Saving water and spending energy?

This cross-cutting theme explores energy consumption issues and trade-offs faced by the recycled water case studies and by recycled water schemes more generally. The paper examines the energy intensity of treatment and distribution systems and strategies to reduce energy consumption.

Recycled water energy intensity is high by definition because the source water quality is low. However, energy intensity is further increased when schemes manage risk perceptions by treating beyond the level required. Finally, a systemic view is shown to be necessary in assessing energy implications: sites that report energy savings are benefiting from energy invested elsewhere, and consumers supplied with recycled water have higher water use.

This study is funded by the Australian Water Recycling Centre of Excellence under the Commonwealth's Water for the Future Initiative

ABOUT THE PROJECT

This national collaborative research project entitled "Building industry capability to make recycled water investment decisions" sought to fill significant gaps in the Australian water sector's knowledge by investigating and reporting on actual costs, benefits and risks of water recycling **as they are experienced in practice.**

This project was undertaken with the support of the Australian Water Recycling Centre of Excellence by the Institute for Sustainable Futures (ISF) at the University of Technology Sydney (UTS), in collaboration with 12 partner organisations representing diverse interests, roles and responsibilities in water recycling. ISF is grateful for the generous cash and in-kind support from these partners: UTS, Sydney Water Corporation, Yarra Valley Water, Ku-ring-gai Council, NSW Office of Water, Lend Lease, Independent Pricing and Regulatory Tribunal (IPART), QLD Department Environment & Resource Management, Siemens, WJP Solutions, Sydney Coastal Councils Group, and Water Services Association of Australia (WSAA).

ISF also wishes to acknowledge the generous contributions of the project's research participants – approximately 80 key informants from our 12 project partners and 30 other participating organisations.

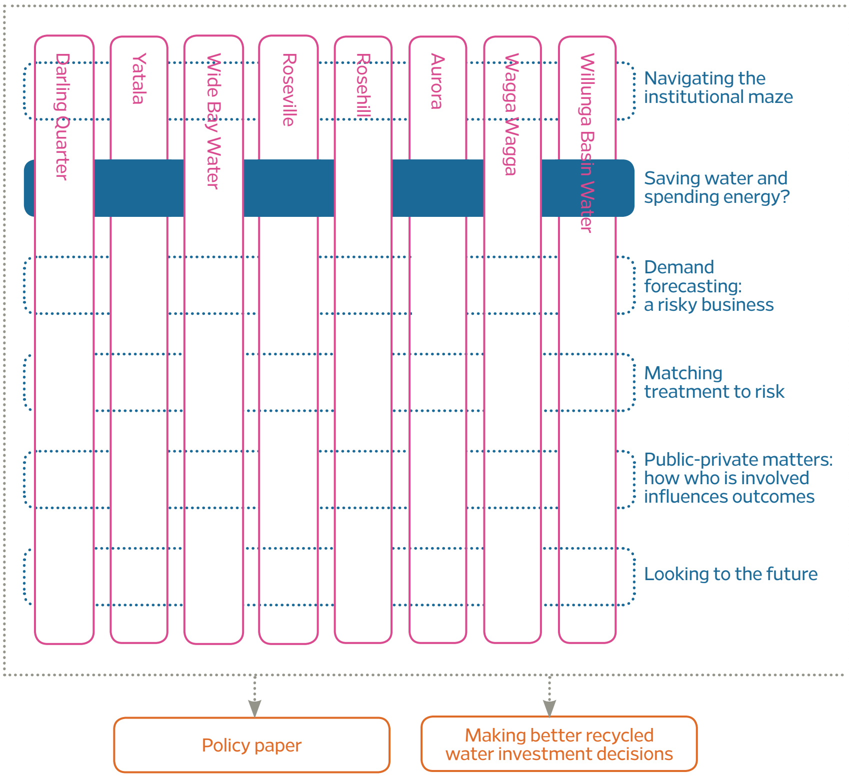
Eight diverse water recycling schemes from across Australia were selected for detailed investigation via a participatory process with project partners. The depth of the case studies is complemented by six papers exploring cross-cutting themes that emerged from the detailed case studies, complemented by insights from outside the water sector.

For each case study and theme, data collection included semi-structured interviews with representatives of all key parties (e.g., regulators, owners/investors, operators, customers, etc) and document review. These inputs were analysed and documented in a case study narrative. In accordance with UTS ethics processes, research participants agreed to participate, and provided feedback on drafts and permission to release outputs. The specific details of the case studies and themes were then integrated into two synthesis documents targeting two distinct groups: policy makers and investors/planners.

The outcomes of the project include this paper and are documented in a suite of practical, accessible resources:

- 8 Case Studies
- 6 Cross-cutting Themes
- Policy Paper, and
- Investment Guide.

For more information about the project, and to access the other resources visit www.waterrecyclinginvestment.com



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The Institute for Sustainable Futures (ISF) is a flagship research institute at the University of Technology, Sydney. ISF's mission is to create change toward sustainable futures through independent, project-based research with government, industry and community. For further information visit www.isf.uts.edu.au

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What about energy consumption?

The question "what about energy consumption?" is commonly raised with regard to new water infrastructure and with good reason. Frequently, recycling schemes or other water systems are put forward as 'greener' or more sustainable alternatives to conventional city water supplies. When sustainability is a driver for implementation, it is especially important to examine some of the other life cycle impacts. This cross-cutting theme paper discusses the energy consumption of the case study schemes within this project and describes the measures undertaken to reduce energy use. Energy use is discussed in the context of broader sustainability objectives and how these schemes compare with other water supply sources.

Reducing the energy consumed in treatment

Membrane technologies tend to have high energy consumption

Membrane bioreactors and other membrane-based treatment systems are frequently used in water recycling applications, including wastewater recycling and desalination. MBRs in particular are widely used in small to medium scale wastewater recycling applications. According to a U.S. study, the energy intensity of MBRs can be as high as 8 MWh/ML and as low as 0.7 MWh/ML (Gil et al, 2010).

High energy intensity represents an ongoing operational cost

Operation and maintenance costs are high for membrane treatment systems. This is primarily due to two key factors: membrane replacement and energy consumption. A study on membrane bioreactors in the United States found that energy represents around 34% of the overall operational costs, with membrane replacement at 28% and other repairs at 19% (Hirani et al., 2009). (See Figure 1). However, membrane use is growing globally, which means that the technology is improving rapidly, resulting in improved efficiency and lower costs.

> "So you add all of those things together – the ongoing comprehensive service costs and the energy that is required to run it – it's probably not the cheapest water you can buy."

A focus on energy yielded reductions at an in-building treatment plant

At the Darling Quarter in-building Moving Bed Bioreactor (MBBR) wastewater recycling plant, energy consumption was monitored closely from the time of commissioning. The building contractor and the treatment plant operator had contractually agreed on a guaranteed maximum energy consumption for the plant. However, both parties wanted to ensure that the plant was highly energy efficient and subsequently invested time and significant effort into fine-tuning the plant to reduce overall energy consumption. Figure 2 shows the energy intensity of the plant during its first eight months of operation. Initially, energy consumption was high, at around 7.2 MWh/ML, however, a series of incremental changes helped to reduce energy consumption down to 4 MWh/ML with an average of approximately 4.6 MWh/ML. It should be noted that energy intensity is affected by water demand, and this can account for the variation in energy intensity from month to month.

Figure 1: Membrane Bioreactor operation & maintenance cost breakdown for a 1 ML/day plant

(Source: Hirani et al., 2009)

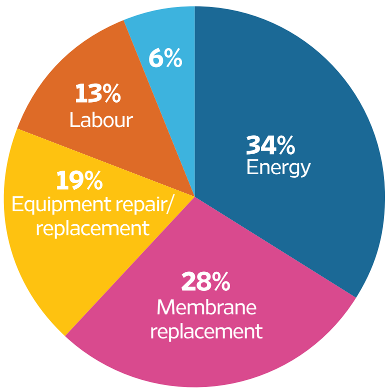
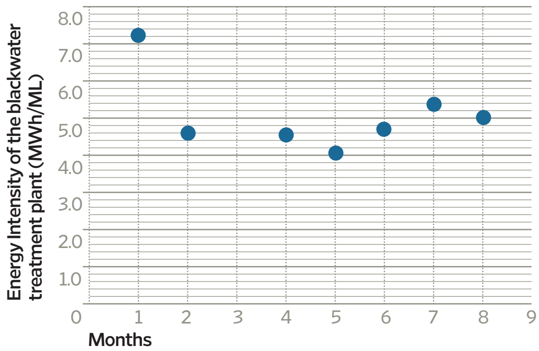


Figure 2: Energy intensity over time at an in-building water recycling plant



Note: The third month had an anomalous value of 30 MWh/ML and was excluded from the chart.

> " Small changes in the area of operation is where you can make the biggest wins"

Reducing energy intensity required an incremental approach

The strategy for reducing energy use at Darling Quarter was to make various incremental changes. Each adjustment or investment in saving energy that was proposed by the plant operators was assessed in light of the potential payback period and against other potential energy savings initiatives that could be carried out elsewhere in the building. In addition to their goals for NABERS energy efficiency ratings, the treatment plant operators saw the likelihood of future energy price rises as a major driver for minimising the energy intensity of the treatment plant.

> "As energy prices go up, water prices go up. If you can save 20% on your energy costs... Then the plants become far more viable"

Once the plant was operational, the plant managers undertook monitoring to identify the components that had the highest energy consumption. These tended to be blowers/aerators and pumps. Once these components were identified, the plant managers started testing the system by winding down the operations of each of these components in turn to find the levels of operation at which energy use could be reduced, while key operational parameters were maintained. As the plant is located within a commercial office building, water demand is significantly lower on weekends. This provides an opportunity to 'wind down' the operation of some elements of the plant. For example, the chlorine recirculating pumps do not need to operate continuously in the storage tanks if there is minimal water demand. Instead, the operators installed analysers in the storage tanks to assess chlorine levels, so that the water is only dosed with chlorine and pumped when required. This greatly reduces pump operation on weekends. A series of incremental changes such as this allowed the plant operators to reduce energy intensity by approximately 3 MWh/ML.

Optimising systems may require dedication from multiple parties due to differences in responsibilities

In the case of Darling Quarter, both the building contractor and plant operator were committed to reducing energy use, which greatly assisted the process of optimisation. Elsewhere however, the building contractor may not have much interest in the operating efficiency of the plant and/or the operator may not pay the electricity bills, which reduces their incentives to engage in energy saving initiatives. In the case of Darling Quarter, the interest in achieving 'as-built' Green Star energy efficiency ratings for and high NABERS ratings may have played a role in the drive for improvement.

Considering system-wide energy consumption

Energy consumption is not confined to treatment

Of course, energy consumption is not limited to treatment and the case study schemes had very different configurations in terms of treatment, transport and reuse application. High quality end uses such as at Darling Quarter (commercial offices) and Yatala (brewery process) require more energy intensive treatment processes than agricultural irrigation applications such as those at Wagga Wagga and Willunga. For example, for two secondary biological treatment plants within Wagga Wagga's agricultural reuse scheme, the energy intensity of treatment is 0.57 MWh/ML and 0.65 MWh/ML, which contrasts with the energy intensity for higher quality end uses (e.g. 4.6 MWh/ML at Darling Quarter). The schemes with higher quality end uses also tended to be on-site plants, operating with space constraints.

A couple of the case study schemes involved both high quality (energy intensive) treatment and significant energy for distribution. At Rosehill, secondary treated wastewater is transported approximately 17 kilometres before being treated by MBR and RO and then distributed through a 20 km network pipeline to urban industrial customers.

Ordinarily, irrigation reuse schemes require less intensive treatment; however the irrigation reuse scheme at Hervey Bay is unusual in that at least part of the scheme was built in readiness for potential potable reuse. It therefore consists of a network of treatment plants, some of which produce B class water and one of which provides A class water. In addition to the pumping energy required to distribute the recycled water product, the higher quality water supply in the mix is likely to be more energy intensive. The plantation irrigation system at Hervey Bay is estimated to use around 0.6-0.7 kWh/kL for pumping alone.

Schemes can be designed or reconfigured to reduce distribution energy consumption

Improved network pumping configurations can reduce energy consumption, even for smaller schemes. At Roseville the shift from potable water to a stormwater harvesting scheme provided an opportunity to reconfigure the golf course and oval irrigation system and to remove some cases of 'triple handling' where water was pumped, stored and re-pumped at different locations before use.

At Yatala, the brewery that set up a new facility on the edge of a small town was faced with the choice of waiting for a municipal trade waste treatment scheme or building its own scheme. By choosing to develop its own on-site recycling scheme, the brewery eliminated the energy costs associated with pumping its trade waste to a municipal plant and as a result, it greatly reduced the volume of potable water required at its plant.

Higher energy consumption was a trade-off for reduced health and demand risks

In several cases, including Darling Quarter and Rosehill, more energy intensive treatment processes such as reverse osmosis (RO) were added to the treatment trains in order to significantly minimise treatment quality risk (see the cross-cutting theme on ‘Matching Treatment to Risk’ for more on this issue of risk perception). In the case of Darling Quarter, the required treatment standards could be achieved without RO, however it was decided to add an RO unit to enable several extra ‘log removals’ and significantly reduce any treatment quality risks. A disadvantage of this approach is that RO-quality water is devoid of salts and as a consequence can corrode valves and tapware. To mitigate this problem, a calcite bed was added after the RO unit to reintroduce salts to the water.

At Rosehill, RO was initially introduced to the treatment plant design so that the treated water could be available for indirect potable reuse (IPR) in the future, and the scheme could potentially be accessed by residential users beyond the industrial scheme. However, community attitudes to IPR have meant that this aspect of the scheme has not gone ahead. The addition of RO to the treatment train did however enable Sydney Water to secure at least one industrial customer who required high quality water. Other customers have also reported benefits from using the low salt, high quality water, due to reduced requirements for on-site water treatment and a greater ability to use the water in cooling systems. In these cases, a high level of treatment, with higher energy use, was an accepted trade-off for risk avoidance.

Energy savings on-site reflect energy increases off-site

In the Rosehill scheme, several customers reported significant operational savings in energy and chemicals. The quality of process water required by these industries is unlikely to have changed – what has changed is the location where the investment of energy is made. That is, the recycled water has a much higher embodied energy content than the potable water previously supplied, so less on-site treatment is required.

Taking a systemic, life cycle view of the embodied energy of water is essential to determine whether there are real improvements overall, or whether there is a just a distributional shift in where the energy is being invested and who is investing.

Energy intensity for city-wide supplies

Energy consumed in water servicing for cities varies by source as well as geography

In considering the energy consumption of distributed recycled water schemes it is worthwhile comparing the energy intensity of other water supply sources, while also taking into account the energy associated with distribution, and recognising that the overall energy intensity of water delivered varies geographically across cities. In Table 1, the energy intensity associated with water treatment and delivery from various supply sources is shown. The major desalination plants built in a number of Australian cities feature as the highest energy

Table 1: Energy intensity from a range of water supply sources

(Adapted from table in Knights et al., 2007)

WATER SOURCE	kWh/kL	REFERENCES
Surface water storage e.g. Sydney’s Warragamba	0.25	(Sydney Water, 2002)
Rainwater tanks	1.5 - 2	(Retamal et al., 2009; Sydney Water, 2012; Tjandraatmadja et al., 2012)
Inter-basin transfer (Shoalhaven to Sydney)	2.4	(Anderson, 2006)
IPR (SEQ)(treatment only)	1.1*	(Cook et al., 2012)
Large scale Indirect Potable Reuse	2.8-3.8	(NSW LC, 2006)
Desalination (SEQ)	3.3	(Cook et al., 2012)
Desalination (Sydney)	4.9	(TAI, 2005)
Desalination (Adelaide)	5	(SA Water, 2008)

*Treatment only

consumers. Indirect potable reuse or high quality wastewater recycling appears slightly less energy intensive, however it should be noted that the examples given here are for major city scale schemes. At the household scale, rainwater harvesting systems generally have lower energy intensity than wastewater recycling.

While Darling Quarter has a highly energy efficient in-building treatment plant, its energy intensity is similar to that of desalination. Considering the effort required to reduce the energy intensity at DQ, this suggests that a focus on reducing energy use might be particularly important for small treatment plants with high water quality parameters.

The total energy intensity of water delivered also depends on the distance travelled and local topography. Many water utilities now have maps of energy intensity for water delivered to different locations within a city. For Sydney, total energy intensity (from treatment to tap) varies from 0.25 MWh/ML in the central area to 1.5 MWh/ML on the suburban fringes. In a couple of outer suburban areas, the energy intensity of water delivered is up to 2 MWh/ML (Sydney Water, 2012). Distributed systems need to be considered in this context, particularly if they are located in urban fringe areas which are energy intensive to service, regardless of whether the supply comes from surface water or recycled water.

Water supplies for Australian cities are influenced by more energy intensive sources

Cities in Australia tend to rely on major surface water sources such as dams and gravity fed distribution systems, which require minimal energy in treatment and distribution. A decade of drought changed this, as major cities invested in desalination, inter-basin transfers and recycling. Figure 3 sets out the energy intensity of water supplies and wastewater treatment in Australian urban centres in 2009/10 (after the drought had ended). At this time, several desalination plants had not yet come online (Melbourne, Adelaide) or had only operated for a short time (South-East Queensland, Sydney). In Sydney overall energy intensity was low at 0.5 MWh/ML as inter-basin transfers from the Shoalhaven had stopped and the new desalination plant only operated for a few months before being switched off.

Perth had the highest overall energy consumption at around 1.1 MWh/ML due to the use of energy intensive water supply sources, namely: desalination and groundwater extraction. The desalination plant in Perth produced just 12% of Perth's water supply, yet it was responsible for 82% of the energy consumption associated with treatment. Distribution energy consumption was less than half the energy required for treatment (Cook et al., 2012). This demonstrates that while alternative sources may only make up a small proportion of water use, they can have a significant impact on energy consumption.

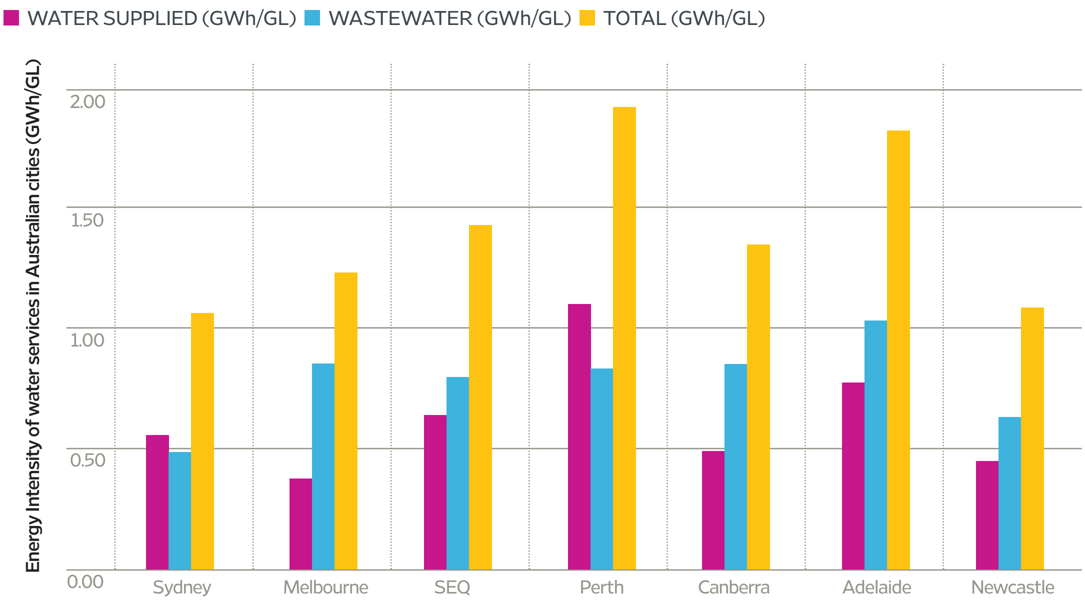
Cleaner energy sources

At several sites cleaner energy sources have been used to minimise both carbon emissions and the costs associated with new water supplies

Some schemes have installed alternative energy sources to mitigate the extra energy requirements. For example, at Roseville the council installed solar panels to cover the

Figure 3: Energy intensity of water services in major Australian cities in 2009/10

(Source: Cook et al., 2012)



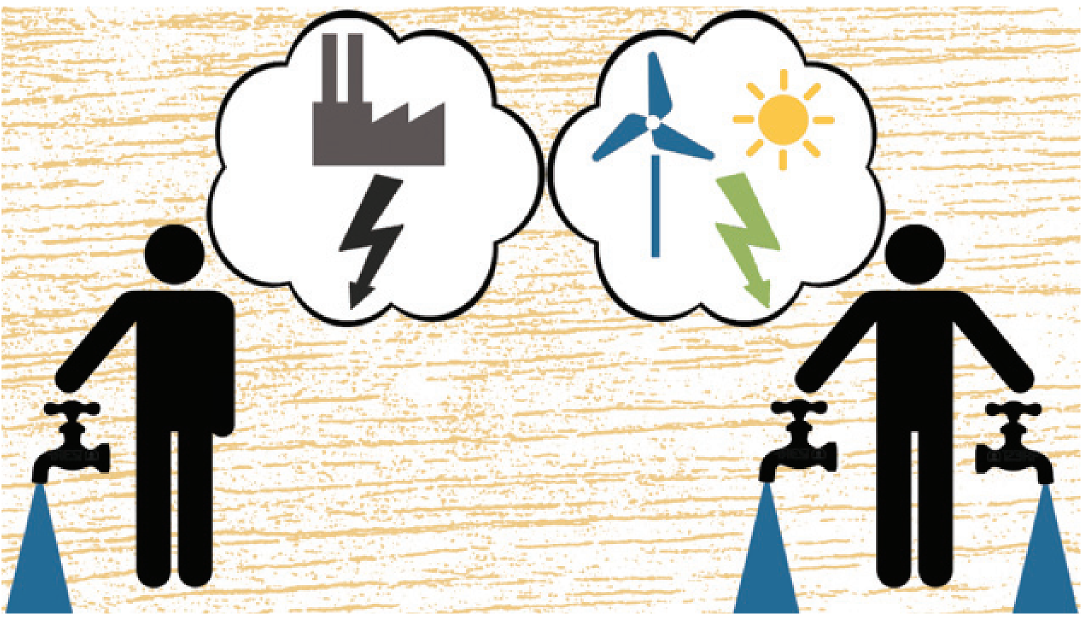
stormwater scheme pumping requirements and at Darling Quarter the scheme uses electricity generated by a natural gas powered trigeneration plant. At Darling Quarter, the energy supplied through trigeneration is about a quarter the price of conventional electricity supplies. At Yatala, the Upflow Anaerobic Sludge Blanket (UASB) system recovers 90% of the energy contained in the wastewater in the form of biogas. This biogas is then used to power the boilers at the brewery. The use of biogas generated on-site provides savings in energy worth $500,000 per annum.

The reduction in carbon emissions gained through cleaner energy can be negated by excessive demand – efficiency remains important

As shown in this case study, the energy intensity of alternative water sources is higher due to the low quality of the initial source water. However, energy intensity in these cases can be reduced by treatment and distribution system optimisation. While some schemes use cleaner energy sources, such as natural gas trigeneration or biogas, these fuels still produce carbon emissions. With alternative water or energy supplies there can be a tendency to use these resources more freely. For example, at the residential Aurora greenfield recycled water scheme, it was found that residents used 10% more water than expected outdoors, probably because they knew they were using recycled water rather than potable water. In these situations, it is critical to maintain efficiency in both water and energy consumption, as the benefits gained from using a cleaner energy source can be lost if overall use increases.

Summary

Membrane treatment technologies typically have high energy consumption and this contributes to high operational costs. However, as knowledge and experience with small scale membrane treatment systems expands, efficiency is improving. A dedicated approach to improving energy efficiency at one of the in-building case study schemes yielded a 36% reduction in energy intensity. The managers of this plant undertook monitoring to identify the highest energy consuming components and then adjusted the operational settings of these components to optimise energy consumption and treatment quality. Energy use needs to be considered in all aspects of a water recycling scheme. Schemes with high quality end uses tend to use more energy in treatment and schemes with high quality end uses in addition to long pumping distances are likely to be much higher still. Similarly, energy investments to produce high quality water for industrial uses need to be viewed systemically – on-site savings reflect off-site investments. The energy used by distributed schemes needs to be considered in context with other alternative water supply technologies and with reference to geographical location. Within cities there can be significant variation in pumping energy intensity, which can make distributed treatment systems relatively less energy intensive if distribution energy use is low. While cleaner energy sources are popular and can reduce carbon emissions, care needs to be taken to ensure that total water consumption does not increase due to perceptions about "green" a water supply source. In other words, recycling water and cleaner energy supply sources can provide environmental benefits, but this is contingent on maintaining efficient use of both these resources.



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