Review

Energy Management in the Water Sector: A Major Sustainability Opportunity

Robert B. Sowby [1,*]

[1] Hansen, Allen & Luce, Inc., 6771 S. 900 E., Midvale, UT, USA; rsowby@hansenallenluce.com
* Correspondence: rsowby@hansenallenluce.com; Tel.: +1-801-566-5599

Abstract: Reliable, high-quality water services are a substantial component of a state's or country's energy consumption profile. Although the water–energy nexus has received much attention in the past few years, relatively little work has addressed water systems' energy use, their potential for energy savings, or their empirical results of energy management. This paper surveys the literature on theoretical energy savings in water systems and compares the estimates with the outcomes of numerous case studies where water systems undertook energy efficiency projects and/or programs. The results in practice confirm that the theoretical estimates are indeed achievable; annual energy savings of 10 to 30 percent are typical among water utilities that pursue energy management. These savings come by capital projects, operational changes, and interagency coordination to deliver water by the most energy-efficient path. Such solutions often help improve hydraulic performance and water quality, showing that energy management is cost effective, prompt, and synergistic, a critical step in advancing sustainable water supply.

Keywords: energy, water distribution, hydraulic modeling, efficiency

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1. Introduction

The water–energy nexus has received considerable attention in the past 10 years. Much of the work has focused on the water intensity of energy generation, local studies of energy intensity for water services, and the research needs in this emerging field. Less work has addressed energy efficiency in the water sector.

Water services are a substantial component of a state's or country's energy consumption. Public water and wastewater utilities consume 2% of all U.S. energy, or about 2 quadrillion BTU annually [1]. Utah, the country's second-driest state, expends about 7% of its energy on water supply [2, 3]. In California, water consumes 19% of the state's electricity and 30% of its natural gas, underscoring the significance of the water sector's role in energy consumption, especially amid California's current multiyear drought [4, 5].

Water is a significant energy demand. As the challenge of managing water and energy resources continues to grow, energy efficiency in the water sector is a ripe sustainability opportunity.

2. Background

Historically, water suppliers have focused on providing reliable, high-quality water without necessarily considering energy requirements. Many have viewed a water system's energy footprint as fixed; several technical, financial, social, and political obstacles have dissuaded water utilities from pursuing energy efficiency [6]. Now, with increasing population, stricter water-quality standards, and rising energy costs, energy efficiency in the water sector is emerging as an optimal solution.

Indeed, "planning by drinking and wastewater utilities is increasingly considering issues of energy use," mostly for financial reasons [7]. According to the U.S. Environmental Protection

Agency (EPA), energy for water and wastewater services is the largest single cost for municipal governments and private utilities, accounting for over 40% of operating expenses; for small cities, the cost can exceed 80% [8]. The World Bank likewise acknowledged that "improving energy efficiency is at the core of measures to reduce operational cost at water and wastewater utilities" [9].

Looking beyond cost savings, the Department of Energy identified the optimization of water management, treatment, and distribution systems as one of its six strategic pillars in the water–energy nexus [10]. Water in the West concluded that "the energy deployed in water treatment and distribution is a principal target for reducing the embedded energy in the nation's water supplies" [11]. The EPA realized that "improved energy efficiency … will help ensure the long-term sustainability of our nation's water and wastewater infrastructure" [8].

2. Energy Management as a Solution

Efficiency is the most immediate, affordable, and environmentally beneficial solution to resource shortages [12]. For power providers, energy management is a least-cost resource; its levelized cost is two to three times less than conventional energy generation [13, 14]. Though power providers are aware of this difference and have targeted residential and commercial energy efficiency, potential savings in the water sector have been largely overlooked until recently. For water utilities, energy efficiency offers reduces their operation costs, shrinks their energy footprints, and improves public acceptance.

3. Theoretical Savings

Potential and theoretical energy efficiency savings for water utilities have been studied extensively, and most estimates indicate that savings of 10%–30% are possible through combinations of operational (no-cost) and capital measures. An EPA Region 9 pilot study found an average of 17% energy savings potential and 26% cost savings potential, regardless of a utility's size [15]; a Massachusetts pilot study identified an average 33% potential savings at 14 water facilities [16]. According to the EPA, water facilities can achieve up to 30% percent reduction in energy use through energy efficiency upgrades and operational measures [17]. The Alliance to Save Energy claimed that 25% savings are possible in most water systems worldwide [18]. The World Bank found that 10%–30% energy savings are common, with relatively short payback periods of one to five years [9]. The U.S. Department of Energy (DOE) observed that "energy usage in delivering water services represents a non-trivial portion of U.S. electricity consumption and may present significant opportunities for both efficiency and renewable generation" [10].

4. Actual Savings

Beyond theory, significant energy savings have been achieved throughout the United States as water utilities and engineers translate theory into action. See Table 1.

In Utah, Jordan Valley Water saved 3.9 million kilowatt-hours (kWh) with operational changes [19]. North Salt Lake's water system saved 32% through no-cost operational changes and Spanish Fork's water system saved 29% after a capital project [20]. Logan, Utah, reduced its water system's energy use by 32% and also observed a 17% decrease in water use and a 40% decrease in mainline breaks, demonstrating that energy efficiency has a synergistic effect that can support rather than oppose improvements in other areas [21]. A large pump station of Nashville's Metro Water Services used 30% less energy after an efficiency upgrade [22]. Equipment upgrades and operational changes saved significant energy at several Arizona water utilities [23]. Energy efficiency in wastewater treatment, though not discussed here, is likewise effective. These cases show that energy savings are not only possible but also catalyze other improvements. Several best practices and resources to help water utilities save energy are available [8, 10, 24–30].

Table 1. Water System Energy Efficiency Results

Water Utility	Location	Annual Energy Savings	Source
City of Yuma	Yuma, Ariz., USA	6,500,000 kWh	[23]
City of Flagstaff	Flagstaff, Ariz., USA	5,800,000 kWh	[23]
Jordan Valley Water Conservancy District	West Jordan, Utah, USA	3,900,000 kWh (10%)	[19]
Dublin San Ramon Services District	San Francisco, Calif., USA	2,232,000 kWh	[17]
City of North Salt Lake	North Salt Lake, Utah, USA	1,800,000 kWh (32%)	[20]
City of Holbrook	Holbrook, Ariz., USA	1,750,000 kWh	[23]
Spanish Fork City	Spanish Fork, Utah, USA	1,100,000 kWh (29%)	[20]
Logan City Water	Logan, Utah, USA	900,000 kWh (32%)	[21]
Carefree Water Company	Carefree, Ariz., USA	425,000 kWh	[23]
Metro Water Services	Nashville, Tenn., USA	30% (facility)	[22]

5. Discussion

To date, most of the literature and practice has focused on equipment energy efficiency at water facilities. While those advances are welcome, there many opportunities beyond the facility. A typical water system is a collection of water sources, treatment plants, pump stations, storage tanks, and other facilities that function not as discrete elements but as an interdependent system. Many potential water delivery paths exist, each with different energy requirements. The underlying assumption in the value of facility-specific equipment upgrades is that the facility lies along the most energy-efficient water delivery path. This is not always true, since in many cases there is a better way to deliver water by thinking "outside the box"—that is, thinking outside the facility—on a system level. For example, Jordan Valley Water saved energy by prioritizing its most efficient water sources, and North Salt Lake saved energy by adjusting pressure-reducing valves to keep water in the intended pressure zone without excessive pumping. Rather than undertake capital projects to upgrade certain facilities, both water utilities found a more efficient water delivery path that leverages their existing efficient facilities and avoids inefficient ones. The practice of water system optimization considers such system-wide possibilities and aligns energy efficiency with water quality and level of service, the three main constrains of public water supply [26].

The next level of optimization is thinking outside the system—forging mutually beneficial partnerships among neighboring water suppliers to give and take water in ways that lower the overall energy requirements. Several water utilities in the Salt Lake Valley area are negotiating such agreements, which may be the first of their kind.

6. Conclusions

Energy efficiency in the water sector is an untapped sustainability opportunity. Research and case studies demonstrate that energy reductions of 10% to 30% are typical for water utilities that pursue efficiency. Such solutions are cost-effective, prompt, and synergistic.

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