Determining key factors and challenges that affect the future of water reuse

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ABSTRACT

Long range planning for water reuse is very complex due to the interplay of numerous factors. A multi-faceted study was conducted to improve the understanding of these factors, to analyze how different scenarios of the future may affect these factors and water reuse, and to help determine which of these factors and issues are most important to address in order to ensure that water reuse is a successful water supply option in the future. This paper follows a series of surveys, expert workshops and scenario studies that were conducted, with the goal of refining a list of factors and issues that affect water reuse down to a few key items. From this process, the following aspects were concluded to be most important to focus on because they have the most impact, and thus will affect the future of water reuse the most: expanding the perceived role of water reuse; taking action to improve public acceptance; creating a supportive regulatory and legal environment; integrating resource management; expanding economic analysis; considering energy, climate and sustainability issues; creating water reuse institutions and associations; and, encouraging technology advancement and innovation. Discussions of these issues, along with suggestions for further research and innovation are included.

Key words | expert workshop, factor and issue analysis, research suggestions, scenario study, water reuse

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INTRODUCTION

Fresh surface water and groundwater resources can only provide a finite quantity of clean water. Population growth, climate change, and regional droughts are placing increased pressure on the balance between water supply and demand. This leads to widespread concern that there will not be an adequate supply of freshwater in the future. It is therefore increasingly necessary to expand the available water resources through water reuse and desalination.

When entities consider water reuse as a water supply option, there are a number of technical, environmental, institutional, legal, and socioeconomic issues that need to be addressed. These include determining how to integrate water reuse into existing institutional structures, ensuring that reclaimed water does not negatively affect public or environmental health, reducing the energy intensity required for some treatment techniques, encouraging public acceptance of water reuse, and addressing water rights and other legalities.

In addition, effective water reuse practices vary widely from one location to the next. This is because each location has unique characteristics, such as its geography, climate, infrastructure, government, available water supply, and water demand. In addition, each installation involves different water reuse applications, technologies and standards. This diversity makes projecting future needs for water reuse very challenging. It is essential that a careful strategy for the development of water reuse is devised that incorporates all of these concerns in order to ensure that water reuse is a substantial and sustainable part of water supply solutions in the future.

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To help determine how to best advance water reuse over the next 20 years, a study was conducted to help improve the understanding of these issues and their interactions, to analyze how different scenarios of the future may affect water reuse, and to help determine which strategies and research foci will best serve the water reuse industry over the next two decades (Linden *et al.* 2012). The main components of the study include a survey completed by entities that are currently practicing water reuse or utilizing reclaimed water, expert elicitation, and qualitative scenario studies. Each of these components built upon the results of the previous step. Thus, the qualitative scenario studies were the culmination of the study, developed from the conclusions drawn from the survey and expert elicitation. This paper provides an overview of the main factors, issues and challenges that were found to affect water reuse most. In addition, there is discussion of the conclusions reached as a result of this study and a summary of the strategies that were determined to be most important for the next 20 years of water reuse.

METHODS

As can be inferred from the discussion above, water reuse planning and implementation depend upon numerous complex and interrelated factors. Every time reuse implementation is considered, there is a unique set of characteristics that describe that location's infrastructure, technology, social structure, government, available water supply, demand, climate, needs and objectives. When these many considerations are considered over time for planning purposes, it can be overwhelming, and perhaps stymying, to determine which of these factors is most important to focus on. Therefore, it would be helpful to know which would be best to focus on. Multiple methods were used to help discover which factors have the most impact upon water reuse, and are thus most important to consider. These methods include surveys, expert workshops, qualitative scenario studies, and statistical analysis. The philosophy behind using multiple methods was to start broadly, including as many factors as possible, and using the subsequent methods to reduce the number of key factors that must be considered in order to attain a small subset of factors with the most influence over water reuse. It was hoped that multiple methods will provide some agreement as to which factors are most important.

Survey participants identified critical drivers and factors affecting water reuse from a list that was compiled from literature review. This list of factors and drivers was further analyzed and refined over the course of the expert workshops. Scenario studies and group discussions were used to analyze these factors to determine which of them are most critical to focus upon over the next 20 years. Those determined to be most important became the key factors in illustrative scenarios. The illustrative scenarios were used to further refine the list of key factors and identify some key challenges that the water reuse industry needs to focus on during the next 20 years. An overview of each method follows.

Surveys

A survey was developed to provide a view of the current and future state of water reuse according to the viewpoints of member utilities of the WateReuse Research Association, water reuse providers in the Water Services Association of Australia (WSAA), and utility participants in the expert workshops. It sought to determine where and how water reuse is being implemented and what plans and concerns there may be regarding water reuse in the future. Surveys were sent to over 180 United States participants, with 108 completed from 78 different entities. Of these 78, 69 of them produce reclaimed water. Participants included municipalities, utilities, consultants, government, regulating agencies, researchers, wholesalers, and industrial representatives. In Australia, surveys were sent to all 35 members of WSAA, with nine replies received, each from separate entities. The results of surveys formed the basis of subsequent workshop discussions.

Expert workshops

The first of two expert workshops convened in Denver, Colorado in June 2009. Attendees included representatives from government, professional societies and research foundations, utilities and municipalities practicing water reuse,

academia, and consulting. The workshop consisted of a series of plenary and breakout group sessions with the goal of painting a picture of the state of water reuse in the year 2030, focusing on the issues of water supply and demand, as well as environmental, energy, social, and economic conditions. Workshop participants discussed these issues, identified factors that influence them, analyzed how scenarios of the future may affect them, and identified which strategies and research endeavors need to be pursued. From these discussions, over 50 different factors that affect water reuse were identified. These fell into the categories of social, political, institutional, regulatory and legal, technology, energy, water, research, economic, and environmental issues.

The second expert workshop was held in Brisbane, Australia in September of 2009. Attendees included representatives from government, professional water societies, utilities and municipalities practicing water reuse, academia, and consulting. The workshop consisted of a series of plenary and breakout group sessions, building upon the outcomes of the first workshop, with the goal of enhancing the previously depicted state of water reuse in the year 2030, focusing on various factors that affect water reuse, and incorporating international views. It was also discussed how these factors affect each other, which may in turn determine how water reuse practices are utilized. They also debated how the influences of these factors would be affected under different scenarios. From these discussions, a list of conditions and challenges that may influence water reuse over the 20 years until the year 2030 was developed, and suggestions for adaptive strategies and research opportunities were provided.

Scenario studies

The future of water reuse and how different factors may affect it was investigated during the expert workshops using scenario analysis. The Intergovernmental Panel on Climate Change (IPCC) created the IPCC Special Report on Emissions Scenarios (SRES), which are based upon four storylines (A1, B1, A2, B2) which became 'families' of scenarios (IPCC 2000). Each storyline encompasses a distinctly different direction of future development. (Figure 1 shows how the states of different factors change under each storyline.) These IPCC scenario families were used to create scenarios to help investigate how different 'worlds' in the year 2030 may affect water reuse practices.

While the IPCC scenarios are centered on climate change impacts and adaptations, they also cover aspects such as demographic, economic, and technological change. In addition to information from the IPCC scenarios,

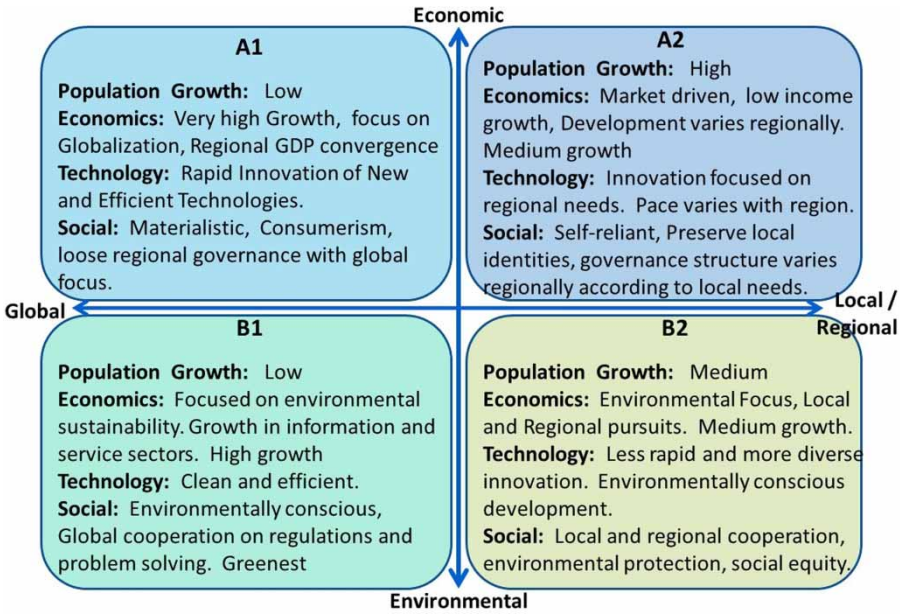

Figure 1 | The basis for the four major IPCC storylines, which formed the basis of the Water Reuse 2030 scenario studies.

criteria from other scenario studies were combined in order to make the scenarios used in the expert workshops applicable to water reuse. Downscaled GDP (gross domestic product) and population data were incorporated from Columbia University (CIESIN 2002). Water withdrawal information was provided from a study by Shen *et al.* (2008) that used global climate models and the IPCC storylines to create water use scenarios that correspond with the A1b, A2, B1, and B2 IPCC scenarios. Some of the future water reuse and resource management trends are derived from a scenario study by Makropoulos *et al.* (2008). Another scenario study performed by the International Food Policy Research Institute and the International Water Management Institute is used as a basis for determining the outlook of future water and food issues (Rosegrant *et al.* 2002). In all, there were ten different attributes that were categorized for each of the four different scenarios. These attributes included: population growth; economics; technology; energy; climate change policy; social issues; institutions, legal and regulatory issues; water use; water stress; and public attitudes about water.

Each scenario was evaluated by multiple breakout groups in order to discuss the state of water reuse in each possible future, identify influential factors, highlight the challenges that will confront water reuse, and deduce research efforts and other actions that should have been taken in order to better facilitate water reuse.

RESULTS AND DISCUSSION

This section will provide an overview of the results obtained from each method. The surveys involved a very large number of factors that were identified as impacting water reuse. In the first expert workshop, the results of the survey informed the factors that were focused upon. The conclusions from the first workshop were used to narrow the focus of the second workshop. The second workshop resulted in a list of challenges and opportunities that face the water reuse industry, and a much more condensed list of the key factors that influence water reuse the most. Considering the outcomes of the surveys and the expert workshops together, there were some factors that were always identified as being very important. These are the points that form the basis of the conclusions of this paper.

Surveys

In the surveys, participants were asked to rank how critical certain factors and issues may be in water reuse over the next 20 years. These issues are listed below, from the most to least critical, in Figure 2.

Participants in both nations felt that maintaining an adequate water supply will be the largest challenge faced. Other issues such as lack of funding, pricing structures of water services, and unsupportive regulations were ranked the same in both countries. The order of ranking of the other issues reflects the conditions in those countries at the time of the surveys. For example, poor public perception is predicted to be more critical in Australia, which is likely due to several water recycling projects there that recently have not been implemented due to public perception issues derived from opportunistic political and press comments. Climate change is also an important issue in Australia, which explains why it was ranked to be second in importance. On the other hand, water entitlement issues are much more of an issue in the United States, especially in the West, which explains why it is towards the top of the list for that country, whereas entitlements and allocations are more clearly defined and differentiated in Australia. Additionally, participants were given the opportunity to list any other specific issues they felt were important for the future of water reuse. Nearly 100 specific issues were added to those listed above in the categories of: energy; technology; institutional, legal and regulatory; economics; public perception, agriculture; water resources planning; and water treatment.

Expert workshops

Clearly, the surveys did not provide enough information to determine a small subset of factors that are most important for water reuse. Thus, more analysis was conducted in the expert workshops. Participants in the Australia expert workshop were asked to rate factors for how much they impact water reuse practices. The ratings were done on a seven point Likert scale ranging from no impact to 'very high'

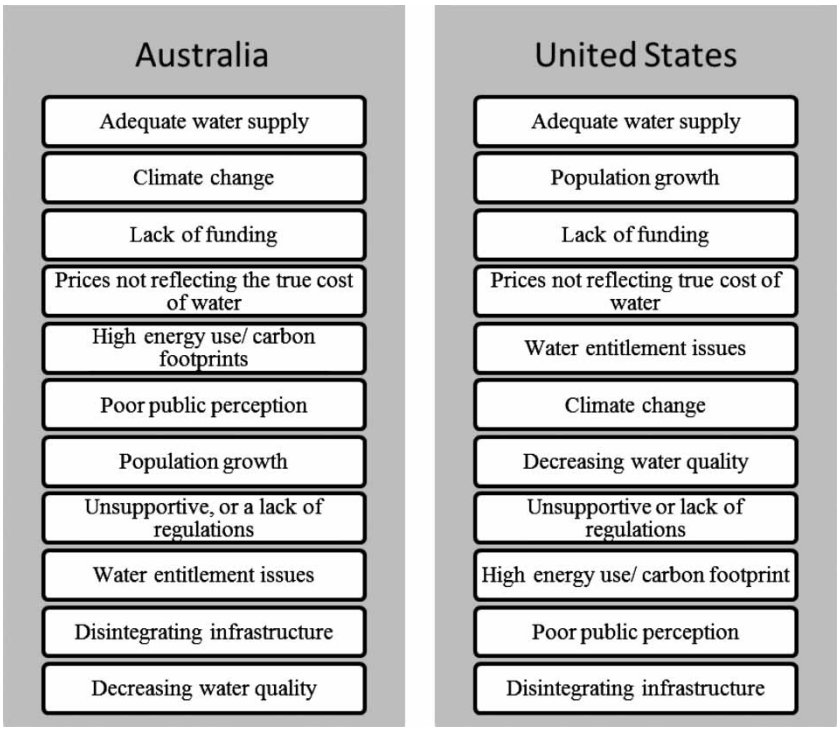

Figure 2 | Critical issues that the water reuse industry will face in the next 20 years: the issues were identified in the surveys administered in each country. They are listed in the order of their rankings received, from the most critical to the least critical.

impact. The average ratings for each of the factors as rated by the Australia Workshop participants are shown in Figure 3.

Note that the average rating for every factor is at or above moderate. This is due to a bias that was implicit. All participants in the workshops had some current involvement in water reuse, and all of the factors rated were initially included because they were deemed important. The factors related to the effects of water availability and demand, along with environmental factors, such as climate change, have the highest rating. Thus, the experts involved found these factors to have the most impact upon water reuse practices. These same factors also show the most agreement between raters because the spread of ratings provided is the smallest.

Scenario studies

For each scenario analyzed, many different factors were found to have the most impact, and multiple courses of action were identified that would be of benefit to the water reuse industry to pursue over the next 20 years. From these analyses, a few key factors and courses of action emerged as more important for promoting water reuse, regardless of which future was being considered. These are as follows:

1. *Research and innovation*: A continued flow of science and innovative solutions that is well collaborated is required to enable effective establishment and sharing of a knowledge base. There are many more questions and needs that need to be addressed.
2. *Regulatory support*: More supportive regulations that are directly applicable or attuned to water reuse, rather than those that address it as an afterthought.
3. *Public communication and education*: Thoughtful, careful use of language and images that represent water, wastewater, and water reuse in a favorable way need to be developed for use when educating and communicating with the public, both formally and informally.
4. *Economics*: More accurate (true market economy) pricing, inclusive of externalities, that will help show the long-term economic benefit of water reuse, and support operations.

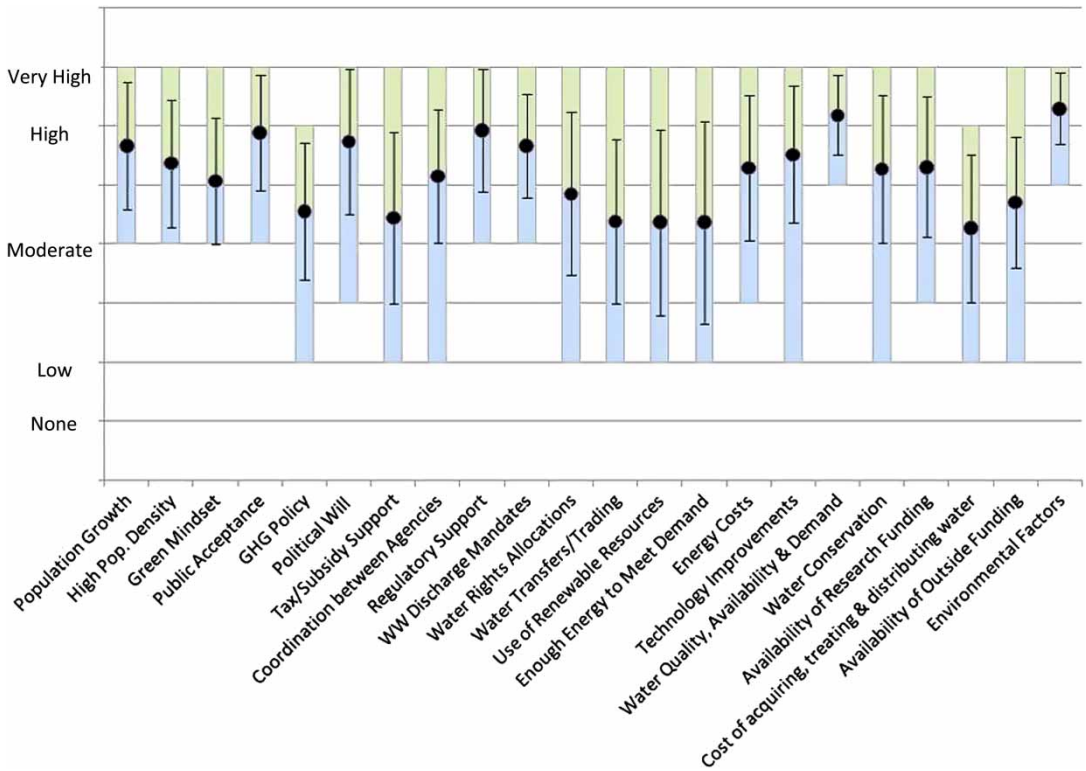

Figure 3 | Impact analysis of key water reuse factors. Factors are divided according to broad categories. The dot indicates the average rating, and the whiskers indicate the standard deviation. High and low ratings are shown by the extents of the shaded areas.

5. *Resource management*: Integrated management of water and other resources in which reuse is an essential element.
6. *Advocacy*: Water professionals, institutions, professional associations, representatives, lobbyists, and research organizations need to be utilized to educate others, pursue legislation, develop regulations, assist in planning and policy writing, and coordinate and fund research.

CONCLUSIONS

While investigating the multitude of issues, factors, and challenges that affect water reuse, it was possible to identify a small subset of factors and needs which were found to be important with all of the methods. Therefore, it follows that these particular factors and needs are very likely the most important for researchers, planners and water reuse practitioners to focus on for the next 15–20 years. These aspects include:

- expanding the perceived role of water reuse;
- taking action to improve public acceptance;
- creating a supportive regulatory and legal environment;
- integrating resource management;
- expanding economic analysis;
- considering energy, climate and sustainability issues;
- creating water reuse institutions and associations; and
- encouraging technology advancement and innovation.

Continued research and innovation in these areas can help to ensure that water reuse is an effective water provision solution in the future. These aspects along with related suggestions for research and advancement are discussed below.

Expanding the perceived role of water reuse

It is necessary that water reuse moves beyond being seen as another step in conserving and treating water. Instead, it needs to be introduced as a way to recover important resources such as water, energy, nutrients, salts, and other

constituents. Also, the source waters that are seen as typical for reuse installations need to be expanded to include stormwater, agricultural runoff, power plant evaporation water, and graywater, in addition to treated wastewater effluent.

Taking action to improve public acceptance

It is necessary to develop 'advanced technologies' for helping the public recognize the value of water, and give people the opportunity to participate in decision making processes. To enable this, there needs to be a shift in the current techniques of educating and communicating with the public. Water professionals, governments, and other individuals and entities need to take a more participatory approach, and communicate using clearer words that avoid technical jargon. Using clearer language could include focusing on how we use water, what we put in water and how we take those things out; promoting the use of the right water for the right use; and discussing how risks are minimized by doing so. In addition, the word 'water' should be used to indicate all water, whether it is at a wastewater treatment plant or coming out of the tap. To better communicate risk, there needs to be information that describes the qualities of different waters that are used for different purposes, along with non-threatening but honest information on the risks of each of these different waters. The benefits of water reuse, such as increased water supply, reservoirs, walking trails, and wildlife areas need to be highlighted. Additionally, this information needs to be provided in a context that will allow the public to understand how all of these components relate to the water management decisions that will be faced now and in the future. There needs to be further investigation as to how to best achieve these goals. (Macpherson & Slovic 2010)

Creating a supportive regulatory and legal environment

Effective regulation of water reuse is essential for ensuring that it plays a robust, feasible and widespread role in the future. It would be beneficial to develop a set of guidelines that are widely applicable and able to be streamlined into existing regulatory structures. Ideally, these guidelines would categorize water according to quality and risk, and be applicable to a wide range of end uses. Doing so will help to provide entities with the flexibility to address local constraints and priorities such as economics, governance, and attitudes, without draining resources necessary to develop guidelines and standards on their own. Developing a widely applicable structure for guidelines will also help to develop regulations that are supportive of water reuse while still ensuring the protection of public and environmental health. To assist in the development of such guidelines, tools and procedures for performing robust risk assessments need to be developed.

There are also other regulatory needs regarding source control and contaminants. Source control requirements will help to maintain public and environmental health, while keeping water treatment processes and requirements manageable. Further research on the long-term human and ecological effects of emerging contaminants such as pharmaceuticals and personal care products will help to ensure that public and environmental health are maintained, while keeping removal requirements achievable by treatment processes. Also, it is essential to find appropriate indicators and surrogates of contaminants for regulatory applications in order to make monitoring and enforcement effective.

It is also important to gain understanding of how laws need to be revised to support water reuse. Uncertainties about how to best allocate water rights to reclaimed water need to be addressed. In addition, laws governing water quality, and laws specifying when and how recycled water can be used need to be developed.

Integrating resource management

The myriad of agencies and institutions that exist to deal with water, and the difficulty in navigating through them, result in difficulties implementing water reuse projects. It can also result in negative perceptions of utilities, agencies, governments, and water reuse in general. Managing water reuse within a more holistic scheme, through integrated resource management and resource recovery, can help ensure that water and other resources are being sustainably used to their greatest potential. It can also lead to flexibility that will be necessary to manage water when supply and demand fluctuates, and help achieve greater operational

efficiency and possibly make the economics of water reuse more favorable. It is essential that integrated water resource plans are employed at the local, regional, and national levels. Also, because different sectors such as water, energy, air quality, earth systems, ecology, biology, and climate depend on the state of the others, broad integration of managing these sectors is key in order to achieve intelligent solutions for challenges such as addressing the interdependency of water and energy, and the minimizing negative effects that the use, treatment, and reuse of water many have upon the atmosphere, agricultural soils, and flora and fauna.

These sorts of management scheme are likely to be remarkably difficult to create, even on a regional scale. Therefore, research into methods that are best to develop such plans is essential. An effective integrated management scheme needs to be governed by flexible guidelines provided by a state or national government, and monitored and run by coalition of local officials, citizens, and researchers, according to local needs. Effective management should be based on watershed boundaries, assisted by a variety of climate models and scenarios to help assess the vulnerabilities, and also consider factors such as hydrology, economy, demographics, trade, energy and agriculture. In order to ensure sustainable management, the limits of sustainable use for each resource need to be established. In addition, further research into resource recovery and recycling needs to be conducted (NDIC 1995).

Expanding economic analysis

As water becomes scarcer, and technologies improve, wastewater and its components such as nitrogen and phosphorus may emerge as being a very valuable resource worldwide due to increased reuse or reduced wastewater discharges due to conservation (Devi *et al*. 2007). However, presently the implementation of water reuse is often hindered by economic and financial arguments. Economic difficulties also exist for water reuse because it involves water and wastewater agencies, which can duplicate some necessary funding. To improve these circumstances, there needs to be economic research that quantifies the true short- and long-term costs and externalities related to water reuse, and to other water supply options. This sort of research will enable more accurate comparisons of proposed water supply, treatment, and reuse schemes, and will help optimize how water reuse is provided. In order to ensure water is used efficiently in the future, it is necessary to identify where water reuse will be economically viable and which options exist for the use of reclaimed water. The effects of subsidizing water reuse also need to be analyzed in order to determine whether subsidies provide economic benefit or whether they lead to economic inefficiency.

There are other economic considerations that also need to be investigated. It has been stated that water is most efficient economically when there is a limited quantity that is allocated between many users (Freebairn 2003). In order to ensure this sort of efficiency in the future, considerations need to be made that help to identify where water reuse will be economically viable and which options exist for the use of reclaimed water. These considerations include determining a large number of sectors within society that can implement water reuse, assessing the viability of using non-traditional source waters such as agricultural runoff, investigating further the option of utilizing reuse water that is treated to less than potable standards for certain uses, and analyzing the decentralization of water treatment, distribution, and reuse.

Considering energy, climate and sustainability issues

Water scarcity and climate change may pose a great threat to the future quantity and quality of water supplies. This awareness presents a great opportunity to promote water reuse as a standard water supply option that will help reduce these water quality and quantity concerns. To help address these potential impacts, water reuse practices need to be developed that utilize numerous sources of water (such as stormwater, graywater, wastewater effluent, rainwater, agricultural return water, industrial effluents), and produce waters with a wide spectrum of qualities that can be tailored to specific uses. Another issue that needs to be investigated is the issue of water reuse supply hardening. Water scarcity often leads to water conservation, which may lead to a lack of sufficient water to reclaim and still support environmental and other needs. Thus, it is important to

determine where the beneficial balance of water use, water conservation, and water reuse lies, as well as which factors determine such a balance. Additionally, in order for water reuse to best serve communities affected by climate change, there needs to be more research that aims to determine the scale and scope of climate change impacts on water resources.

In response to climate change fears, it is very likely that policies aiming to limit greenhouse gas footprints will affect the water reuse industry by mandating lower emissions during water treatment. Therefore, the greenhouse gas footprints of water, wastewater, and reuse plants need to be analyzed and optimized. Ways to minimize methane and nitrous oxide emissions from wastewater treatment plants need to be developed. Technologies and methods to achieve energy efficiency and an energy balance at these plants also need to be devised. In addition, green infrastructure approaches that will decrease greenhouse gas emissions, such as natural treatment and sustainable drainage practices, need to be investigated further and given more consideration for meeting the demands of communities. It would also be useful to investigate the viability of using reclaimed water combined with urban agricultural practices, which would not only help to feed growing urban populations, but also have a cooling effect due to irrigation and the presence of vegetation.

Creating water reuse institutions and associations

In order to promote water reuse, there is a need for institutions solely dedicated to water reuse, including professional associations, representatives and lobbyists, dedicated regulators, and research organizations. These institutions can serve as 'champions' for water reuse, assist in government planning and policy, push for dedicated regulations, and assist in other industrial needs such as funding research, providing lobbyists to government, and instigating efforts at the grassroots level.

Encouraging technology advancement and innovation

There is no one-size-fits-all solution for implementing water reuse. Each location is unique in how it is governed, its economy, the available supply of water, its climate, and preferred technologies. In addition, the future is uncertain. Technology will continue to evolve, climates may change, and economies will grow and decline, along with numerous unforeseen events. Therefore, one of the most important (if not the most important) challenges that water reuse is facing is to ensure that the water reuse technology and operating schemes develop in a manner that is diverse and flexible. This will help to ensure that water reuse is a feasible solution in any region, and that future needs can be met, no matter how uncertain.

Much of this need for flexibility can be attained through technology advancement and by specifically focusing more on the practice of decentralized water reuse. Decentralized systems offer the possibility of providing treatment that is widely applicable and can function in extreme situations such as rapid growth and high population density. Energy efficiency and energy neutrality of these systems also need to be investigated. There also needs to be economic analysis of the feasibility of decentralization, educational programs for operators, training for those responsible for upkeep of the systems, and a strong set of guidelines to direct decentralized water reuse regulations.

Technology advancement can help serve to reduce costs, ensure safety, enhance production, increase efficiency, and improve water quality. By developing with a broad focus on technology improvement, it is possible to ensure that a diverse range of source waters, a wide selection of end-uses for reclaimed water, uses for treatment by-products, and other improvements are realized. Developing operating schemes (and the supporting technology) that are rapidly adaptable to flow and quality variations will help treatment plants adjust for unforeseen circumstances. In addition, the development of equipment and methods for online water quality testing will allow for rapid adjustments in operations when necessary and offer confidence that operating schemes are safe and effective. Also having some emphasis on natural treatment processes and agricultural reuse is important.

Summary of key factors and challenges

Table 1 lists many of the key factors, along with suggestions for innovation that is key for ensuring that water reuse is a viable water supply option in the year 2030.

Table 1 | Research and innovation needs for water reuse

Climate change and related policy
Determine the scale and scope of climate change impacts that will affect water resources and water reuse practices
Analyze and optimize the greenhouse gas footprints of water, wastewater, and reuse plants need to be analyzed and optimized. Strive to attain an energy balance
Economics
Find the real marginal cost of all water supply options in order to help establish an accurate representation of the economics of water reuse
Investigate how to efficiently allocate water resources, including reuse supplies
Compare the economics of decentralized reuse versus centralized schemes
Water quality/quantity
Discover how the water quality of stored reclaimed water changes over time
Develop risk assessment research tools, guidelines for robust risk assessments, and tools to help assess water quality
Determine indicators/surrogates for regulatory applications
Research the effect of long-term exposure to micro-pollutants and how they are affected and concentrated through multiple reuse cycles
Investigate the extent to which water really needs to be treated for various end uses. The toxicological relevance for many different uses of water needs to be investigated
Determine the ecological effects of emerging contaminants such as personal care products and pharmaceuticals
Public perception
Develop outreach efforts and communications schemes that will result in the most favorable public perception of water reuse possible
Discover how taxes and subsidies affect public perception of the value of water to help support implementing value-driven pricing in the future
Technology
Promote technological innovation in order to reduce costs, enhance yields, improve water efficiency, and improve water quality
Find effective methods for mapping energy use, efficiency, and energy recovery
Develop methods to perform online water quality testing, and to assess the toxicity of treated effluents (this will also help increase customer confidence)
Develop low tech and decentralized methods for treating water in order to help encourage water reuse in the developing world, and provide more options for more developed nations
Regulatory and legal
Gain a legal understanding of how laws need to be revised to promote reuse, including laws governing water quality, how reclaimed water can be used, water rights laws, etc.
Structure water rights to help avoid fractional management of water resources that occurs because they vary from region to region
In the United States, get the Safe Water Drinking Act and the Clean Water Act placed under the same jurisdiction so that they can be integrated to promote reuse. Currently, these two acts have some conflicts that result in circumstances not supportive of water reuse
Evaluate why the original intent of promoting water reuse in the Clean Water Act (Johnson 1980) was never really realized. Use this information to update the act
Integrated resource management
Develop methods for developing integrated water resource management plans on a regional, national, and international scale
Determine a beneficial balance of water use, water conservation, and water reuse

Closing thoughts

Regardless of what conditions may be in the future, it is essential to focus on the key issues discussed above and pursue, accomplishing the suggestions provided. Doing so will help to ensure that water reuse is an effective part of water provision far into the future. More specifically, expanding the perceived role of water reuse beyond the

provision of domestic water supply will help to broaden how water reuse is used. Taking action to improve public acceptance and ensure regulatory and legal support will ensure that water reuse practices are acknowledged as effective and conventional methods in creating a water portfolio. Economic analysis and optimization, combined with integrating resource management, will serve to make water reuse efficient and competitive. By considering energy, climate, and sustainability issues, future technology will be more efficient and adaptable to changing conditions. Finally, encouraging innovation and technology advancement, along with supporting all these efforts with dedicated institutions and associations, parts of the water will serve to make the growth and development of water reuse better coordinated and as efficient as possible.

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