An integrated approach to water conservation for large users

Guenter Hauber-Davidson

ABSTRACT

Water conservation programs targeted at large users will play an integral role securing water supplies for cities in years to come. A hierarchical approach to water conservation—reducing consumption as a priority, then considering internal re-use of water and replacement of potable water with alternative sources—should be the key principle in sustainable water management. The application of this approach relies on a sound understanding of water consumption at a site: where water is used, why, when and how. This entails smart- and sub-metering of the water supply and detailed analysis of site activities to produce a site water balance. The hierarchical approach can then be applied, and conservation options can be costed to assess financial viability. 'Packaging' measures with different payback times together should be considered, along with funding support available. Based on implemented projects in Australia, an estimated 30% of potable water consumption within the commercial and industrial sectors could be saved at attractive payback periods. By adopting this integrated water conservation and management approach the same outcomes can be achieved with less potable water consumption. Appropriate source substitution is a pillar of sustainable water supply, providing water at less environmental, social and financial cost than the alternatives.

Key words | efficiency, industrial/commercial use, rainwater harvesting, smart metering, water conservation

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INTRODUCTION

Water conservation programs targeted at large users will play an integral role securing water supplies for cities around the world in years to come. In Australia in recent years, programs such as Water Savings Action Plans in New South Wales (NSW Department of Energy, Utilities and Sustainability 2005) and Water Efficiency Management Plans in Queensland (Brisbane City Council 2007) have been implemented to ensure that large water consumers in urban settings make an effort to reduce their consumption and thus make a contribution towards securing whole-of-city water supply. The need for government regulation in this area comes as no surprise, given that there is still frequently a very wasteful attitude towards water in the commercial and industrial sectors. All too often, an abundant amount of water of the highest quality is used in one single pass through a facility or building. This might have been tolerated as long as there was plenty of water–it was environmentally and socially acceptable, and it was affordable.

None of those factors apply any more. In Australia with South-East Queensland on Level 6 restrictions and other cities on Level 4 restrictions or fast approaching them, costs rising dramatically, and stakeholders and employees expecting companies to do their part towards sustainability, we must move on from this simple but wasteful philosophy. We need to heed what was said almost half a century ago by the United Nations Economic and Social Council: "No higher quality of water, unless there is a surplus of it, should be used for a purpose that can tolerate a lower grade" (United Nations Economic and Social Council 1958).

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Yet enthusiastically embarking on one or two particular water saving initiatives without due consideration of the overall impacts–such as public health, facility operation, production requirements, reliability of supply, additional operating and ongoing monitoring demands, safety and product risks as well as a comprehensive economic analysis–will not only fall well short of the sustainable long term water savings potential. It also creates the risk of a backlash against some of these initiatives for all the wrong reasons.

It is the purpose of this paper to warn of these pitfalls by outlining an integrated approach based on analysis and data so that large water users can maximise their potable water savings yield. Applying a hierarchical approach to water conservation–reducing water consumption as a priority, then considering internal re-use of water followed by replacement of potable water with alternative sources–should be the key principle in a sustainable water management regime.

UNDERSTANDING SITE WATER USE

To determine how water use can be minimised and where potable water could be replaced by other sources we first need to get a sound understanding of the water use at a site. We need to know when, where, why and how water is used, and for what purpose (Sturman *et al.* 2004). This allows the minimum acceptable quality required for each use to be defined. Yet even achieving this basic understanding of site use is often easier said than done. Frequently, it is not even clear where the water comes from, how many billing meters there are and where the accounts go to. There is normally only one water meter on site, read quarterly even for accounts that use more than 100 ML/year. No resource can be managed with four data points per year.

However with water in Australia and many other countries still being relatively cheap, and the cost of sub- and smart metering (even for a 25 mm line) around $2,500 to $4,000, few companies are willing to embark on an extensive $40,000 monitoring program just to find out where perhaps $30,000 worth of water is going. Smart metering at least the main meter by connecting it to a device that allows the continuous electronic reading and display of water consumption data back to a PC (Hauber-Davidson & Idris 2006) should be the minimum step on a long term basis. However, particularly for large complex sites this can be of questionable value as there are too many overlaying uses to deduct meaningful information. For more simple sites, the data gathered can be extremely helpful in identifying possible

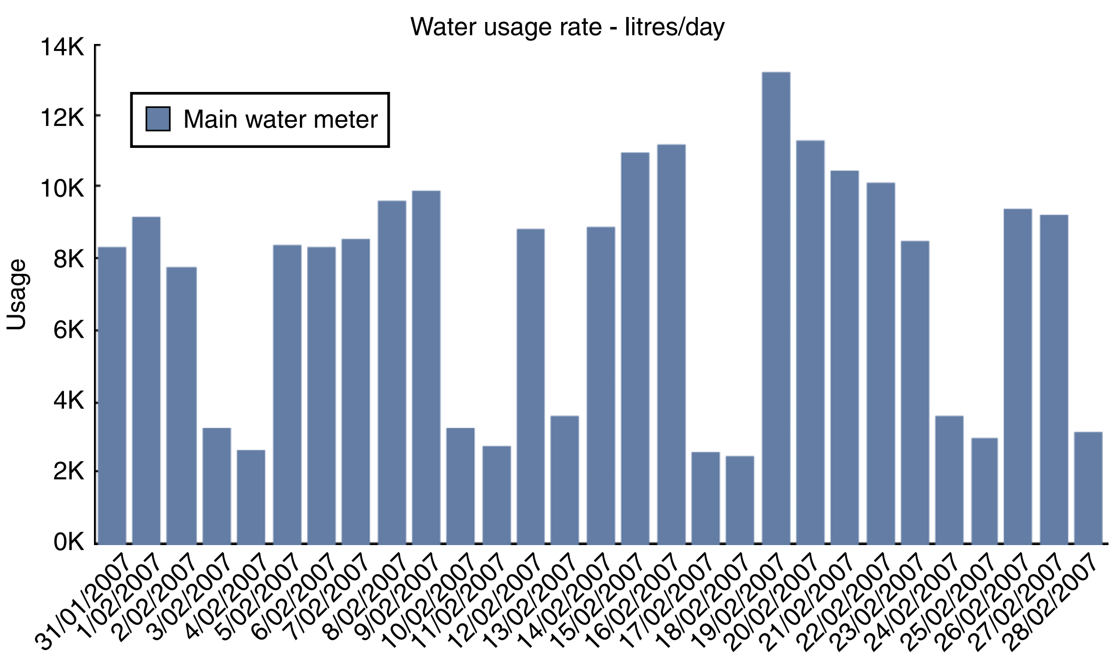

Figure 1 | Sample of daily use measured by smart meter at a large site.

leaks early, before they grow and cost vast amounts in lost water and repair costs (Figure 1).

At complex sites, better value may be obtained by installing individual sub-meters at high use areas like cooling towers, pool backwash, food preparation, amenities or irrigation to show where the water goes. Adding a smart metering capability to these sub-meters then provides the base for a sound water management system. For initial analysis, inexpensive simple logging tools are available for approximately $250 and are capable of recording four to eight weeks worth of continuous, time-stamped meter readings. Data is simply downloaded via a USB port and can be analysed to determine use, identify possible leaks and help pinpoint locations for permanent smart metering. Example output from a sub-meter is shown below, indicating constant flows of minimum 11.6 kL/hr overnight when no use is expected–a likely leak of 190 L/min (Figure 2).

A carefully evaluated compromise needs to be found between actually measured (costly) data versus site water use analysis models. Old fashioned manual readings will be better than nothing, and sometimes they are all that is required. For example, if water consumption *should* be close to zero overnight then a few manual readings taken by security personnel after adequate training may suffice.

By building a detailed site water use model (as shown in Figure 3), that is being continuously refined as further water use information from other projects is gathered, it is possible to obtain a reasonable understanding of the water use on a site.

The key element is to narrow down the individual usage patterns that cause a water consumption as accurately as possible, and then link them to measured flow rates and volumes. These can readily be determined during a site investigation being flow rates from taps, showers, process streams etc and flush volumes from toilets, urinals and batch processes (Sturman *et al.* 2004).

Usage patterns may be generic–such as the amenities use of office workers–or specific to a site. Accurately understanding these patterns must be another objective during the site investigation. For particularly complex sites a user survey may be required. These user patterns can then be incorporated into the model, with specific parameters for each use pattern e.g. amenity taps, toilets and showers.

The model output in terms of total water consumption can be checked against a single meter reading, if nothing else exists. Otherwise sub-metering of main use areas if available can be used. The reliability of the model depends on how accurately the input parameters can be determined. The difference between the modelled consumption and the meter reading points to leaks or unexplained water consumption. If leaks are ruled out but unallocated use is large, further investigation is warranted (Figure 4).

Once a water balance exists, the hierarchical approach can be applied (Figure 5). Areas in which potable water

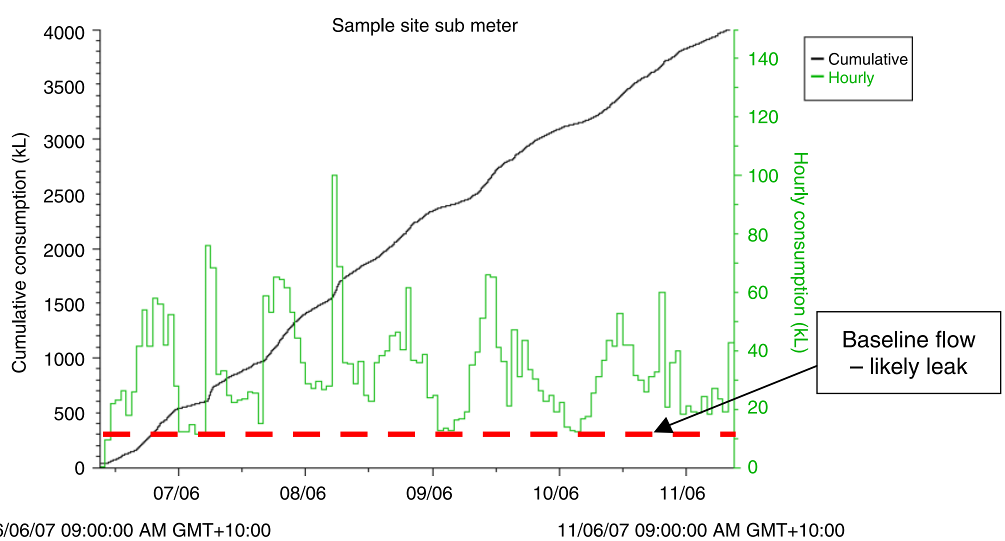

Figure 2 | Sample of temporary smart-metering output showing high baseline flows.

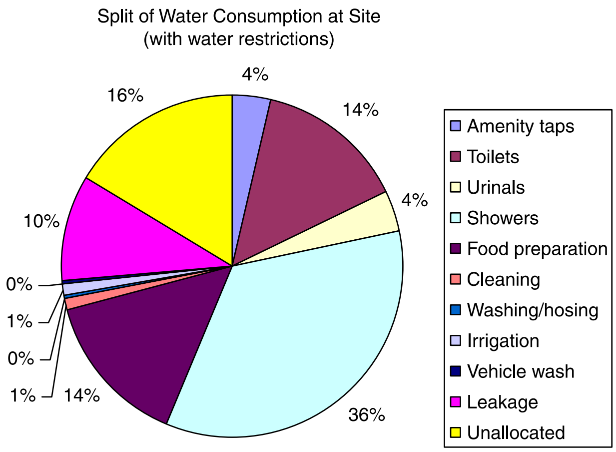

Figure 3 | Sample of site water allocation.

consumption can be reduced should be identified, along with details of *how* such reductions can be achieved e.g. through more water-efficient fittings, behavioural change or leak reduction. Internal reuse options can also be considered and finally replacement of potable water with other sources can be assessed using a ‘fit for purpose’ reuse matrix. The range of alternative water resources considered spans from rainwater, process water and grey water to black water reuse, sewer mining and use of recycled effluent. Each of these measures is considered in more detail below.

REDUCING CONSUMPTION

The first priority in any water conservation program should always be to implement water efficiency gains. Often the same can be done with less, sometimes even increasing the amenity value. Taps running at 17 L/min splashing water everywhere versus flow controlled and aerated ones at 4 L/min are a classic example. Adding sensor-controlled electronic tapware with immediate shut-off is a further step that can be taken towards water efficiency.

Similar flow controls can be applied to toilets and urinals. However, for these fixtures to still work properly and find user acceptance, the scope of flow reductions may be limited. The best path forward may be to embark on a well overdue amenity upgrade during which old style toilet pans (that require 8–11 L of water to achieve a proper

Site Water Balance Model

Part I: Sanitary Water Uses

User Information	Description	No. of users	Usage pattern	% Female	% Male	Toilet uses per day	Amenity Tap uses per day	Kitchen uses per day	Shower uses per day
User Type 1	Office worker	100	5 day week	50%	50%	2.5	2.5	3	0
User Type 2	Gym user	25	7 day week	50%	50%	2.5	1	0.5	0.9
User Type 3	Shift worker	200	12 hour shift	10%	90%	4	4	2	0.7
Add a new row									

Details of Fittings

Toilets	Type	No. at site	Flow full flush	Flow half flush
Toilet Type 1	Single flush	10	10	-
Toilet Type 2	Dual flush	25	9	4.5
Add a new row				

Urinals	Type	No. at site	Flow per flush	Time between flushes
Urinal Type 1	Manual flush	3	6	-
Urinal Type 2	Timer	15	-	
Add a new row				

Taps	Type	No. at site	Flow rate
Amenity Tap Type 1	Lever mixer	5	10
Amenity Tap Type 2	Single tap	10	12
Amenity Tap Type 3	2 taps	20	9
Kitchen Tap Type 1	Lever mixer	4	10
Add a new row			

Showers	Type	No. at site	Flow rate	Shower duration (min)
Showers Type 1	Unrestricted head	5	18	6
Showers Type 2	Low-flow head	5	9	6
Add a new row				

Figure 4 | Partial sample input screen from a site water balance model.

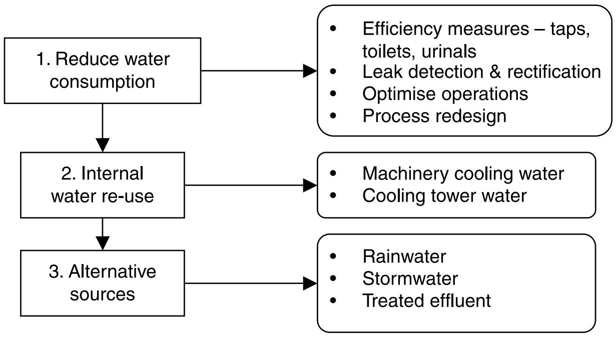

Figure 5 | Schematic of hierarchical approach.

flush) are replaced with modern 4.5/3 L dual flush toilets. Similarly, high use urinals can–where the existing plumbing allows (copper pipes are often a key obstacle here)–be converted to the low water or waterless type (Figure 6).

Similarly, there is no excuse to splash irrigation water everywhere just because a rainwater tank has been installed. Modern capillary suction subsoil irrigation systems are so much more efficient that they can achieve the same with up to 70% less water than overhead sprinklers. Optimising, properly controlling, monitoring and automating water using processes including filter backwash (e.g. from pools), bleed and blowdown operation can lead to further substantial savings. In many cases these measures result in additional integrated savings from reduced energy demands (e.g. less hot water), reduced chemical, wastewater, and/or trade waste charges.

Sometimes, as in the case of water-based cooling towers, one of the most effective ways to save water is to target energy savings and through this enjoy automatic water savings. Since some 85% of a cooling tower's water use is related to its evaporative cooling load, saving 10% on cooling energy will lead to overall water savings of 8.5%, whilst saving 20% of the 15% bleed water consumption will only save 3% of overall water use (Sydney Water undated).

Costing and initial design of identified water conservation options can then be carried out, to enable users to assess financial indicators such as internal rate of return and payback period. When a range of measures vary in economic viability, 'packaging' them together should be considered so that the measures with low payback times 'subsidise' those that are less attractive. Funding support may also become available when measures are packaged to achieve certain levels of savings.

Figure 6 | Improvement of amenity presentation—upgrading a urinal trough to a waterless urinal system.

Based on real life examples from implemented projects, as a conservative estimate at least 30% of potable water consumption within the commercial, industrial, institutional and large residential sector could be saved at economically attractive payback periods of three to five years.

INTERNAL RE-USE AND SUBSTITUTION OF POTABLE WATER

Once all reasonable water efficiency measures have been exhausted, internal or external water reuse and source substitution should be considered. Drawing from the previously collected individual water use data, consumers and processes that could be fed non-potable water can be identified. The table (Figure 7) below demonstrates desirable,

Item	Measure	Water savings kL/yr	Total savings $/yr	Budget cost	Payback yrs
Amenity Taps	Reduce flow, fix taps	271	$797	$6,175	7.7
Toilets	Modify cistern, reduce flush	680	$1,651	$3,507	2.1
Urinals	Modify/manage flush, some waterless	581	$1,412	$11,086	7.9
Showers	Modify high/med flow showers	2,100	$8,491	$7,920	0.9
Food preparation	Low-rinse showers	158	$607	$840	1.4
Leakage	Find and address leaks	945	$2,646	$8,400	3.2
Smart metering	Main meter, 3 sub meters	850	$2,193	$10,800	4.9
Water management	Active monitoring and alerting	350	$903	$5,000	5.5
User awareness/ Training	PR campaign, suport materials	200	$537	$5,200	9.7
Rainwater harvesting	From building 3 for use in amenities & hot water	4,263	$10,353	$183,000	17.7
Total		**10,398**	**$29,590**	**$241,928**	**8.2**
% Water saved		**58%**			

Figure 7 | Sample cost and savings assessment table.

acceptable and non-compatible uses of different sources (Coombes 2006).

The challenge in a truly integrated water conservation project is to find the right balance between supply and demand of individual stream versus the effort required to collect, treat and supply this water to its end use (Coombes 2006). When doing this, using different water sources and excessive internal recycling need to be taken into account as they can quickly lead to other problems like up-concentration of salts in the recycle loop if not carefully considered.

Generally, the best results are obtained by matching the largest individual source streams with large single point supplies for non-potable uses. Going beyond the now generally accepted replacement of town water with e.g. rainwater, and extending its possible use to the likes of the hot water system, pool top-up or cooling towers can lead to further significant savings; and to a more cost efficient system. The closer the supply is to demand, the better the return on investment. For a rainwater harvesting system this means the best approach is to make it work hard, i.e. to connect to large and ideally constant consumers as this will get best value out of the system.

Selecting the most appropriate point of collection is another critical design parameter. The closer to the source an individual stream is collected, the less treatment it will require and the easier it is to reuse. However, additional collection and supply costs can soon offset that benefit. Classic examples are collecting rainwater from downpipes (yielding a relatively clean and well defined water quality) versus collecting it as stormwater from drains that contain known and possibly unknown sources of surface runoff. Balancing greywater treatment (with significantly lower treatment requirements and less operational and public health risks but higher collection costs due to the need to have two separate waste stack systems) versus the higher treatment cost and complexity of a black water reuse system is another example. Sites that have big sewers nearby with a single large point of supply for non- potable use can embark on a sewer mining program to source additional water. A similar approach could apply to those near a recycled effluent pipeline (Figure 8).

USER BEHAVIOUR AND MANAGEMENT SYSTEMS

Further benefits and water savings can be obtained by not only relying on technical water conservation measures but also by working towards behavioural change by raising awareness. This can include review of management systems, induction processes, contracts and manuals for opportunities to include small but significant changes to raise water awareness.

Once water consumption has been include as a KPI for a contractor, he or she will suddenly place importance on how much water they use in their process. Additional

Key: ● Preferred use ● Compatible use ○ Non-preferred use ▨ Requires high level treatment

	Amenities/ bathroom	Kitchen/ food prep.	Hot water system	Toilet flushing	Laundry	Irrigation	Vehicle/gear washing	Cooling tower	Pool top up water	Other process water
Potable water supply	Preferred use	Preferred use	Preferred use	Non-preferred use	Compatible use	Non-preferred use	Non-preferred use	Non-preferred use	Preferred use	Depends on process
Own water supply (eg bore water)	Preferred use	Preferred use	Preferred use	Non-preferred use	Compatible use	Non-preferred use	Compatible use	Non-preferred use	Preferred use	
Rainwater (from roof only)	Compatible use	Compatible use	Preferred use	Compatible use	Preferred use	Compatible use	Preferred use	Preferred use	Preferred use	
Stormwater (roof and ground)	Requires high level treatment	Requires high level treatment	Requires high level treatment	Compatible use	Requires high level treatment	Preferred use	Preferred use	Compatible use	Compatible use	
Treated greywater	Requires high level treatment	Requires high level treatment	Requires high level treatment	Preferred use	Requires high level treatment	Preferred use	Requires high level treatment	Non-preferred use	Requires high level treatment	
Treated wastewater	Requires high level treatment	Requires high level treatment	Requires high level treatment	Preferred use	Requires high level treatment	Preferred use	Requires high level treatment	Requires high level treatment	Requires high level treatment	

Figure 8 | Fit-for-purpose water reuse matrix.

prompts, displays and new products like shower monitors can lead to significant further ongoing water savings.

The cornerstone of any such system must be a water management system that is better than obtaining four meter readings per year. Any site with substantial water use should have at least their main meter smart-metered such that water consumption is readily displayed to the facility's water manger via the building management system (BMS) or a web interface. The same applies to large or significant sub-use streams (Figure 9).

Ideally, particularly sub-streams with a tendency for leaks such as amenity blocks, cooling tower make-up or facilities with old distributed pipe networks (such as schools) should make use of additional functionalities provided by some of today's smart meters. They allow automatic leak detection coupled with automatic alarm send-outs via SMS or e-mail. Some systems can even directly turn off the water. These systems also allow a convenient way to turn off the water altogether during times of no use, e.g. overnight or holidays.

An active water management system is the key tool to ensure that savings are maintained beyond the initial project euphoria and to ensure that further savings opportunities are identified.

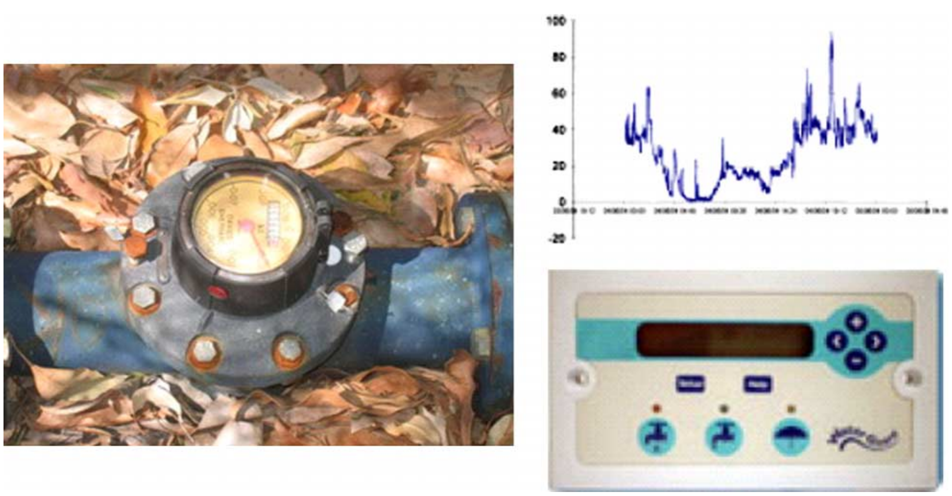

Figure 9 | Combining old technology with new to turn a water meter into a water efficiency and management tool.

CONCLUSION

By combing the right type of water efficiency measures with appropriate alternative water supplies such as rainwater and recycled water from on- or off-site sources and putting in appropriate management systems, a truly integrated water conservation scheme can be achieved. It can typically generate at least 25% to 35% savings, even on existing sites. This can extend to over half of the water saved with simple paybacks in the order of five to ten years. For new facilities the savings can amount to 70% to 80%, with very attractive economic parameters.

Using the high payback of some individual water conservation measures such as flow restrictors on showers to internally "cross subsidise" the lower payback of a rainwater harvesting scheme, or to support the hard-to-demonstrate payback of a water management system, allows large users to package up an integrated water conservation concept such that it can meet financial hurdles whilst maximising water savings initiatives.

Large water users with a greater vision, accepting the scarcity of water and the role they play towards making our water supplies more sustainable, or those who have no choice as potable water is no longer available for their desired use, can or have to go much further.

Implementing both simple and advanced, yet effective and necessary measures will not only future-proof the water supplies for large users and safe guard against increasingly expensive water, it will also go a long way towards providing water at less environmental, social and financial cost than the alternatives: large scale energy hungry end-of-pipe recycling and pumping or desalination schemes.

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