
Manitou Falls	1998
Mary Hill Park	1998
Milladore	1999
Pence	1997 through 1999
Ray Huppert Utility, Inc.	1998 through 2000
Van Woods Estates	1999 and 2000

Table 3.26.

Alphabetical list of the ten Class D utilities with the highest values of water loss.

Utility	Years Achieved
Almena	2000
Applewood Hill	2000
Avoca	1997 through 1999
Blanchardville	1997
Burke	1998
Lincoln	1999
Maplewood	1997
North Cape	1997 and 1998
Pence	2000
Yuba	1997

## CONCLUSIONS AND RECOMMENDATIONS

Wisconsin's drinking water utilities consumed over 300 million kWh/year of energy for water production. The state's largest utilities, those in Class AB, consumed about 75% of this total. The median values for normalized energy use, normalized energy expenditures, electric rate, and percent water loss for each of the classes are listed in Table 3.27. Class AB had the lowest resulting median values for each of these categories.

Although some differences in median values are evident in Table 3.27, the key difference is in the variability of the reported values. The range of values reported by Class AB utilities was much smaller than the range of values reported by Class C utilities. Class D utilities exhibited the widest variability. This may be a result of poorer data quality with the smaller utilities and the Wisconsin Public Service Commission is encouraged to determine if this is the case.

In Class AB, seven of the ten utilities at or below the 10<sup>th</sup> percentile of kWh/1000 gallons of water pumped from 1997-2000 were utilities that purchased water. Six of the 21 utilities achieving the lowest energy use in Class C were also water purchasers. Similar trends were seen for energy expenditures per gallon of water produced. Therefore, to continue developing future lists of model utilities having the lowest energy use, those utilities that purchase water need to be removed from the database. Class AB utilities that consistently used the least amount of energy per gallon of water produced were Eau Claire, Racine, Sheboygan, Two Rivers, Waterloo, and Watertown. An in depth analysis of these utilities is encouraged to determine the reasons for their low energy use. Such an analysis can help other utilities develop alternative strategies for reducing energy use.

Table 3.27.

Comparison of median values between classes.

Class	kWh/1000 gal	\$/1000 gal	\$/kWh	% Water Loss
AB	1.51	0.053	0.084	9.6
C	1.85	0.065	0.113	11.7
D	1.89	0.075	0.151	12.6

Geographic location appeared to be a significant factor for those Class AB and Class C utilities that used the most energy. All of the utilities that reported high energy use were groundwater utilities, with the exception of two utilities (Glendale and Fox Point) that purchase water from the North Shore Water Commission. Most of the high energy users were in Brown, Waukesha, and Walworth Counties. These counties are all in areas of significant water table drawdown in the deep sandstone aquifer. A significant number of high energy users also appear in the southwestern part of Wisconsin, from Trempealeau County to Grant County. There may be little that these utilities can do to significantly reduce energy consumption unless alternative water supplies are used, more stringent water conservation measures are employed, or regional policies are implemented to reverse the drawdown trend. Such measures may not be economically justifiable and need to be reviewed on a case-by-case basis.

Energy use and energy expenditures were not related to water loss in any of the three classes. However, on a statewide basis, about 38 million kWh/year of energy was used to produce lost water at an annual energy cost of approximately \$2 million. Class AB utilities accounted for about 70% of the energy used to produce lost water. Although the state may economically benefit from a reduction in water loss, it is not clear whether each utility can justify a reduction in water loss because it may cost more money to reduce water loss than would be saved. The state may need to consider an incentive program of some type to get individual utilities to reduce water loss.

Differences in groundwater and surface water utilities were observed both in energy use and expenditures. Groundwater utilities used approximately 1.3% more energy per gallon of water produced than surface water utilities. However, approximately 4.3% of Wisconsin's utilities are producing 41% of the state's drinking water from a surface water source. Therefore, changes in energy use at this small number of utilities affects a large number of consumers.

New technologies were seen to have effects on energy use and expenditures for surface water utilities. Ozone disinfection and membrane filtration increased both energy use and energy expenditures at those utilities that implemented these technologies between 1997 and 2001. The estimated annual increases in energy use and expenditures for ozone implementation were 0.12 to 0.55 kWh/1000 gallons pumped and \$0.007 to \$0.025/1000 gallons pumped, respectively. The estimated annual increases in energy use and expenditures for implementation of microfiltration were 0.0 to 0.7 kWh/1000 gallons pumped and \$0.005 to \$0.040/1000 gallons

pumped, respectively. No estimates could be made regarding ultrafiltration since not enough data was available. The surface water utilities implementing these new processes should continue to be monitored to see if energy use and expenditures continue to increase relative to groundwater utilities in the near future.

Overall, the most energy and money can be saved by reducing energy use in Class AB because Class AB utilities used the most energy, treated the most water, and served the largest number of consumers. Even though Class AB utilities are using the least amount of energy per 1000 gallons of water pumped, this class has the most potential for energy savings. Utilities at or below the 10<sup>th</sup> percentile and at or above the 90<sup>th</sup> percentile for energy use, energy expenditure, and water loss should be evaluated further to determine what in these specific utilities is placing them in the aforementioned percentiles. This analysis should help utilities in the high percentiles lower their energy use and costs while still providing a quality product to the residents of Wisconsin.



**CHAPTER 4**  
**LITERATURE REVIEW OF ENERGY-SAVING OPPORTUNITIES**  
**FOR DRINKING WATER UTILITIES**

**ELECTRIC BILLING AND AUDITS**

Water utility managers must first understand two key items before defining opportunities for energy savings in their utility. First, managers need to understand the components of their electric bill and their electric rate structure. Second, managers need to understand the specific energy consumption characteristics of equipment at the plant. The latter item is usually achieved by conducting an energy audit.

*Electric bill and rate structure*

A list of important items on an electric bill is given in Table 4.1 (EPRI 1994). The two key charges on an electric bill are “energy” charges and “demand” charges. Energy charges are for total electric use and are reported in kilowatt-hours (kWh). Demand charges are for peak rate of electric use measured over short intervals like 15 to 30 minutes and are reported in kilowatts (kW). Since electricity is not easily stored, electric utilities must generate electricity as it is needed. Therefore, electric utilities invest in generating and distribution equipment to supply enough power to meet demand. Electric utilities must have adequate capacity to supply for both quantity (kWh) and power level (kW). Rates are set to cover the total costs of supplying electricity.

Electric utilities may use “ratchet charges” to bill water utilities over a 12-month period for maximum demand set in a single month. This creates an incentive for water utilities to find ways of minimizing peak electricity demands. For example, by turning off one pump before turning on another pump, a water utility can significantly reduce the peak demand and, thus, the ratchet charge.

The “power factor” is a measure of how efficiently a motor converts electricity into useful energy and is usually presented as a percentage. The most efficient power factor is 100% and occurs when current and voltage are perfectly in phase. Electric utilities usually issue a

Table 4.1.

Reference checklist for coding an electric bill (EPRI 1994).

1	Rate Schedule: Identification of formulas by which the bill is calculated.
2	Meter reading at start of period.
3	Meter reading at end of period.
4	Multiplier: this constant is multiplied by the difference between the meter readings to calculate the kilowatt-hours used.
5	Kilowatt-hours used in each category (on-peak, off-peak, etc.)
6	Cost per kilowatt-hour in each category (on-peak, off-peak, etc.)
7	Kilowatt-hour charge in each category (on-peak, off-peak, etc.). This charge is the kilowatt-hours used multiplied by the cost per kilowatt-hour in each billing category.
8	Actual peak kilowatt demand: “real power” measured by meter.
9	Actual peak kVA (kilovolt-amperes): “apparent power” measured by meter.
10	Billing demand (includes adjustments for poor power factor, ratchet clause, and others).
11	Cost per unit of billing demand.
12	Billing demand charge: billing demand multiplied by cost per unit.
13	Fuel cost adjustment per kilowatt-hour: may change monthly according to current cost of fuel; may be positive or negative.
14	Total fuel cost adjustment: total kilowatt-hours used times cost adjustment per kilowatt-hour.
15	Basic service charge: basic charge to keep account open.
16	Power factor charge (if separate from billing demand).
17	Minimum and maximum charges.
18	Finance charges and interest on deposit.
19	Transformer, voltage, or other credits.
20	Surcharges and taxes.
21	Other.

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penalty for power factors smaller than 90%. Motors running less than fully loaded are the major contributors to poor power factors and to high power factor charges in water treatment.

In addition, most electric utilities use some type of rate schedule, charging more for electrical use during on-peak hours (periods of high electricity use) and less during off-peak hours (periods of low electricity use). Electric utilities charge more during on-peak hours because electricity is more expensive to produce at this time. Energy costs may be reduced without significantly modifying any equipment or processes by performing certain operations when off-peak rates apply.

Other types of rate schedules, called interruptible or curtailment rates, bill a customer at lower rates in exchange for the curtailment of electrical use during periods of high demand. This works well for water utilities with stand-up generators who are able to supply their own electricity during expensive, peak periods of electricity use (Arora and LeChevallier 1998).

### ***Energy Audits***

The best way to identify energy saving opportunities within a water plant is to perform an energy audit. Audits can identify feasible energy conservation measures along with their energy saving potential and costs of implementation. Audits require plant design drawings, electricity and gas bills, operational data, and site visits. Site visits include meetings with operators, operation engineers, the production superintendent, and the local electric utility representative. On-site energy use data for pumps, motors, or throttling valves are also very useful (Arora and LeChevallier 1998).

In addition, operators should meet with the facility's electric account representative, who will be able to answer any questions regarding the electric bill or rate structure options.

### ***Energy Conserving Opportunities***

Energy surveys were conducted on 109 American Water System water treatment facilities as well as 3 audits. The audits were used to identify some energy saving opportunities based on the cost effectiveness of their implementation. These opportunities, identified by Arora and LeChevallier (1998), are described in the remainder of this section.

### *Most Cost Effective Options*

*Base-load most efficient treatment plant.* For multi-plant districts, water production should be maximized to meet most of the demand at the least costly plant.

*Manage demand.* Periods of high electricity use, even for short periods, can result in high charges. Therefore, managing the demand during peak electric rate periods can result in significant energy cost savings. Examples of demand management opportunities include:

- 1) Filling wash-water tanks during off-peak electric rates.
- 2) Turning one pump off before starting another.
- 3) Using available storage to shift pumping during off peak hours.
- 4) Operating wastewater treatment facilities during off peak hours.
- 5) Operating satellite stations like augmenting wells during peak hours.
- 6) Backwashing filters during off peak hours.
- 7) Matching the pump flow to avoid use of additional pumps.
- 8) Using one pump instead of two to refill wash water tank.
- 9) Using a diesel driven pump during peak periods of electric rates

Based on the completed surveys of the 109 American Water System treatment plants, implementation of these demand management strategies throughout the 109 treatment plants could result in \$1,510,300 in energy savings with an implementation cost of \$912,200. The payback was estimated to be less than one year for implementation of these strategies

### *Less Cost Effective Options*

*Modify pumps.* Adjusting or replacing inefficient pumps, reducing impeller size instead of operating with partially closed valves, and increasing impeller size to increase efficiency and reduce peak demand were identified as less cost-effective options.

*Install efficient lighting.* Other less cost-effective options included the installation of more energy efficient lighting. This includes:

1. the use of motion detectors to activate lights when a room is in use and to turn off lights when a room is not in use,
2. the use of photocells for exterior lighting,
3. replacement of standard incandescent and fluorescent lamps with compact fluorescent lamps,
4. replacement of standard fluorescent lamps and ballasts with energy-efficient triphosphor lamps and electronic ballasts, and
5. replacement of mercury vapor lamps with high-pressure sodium lamps.

*Use variable frequency drives.* Variable-frequency drives control pump speed and flow electronically and are more efficient than throttling valves for fixed-speed drives. Utility incentives can result in lower implementation costs, rendering installation cost effective.

*Install energy efficient motors.* Energy-efficient motors consume less energy than standard-efficiency motors. Efficient motors are more expensive to install, but energy savings can result in lower operating costs. Rarely is it cost effective to replace an existing motor with an energy-efficient model, therefore it is recommended only for new systems.

*Use stand-by generators during times of peak rates.* Stand-by generators can be used to reduce both demand and total electrical charges during peak electrical rates. Usually, they are only used to supply minimum water demand during a power failure, but are not cost effective to install. Possible savings may result from use during peak demand if interruptible rates are provided by the electric utility.

## **EQUIPMENT**

The following section provides energy saving techniques on specific equipment used in water treatment plants. All the information in this section was provided by CDM (1991) unless otherwise noted.

## ***Motors***

Most motors in water treatment facilities use alternating current and such motors are either single phase or polyphase. Single phase motors are generally small, less than ½ hp. Polyphase motors generate higher torque and power. Types of polyphase motors include squirrel cage induction, wound rotor induction, and synchronous.

Most motors are oversized for their application, creating inefficient energy use. Energy savings opportunities include:

- Replacing motors that are oversized by more than 50% with correctly sized, high efficiency motors.
- Replacing standard efficiency motors that are at least 5 years old and run at least 75% of the time.
- Measuring power efficiency and load factors on all motors. Modern, high efficiency motors are 15 to 25% more expensive than standard motors but payback may be as short as 1 year.

## ***Drives***

Drives transfer energy from a motor or engine to a pump or blower by converting electrical energy to mechanical energy. Drives are either constant-speed or variable speed. Using a variable-speed drive is almost always more efficient than relying on the throttle of a pump. Older drives should be replaced with newer, more efficient drives. Also, proper maintenance will reduce energy losses.

## ***Pumps***

Pumps are either positive displacement or dynamic. Positive displacement pumps include reciprocating types like piston pumps and rotary types like centrifugal pumps. Energy consumption by pumps is needed to change water elevation; overcome energy loss in pipes,

channels, valves, and treatment processes; and to accelerate the fluid. The sum of these items is called the total dynamic head. Energy saving opportunities include:

- Choosing the best combination of pump, drive, and motor for the application (i.e., high volume and low head, etc.)
- Using variable speed drives to vary pump speed to match flow rate.
- Selecting pumps based on existing flows, with the ability to increase impeller size to handle larger flows.
- Selecting pumps to match base or average flow and using supplemental pumps for peak flow.
- Minimizing the elevation change a pump has to lift as well as friction loss from valves and bends, if possible.

Walski (1993) points out that most pump systems operate at less than optimal conditions, but inefficiencies will not be noticed unless problems are actively sought after. Causes of inefficiency include:

- Incorrectly selected pumps
- Worn out or incorrectly set clearances
- Limited capacity in transmission/distribution system
- Limited storage capacity
- Inefficient operation of pressure (hydropneumatic) tanks
- Inadequate or inaccurate telemetry equipment
- Incapability to control pumps or valves automatically or remotely
- Time-of-day or seasonal energy pricing penalty
- Misunderstood demand or capacity power charges
- Operator error
- Less than optimal pump control strategies

Computer programs like KYPIPE2 and KYPIPE can operate distribution systems based on both pressure and costs (Daniel *et al.* 1994). The computer program monitors pressure and turns pumps on or off when necessary. The program determines the most cost effective group of pumps that will deliver a flow equal to demand. Operators must actually use the program for it to be effective. Also, sufficient calibration of pumps is necessary for the program to yield accurate results.

The annual cost of energy consumption for a specific pump is directly proportional to the discharge flow rate and total dynamic head, and inversely proportional to the efficiency of the pump at a specific operating point (Equation 4.1).

$$\text{Energy Cost (\$/yr)} = 11.4 \left[ \sum_{i=1}^n \left( \frac{Q_i h_i p_i F_i}{e_i} \right) \right] \quad (4.1)$$

where  $n$  = number of operating points,  
 $Q_i$  = discharge flow rate (mgd) at operating point  $i$ ,  
 $h_i$  = total dynamic head (ft) at operating point  $i$ ,  
 $p_i$  = price ( $\text{\$/kWh}$ ) of energy at operating point  $i$ ,  
 $e_i$  = wire-to-water efficiency (expressed as a fraction) at operating point  $i$ , and  
 $F_i$  = fraction of time that pump is on at operating point  $i$ .

As shown by Equation 4.1, energy costs can be reduced by:

- decreasing the volume of water pumped,
- decreasing the head against which it is pumped,
- decreasing the price of energy, or
- increasing the efficiency of pumps

These items can be controlled with the alternatives described in the following sections.

### *Volume pumped*

Water conservation and minimization of water loss are examples of methods that can reduce the volume of water treated by the plant.

### *Reduction of head*

Utilities can reduce head by keeping distribution system storage tanks less than full and by keeping suction storage tanks (wet wells and clearwells) at full capacity. This reduces the elevation difference between the two water levels. With this strategy, more contact time is available for disinfection in suction storage tanks but less contact time is available for disinfection in distribution system storage tanks. These contact time issues will also influence the utility's ability to meet disinfection byproduct standards. One drawback to this strategy is that less water is available in emergency situations like power outages and fires.

Head produced by a pump goes toward either lifting water or overcoming friction losses in downstream pipes, channels, valves, or treatment processes. If the elevation difference is small, little energy savings are seen by reducing head. If most of the head is used to overcome friction losses, then the pumps should be run as close to a constant discharge as possible (e.g., it takes less energy to run one pump for two hours instead of two pumps for one hour).

### *Cost of Electricity*

Utilities are advised to avoid peak-hour pumping by filling storage tanks and backwash filters during off-peak hours, usually at night. Stand-by generators may also be installed to provide additional energy during on-peak hours.

### *Efficiency of Pumps*

Utilities are also advised to check the efficiency of all pumps periodically and ensure that pumps are operating near their best efficiency point. Utilities should also make certain that all meters and gauges are calibrated periodically.

Centrifugal pumps are often oversized because exact pumping requirements are not known during design. This may result in the routine use of a partially closed discharge valve to balance the system. An alternative to that approach is to trim the pump's impeller or replace the impeller with one of a smaller diameter. For a pump that runs at 10% less than design capacity, trimming the impellers may reduce electric consumption by 25%. This technique is most appropriate on pumps with constant flow rates, that have a partially closed discharge valve, and that have no process changes planned. The pump distributor should be contacted prior to trimming for impeller trimming assistance (ECW 1999).

### ***Valves (Andersson 1997)***

Valves can produce significant head loss, increasing the energy required for pumping. Using ball check valves or flapper check valves can reduce head loss. The three types of valves used in water treatment are:

- Swing check valves – higher head loss, adjustable closing speeds.
- Ball check valves – low head loss, slow closing speeds.
- Flapper check valves – very low head loss, but slow, non-adjustable closing speeds and they do not work with cleaning pigs.

### ***Blowers and Compressors***

Blowers produce high volumes of air at 6 to 10 psi above atmospheric pressure while compressors produce low volumes of air at 80 to 140 psi. Blowers are labeled as either dynamic or positive displacement. Dynamic blowers are the centrifugal type, while positive displacement types include straight-lobed or cycloidal-rotary, reciprocating piston, diaphragm, rotary vane, and rotary-screw. Positive displacement blowers are generally more efficient than dynamic blowers, but dynamic blowers are usually more suitable for high volume or variable air flows and may have lower maintenance costs. Minimizing energy use may be accomplished by:

- Closing the valve on the inlet side if a centrifugal blower must be throttled.

- Monitoring pressure and cleaning filters regularly.
- Operating centrifugal blowers at more than 50% of their rated capacity.
- Monitoring daily loads with watt-hour meters.
- Maintaining blower operation within manufacturer's recommended speeds.

### ***Lighting***

Lighting consumes around 2% or more of a plant's total energy load. Fluorescent and high-pressure sodium lights are the most efficient and longest lasting. To conserve energy:

- Use 1 watt/ft<sup>2</sup> in process areas and 1.5 watts/ft<sup>2</sup> in administrative areas.
- Use electronic ballasts where illumination time is 10 hours per day or more.
- When replacing fluorescent bulbs, also replace the ballast.
- Install timers, local control switches, photocells, or occupancy motors where light is not needed continuously.

### ***Heating, Ventilating, and Air Conditioning***

Heating, ventilating, and air conditioning systems consume a small amount of energy relative to other processes like pumping. Increased efficiency through use of better insulation can reduce heating and air conditioning costs.

## **WATER TREATMENT PROCESSES**

### ***Ozone Disinfection (Rice 1996)***

Ozone generation is an energy intensive process. The specific energy for ozone generation is around 8 kWh/lb O<sub>3</sub> at 1 to 4% ozone by weight, but can vary based on the generator used, production rate, and ozone concentration. The energy required to dry the feed gas is a function of the composition of the feed gas (air/O<sub>2</sub> ratio and moisture content) and equates to about 3 kWh/lb O<sub>3</sub>. Cooling of the ozone generator equipment is about 1 to 5% of the

cost of ozone generation. Energy requirements for the ozone contact basin depends upon the type of diffuser used. Injection units require some electricity while bubble diffusers consume no electricity. For ozone off-gas destruction, 2 kWh/lb O<sub>3</sub> is required for thermal/catalytic processes while ozone destruction with GAC requires no electricity. Minor levels of energy are required for instrumentation control. Overall, the total energy required for ozone generation is about 20.9 kW/mgd at an O<sub>3</sub> dose of 10 mg/L and 10.4 kW/mgd at an O<sub>3</sub> dose of 5 mg/L.

Accurate determination of ozone generator energy efficiency (kWh/lb O<sub>3</sub>) depends on accurate measurement of ozone concentration, power, and gas flow. Instrument accuracy and ongoing calibration are necessary to maintain accurate records from which process control decisions are made. Also, most plants operate at turn down conditions (less than design capacity), suggesting that energy savings can be achieved by increasing energy efficiency at turn down conditions (Rakness 1995).

The gas used to generate ozone may be air or pure O<sub>2</sub>. Air is the cheapest to supply, but the most costly to prepare while O<sub>2</sub> is more expensive to supply, but relatively cheap to prepare for ozone generation.

Air compressors are used to feed the contact basins and the type of compressor used is dependent upon the air drying method. Pressure swing adsorption dryers require more than 7 bars of pressure while heat generation dryers require less than 3 bars of pressure to operate. Liquid ring compressors are energy inefficient, but are reliable and rugged. Oil flooded/oil free compressors are usually chosen for design purposes.

Air must be dried sufficiently before it can be used for ozone generation. The three methods for drying include refrigerant drying, desiccant drying, and heat with regenerative drying. Refrigerant drying is more complex, but consumes less power. Desiccant drying uses several bars of pressure and materials like silica gels, but it is not as energy efficient. Heat with regenerative drying requires energy to heat the air.

Specific energy is the energy required to generate ozone while total energy is the energy required to generate ozone, compress air, and dry air. Table 4.2 shows the specific and total energy requirements for ozone generation using air as the source of oxygen and shows the specific energy requirements for ozone generation when using O<sub>2</sub> as the source of oxygen. Table 4.2 indicates that less specific energy is required when using O<sub>2</sub> as the oxygen source rather than air. Table 4.3 shows the average specific and total energy consumption for generators with

Table 4.2.

Total and specific energy consumption by ozone generators (Rice 1996).

Generator Capacity (lbs O <sub>3</sub> /day)	Specific Energy using Air (kWh/lb O <sub>3</sub> )	Total Energy using Air (kWh/lb O <sub>3</sub> )	Specific Energy using O <sub>2</sub> (kWh/lb O <sub>3</sub> )
1-5	6.5-9.6	9.0-12.0	NA
<5-20	6.5-7.5	11.0-20.0	4.3
<20-100	7.5-9.0	10.8-15	5.5
<100-500	NA	NA	4.5 at 7.5% O <sub>3</sub> 6.4 at 13% O <sub>3</sub>
>500 (1000-5000)	7.0-7.5	9.96-10.9	3.7-5.5

*Note: Publication of this table in the final report is contingent upon receipt of copyright approval.*

Table 4.3.

Average energy consumption for ozone generators (Rice 1996).

Capacity (lbs O <sub>3</sub> /day)	Specific Energy using Air (kWh/lb O <sub>3</sub> )	Total Energy using Air (kWh/lb O <sub>3</sub> )	Specific Energy using O <sub>2</sub> (kWh/lb O <sub>3</sub> )
<100	7.5	15	5.5
>100	7.5	10.5	4.5

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capacities smaller than and larger than 100 lbs O<sub>3</sub>/day. Table 4.3 indicates that the smaller units require more energy on average to produce ozone than larger generators (Rice 1996). Overall, specific energy consumption is minimized by using a generator larger than 100 lbs O<sub>3</sub>/day with O<sub>2</sub> as the source of oxygen. Note that Tables 4.2 and 4.3 show estimates only. Utilities must account for equipment cost, space requirements, power consumption, cost for feed gas, oxygen purchase, yearly maintenance, spare parts, yearly escalation, and other factors. The tables also do not include costs of oxygen production in the estimate of specific energy for using O<sub>2</sub>.

### *Case Studies*

In the early 1990s, the Los Angeles Aqueduct filtration plant produced about 7,900 lbs O<sub>3</sub>/day, used oxygen for the feed gas, and produced ozone at 6% concentration by weight. The specific energy requirement for producing ozone in the range of 4.9 to 6.0% O<sub>3</sub> was between 3.36 and 4.32 kWh/lb O<sub>3</sub>. The energy required to create O<sub>2</sub> was between 2.7 and 3.3 kWh/lb O<sub>2</sub> generated. Therefore, the total energy required to produce ozone at this plant was between 6.66 and 7.02 kWh/lb O<sub>3</sub>.

As of 1991, the Lengg drinking water facility in Zurich, Switzerland used two ozone generators, each with the capability of producing 20 kg O<sub>3</sub>/hr for a total of 40 kg O<sub>3</sub>/hr. Residual ozone was destroyed using thermal destruction with heat recovery. The system handled from 10,560 gpm with 1.3 mg/L O<sub>3</sub> to 56,760 gpm with 3.1 mg/L O<sub>3</sub> in both chambers. Ozone production was flow weighted. The specific energy for ozone production was around 3.70 kWh/lb O<sub>3</sub> and total energy requirements were around 3.86 kWh/lb O<sub>3</sub>. The average total energy requirement for similar sized utilities was 4.5 kWh/lb O<sub>3</sub> (Geering 1991).

### *UV Disinfection (Black and Veatch 1995)*

There are two types of UV light systems typically used in the water industry for disinfection: low pressure and medium pressure. High-pressure UV units exist, but are not commonly used in water treatment.

### *Low-Pressure Systems*

Between 35 and 40% of the energy consumed by low-pressure systems is used for the production of radiation, with the remaining energy producing heat. Nearly all of the radiation produced has a wavelength of 253.7 nm, which is effective at inactivating microorganisms. Lamps can be placed in open or closed systems. Open systems require less capital investment than closed systems.

The energy required for sufficient inactivation of microorganisms is a function of water quality, transmittance, flow rate, and disinfection limits. Typically, energy requirements for low-pressure systems are between 3.2 and 4.8 kWh per mgd.

Opportunities for energy savings include the use of electric ballasts and turning off lamps during low flow periods. Additional savings may be seen by using vertical lamp systems, where several series of lamps may be installed and one series of lamps acts as a “dead” zone while the remaining rows are kept active. The lamps in the “dead” zone are turned off, but a small amount of electricity (5 to 15 watts) is run through them in order to keep them warm. Active lamps run on 70 watts of electricity. After a specified amount of time, the lamps in the “dead” zone are switched. This process can lower energy consumption and reduce the effects of lamp cycling, which reduces lamp life.

### *Medium-Pressure Systems*

Medium-pressure UV systems emit radiation at a higher intensity than low-pressure systems, but do so over a broader range of wavelengths. This requires 15 to 25% of the energy used in medium-pressure lamps. One medium-pressure lamp is the equivalent of 6 to 16 low-pressure lamps. About 4 medium-pressure lamps are needed for every million gallon per day of water treated. Power input must be maintained above 60 to 65% of maximum power at all times. Maximum power requirements per lamp are around 2.5 kW and 65% of maximum power is approximately 1.7 kW. Like low-pressure systems, lamps can be placed either in closed or open systems.

Similar to low-pressure systems, the energy required for sufficient inactivation of microorganisms is a function of water quality, transmittance, flow rate, and disinfection limits.

Typically, energy requirements for medium-pressure systems are around 6.8 kWh/mgd at 65% power.

Opportunities for energy savings also exist for medium-pressure systems. Using electric ballasts and multiple vertical banks that alternate on/off are the same as mentioned for low-pressure systems. In addition, medium-pressure systems may be operated in response to water quality (transmittance) to conserve energy. For example, between 13.4 and 15.0 kW/mgd of electricity is consumed for 50% transmittance, but only 10 kW/mgd is consumed for 65% transmittance. If set on the low power setting (for low flow), only 6.8 kW/mgd are consumed, representing an annual savings of \$4,800/mgd at a rate of \$0.08/kWh.

### ***Membrane Filtration (Crozes 2000)***

The use of membrane filtration in drinking water treatment is becoming an increasingly popular option at facilities looking for an alternative to ozone or chlorine for pathogen control. Membrane filtration is an energy intensive process due to the high pressure it requires. Energy requirements for membranes may be described by the following equation:

$$H_p = \frac{Q(\Delta P)}{1714} \quad (4.2)$$

Where  $\Delta P$  = feed pressure required (psi),

$Q$  = flow rate (gpm), and

$H_p$  = power requirement (kWh/mgd of water produced).

A study funded by the Energy Center of Wisconsin evaluated the possibility of reducing membrane energy requirements by using gravity to supply all or a portion of the required pressure. Although generally thought of as expensive, an ultrafiltration membrane using gravity for pressure head offers lower operating and maintenance costs through decreased pumping. The evaluation was performed in Sheboygan, Wisconsin, where a low head, low flux ultrafiltration membrane system was able to produce 24 gal/(ft<sup>2</sup>·day) of water that met turbidity and particle count limits over 30 days of pilot testing with 20 ft of head (8.7 psi). When higher pressures of

20 psi were introduced with a pump, the system was able to produce 35 gal/(ft<sup>2</sup>·day) for another 30 days of pilot testing. However, the higher pressure was estimated to require an additional 109 kWh per million gallons of water produced. The additional cost for maintaining pressure in the membrane filter was estimated to be \$4.90 per million gallons of water.

## CASE STUDIES

### *Ann Arbor, Michigan (Steglitz and Alford 2001)*

In 1999, the City of Ann Arbor Water Utilities Department began an initiative to minimize operating costs by reducing energy expenditures. Within the Water Utilities Department is the Water Treatment Division, which is made up of a central treatment plant, five pumping stations, and two hydroelectric generating plants. The water treatment plant is a mixed groundwater and surface water plant capable of processing up to 50 mgd of treated water. The major treatment processes include: two-stage lime softening, dual media filtration, primary disinfection with ozone, and secondary disinfection with monochloramine.

Electricity costs represented 20% of the total operating costs for the Water Treatment Division. The raw water pump station and the water treatment plant accounted for 88% of the total annual electric cost for the Water Treatment Division and, therefore, these locations represented the greatest opportunities for cost savings. The Water Treatment Division identified the following five steps to their energy reduction plan:

1. Understand the rate structure of the electricity provider,
2. Install energy monitoring devices,
3. Develop load profiles to analyze usage,
4. Assess process modifications, and
5. Implement recommendations and monitor them.

The electric utility (Detroit Edison) charged a peak rate between 11 am and 7 pm, Monday through Friday, and an off-peak rate at all other times. Demand charges were split into an annual demand charge and a monthly demand charge based on the highest 30-minute average

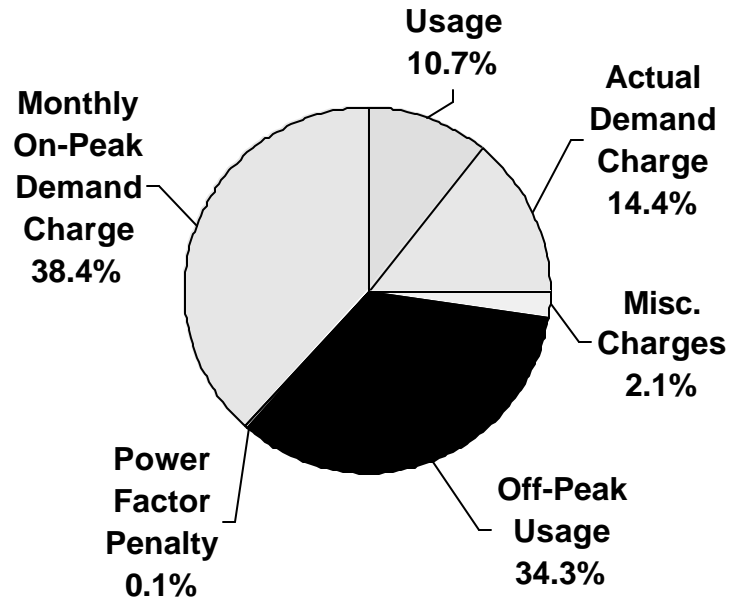


Figure 4.1. Breakdown of Year 2000 Electricity Charges at the Ann Arbor Water Division.

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demand during the previous 12 months and the highest 30-minute average demand during the billing period, respectively. There were also several miscellaneous charges and power factor charges. Figure 4.1 shows the breakdown of electricity charges for the water treatment plant in the year 2000. It shows that the two largest charges were from the monthly on-peak demand charge (38.4%) and from off-peak usage (34.3%). Less significant charges were the annual demand charge (14.4%) and peak usage (10.7%).

After identifying the rate schedule and annual charges, monitoring devices were installed at the four electrical substations that fed the water treatment plant. The Water Treatment Division spent about \$9,000 on monitoring equipment, which provided real-time monitoring of electrical use. In addition, the devices were tied into the plant's SCADA system.

Once the monitoring equipment was installed, load profiles were created to show how the plant consumed electricity and how electrical fluctuations correlated with plant activities. Not surprisingly, electric load profiles indicated that electrical usage increased in the summer as water production and usage also increased. In addition, the profiles indicated large peaks of

electrical usage that contributed to their large monthly demand charges. This identified an opportunity to reduce energy costs by minimizing the peak demands.

After the electrical monitoring equipment was in place and functional, a team of plant operators, plant engineers, and plant management began assessing some potential process modifications. The largest opportunity for cost reductions was from filling reservoirs and backwashing filters during off-peak hours. Since the pumps used to perform these operations had the largest electrical demands of all the electric motor driven equipment in the plant, these activities needed to be staggered to avoid large peaks in demand. In addition, input from plant operators aided in identifying potential energy saving opportunities (e.g., turning off equipment when not in use, etc.). The monitoring data were shown on a screen that was added to the SCADA system. The screen allowed the operators to watch electrical usage and respond to alarms.

From January 1999 to May 2001, the water treatment plant saved between \$1,500 and \$2,000 per month in electrical costs. Also, the load factor (monthly average demand divided by the highest monthly demand) increased from 0.8 to 0.9, indicating better electricity management. This study indicated that significant cost savings can result from a comprehensive plan that includes monitoring and demand management.

***Bexar Metropolitan Water District, Texas (Phillips et al. 2001)***

The Bexar Metropolitan Water District (Bexar Met) in San Antonio, Texas spent over \$1.2 million per year in energy costs to operate 54 groundwater pumping facilities based on a study of the 1998 operational year. Pumps range in size from 10 to 900 hp and must be strategically operated to handle seasonal fluctuations of water table elevations.

Recently, potential energy efficiency improvements to the system were investigated. Specific energy reduction measures were identified for each pumping station that was evaluated. The study found that many of the pumps at the stations were oversized, meaning the pumps were not operating at their most efficient point. In some cases, pumps were converted from a 4-stage vertical turbine pump to a 3-stage vertical turbine pump to increase efficiency. Since there were several pumps at each pumping station, varying flow demands were met by using the additional pumps that were not previously used.

Another energy saving measure was the conversion of all existing check valves to tilting disc or double door check valves. It was estimated that installation of the new check valves could reduce head loss by 50%.

Due to the varying water level in the aquifer from winter to summer, the pumps were rated to operate most efficiently during the dry summer period when water levels were low. Although this worked in the summer, high water levels in the winter reduced the pumping head and caused the pumps to operate far from their most efficient point. Therefore, installing variable-frequency drives on all pumps was proposed so that pump speed would match existing well conditions and the desired flow rate. The estimated savings of this measure were approximately \$12,600 per year. The installation cost for the variable-frequency drives was estimated at \$85,000.

Additional cost savings were proposed by shaving peak electrical usage through the use of SCADA. Bexar Met was charged on its peak 15-minute demand over a billing month. The rate applied for a 12-month period, but Bexar Met was charged for only 80% of the peak if electrical use was below maximum levels. Therefore, by monitoring demand and scheduling pump operation with the aid of SCADA, a flat demand curve could be achieved, thus reducing its peak demand charge. In addition, the use of SCADA could reduce labor and travel associated with maintaining the pumping network. SCADA can also lower energy costs by maximizing pump efficiency.

After construction of mechanical improvements and implementation of a district-wide SCADA system, Bexar Met expected to save a total of \$2.7 million. It was expected that the savings would match the costs, resulting in a net cost to Bexar Met of zero.

## **SUMMARY**

Tables 4.4 and 4.5 give summaries of the items described in this chapter. Table 4.4 provides a checklist of items that can be used to reduce energy consumption and energy costs. Table 4.5 provides a summary of the impacts that different equipment and treatment processes have on peak loading, energy use, payback periods, special costs, and acceptance.

Table 4.4.

Checklist for electricity cost savings (EPRI 1994).

- 
- 1 Compare rate schedules and use the best schedule suited for the facility's operation.
  - 2 Train operators and maintenance workers to be aware of the time of day for utility on-peak charges. Run motors and other electric loads off-peak whenever possible.
  - 3 Analyze relative efficiency (kWh or \$ per million gallons) of major pumps serving the same function. Operate the most efficient pumps.
  - 4 Periodically perform pump efficiency tests to identify maintenance requirements.
  - 5 Use premium high-efficiency motors on fixed speed pumps over 1 hp.
  - 6 Use adjustable speed drives on pumps with variable loads.
  - 7 Avoid periodic motor testing during peak hours.
  - 8 Install capacitors to reduce power factor charges.
  - 9 Use standby generators to reduce peak demand.
  - 10 Install high efficiency lighting systems.
  - 11 In wastewater treatment, convert to efficient air diffusers (fine bubble instead of coarse).
  - 12 In wastewater treatment, use automatic methods for dissolved oxygen control.
  - 13 In water supply systems, increase storage during off-peak periods. Deplete storage during on-peak periods.
  - 14 In water filtration plants, turn off one pump while operating another large pump for a short period. For example, turn off the main supply pump while using backwash pumps or sludge scrapers. Alternatively, backwash during off-peak periods. The peak demand and demand charges will be lowered.
- 

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Table 4.5.  
Summary of electric consuming technologies and  
potential for energy savings in water treatment facilities (Burton 1996).

Category	Technology	Load Shape Objectives			Utility Criteria		Customer Criteria		
		I	II	III	Pk Load Impact kW	Energy Impact kWh	Benefits	Costs	Acceptance
General	High Efficiency Motors				3	3	D	F	I
	Adjustable Speed Drives				2	2	B	F	H
	Increased Instrumentation and Control				2	2	B,C	F,G	I
	Gas or Diesel Drivers for Peak Demand Periods				1	3	D	E,F	I
Water Transmission	Energy Recovery from High Head Transmission Systems				2	2D	G	I	
Filtration	Deep Bed Filters				5	5D	G	I	
	Automatic Backwash Filters				1	2D	G	I	
	Gravity Backwash Filters				1	2	D	G	I
	Membrane Filters				5	5	D	G	J
Disinfection	Ozone				5	5D	G	H,I	
	UV Radiation				5	5D	G	J	
	Chloramination				4	4	D	E	I
Residuals Management	Belt Filter Press				1	1	D	G	I
Water Distribution	Storage Reservoirs				1	4	D	G	H
	Pressure Zone Control				2	2	B,C	F,G	I
	Headloss Control				2	2	B	F,G	I

KEY	Load Shape Objectives
I	Load Management
II	Strategic Conservation
III	Load Growth
Significant Impact	
Moderate Impact	
Some Impact	
No Impact or NA	

KEY	Utility Criteria
1	>20% Decrease
2	10-20% Decrease
3	3-10% Decrease
4	No Increase or Decrease
5	Potential Increase

KEY	Customer Criteria				
	Relative Benefits		Relative Costs		Acceptance
A	<2 year payback	E	Low (funded from annual budgets)		H   Excellent
B	2-5 year payback	F	Moderate (2-3 year funding)		I   Good
C	>5 year payback	G	High (special funding)		J   Fair
D	Other				K   Poor

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## ABBREVIATIONS

CDM	Camp Dresser and McKee
ECW	Energy Center of Wisconsin
EPRI	Electric Power Research Institute
ft	feet
gpm	gallons per minute
hp	horsepower
kg	kilograms
kVA	kilovolt amperes
kW	kilowatts
kWh	kilowatt-hours
L	liters
lb	pounds
mg	milligrams
mgd	million gallons per day
psi	pounds per square inch
SCADA	supervisory control and data acquisition
UV	ultraviolet