Correlation of Energy Management Policies with Lower Energy Use in Public Water Systems*

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ABSTRACT

One question in the increasingly frequent discussions about energy management among water utilities is whether energy management policies have any effect on their energy footprints. This study examines the question using new data from public water systems in the United States. A statistically significant difference was found, indicating that water utilities with documented energy management policies, plans, or programs use about 30% less energy, on average, than those without, even after considering other important factors such as water system size, water source type, and climate conditions. This finding suggests that voluntary, organization-specific policies should be included among other best practices for sustainably managing water utilities' energy use.

INTRODUCTION

Modern water utilities require significant amounts of energy to extract, treat, and deliver high-quality drinking water. This energy use leads to significant environmental, financial, and social impacts that suggest sustainability opportunities through energy management. (Here, "energy management" is a broad set of activities that includes energy conservation, efficiency, auditing, planning, training, etc.) In recent years much technical guidance has emerged to help water utilities manage their energy use while still providing adequate service.

One point of interest in policy research is the role of policy in resource management, including energy. Past studies of the industrial sector suggest that well-designed policies can result in substantial energy savings (Geller et al. 2006; Tanaka 2011) and that energy management policies, plans, and programs are cost-effective in dealing with environmental problems, particularly when they are voluntary (Price 2005; Ates and Durakbasa 2012; Stenqvist and Nilsson 2012; Lee and Yik 2004).

Among the ongoing discussions about how to sustainably manage energy use in the water industry, technical solutions abound but policy aspects have received little attention. The question then arises as to whether voluntary energy management policies have any effect on water utilities' energy use and whether they belong among other energy management strategies. This study compares energy footprints of water utilities with and without energy management policies to determine if a statistically significant difference exists supporting a correlation with policy presence.

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METHODS

Data for this research originated in a primary survey of 109 U.S. drinking water utilities by Sowby and Burian (2017), the most relevant and complete dataset of its kind that characterizes the energy footprints of drinking water operations from the natural water source to the customer meter. The data include annual energy use and annual water delivery, as well as basic information on each system's water sources and climate setting. In subsequent work, the same researchers developed this information into a validated statistical model that estimates a water utility's operational energy footprint as a function of these variables (Sowby and Burian in press).

A follow-up survey on the same water utilities was conducted here to determine the existence of a documented policy, plan, and/or program designed specifically to help manage the water utility's energy use (collectively referred to hereafter as "energy management policy"). Since few state and national policies currently address this subject, all such policies found in this study were voluntary and specific to the organization. Examples include a board-adopted policy on energy conservation, a written plan to track energy and water usage together, or a documented program of performing energy audits on water facilities. Broader municipal energy and/or sustainability policies were counted only if they specifically addressed the drinking water system. While the nature and extent of the policies differed, the objective was to determine whether the water utility had made a documented commitment to energy management. Details of the policies' history, contents, structure, and implementation were not available and are reserved for future analysis.

Of the 109 water utilities in the original survey, 78 responded to the inquiry about energy management policies. Forty-eight indicated that they had such a policy and 30 indicated that they did not. Both groups contain large and small water utilities with similar geographic distributions.

The relationship between policy and energy use was tested through an ordinary least squares (OLS) regression. The regression followed the statistical model developed by Sowby and Burian (in press) that considers the water utility's size (as annual water delivery volume), water source type, average annual precipitation, and average annual air temperature, which were found to explain most of the variation in the natural logarithm of the water utilities' energy use and therefore facilitate more equitable comparisons. The author added a policy presence indicator to the model; the regression then expressed the significance of each variable individually. The null hypothesis was that policy presence does not correlate with energy use; the alternative hypothesis was that it does. A 95% confidence level was selected (significance level $\alpha = 0.05$). If the test statistic's probability, p, for policy presence was below 0.05, the null hypothesis would be rejected and the alternative hypothesis would be accepted. In other words, the method computes the probability that the observed energy use value would occur if policy presence were ignored. A low probability of this random behavior would support a strong relationship between policy presence and energy use. The magnitude and sign of the coefficient, respectively, would indicate how important the relationship is and whether it corresponds to lower energy use (negative) or higher energy use (positive).

RESULTS

Figure 1 shows both groups of water utilities (with and without energy management policies) plotted according to water delivery and energy use. Table 1 shows the regression results, with a relatively high coefficient of correlation (adjusted $R^2 = 0.94$) that matches the original statistical model by Sowby and Burian (in press). Policy presence is statistically significant. The regression yielded $p = 0.0062$ for policy presence, meaning that the null hypothesis of no correlation can be rejected and the alternative hypothesis of correlation can be accepted at a significance level of $\alpha = 0.05$.

The coefficient for policy presence is −0.37, which indicates a negative relationship. The 95% confidence interval for this coefficient is −0.63 to −0.11 (of which −0.37 is the mean), meaning that in repeated sampling, the coefficient would fall in this interval 95% of the time. Since the interval is strictly negative, the author concludes that even when allowing for substantial deviation, the negative correlation still holds. All other regression variables being equal, the presence of an energy management policy correlates with lower energy use. This is apparent even when plotted against only one variable as in Figure 1.

Determining how much lower requires some interpretation. The statistical model computes the natural logarithm of energy use rather than energy use, so the result must be exponentiated to obtain energy use. Since the coefficient of −0.37 for policy presence is multiplied by 1 when a policy is present and 0 when absent, this subtracts 0.37 from the exponent when a policy is present. Suppose that the other terms in the exponent, collectively denoted *c*, remain unchanged. One then compares the energy use, *E*, in cases with and without energy management policies:

$$\begin{gathered} E_{\text{with}} = e^{c-0.37} \\ E_{\text{without}} = e^{c} \end{gathered} \tag{1}$$

Since comparing energy use directly is not useful given the wide range of values among water utilities, a ratio is more appropriate:

$$\begin{gathered} \frac{E_{\text{without}} - E_{\text{with}}}{E_{\text{without}}} = 1 - \frac{E_{\text{with}}}{E_{\text{without}}} = 1 - \frac{e^{c-0.37}}{e^{c}} \\ = 1 - (e^{c-0.37})(e^{c})^{-1} = 1 - (e^{c-0.37})(e^{-c}) = 1 - e^{c-0.37-c} \\ = 1 - e^{-0.37} = 0.31 \end{gathered} \tag{2}$$

This means that, even after accounting for differences in size, water source type, and climate, water utilities with energy management policies use, on average, 31% less energy than those without. Repeating the calculation over the 95% confidence interval of −0.63 to −0.11, the difference in energy use between the groups with and without policies is 10%–47%.

DISCUSSION

The consensus from the literature is that voluntary policies can support energy savings among industrial users. This work’s finding, namely that the presence of a voluntary energy management policy correlates with lower energy use, supports the consensus specifically for water utilities.

Though energy use and policy presence are correlated, it is not immediately clear if the relationship is causal. One explanation is that the policy causes lower energy use. This is logical since the policy, whose purpose is to help reduce energy use, would be part of the organization’s culture and operation and thereby exert a positive effect on its energy management efforts, resulting in lower energy use. Another explanation is that a lower energy use causes a policy to emerge, as if a water utility with already-low energy use would need a policy to make it even lower. This seems less plausible, leading one to favor the former explanation that the policy affects the energy use. The author acknowledges that policy presence may actually be a surrogate for a number of other causal factors that cannot be observed directly. Since cause and effect cannot be proved with the given information, the finding is expressed as a correlation and the determination of cause and effect should be explored in future work.

It follows, therefore, that voluntary, organization-specific policies should be recognized as important measures to conserve energy in the water industry. From the top down, it is recommended that federal and state government agencies regulating drinking water, electricity, and related resources encourage water utilities to develop, adopt, and implement energy management policies. From the bottom up, it is recommended that individual water utilities pursue energy management activities and that relevant policies be included, along with technical measures, in their overall energy management strategies. Sample energy management policies are provided in the supplemental material to this manuscript.

With or without energy-specific policies, water utilities have opportunities to reduce their energy footprints through deliberate energy management. Regardless of size, location, or energy use, most water utilities can decrease their energy use by 10% to 30% through cost-effective actions, according to estimates by the U.S. Environmental Protection Agency (EPA 2017; Horne et al. 2014; EPA 2013; EPA 2008), the World Bank (Liu et al. 2012), and the Alliance to Save Energy (2016). In recent years many water utilities have undertaken focused energy management programs and successfully reduced their energy use by 10% to 50% while still providing adequate hydraulic performance and water quality (Sowby et al. 2017; Sowby 2016; Jones et al. 2015; Jones and Sowby 2014). Interestingly, these theoretical and actual savings correspond with this study's result of a 10% to 47% difference in favor of water utilities with a documented energy management commitment. With scarcer water resources and stricter water quality standards, energy use in the water industry is expected to increase, making energy management a higher priority for water suppliers (EPA 2008). All water utilities stand to benefit from efforts to reduce their energy footprints and operate more sustainably.

CONCLUSION

This study compared the energy footprints of water utilities with and without energy management policies and found a statistically significant difference in favor of those with policies, which on average use about 30% less energy than those without. This finding suggests that voluntary, organization-specific policies should be included among other best practices for sustainably managing water utilities' energy use.

Further work may explore the cause-and-effect relationship of such policies. More comprehensive analysis of the policies and their development, contents, implementation, and acceptance is also recommended.

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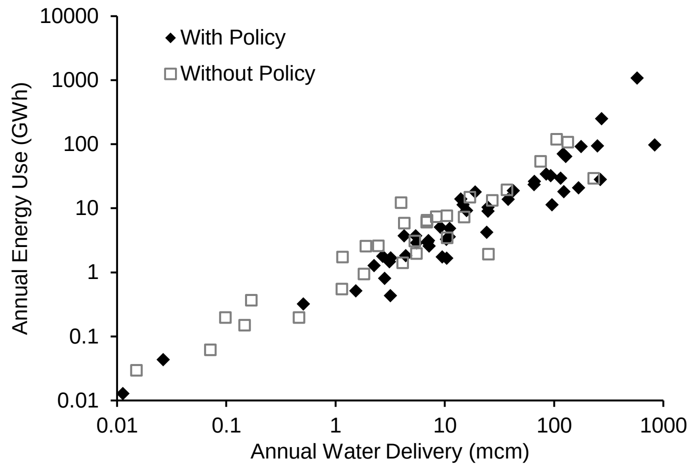

Figure 1: Energy Use of Water Utilities with and without Energy Management Policies

Table 1: Regression Model Results for Natural Logarithm of Water Utility Energy Use

Variable	**Coefficient**	***t***	***p***
Intercept	1.4	3.4	0.0013
Natural logarithm of water use in cubic meters	0.88	28	5.8×10^{-40}
Indicator of imported water supply (1 if over 50% of supply, 0 otherwise)	1.3	4.2	6.8×10^{-5}
Indicator of gravity-fed surface water supply (1 if over 50% of supply, 0 otherwise)	−0.88	−4.5	2.6×10^{-5}
Average annual precipitation in centimeters	−0.0039	−1.8	0.079
Average annual air temperature in degrees Celsius	0.029	1.7	0.094
Indicator of energy management policy presence (1 if present, 0 otherwise)	−0.37	−2.8	0.0062

Adjusted R^2 = 0.94
Coefficient: Value multiplied by variable in regression
t: *t*-test statistic
p: probability of exceeding *t* in null hypothesis