

## Key decisions for sustainable utility energy management

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### ABSTRACT

This paper summarizes the outcomes of the international sustainable energy management workshop as part of the Water Research Foundation project “Decision Support System for Sustainable Energy Management.” This paper provides a review of key decisions and barriers to water utility energy management. This paper also provides a discussion of a decision framework to address sustainable energy management in the water/wastewater industry. This work represents a 17 utility, international cooperative project, aimed at creating a Decision Support System (DSS). When concluded, the assembled tool is expected to help identify energy, greenhouse, and cost-saving approaches that will be of wide practical benefit to water utilities.

**Key words** | efficient use, energy management, greenhouse gas emissions, sustainability, utility management

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### INTRODUCTION

Many utilities have government or self-imposed restrictions on water supplies, water quality, water treatment, and water operations. However, few manage energy under analogous restrictions. Urban water systems require substantial energy input and most new water supply solutions and treatment technologies will involve further energy input, contributing to additional GHG emissions (Kenway *et al.* 2008). Energy is required for all facets of the urban water cycle from the collection, pumping and treatment of supply water, transmission and distribution, and wastewater pumping and treatment (AWWARF 2007).

In approaching sustainable energy management, utilities ask key questions, many of which a DSS could support. These may include questions about capital plans, forecasting future water supplies, improvements in regional operations, or investments in alternative energy and water and wastewater technologies.

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### Managing existing energy to greenhouse performance

Literature identifies a number of important activities and factors that affect energy and greenhouse gas emissions for water and wastewater utilities. The water and wastewater sector make a relatively small contribution to greenhouse gas emissions compared with other sectors. However, individual utilities can be some of the largest users of energy at a company level, and energy-intensive sources of water may increase energy use in the future.

In the United States, 3% of total electricity generated, or 75 billion kWh per year, is used by publicly owned water and wastewater utilities (Cohen *et al.* 2004). It is estimated that energy use in the water and wastewater sector will grow by 40% over the next twenty years, which will be driven by new regulations and population growth (Arpke & Hutzler 2006). In Australia, the water and wastewater sector is approximately 0.5% of greenhouse gas emissions, excluding

diffuse emissions (Foley & Lant 2007). A number of scenarios of future water supply from energy intensive sources indicate that energy use for utilities may increase significantly but will still not become a large contributor in the context of the Australian economy (Kenway *et al.* 2008).

Urban water systems will rely on substantial and increasing amounts of energy. Many management strategies focus on the energy of water and wastewater treatment and pumping but omit water end use. For instance, total emissions through the full life cycle of the water “product” are often overlooked (Racoviceanu *et al.* 2007; Kenway *et al.* 2008).

Literature identified various steps utilities are taking to reduce energy and GHG emissions that include (WSAA 2007):

- Avoiding energy use where other options exist to achieve the same outcome;
- Improving energy efficiency measures (e.g. deploying advanced control for operations optimization, implementing energy management systems, installation of variable speed pumps rather than fixed speed);
- Using wastes to generate renewable power;
- Sequestering carbon and purchasing carbon offsets;

### Pumping

Influenced by topology and distance, pumping represents significant energy use for many water and wastewater systems. For instance, in Australia (for cities such as Sydney, Brisbane and especially Adelaide), pumping energy is relatively large even when compared to water treatment energy. Albeit, cities such as Melbourne have lower pumping energy requirements as they rely on gravity for distribution from pristine sources. Variation in wastewater pumping is less irregular, as pumping accounts for less than half of the energy required for treating wastewater.

Energy used during pumping is additionally sizeable in the United States. For example, in Wisconsin, pumping water accounts for 85% of the energy required to (Kenway *et al.* 2008) provide drinking water. This percentage increases in areas utilizing only groundwater systems, or in areas where water treatment is not required (Elliott *et al.* 2003). In addition, utilities with complex transmission systems, such as those in Northern and Southern California face considerable pumping requirements. Pumping water

over the Tehachapi Mountains, the highest point of any water system in the world (Cohen *et al.* 2004), to Southern California requires significant energy, comparable only to desalination (Stokes & Horvath 2006).

Increasing the efficiency of pumping operations offers significant scope for reductions in energy usage. Opportunities include: installing efficient pumps and variable speed drives, and using effective instrumentation and controls to manage pumping operations. However, achieving universal approaches for energy efficiency is difficult given that energy use is not always a linear relationship to the volume of water transported or used. For example, pumps are more efficient when operating at design capacity, so a pump operating at half capacity will use more energy per m<sup>3</sup> of water pumped than one at design capacity (Cohen *et al.* 2004).

### Pressure reduction and leakage

Leaks result in significant water loss and account for misdirected energy use in many utilities. For instance, in California, typical losses for urban utilities range from 5 to 15 percent of total supply and can be as high as 30%. Reducing pressure can reduce leakage losses that in turn reduce water and energy, as well as offer a cost strategy (Girard & Stewart 2007). Leak control programs are efficiency measures explored by a number of utilities in Australia (QWC 2008; Schott & Cooper 2008). Moreover, integrating computer systems with the operation of the water system, including pressure and leakage management, saved Fresno \$725,000 per year in energy and water costs (Cohen *et al.* 2004).

### New water technologies

Changing water supply technologies will affect a utility's overall energy requirement. New water technologies such as desalination use large amounts of energy per unit of water produced, and their energy use is reflected in the cost for supply (Cohen *et al.* 2004). The amount of energy new technologies use depends on the quality of the input water and the process (Meerganz von Medeazza & Moreau 2007). However, it is expected that new technologies will likely increase a utility's energy footprint (Proust *et al.* 2007).

Increases in energy will come from new water treatment systems, more stringent water quality requirements, and

capturing and distributing alternative water supplies. For instance, desalination plants are often located on the coastline and considerable pumping is often required to distribute water inland (Kenway *et al.* 2008). Individual desalination plants can have a large impact on energy use for a whole region that in turn may place additional demand on water use to generate the required electricity. It is estimated that a new desalination plant in Sydney would increase the electricity consumption for the whole state of New South Wales by 1.5% (Australia Institute 2005). Desalination uptake has been impeded by costs associated with required capital investment, energy consumption, and operation and maintenance as well as environmental impacts associated with discharge of super-saline brine and increased greenhouse gas emissions. However, despite these impediments, increased pressure on traditional water sources is leading to increased desalination (Meerganz von Medeazza & Moreau 2007).

Other alternative water supplies may also require additional energy. Energy requirements for water recycling are a function of the treatment needed to treat wastewater to quality levels required by intended end use, and the energy required to convey treated wastewater to point of use (Cohen *et al.* 2004). Identifying the level of water quality required provides the opportunity to offset high quality potable water production through supply of lower quality water. The US and Australia provide examples where power stations, for instance, can use recycled water instead of potable water (Stokes & Horvath 2006; QWC 2008).

Existing supplies may also require additional energy with new water quality technologies. For instance, replacement of membranes can have significant energy and cost implications (Stokes & Horvath 2006). There is a trend in urban water services for more energy-intensive treatment methods of disinfection, such as ozonation and ultraviolet radiation for health and safety reasons (Elliott *et al.* 2003; Cohen *et al.* 2004).

### New wastewater technologies

Future trends in wastewater, such as new combined sewer overflow regulations, watershed recovery programs, and emission regulations will significantly influence energy use in wastewater treatment plants (NYSERDA 2008).

New technologies addressing these trends will have competing goals for utilities in trying to achieve increasingly stringent wastewater discharge limits, while at the same time reducing energy consumption (Gaterell *et al.* 2005). Achieving improved discharge performance will in most cases incur the cost of more energy-intensive treatment operations. Karlsson (1996) notes the need to consider all environmental burdens associated with different wastewater treatment processes in order to evaluate the most energy-efficient ones.

In many cases, larger centralized plants may offer more opportunities for efficiency, but this will be site-specific (Gaterell *et al.* 2005; NYSERDA 2008). Potential opportunities to reduce operational energy from wastewater treatment processes include use of renewable energy sources or energy from waste sources, and development of a high-efficiency mechanical and electrical plant. One potential alternative is the application of pre-treatment technologies with low energy requirements capable of reducing the organic load entering secondary treatment phases. An example of this is anaerobic reactors (Gaterell *et al.* 2005; NYSERDA 2008).

### Relation between energy pricing and water consumption

There is a strong relationship between the price of one resource and the consumption of another. For example, an increase in the price of electricity in Copenhagen, Denmark saw a reduction in residential water consumption (Hansen 1996 cited in Marsh & Sharma (2007)), while in the United States, reduced water prices encouraged water use that led to increased energy consumption (From: Schuck *et al.* 2002 in Marsh & Sharma (2007)).

Water use for energy supply—Energy production can be one of the largest industrial users of urban water. Reducing energy use has an additional benefit of reducing water consumption. However, the degree of benefit depends on the local energy production system. In 1995 in the United States, thermo electric power generators consumed 3.3% of urban water (von Uexküll 2004). In Australia in 2005, approximately 1% of total water consumed for power generation and water use for power generation increased by 6% from 2001 to 2005 (ABS 2006).

## Demand management and efficient end use

Demand management and end use efficiency measures such as water efficient showerheads and gas or solar hot water systems can reduce significant amounts of the energy and greenhouse emissions as used for the provision of water and wastewater services. For instance, in the United States, 93 to 97% of the energy consumed in the domestic water cycle was for water heating, and it was estimated that in 1990 over \$15 billion was spent heating residential water.

de Monsabert & Liner (1998) estimates that the breakdown of energy sources for residential water heating in the United States is 35% electric, 60% natural gas, and 5% others such as fuel oil and solar. In Australia, GHG emissions associated with operating household appliances linked with residential end use of water comprised between 90 and 97% of total system-wide annual GHG emissions (Flower *et al.* 2007). Moreover, in Australia, water heating accounts for approximately 85% of the combined system-wide energy of both the water and wastewater sectors. Water heating is also found to be dominant in the urban water cycle in cities such as Taipei. In addition, it was estimated that every time a resident runs a hot water tap to expel cooled water in the pipes, around 5.06 m<sup>3</sup> of previously heated water is lost (Cheng 2002).

Upgrading domestic water heaters from electricity to gas or solar could offset all of the energy use of water and wastewater utilities. Further, water-efficient shower heads can also save both water and energy (Kenway *et al.* 2008) and use of natural gas water heating instead of electrical water heating would reduce the energy consumed for water heating (Arpke & Hutzler 2006). Water utilities, such as Sydney Water, have run programs to install water-efficient shower heads and have earned carbon credits (Schott & Cooper 2008), and could offset all carbon dioxide emissions if implemented across the customer base (Lundie *et al.* 2005).

## Energy recovery

Utilities can offset much of their energy use by generating power through capture and use of methane (Karlsson 1996; NYSERDA 2008) or utilizing hydraulic head to generate power (Kenway *et al.* 2008). Many of the case study utilities discussed later in this report capture and generate power.

For instance, utilities such as Sydney Water, in Australia, currently have three large cogeneration plants and another five approved for construction (Schott & Cooper 2008). Sydney Water also has a number of hydroelectric plants approved for construction.

## Influence from climate change

The influence from climate change is still being evaluated, and how climate change will affect energy and water supply is uncertain. Effects range from increased energy needs to maintain facilities, reduced water availability and increased customer demand, to extreme weather and precipitation, and increased variability (IPCC 2008). A number of Australian water utilities have already factored reduced water yields due to climate change into their long-term planning. The effect on evaporation and end use patterns is also noted (QWC 2008; Schott & Cooper 2008). In East England, it has been found that water resources are vulnerable to climate change through increased temperature and changes to the distribution and amount of rainfall (Dessai & Hulme 2007), both potentially influencing operations and energy requirements. Climate conditions can affect energy requirements of processes, particularly where heating is required, such as the digestion process in a sewage treatment plant (Zhang & Wilson 2000). Moreover, peak energy and water demands often coincide, especially in hot dry summers, potentially causing shortages in both energy and water (Cohen *et al.* 2004).

The uncertainty around climate modeling and sensitivity of regional climate response raises the question of how much certainty is required in climate change projections to justify investment in adaptation measures. In order for long-term water resources plans to be robust to climate change uncertainties, there will generally be the need for higher investment in a multitude of strategies.

## Operational energy decisions

Operations at water utilities typically follow consumption and pressure management (Jentgen *et al.* 2007). That is, wells and booster pumps are automatically controlled based on reservoir levels and distribution pressures. Energy and cost savings are possible through the use of advanced control

systems designed to optimize energy cost and water quality. Energy management frameworks, such as the Energy Water Quality Management System (EWQMS) framework, provide a means to capture these benefits. An EWQMS is a collection of individual application software programs which provides information to decision makers to solve water quality and energy management problems associated with carrying out the company's mission (Jentgen *et al.* 2005).

### Barriers to implementing energy management decisions

The prospect of implementing sustainable energy management is significant. However, many barriers exist, requiring decision makers to pay special attention to implementation approaches to ensure both the ability to make a decision and that decisions are implemented. This section briefly discusses some of the barriers to energy management, GHG emission management, and organizational change.

Barriers inhibit effective energy management decisions throughout the utility organization. The following identifies a few of those that have been listed in literature, many of which have been identified by our utility case studies.

*Operational barriers.* Organizational staff typically have distinct roles in facility operations and crossover responsibility is limited. This segmentation of staff reduces the ability to implement broad energy management programs (NYSERDA 2008).

*Institutional barriers.* Water utilities are responsible for the provisioning of the urban water cycle and do not see themselves in the business of energy management. This creates difficulty in accessing energy data required for energy accounting and changing operations to maximize energy efficiency and cost (Jentgen *et al.* 2005).

*Regulatory barriers.* Energy is not currently regulated within water utilities, and compliance with water regulations often conflicts with optimal energy and GHG management options. Water managers often select conservative options (such as over-sizing pumps) to ensure regulatory compliance, or face resistance from executive management when opting for new technologies without a previous proven life cycle (Arpke & Hutzler 2006).

*Financial barriers.* Most utilities operate under constrained financial budgets and are either reluctant to

increase these budgets or are unable to do so due to regulatory constraints. Energy management is then tied to cost savings, not efficiency savings, creating difficulties for utilities to consider energy efficiency or GHG reductions that do not demonstrate cost savings (Golove & Eto 1996).

*Information asymmetries.* Information is often held within a single group and not available to managers to make appropriate decisions (Golove & Eto 1996). The lack of information makes it difficult to identify the full impact of a decision.

*Stakeholder barriers.* Similar to political barriers, utility managers must respond to stakeholder (e.g. customer, upstream/downstream utilities, government agencies) concerns that often conflict with energy management. While stakeholders may hold conflicting views, decisions are better supported when they are made in conjunction with stakeholder participation (Breuer *et al.* 2008).

*Risk management barriers.* Management concern over uncertainty is often stated as a reason for inaction (AWWARF 2008). While risk and uncertainty will always be present in energy management, a firm understanding of risk and how decision support can address risk, will allow decisions under uncertainty (Salewicz & Nakayama 2004).

### Decisions in literature

Literature highlights the focus of decisions utilities make in regard to sustainable energy management as: (1) energy consumption; (2) Greenhouse Gas Emissions; (3) Energy Generation or Recovery. However, these areas broadly encompass numerous questions facing utilities today. To refine these areas, the project conducted an international workshop, centred on the *key* decisions utilities make in regard to sustainable energy management

### WORKSHOP

In May, 2009 the project team conducted an international workshop in Denver, Colorado with seven water/wastewater utilities from Canada, the United States, UK, and Australia. The workshop included:

- Case studies of utilities that have gone through recent significant decision process for sustainable energy management;
- A synopsis of the existing tools analysis—for software tools that may be useful within the DSS;
- Breakout sessions to identify essential functional elements of the DSS;
- A summary discussion by the entire group.

### Case studies

The following case studies were presented in Denver Colorado, May, 2009:

*United Water.* United Water has a goal of achieving an 80% reduction in its carbon footprint by 2050. It has developed a carbon reduction plan and is already achieving some of its reduction. It has achieved its reduction to date using process optimization, advanced control and greater use of sewage gas in heating and power generation.

*Tarrant Regional Water (TRW).* TRW drivers for energy management include better control of energy supply and cost in the newly deregulated Texas energy market as well as being proactive for possible new carbon regulations. They have improved the efficiency of their pumping operation. They also have minimized required pumping and are making better energy purchasing decisions due to operations planning. They are adding a hydro power generation facility. In addition, they are looking into integration with the Dallas Water system to achieve further energy savings.

*Metro Vancouver.* Metro Vancouver drivers for energy reduction include provincial GHG reduction targets as well as a sustainable regional initiative. They have a GHG reduction target of 33% by 2020 as well as a goal of becoming a net energy contributor by 2015. They are striving to achieve these goals by (1) conservation and reuse; (2) maximizing energy recovery; and (3) sequestration. Their energy recovery plans include further biogas and hydropower use as well as waste to energy generation for their solid waste.

*Alexandria Sanitation Authority (ASA).* ASA has internal sustainability goals and has had significant increases in treatment levels that have increased energy use. They have a process to better manage energy.

The first step is to conduct an independent audit of energy use. They then will design improvements with a 15 year (or better) payback. They plan on using an ESCO (Energy Service Company) as a delivery and financing mechanism for implementation of energy saving projects. ASA also expects to incorporate efficiency, conservation, and resource recovery in future plant upgrades.

*American Water.* American Water's main driver for energy reduction is good corporate citizenship. In addition, they want to understand and control future energy needs and costs. As a first step, they are performing energy use and GHG audits. They have a 5-year plan for improving energy efficiency and reducing their carbon footprint. Improvements include better pumping system efficiency, more efficient lighting systems, and a new standard pump station design that is more energy efficient.

*Sydney Water.* Sydney Water identified the need for a strategic focus, the top 3 decisions (1) Embedded lifecycle greenhouse and energy costs; 2) Trade offs between treatment standards and energy/greenhouse; 3) Comparison of fixed vs. variable energy consumption), data input and output requirements as well as barriers to action.

*Yarra Valley Water.* Yarra Valley Water identified key decisions (servicing new areas and renewing/replacing existing infrastructure) and functional requirements (broad scope of sustainability for option selection and compatible with existing tools which include multi-criteria Analysis, Life Cycle Assessment, Net Present Value).

Following a facilitated discussion, the workshop identified key examples of decision types.

### Energy consumption

1. Control of energy performance and costs:
  - (a) Comparison of fixed vs. variable energy consumption;
  - (b) Procuring alternative energy supplies;
  - (c) Methods to reduce pumping energy;
  - (d) Methods to minimize Activated Sludge aeration energy use while maintaining treatment levels;
  - (e) Efficiency improvement of existing equipment.
2. Encouraging reduction in customer water use and its affect on the energy use of the utility:

### 3. New service area and/or treatment level and replacement of existing infrastructure:

- (a) Managing infrastructure (existing and new assets) using operational strategies;
- (b) Asset design for reduced energy use and GHG performance;

## Greenhouse gas emissions

### 1. Carbon and GHG management:

- (a) Tradeoffs between treatment levels and energy use/GHG emissions;
- (b) GHG implications of changing energy source mix;
- (c) GHG accounting.

## Energy generation or recovery

### 1. Best options for energy recovery and generation.

## DISCUSSION

The environment in which energy decisions must be made is more complex than ever. In appraising the potential to invest in new programs/infrastructure or the elimination of existing programs/infrastructure, a utility should not only consider the multifaceted costs and benefits of its options, but also the diversity of often conflicting viewpoints and concerns. The following summarize a few of the reasons why a Decision Support System is needed for sustainable energy management.

*Multiple objectives.* Energy decisions often requiring achieving multiple objectives such as minimizing energy costs and minimizing GHG emissions. Because often this cannot be achieved by a single action, it is important to evaluate the degree to which various options achieve each objective.

*Difficulty in identifying good options.* because many options are unknown to utilities, a good deal of investigation is required before utilities can begin the process.

*Intangibles.* Each outcome will possibly include levels of goodwill to the public, morale of workers, and support by upper governance. Although it is difficult to measure intangibles, they are often critical factors in deciding the best option.

*Lengthy time scales.* The consequence of many options could be observed over 5–100 years. Future implications of today's alternatives should be included in the decision making process.

*Many stakeholders.* Major decision often affect groups of people whose attitudes and preference greatly differ. Because of these differences, concern for equity contributes to the complexity of reaching an acceptable solution.

*Risk and Uncertainty.* With many options, it is not possible to predict precisely the consequence of each alternative. Each action involves risk and uncertainty—new technologies may fail, a new reservoir may break, government reorganization may result in inefficiencies, or a new energy supply may turn out to be less reliable than existing sources. Assumptions and risk levels must be developed for each option to adequately weigh decisions.

*Several decision makers.* One decision maker rarely holds all the cards with respect to major decisions. Several individuals, often in separate departments or organizations, control critical aspects in the final decision making process.

*Value tradeoffs.* Important decisions often involve critical value tradeoffs between the relative desirability of each option to achieve core organizational goals.

*Risk attitude.* A utility that is operating according to today's status quo may tomorrow be lagging in performance. Conversely, a utility that adopts an innovative strategy may have the risk of investing in options that never become an industry standard. Understanding the risk attitude of the organization is essential to appraise the appropriateness of accepting risk for each alternative.

*Sequential decision-making.* Decisions are rarely made isolated from the influence of other decisions. Choices today affect not only the outcome of the immediate decision but may open or close future options.

Complexity cannot be avoided when making decisions; it is part of the problem as well as part of the solution process. In any case, the process of making decisions is a difficult task that requires balancing the pros and cons. A DSS provides the assistance of a formal framework to guide the decision maker.

## DSS Framework

The purpose of a formal DSS framework is to establish a common and consistent approach to guide the decision

maker. The way in which energy decisions must be made is more complex and difficult than ever and involves a balancing of both the pros and cons of any decision. The DSS must provide an effective means for responding to emerging goals for reducing energy and emissions and the capability to influence a desired direction.

### Sustainable energy management decision process

The sustainable energy management decision process proposed by this research contains six steps for utilities to follow. The steps provide a strategic underpinning in the development of a plan by starting with an understanding of the utility drivers through the development of broad goals in regard to energy. This does not preclude strategies and decisions that are tactical and/or operational. These steps are summarized below:

- Step 1: Understand utilities drivers
- Step 2: Define broad goals
- Step 3: Define baseline (current and future) status
- Step 4: Determine potential options to meet goals
- Step 5: Analyze each potential strategy in regard to meeting goals
- Step 6: Finalize overall plan for attaining goals.

### CONCLUSIONS

As water and wastewater treatment processes become more energy-intensive, water utilities and resource managers are met with a significant challenge to identify the best strategic and operational energy management decisions to effectively manage and ultimately reduce energy consumption and resulting greenhouse gas emissions. This research identified key energy decisions and proposed a *Sustainable Energy Management Decision Process* to define the development of a form DSS tool.

When completed, the DSS will provide a tool to measure, evaluate, and document these steps in terms of energy use (equivalent KWH/yr), emissions (equivalent CO<sub>2</sub> tons/yr) and energy recovery/generation (equivalent KWH/yr). The goals for energy emission reduction (%) and timeframe for meeting these goals (e.g. 2020, 2030) will be defined by the users. Strategies to achieve these goals will address ways to conserve, optimize, create and/or trade

energy and emissions. Several water/wastewater utilities that are participating in this project will pilot the DSS tool in early 2010.

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