Modelling the impacts of water efficient technologies on energy intensive water systems in remote and isolated communities

C. Beal[*]

Smart Water Research Centre, and School of Engineering, Griffith University, Qld, Australia

e-mail: c.beal@griffith.edu.au

Thulo Ram Gurung

School of Engineering, Griffith University, Qld, Australia

e-mail: r.gurung@griffith.edu.au

R.A. Stewart

School of Engineering, Griffith University, Qld, Australia

e-mail: r.stewart@griffith.edu.au

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[*] Corresponding author

Abstract

Essential service providers face unique challenges that are specific delivering a secure and safe water and energy supply to remote communities such as islands and isolated mainland townships. Many remote communities rely on energy intensive water supply systems which are inherently costly to operate. Water demand management programs such as retrofitting households with water-efficient devices and appliances are one way of reducing the water-energy costs in these communities. This paper presents modelling results from a comparison between business as usual and a scenario where water efficient strategies were retrofitted in households in three remote communities in Northern Australia. The modelling demonstrated considerable savings to both the water and energy average daily consumption and associated economic costs though reduced reliance on desalination plants and bore pumping. The retrofit scenario was shown to reduce water demand by between 14 and 39 ML/y and total energy demand in off-grid communities by between 83 and 208 MWh/y. Cost reductions for delivering treated water to households ranged between around AUD$11,000 and AUD$70,000 per year, depending on uptake rates of the retrofit program by each community. This paper forms part of Stage 1 of the Remote and Isolated Communities Essential Services (RICES) project. Stage 2 will confirm many of the assumptions underlying the modelling and build on the smart metering datasets and community engagement process currently underway in Stage 1. The overall outcome of the RICES project is to ensure that such strategies are practical to implement on a broader scale to ultimately achieve more sustainable water and energy efficient off-grid communities.

Keywords

Water-energy nexus, off-grid, energy efficiency, demand management, island communities, Indigenous communities

Introduction

In Australia, there is typically a high percentage of Aboriginal and/or Torres Strait Island people living and working in regional, isolated and remote communities both on the mainland and coastal islands. Often these isolated Indigenous communities are not well serviced and suffer from poor health, social disunity and a lack of accessible education and health services (Moran and Corpus, 2013) In some cases, the social and economic conditions of such communities can reflect those of developing countries where access to reliable health, education, water and energy services are tenuous at best. Adequate, safe and reliable supply of water and energy is intimately linked to Indigenous health and social well-being, be it in Australia (Burgess et al. 2013; Hunter 2007) or elsewhere (Mohtar and Lawford, 2016; Kaygusuz 2011). Water supply choice in regional and remote communities is often limited and seasonally unreliable, impacting on delivery infrastructure, the function of household stock, and the health and well-being of residents Beard et al. (2011). Despite this, many Australian Indigenous communities have very high (>700 litres) per capita water consumption (Beard et al. 2011, Hoverman and Ayre 2012) and often require energy intensive water supply systems for providing reliable potable water (Grey-Gardner 2008, Willis et al 2008). For example, most Torres Strait Islanders rely solely on energy intensive desalinated water, powered by diesel generators, to supply their community needs, resulting in

significant economic and environmental impacts (Richards and Schäfer 2003, Werner and Schäfer 2007) The need for improved management of essential services (water and energy) in Indigenous communities is well acknowledged (Hoverman and Ayre 2012, Fisher et al. 2011, and gaining a good understanding of the typical baseline energy and water flows within such communities is a critical first step (Beal et al 2014). Essentially: knowing the "how, when and where" of the water and water related-energy within these communities is the fundamental starting point from which all subsequent planning and management initiatives can begin.

Challenges in managing essential services in isolated communities

There are a multitude of unique challenges that relate to remote and isolated Aboriginal and Torres Strait Island communities and their service providers in northern Australia. Community-based challenges include: geographic isolation and distance to larger townships; increased isolation during the wet season; variable reliability of energy supplies; infrequent maintenance support for supply infrastructure due to challenging remote locations; and the high and ever-increasing cost of energy supply (Hoverman and Ayre 2012). Underlying all these practical challenges are the cultural and social complexities inherent in Indigenous communities which need to be fully integrated into any long-term strategies in addressing essential service management (Yuen 2004).

Challenges for the essential services provider include: increased demand of energy and water-related energy; balancing the increased demand with supply, delivery and maintenance costs; uncertainty in planning future infrastructure due to a lack of baseline consumption data (across seasons and populations); energy generation and water treatment systems with variable capacity and changing demand patterns (transient population); variable reliability of on-site services (e.g. diesel pump for energy supply, water pump); and variable skill base for maintenance and repairs.

One of the biggest challenges for supplying water and energy to remote and isolated communities is that the necessary subsidies for covering the shortfall between the cost and revenue for providing these services sometimes means there is less focus on efficiency and higher rates of consumption than in urban areas. For example, approximately 75,000 L/annum of diesel is estimated to power the desalination plants on one Torres Strait Island to provide potable water to the community. The cost to supply barged water is $14 per kilolitre (about 26 times the national average) and desalinated water is about $7 per kilolitre (about 10 times national average). This diesel is needed to be shipped by transporter from mainland Australia – adding further environmental and financial costs to the water supply chain. Demand management education and retrofit programs underpinned by empirical data and suitably adapted for Indigenous communities, could help reduce the shortfall between cost and revenue, while also improving the long-term sustainability of water and energy supply. While modern alternative supply technologies (e.g. renewable energy systems with storage for energy supply; wind-DG-battery forward osmosis for water) can significantly reduce the resource intensity of supply (Werner and

Schäfer 2007, Shezan et al. 2015), demand management activities such as education and appliance retrofit programs could also help to reduce demand and put the community on a more sustainable path to long-term water and energy supply. This is particularly pertinent in areas where these modern alternative supplies mentioned above are constrained by various climatic, economic, social and environmental challenges that are inherent isolated and remote towns in Australia.

The Remote and Isolated Communities Essential Services Project

There are an increasing number of water monitoring and conservation projects that have been developed and rolled out by service providers in remote Indigenous towns, ranging from small ($n<10$) pilot studies to whole-of-community water use monitoring and water conservation programs (Yuen 2004, Beard et al 2013, Jenkins 2013, Ross et al. 2014). However, there is little detailed understanding of water and energy use trends in these communities at a disaggregated end-use resolution. Knowledge of the detailed water and energy end-use consumption patterns of residents, and understanding the drivers behind water use behaviours and attitudes, will improve the ability of planners, essential services staff, engineers, policy makers and community engagement officers to deliver suitable, efficient and fit-for-purpose water and wastewater infrastructure to those communities.

The Remote and Isolated Communities Essential Services (RICES) project is a three year research effort aimed at gathering baseline evidence and subsequently identifying sustainable strategies to reduce energy and water consumption in remote Aboriginal and Torres Strait Island communities. There are three broad objectives or stages of the RICES project i) identifying baseline water and energy use through the use of desktop modelling of existing datasets and installation of intelligent metering technology to gather high resolution end-use data ii) testing community-led water and energy efficiency strategies including technological and behavioural approaches and iii) developing a strategic framework/handbook to facilitate the successful adoption of identified appropriate efficiency education and retrofit strategies across northern Australian remote communities. Fig 1 is a broad representation of the methods for each stage of the project. Stage 1 of the research is currently underway where approximately 45 households in three remote Aboriginal and Torres Strait Island communities in Queensland and Northern Territory are being monitored for water (total and hot water) and energy (total and hot water system). Household water use surveys are also being conducted for all participating households to characterise the water and energy stock within each home and also to capture some behavioural and attitudinal data regarding household and community water and energy use. Concurrent to this, Stage 1 also involves desktop modelling using existing baseline water and energy data to provide some initial insights into the current water-energy demand, and potential range of reductions that may be achieved from implementing water efficient strategies. This paper reports on this desktop modelling component.

Three case study communities have been selected for the desktop study. The first is located: in the Torres Strait Islands (i.e. Coral Sea), Queensland and shall be identified as "Site 1", the second is located in central Northern Territory ("Site 2") and the third is situated on Cape York, Far North Qld ("Site 3"). Site 1 has 315 residents who rely on their electricity supply via diesel generators and their potable water supply from a high energy intensity desalination plant Site 2 is a small community in Central Australia where around 530 residents rely on treated bore water. Unlike the other sites, their electricity supply is via a grid network, thus they are not reliant on diesel generators. Site 3 is a remote, off-grid coastal town in Cape York Peninsula of around 270 people who rely on diesel generated groundwater bores to supply water.
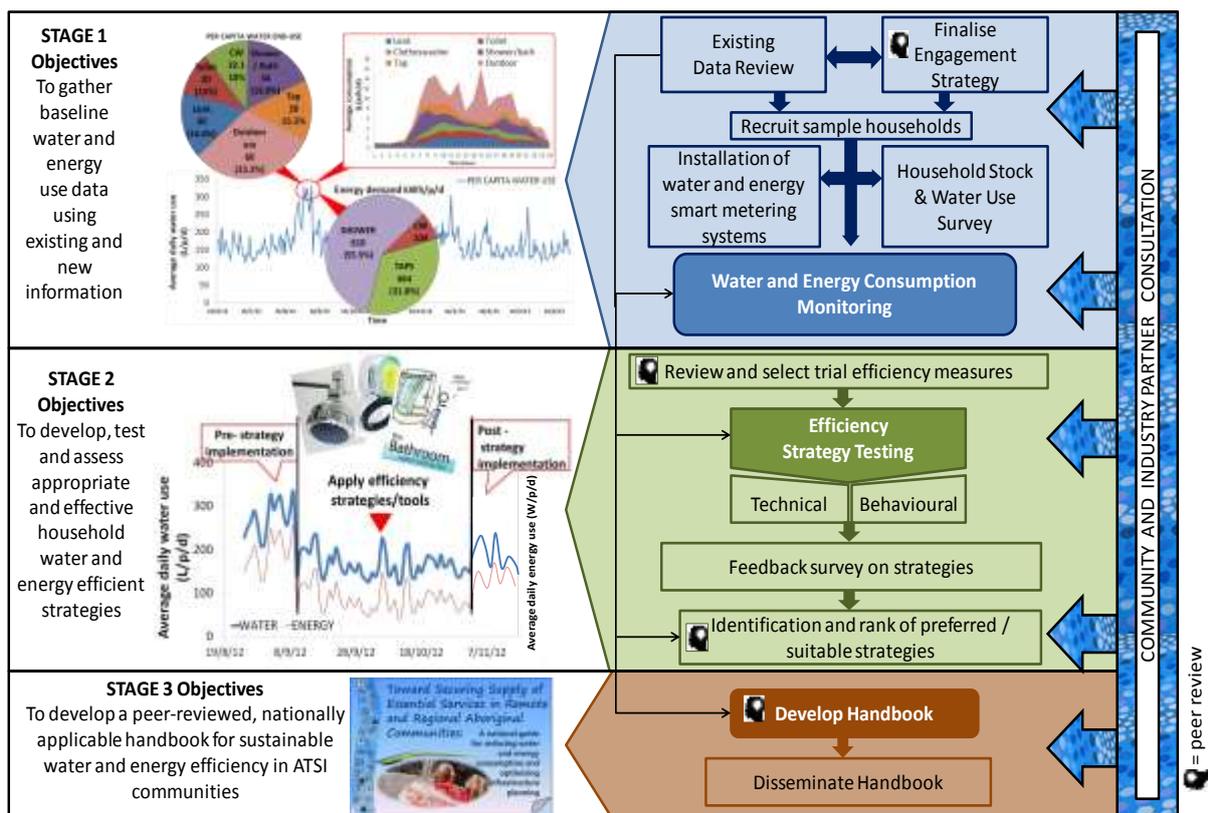
Fig. 1. Overview of objectives and methods for the RICES project

Methods

Modelling for this desktop study presented herein is based on comparing a before and after scenario where business as usual (BAU) water and energy demand from residential and non-residential activities is compared with post-retrofit water and water-related energy consumption. Retrofit refers to water-efficient technology replacing standard water using fixtures and appliances within the home. The method and assumptions used in the modelling are described below.

Water demand modelling

Separating the residential and non-residential component

Available water consumption data for the three study areas was supplied by the service providers and was quite variable in terms of resolution, source and time period. The data consisted of average annual water consumption data for Site 1, monthly water consumption in Site 2 (from January 2014 to June 2015), and daily bore water extraction of Site 3 (from January 2015 to April 2016). The water consumption data for Site 2 and Site 3 are shown in Fig 2. The population profiles (i.e. total population and persons per household) for the study areas were obtained from the Australian Bureau of Statistics (ABS) and the Office of Economic and Statistical Research (OESR). This information was used to estimate average water demand for each study area on a litre per person per day (L/p/d) basis.

For Sites 1 and 3, only total water consumption was available, the residential and non-residential demand (e.g. commercial demand, non-revenue water losses), components were firstly needed to be determined. This was able to be done using data for Site 2, where hourly residential water consumption data for 14 homes were available for the period May 2015 to July 2015. The average day demand for these 14 homes were extrapolated across the population and compared against recorded total water demand for the same period. The difference was taken to be the non-residential component and expressed as a percentage of the total average per person demand, resulting in a 66% and 34% split for the residential and non-residential components, respectively. These distributions were applied to Site 1 and Site 3 to separate the two demand components.

Estimating individual end-use consumption

The study used the method derived from a previous study (Gurung et al., 2014) which was based on smart water meter data from the South East Queensland Residential end use study (SEQREUS) (Beal and Stewart, 2011) to estimate the demand for the different water end-uses. The method firstly requires the indoor and outdoor demand to be separated using linear regression equations obtained for the two components in the SEQ region (Gurung et al., 2014). Indoor end-use demands were then estimated by applying the obtained indoor demand to individual indoor end-use distributions provided in Gurung et al. (2014). Measured differences in end-use consumption between efficient and non-efficient appliances, including shower, taps, toilets and clothes washers, were obtained from Gurung et al. (2015). These savings were then used to calculate water demand from each of the end-uses assuming a scenario where water-efficient technology has been retrofitted in each home for all three communities. A conservative estimate of a 50% reduction in leakage was used based on Britton et al. (2013) and Ross et al (2014).

Beal et al. (2011) and Willis et al. (2013) discuss the impacts of water-efficient devices on total household water consumption (and water-related energy e.g. hot water reductions) and also on specific end-uses. For this modelling exercise, the BAU and post-retrofit for seven end uses were compared.

Shower consumption efficiency was assumed to occur from the installation of low-flow showerheads that have shown to be significant in reducing cold and hot water use. Tap (bath and sink taps) end-uses can be reduced through the installation of flow restrictors and flow aerators. Clothes washing water demand can be reduced by using water-efficient, "5 star" rated machines that are often front-loading and require one (cold) tap fitting only. Many toilets are now dual systems with full and half flush options, although survey results from recent field work for the RICES project suggest very few toilets in remote Indigenous communities are equipped with dual flush systems. Outdoor water use can be supplemented from rainwater tanks (see below) and also reduced through the use of trigger hoses and tap aerator devices. The reduction in leaks were based on households that have all these types of water-efficient devices and the related reduction in leaks that have been measured (Beal and Stewart 2011).

Rainwater tank demand

Although rainwater tanks are installed in some of the households in the study areas, many were found to be used either intermittently or not at all, particularly at Sites 2 and 3. Hence, this modelling also considers the effective utilisation of rainwater tanks in contributing to water savings. The urban water balance model UVQ (Mitchell and Diaper, 2010) was used to determine water savings for rainwater tanks for each community. Individual rainwater tanks in Site 3 were observed to be between 5 kL and 10 kL; hence, a tank size of 7.5 kL was used in the model. The runoff coefficient was taken as 0.875, and average roof areas for each study site was estimated using Google Earth™. Historic rainfall data were obtained from the Bureau of Meteorology (BOM) and the tanks were assumed to supply outdoor demand only.

Energy savings

Energy intensity

To estimate the costs savings of reduced energy consumption from reduced water consumption as a result of the retrofitting, the energy intensities (kWh/kL), which is the energy (kWh) required in pumping or treating a unit (kL) of water, of the water infrastructure in the three study areas were determined from available data.

The average energy intensity for the desalination and water treatment plant in Site 1 was estimated to be 5.4 kWh/kL based on an annual energy consumption of 27,000 kWh and the community's water demand of 50,000 kL. Of the total energy intensity, 5.0 kWh/kL was assumed for desalination purposes and 0.4 kWh/kL for pumping and treatment. An energy intensity of 0.15 kWh/kL was used for the treatment unit based on data from Site 2; this energy intensity was also used for the water treatment plant in Site 3, and the remaining 0.25 kWh/kL for pumping.

The energy intensity of the bore and transfer pumps, and the water treatment unit in Site 2 were estimated through available energy and water consumption data for the period of January 2014 to June

2015. In Site 3, pump energy data was provided for March 2016 and April 2016 and used alongside bore water extraction for the same period to determine the energy intensity of the bore pumps. The recirculation pumps in Site 3 are variable speed pumps with a small pressure vessel, and any water use triggers the pumps according to demand required. As it is difficult to estimate pumping capacities of variable systems, due to the flow and energy variability, an average energy intensity of 3.02 kWh/kL was used from a study of a communal rainwater system (Cook et al., 2013) using a similar recirculation pumping system. The monthly water and energy consumption data for Site 2 and water demand for Site 3 are shown in Fig 2.

All homes in the study areas are assumed to have a solar water heater system with electricity booster (i.e. electricity as a backup system). An energy intensity of 10.8 kWh/kL was used based on a study on water heaters in Brisbane by Vieira et al. (2014).
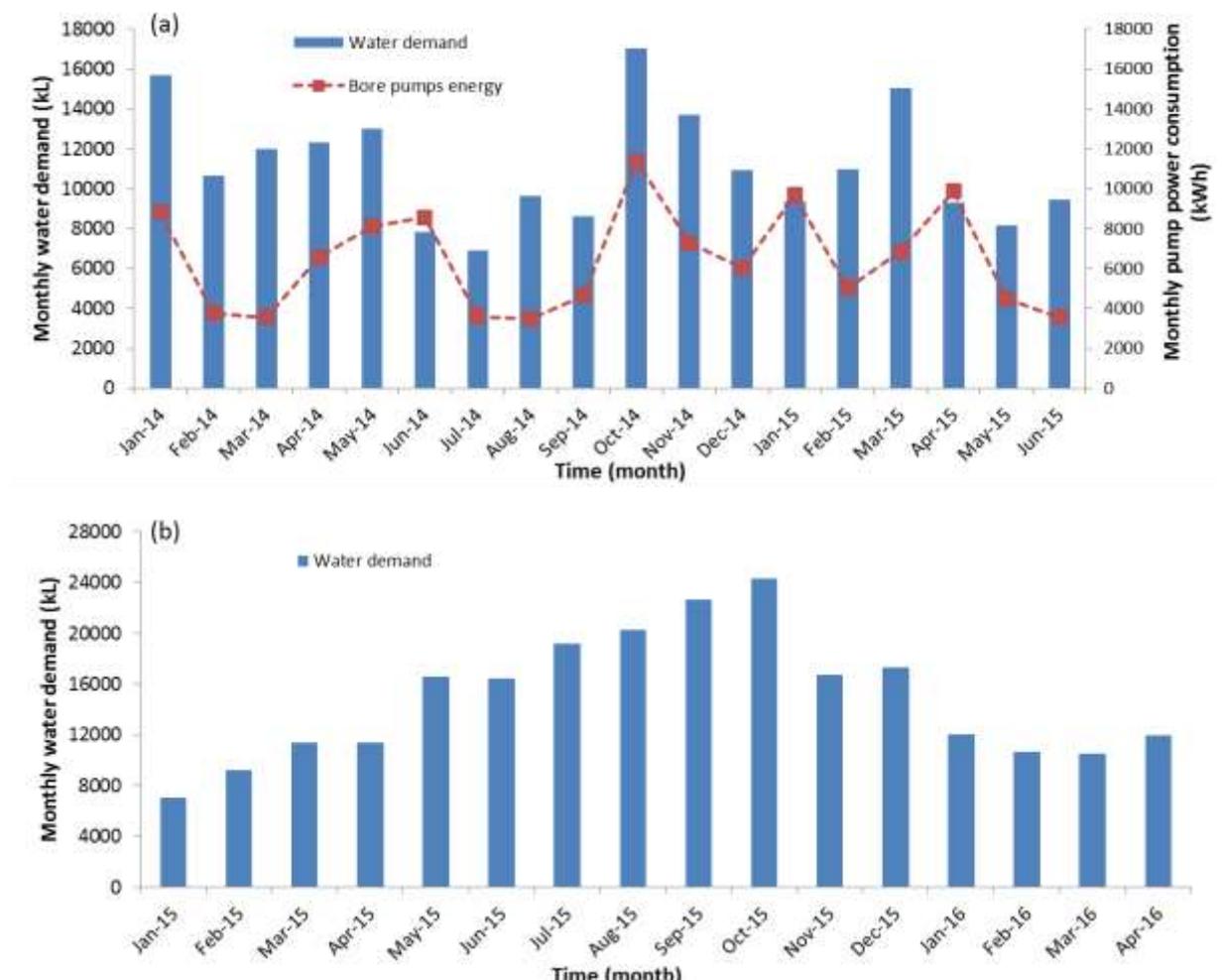
Fig 2 (a) Water demand, bore pump and treatment unit energy consumption in Site 2 (b) Bore water extraction in Site 3.

Energy costs

A one year average (May 2015 to May 2016) Australian wholesale diesel price (including taxes) of $1.09 per litre, obtained from the Australian Institute of Petroleum (AIP), was used to estimate the cost savings in running the diesel generators for Site 1 and Site 3 following reduced demand from retrofitting water-efficient technology. Power and Water Corporation, the energy provider for the Northern Territory site, estimates the cost of providing electricity in Site 2 to be $0.2554 per kWh.

Modelling parameters

A summary of final modelling parameters used to undertake the analysis are shown in Table 1.

Table 1 Summary of modelling input parameters and assumptions

Input parameter	Site 1	Site 2	Site 3	Unit	Comments / sources
Population profile					
Population	315	535	270	persons	
Average household size	3.6	4.8	3.3	persons/ home	Site 1 (ABS, 2011a), Site 2 (ABS, 2011b), Site 3 (OESR, 2012)
Water consumption					
Total water consumption	435	687	1,835	L/p/d	Water consumption data
- Residential	287	453	1,211	L/p/d	66% of total consumption
- Non- residential	148	234	624	L/p/d	34% of total consumption
Rainwater tank modelling					
Roof area	290	220	220	m^2	Google Earth™
Amount of rainfall data	13	20	20	Years (y)	Bureau of Meteorology Climate Data online stations 027045, 027054, 015608)
Energy intensity					
Desalination plant	5.00	N/A	N/A	kWh/kL	~ 270,000 kWh to treat ~50,000 kL per annum. Data provided by service provider.
Bore pumps	N/A	0.58	0.36	kWh/kL	Water and energy consumption data provided by service provider.
Transfer/ recirculation pumps	0.25	0.15	3.02	kWh/kL	Water and energy consumption data provided by service provider.
Water treatment plant	0.15	0.15	0.15	kWh/kL	Estimated from Site 2 data
Solar water heaters	10.8	10.8	10.8	kWh/kL	Vieira et al. (2014)
Cost parameters					
Cost of diesel per litre	1.09			$/L	AIP (2016)
Diesel for powering generators	0.30			L/kWh	Ergon Energy

Cost of diesel for powering desalination/ bore pump	0.327	N/A	0.327	$/kWh	AIP (2016)
Cost of supplying from power grid	N/A	0.2554	N/A	$/kWh	Power and Water Corporation

Results and discussion

Water demand modelling

The business as usual (BAU) residential water consumption for the three study areas were 287 L/p/d, 453 L/p/d and 1,211 L/p/d for Site 1, Site 2 and Site 3, respectively. Water consumption for all study areas were disaggregated into individual end-uses and the assumed reduced consumption from the water efficient appliance retrofit scenario was applied to determine the water savings for indoor appliances. Outdoor water savings from utilising rainwater tanks were determined through the use of the water balance model, UVQ, and were calculated to be 58%, 17% and 31% for Site 1, Site 2 and Site 3, respectively.

The results of the water demand modelling indicate that the use of water efficient appliances and rainwater tanks have the potential to reduce total water consumption in the three areas by 43% for Site 1, 28% for Site 2 and 33% for Site 3. The modelled water demand for individual end-uses for the BAU and retrofit scenarios are presented in Table 2.

Table 2 Modelled end use demands for BAU and retrofit scenarios in the three study areas

	Indoor use (%)	BAU (L/p/d)			Retrofit (L/p/d)			
		Site 1	Site 2	Site 3	Assumed Savings (%)	Site 1	Site 2	Site 3
Shower	35	67.5	93.1	209.7	40	40.5	55.8	125.8
Tap	16	30.8	42.5	95.9	20	24.7	34.0	76.7
Bath	2	3.9	5.3	12.0	0	3.9	5.3	12.0
Toilet	19	36.6	50.5	113.9	20	29.3	40.4	91.1
Clothes washer	23	44.3	61.2	137.8	50	22.2	30.6	68.9
Leakage	5	9.6	13.3	30.0	50	4.8	6.6	15.0
Outdoor	N/A*	94.4	187.5	611.9	17–58**	39.6 (58%)	155.6 (17%)	422.2 (31%)
Total	N/A	287.1	453.4	1211.1	N/A	164.9	328.5	811.7

*Outdoor demand obtained from indoor-outdoor demand split. **Calculated outdoor water savings from rainwater tanks are in parentheses for each study area.

Hot water demand was estimated as a percentage of the obtained indoor individual end-use consumption; 25% for clothes washer (EBMUD, 2008) and 50% for showers, taps and bath (Kenway

et al., 2008). In all areas, hot water demand reduced by 36% of the original hot water demand; potentially representing significant energy savings. Table 3 shows the BAU and retrofitted hot water demand for the individual appliances.

Table 3 Modelled hot water demand of each end-use for BAU and retrofit scenarios

	Hot water proportion (%)	BAU (L/p/d)			Retrofit (L/p/d)		
		Site 1	Site 2	Site 3	Site 1	Site 2	Site 3
Shower	50	33.7	46.5	104.9	20.2	27.9	62.9
Tap	50	15.4	21.3	47.9	12.3	17.0	38.4
Bath	50	1.9	2.7	6.0	1.9	2.7	6.0
Clothes washer	25	0.0	0.0	0.0	0.0	0.0	0.0
Total	-	0.0	0.0	0.0	0.0	0.0	0.0

+Hot water proportion is represented as a percentage of the modelled demand for each end-use

Water and energy savings

The results from the modelling show that retrofitting toilets, taps, clothes washers and shower heads with efficient appliances in the community and the efficient use of rainwater tanks for outdoor use is expected to reduce residential consumption by 43%, 28% and 33% in Site 1, Site 2 and Site 3, respectively. This represents a corresponding annual water reduction of 14 ML, 24 ML and 39 ML, respectively for Sites 1, 2 and 3. There is potential for further water savings to be achieved as the modelling does not take into account the potential for using water efficient technology in non-residential areas. Table 4 presents the overall annual water and energy savings from the retrofitting project.

The reductions in water demand are expected to result in lower energy consumption in all three study areas due to reduced desalination, treatment and pumping demand, as well as a decrease in the energy required for heating water (i.e. reduced hot water use meant less diesel generated energy needed for electric heating systems). Diesel savings of 31,000 kL and 63,640 kL per year are expected in Site 1 and Site 3, respectively, while Site 2, which is supplied through a normal electricity grid, is expected to save 87,700 kWh.

The energy intensities for the pumps transferring/reticulating treated water at Site 1 and Site 2 are considerably lower than for Site 3 (Column E in Table 4). This is due to that fact that at these sites, treated water is transferred to an elevated tank, compared with Site 3 where the pressurised recirculation pumps are used to distributed the treated water, up to 5 km away, thus the opportunity for savings gained from reduced demand will be greater at Site 3.

Table 4 Estimated annual savings in water, energy and cost from the retrofitting project

Item	Description				Unit#
A	Water savings – total demand	Site 1	Site 2	Site 3	
	Annual BAU water demand	50,014	134,154	180,839	kL/a
	Post retrofit demand	35,966	109,756	141,477	kL/a
B	**Total water savings from retrofit (100% diffusion)**	**14,048**	**24,398**	**39,362**	**kL/y**
C	Water related savings in energy (diesel and power grid)				
	BAU energy required for desal. plant/ bore pumps	250,071	77,809	65,102	kWh/y
	Post retrofit energy required for desal. plant/ bore pumps	179,829	63,658	50,932	kWh/y
	Savings in energy for desal. plant/ bore pumps	70,242	14,151	14,170	kWh/y
	Cost savings for energy	22,969	3,614	4,634	$/y
D	Savings in water treatment (diesel and power grid)				
	BAU estimated energy demand for treatment	7,502	20,123	27,126	kWh/y
	Post retrofit energy required for treatment	5,395	16,463	21,222	kWh/y
	Savings in energy for treatment	2,107	3,660	5,904	kWh/y
	Cost savings for energy	689	935	1,931	$/y
E	Savings in transfer/ recirculation pumps energy (diesel and power grid)				
	BAU pumping energy required for transfer/ recirc. pumps	12,504	20,123	546,135	kWh/y
	Post retrofit energy required for transfer/ recirc. pumps	8,991	16,463	427,262	kWh/y
	Savings in energy for transfer/ recirc. pumps	3,512	3,660	118,873	kWh/y
	Cost savings for energy	1,148	935	38,871	$/y
F	Hot water savings in energy (diesel and power grid)				
	Annual BAU hot water demand	7,147	16,745	19,045	kL/y
	Annual post retrofit hot water demand	4,604	10,787	12,269	kL/y
	Reduction in hot water demand	2,543	5,958	6,777	kL/y
	Savings in energy for reduced hot water required	27,464	64,348	73,187	kWh/y
	Cost savings for energy	8,981	16,434	23,932	$/y
G	**Total energy savings from retrofit (100% diffusion)**	**98,746**	**83,094**	**208,161**	
H	Total energy costs				
	BAU costs	113,672	74,936	225,158	$/y
	Retrofitted costs	80,257	53,737	167,202	$/y
I	**Total monetary savings**				
	100% diffusion of retrofit programme to population	33,787	21,918	69,368	$/y
	75% diffusion of retrofit programme to population	25,341	16,439	52,026	$/y
	50% diffusion of retrofit programme to population	16,894	10,959	34,684	$/y

Units: kL/a - kilolitre per annum; kWh/a - kilowatt hour per annum; $/a – Australian dollars (AUD) per annum

A reduction of around 36% for residential post-retrofit hot water use represents a substantial portion of the water and water-related energy demand per household compared to BAU (Table 3). The main driver for this reduction is the lower shower hot water use resulting from the retrofitting of low flow showerheads. This end-use comprises the highest proportion of indoor use (35%) with half of its total volume being supplied by hot water. Others have also reported that replacing standard shower heads with water efficient shower heads (e.g. 9 L/minute) can reduce both hot and cold water consumption significantly (Beal et al., 2012; Vieira et al., 2014).

Monetary savings have been estimated from this program which range from AUD $11,000 per year (50% diffusion of the program on residential properties) to around $69,400 per annum (100% diffusion). A halfway point for this is the 75% diffusion which is the most likely scenario given the small population of the three study areas and relative ease of widespread social diffusion of the program. This would amount to around annual savings of $25,300, $16,400 and $52,000 for Site 1, Site 2 and Site 3, respectively, which would represent a savings of approximately 22% of original BAU costs. This also does not consider the reduction in community service obligation payments that the Queensland Government are required to subsidise energy utilities in non-urban regions.

Further energy savings will also be possible through integrating more capital intensive supply side solutions such as a renewable energy system (wind and solar farm) on the island with an energy storage bank. To highlight this, an analysis was conducted considering the installation of solar bore pumps in the two sites using bore-water; one pump in Site 2 and two pumps in Site 3. These solar bore pumps were assumed to have similar specifications to currently operational bore pumps in these two sites. The average daily peak sun hours were estimated from 20-year solar data obtained from the BOM and were 6.2 hours and 5.7 hours for Site 2 and Site 3, respectively. The peak sun hours were used to calculate the total demand the bore pumps are able to pump when operating at full capacities, with the remaining demand pumped by the existing bore pumps. Table 5 presents the annual energy and cost savings from installing solar bore pumps.

Table 5 Annual energy and cost savings from installing solar bore pumps

	Uptake of retrofit program	Site 2				Site 3			
Scenario		Water demand (kL)	Pumping energy required (kWh)	Energy costs ($)	Cost savings ($)	Water demand (kL)	Pumping energy required (kWh)	Energy costs ($)	Cost savings ($)
BAU	-	134,154	77,809	19,872	-	180,839	65,102	21,288	-
Solar pumps installed	100%	109,756	35,307	9,018	10,855	141,477	33,855	11,071	10,218
	75%	115,855	38,845	9,921	9,951	151,318	37,398	12,229	9,059
	50%	121,955	42,383	10,825	9,048	161,158	40,940	13,387	7,901

The results of the analysis indicate that there are considerable savings. Assuming a scenario of 75% diffusion of retrofit technology and the installation of solar-powered bore pumps, an annual cost savings of $9,921 and $9,059 are estimated for Site 2 and Site 3, respectively, representing almost 50% of original pumping energy costs. Although the capital and operating costs of the solar pumps have not been taken into consideration, the pump energy savings, along with the original costs savings from the retrofitting scheme, are expected to offset these costs.

Energy prices continue to rise globally and there is potential for the water-related energy savings from the efficiency project to increase over the long term. Hall (2013) predicted electricity prices to 'most likely' rise by 5% in the future, while oil prices are more erratic and difficult to predict and are influenced by global demand. Hence, based on a 5% annual increase in the cost of electricity and diesel fuel, the estimated 10 year savings are approximately $360,000, $234,000 and $739,000 for Site 1, Site 2 and Site 3, respectively, assuming a 75% uptake of the retrofit efficiency scheme. With the use of solar bore pumps, the latter two savings correspondingly increase to approximately $375,000 and $848,000. These savings do not take into account the cost of retrofitting the appliances or the cost of the bore pumps. However, the substantial costs savings provide evidence that the implementation of the retrofitting project has the potential to offset any additional costs which the scheme may incur. This is outside the scope of this modelling study and additional research is required on the potential net positive benefits for retrofitting appliances in remote communities.

Along with the cost and energy savings produced from this study, there are several other direct and indirect benefits and savings to be realised from introducing a water-efficient technology retrofit program. These include:
- reduced transport of diesel to remote islands and communities;
- reduced greenhouse gas emissions for diesel fuel us;
- instilling ongoing water and energy conservation practices amongst residents;
- desalination plant operation and maintenance cost reduction;
- power plant operation and maintenance cost reduction; and
- more accurate consideration of the capital and life cycle cost benefits of plant life spans.

Modelling assumptions and limitations

There are a number of assumptions and limitations associated with any modelling approach. For this study, the known average total per capita water use on the three sites was disaggregated into seven end-uses based on the SEQREUS – an urban residential end-use study that comprised a very minimal representation of Aboriginal and Torres Strait Islander people. The modelling also assumes that the savings that were achieved from water efficient technologies and behaviours in south east Queensland (urban residential) will be directly transferable to regional Indigenous communities. Obviously, this is

unlikely to be the case, particularly for any associated behavioural changes where cultural practices, social norms and attitudes to water use may be quite different (Jackson, 2006). To attempt to dampen the error relating to this, the modelling only assumes the savings based on the introduction of water efficient technologies (e.g. low flow shower heads, tap restrictors and water efficient clothes washers), rather than also assuming ongoing reductions to water consumption. It is acknowledged that there will still be differences in use of the fixtures and appliances by both groups (urban vs isolated), however once empirical data has been obtained from Stage 2 of the RICES project, the predicted savings will be compared to the observed savings in order to verify the model and the effectiveness of the strategies. The model also assumes that there is no existing penetration of the water efficient technologies within the community to start with. Although not exhaustive, 30 household water use surveys conducted in Site 2 and Site 3 did indicate that there is very limited penetration of water-efficient devices (e.g. no indication of low-flow shower heads, outdoor trigger hoses, and tap aerators and restrictors were observed during the household water use surveys).

Furthermore, it is acknowledged that there are some underlying assumptions of transferability between the communities in terms of the proportion of non-residential and residential properties, however there are strong similarities between the sizes of the communities and the number and type of non-residential premises (e.g. all have council offices, schools, health centres, shops and community buildings). What is less certain are the behavioural aspects of water use for residential and non-residential activities and whether these are transferable across the communities. Stage 2 of the RICES project will identify and clarify many of these assumptions and incorporate them into the final modelling phase of this work.

Conclusions

This paper presents modelling results from a scenario where water efficient strategies were retrofitted in three remote communities in Far North Queensland and central Northern Territory. The modelling demonstrated appreciable savings to both the water and energy average daily consumption through demand reduction on the energy intensive desalination plants or water pumping infrastructure. It has been estimated that such a retrofit program could potentially save between $16,400 and $52,000 (Australian Dollars) per year in saved energy costs, assuming 75% of the population implement the water efficiency retrofit program. Based on a 5% annual increase in the cost of diesel, the estimated 10 year savings achievable is between $234,000 and $739,000. Further savings were realised by substituting diesel-run bore pumps with solar powered pumps for the two sites that rely on bore water. This desktop case study represents the initial stages of a larger project examining the management of essential water and energy services in remote and isolated communities. The overall outcome of the project is to ensure that such strategies are practical to implement on a broader scale to ultimately achieve more sustainable water and energy efficient off-grid communities.

Acknowledgements

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