Sustainable Choices for Residential Water Supply in Auckland

Dr. Nalanie Mithraratne# and Dr. Robert Vale*
(# Research Fellow, **Presenter**, *Senior Researcher)
Centre for Urban Ecosystem Sustainability, Landcare Research, Private Bag 92170, Auckland,
NEW ZEALAND
Telephone: 64 9 574 4137 Fax: 64 9 5744101
E-mail: MithraratneN@LandcareResearch.co.nz; ValeR@LandcareResearch.co.nz

Intended Category: Philosophy and Science of Sustainability

Abstract

The current norm for residential water supply in urban locations is to rely on pipe-borne services. This involves collecting, storing, treating and transporting water over long distances. The extended infrastructure provision, combined with the resultant loss of water due to leaks and pipe bursts, means that the level of investment and intervention required for satisfactory functioning of the system could be more resource intensive than localized measures such as rain tanks. Due to increased development activity in the residential sector during recent times there is a need to expand the existing ageing water supply network in Auckland. This paper looks at conventional and alternative water supply systems over the useful life of an average New Zealand house to identify those systems with the least life-cycle energy, life-cycle CO_2 emissions and life-cycle cost. Settlement pattern could have implications for efficient use of resources for both rain tanks and mains supply. A series of settlements with various development patterns, building densities (in terms of plot coverage and number of units), and site configurations are analysed to identify which settlement pattern leads to the most efficient water supply system in life-cycle terms. However, the strength of the case for adopting efficient water supply systems depends on the relative importance of water supply in the overall performance of individual houses. Therefore the relative importance of the water supply system as a fraction of the total life-cycle energy, CO_2 and financial cost of the construction, operation and maintenance of average New Zealand houses is considered.

Key words:

water supply infrastructure, rain tanks, life-cycle analysis, life-cycle energy, environmental impacts, life-cycle cost

1. INTRODUCTION

UN estimates state that around 2007 the urban population of the world will exceed the rural population [1]. Continued migration from rural to urban locations increases the urban population twice as fast as population growth, so that by the year 2050 the majority of the population in all regions of the world will be living in urban areas [2]. To accommodate this urban population, rate of development of land far exceeds the rate of population growth. During the 1990s the rate of conversion of greenfield sites to new residential developments in the USA alone was 2.3 million acres (0.93 million hectares) per annum [3]. Current patterns of unsustainable consumption combined with urbanisation aggravate environmental problems. Through intensive use of energy and consequent emissions, urbanisation contributes to global warming, climate change, rising sea levels, change in vegetation, and severe weather events, etc.. Water supply is of major importance in urban areas due to growing concerns over future water shortages. Water demands associated with urbanisation directly affect fresh water supplies through the diversion and withdrawal of large volumes [4].

2. URBANIZATION IN AUCKLAND, NEW ZEALAND

Over 85% of the New Zealand population is now living in urban areas [5].

The typical suburban house plot or section, which used to be around 1000 m^2, has decreased in size over the last 20 years, especially in city locations. Research into housing in New Zealand has identified that the standalone house with 3 bedrooms is still the most common type in the Auckland region [6]. Current trends in household sizes however, are expected to increase the size of future housing to four bedrooms or more. Of the current housing stock, 55% has been built since 1970 with a 25% increase in the floor area of an individual house over this time [7]. An increasing proportion of new constructions especially in inner city locations, is for dwellings in multi-unit blocks and apartments. This signals a trend towards higher density urban housing.

It has been suggested that if demands generated by the population increase and the trend in declining household density is to be satisfied, 201,000 new dwellings are required in the Auckland region by the year 2021 [6]. The majority of this future demand for housing will have to be met by developing new greenfield sites. This development will significantly exceed the capacity of local services and built infrastructure, requiring considerable investment in new infrastructure. It has already been pointed out that the ecological footprint of urban areas, especially in Auckland and Wellington, exceeds the physical area occupied by the urban settlements, causing an ecological overshoot [8]. If our urban settlements are to be more sustainable, it is necessary to reconsider resource use in the development and maintenance of these settlements and their supporting infrastructure.

3. LIFE CYCLE PERFORMANCE OF MAINS WATER SUPPLY SYSTEM – NEIGHBOURHOOD SCALE

The current norm for residential water supply in urban locations is to rely on pipe-borne services that involve collecting, storing, treating and transporting water over long distances. The extended infrastructure provision combined with loss of water due to leaks and pipe bursts mean a high level of investment and intervention is needed for satisfactory functioning of the system. If future growth in residential areas in Auckland is on greenfield sites lacking any built infrastructure, the existing water supply network has to be expanded. This could not only be very costly but also resource intensive. Urban intensification, on the other hand, is considered to be more resource efficient and cost effective [8, 9]. Alternative water supply measures, such as rain tanks, can reduce the demand for new network infrastructure but are not feasible in high density developments due to limitations in roof and site area. High density developments will therefore have to continue to rely on reticulated water supply.

A life-cycle study [10] to quantify resource use of Auckland City's mains water supply system considered the initial construction, maintenance, and operating requirements over a period of 100 years. Resource use was evaluated in terms of life-cycle energy and associated emissions. The study found that the system operating requirements far exceeded the construction requirements of the infrastructure necessary to collect, treat and transport water. However, the materials used for construction of system components were a determining factor of construction resource efficiency.

The above study [10] also considered four subdivisions in Auckland City with various development patterns, building densities (in terms of plot coverage and number of units) and site configurations to investigate the impact of settlement characteristics on the life-cycle resource use of the reticulated water supply system. For the purpose of this analysis, a settlement was considered as a group of residential dwellings (between 35 and 120) in a defined area. The analysis demonstrated that the actual resource use for the water supply system was not directly dependant on settlement characteristics but rather on the materials used for the network and the length of the network necessary to supply each house. Lack of reliable data on reticulated supply systems, due to inadequate records and changes to the pipe material over years, was also identified as a hindrance to any precise evaluations of resource use. However, the study highlighted the significance of reducing water consumption as a way to increase resource efficiency and reduce environmental impacts. Since operating requirements, which are related to the volume of water supplied, were identified as outweighing the resource use for the network, any measures that reduce the water consumption improve the efficiency of resource use and reduce the environmental impact of the mains water supply system.

As a first step to achieving this, simple technical measures such as low-flow shower heads, dual-flush cisterns for toilets, front-loading washing machines, and flow restrictors would be necessary in average New Zealand houses. Research has found that these could reduce current water consumption by 50% [11].

Localized alternatives to mains water supply, such as rain tanks, can harvest only about 42–56% of the current consumption volume, depending on the roof area of a house located in Auckland [12]. Since the current trend in Auckland is for larger houses and lower household densities, the use of rain tanks to supply all domestic water needs for individual houses would be practical provided the demand reduction measures described above [11] are implemented and sufficient garden area is available to accommodate the rain tanks. Use of rain tanks could also reduce wastage of water due to leaks and pipe bursts. In addition to the technical demand reduction measures, behavioural changes would also be necessary if rain tanks alone were to be used to supply the total domestic water demand in smaller New Zealand houses. Behavioural changes, however, are not embraced by society without resistance [13], and the use of rain tanks for all domestic water needs in smaller houses in Auckland may therefore not be immediately feasible.

Currently more than 10% of the New Zealand population (mostly in rural locations) use rain tanks for all domestic water requirements [14]. There are two main concerns, however, with the use of rain tanks to supply all domestic water needs: water quality and water availability for fire fighting. When collected from roof surfaces, especially in urban locations, rain water can contain impurities that are a major concern to human health [14, 15]. A study of over 600 houses in New Zealand, however, has shown that the main reasons for poor water quality are improper design of collection and storage systems, and lack of maintenance [14]. The use of rain harvesting systems readily available in the market could screen rain water and reduce suspended matter. Further, the New Zealand Ministry of Health suggests that safe drinking quality can be achieved by boiling water for a minute [16]. In the Autonomous House in the United Kingdom (UK), which is in the centre of a town but obtains all its water from rainwater, all rain water collected is pumped to a slow sand filter before being used; cooking and drinking water are filtered using a silver-impregnated filter candle [17]. In Australia it has been possible to conform to National Health and Medical Research Council Guidelines (1991) for drinking water using simple technical measures such as those described above [18].

In addition to supplying potable water to individual properties, the mains water supply system also supports fire fighting requirements. Even though the actual volume of water used to fight fires in a year may be small, capacity for fire fighting is an important component of the pipe borne water supply system. The need to maintain a higher pressure than necessary for normal domestic use increases the network cost significantly. An Australian study has found that the cost of a reticulated system could be reduced by 35–45% by providing for fire fighting on site [19]. This would, however, increase the investment cost to the individual property owners, and may not be practical in smaller sites.

4. LIFE CYCLE PERFORMANCE OF ALTERNATIVE RESIDENTIAL WATER SUPPLY SYSTEMS – HOUSEHOLD SCALE

The life-cycle performance over 100 years of water supply for an average household using the reticulated system was compared with that for one entirely dependant on either concrete or plastic rain tank systems (capacity 25 m^3) [12]. The study assumed household water consumption of 50% of current demand. This is the approximate volume of water collected by an average Auckland house. This study used energy, CO_2 emissions, and cost as the performance indicators. Comparison of the systems based on the 3 indicators used is as shown in Figure 1.

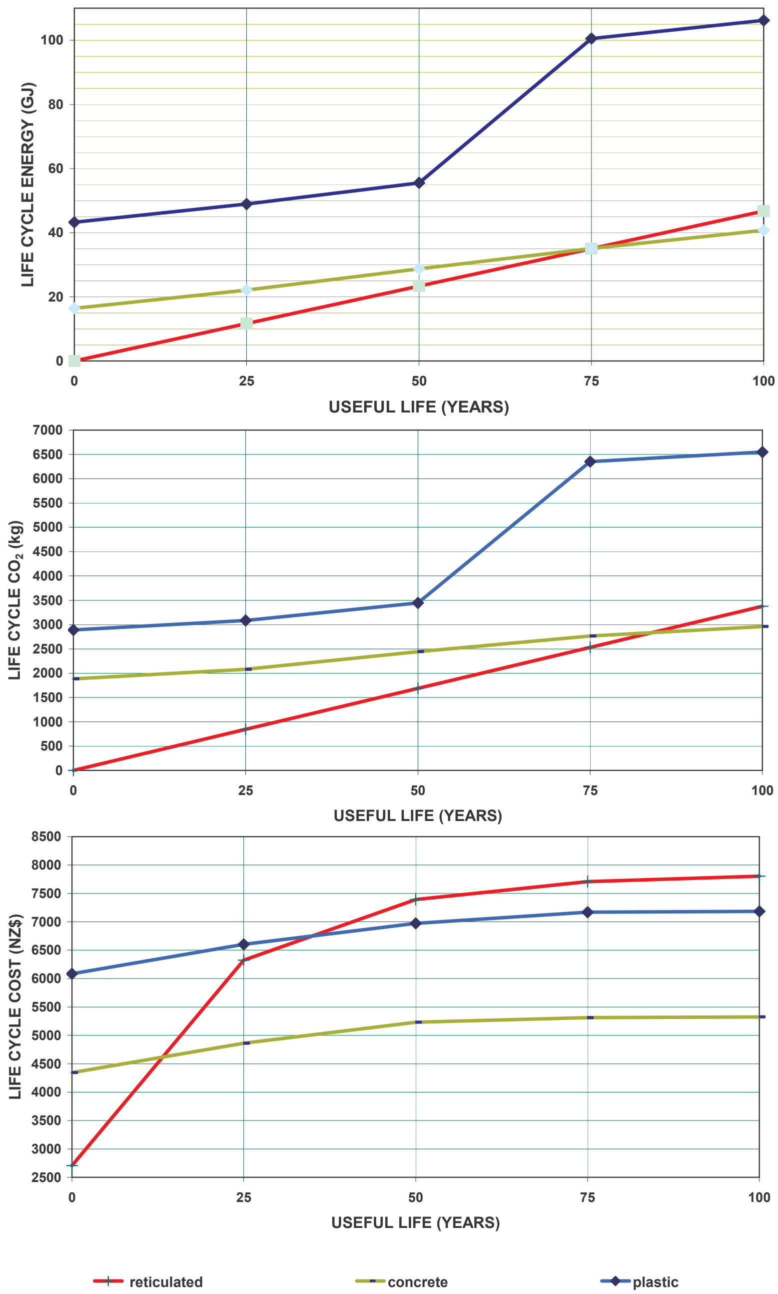

Fig. 1: Comparison of life-cycle energy, CO_2 emissions and cost of water supply systems

In life-cycle energy consumption terms, reticulated water and concrete tanks are approximately equal at 75 years, with the concrete tank using 13% less energy at the end of a 100-year life. A plastic tank, however, uses 127% more energy compared with the reticulated supply system at the end of a 100-year life. Life-cycle CO_2 emissions follow a pattern similar to that of energy, with both mains supply and concrete tank systems emitting similar amounts of CO_2 around year 75. The plastic and concrete tanks were initially 125% and 61% more expensive respectively, at about $6,085 and $4,350 per house, compared with $2,706 for reticulated supply. However, when the annual charges for mains supply and costs of pumping and maintenance for a tank system are considered, the costs for the concrete tank system and reticulated supply are roughly equal at the end of the 8th year. By the end of their useful life, plastic and concrete tanks are respectively 8% and 32% cheaper than reticulated supply.

The study [12] concluded that the use of rain harvesting systems currently available in the market with a concrete rain tank to supply all domestic water needs in houses in Auckland could reduce life-cycle energy use and CO_2 emissions compared with a reticulated supply. Although rain harvesting with a concrete tank is more costly in terms of initial cost, the life-cycle cost of the rain water system is lower than the reticulated supply.

5. WATER SERVICE IN THE CONSTRUCTION AND OPERATION OF AN AVERAGE NEW ZEALAND HOUSE

The New Zealand home ownership rate is among the highest in the OECD. Research has, however, identified a declining trend that suggests housing is becoming less affordable to New Zealanders [7]. When funds are limited, the decision whether or not to invest in efficient water supply systems would depend on the relative importance of water supply in the overall construction and operation of individual houses. A study of a series of houses of varying floor areas representative of common construction practices and operating regimes was used to evaluate the significance of the water supply system using life-cycle analysis [20]. Water consumption from the mains supply was regarded as equal to what could be collected with a rain harvesting system for that house size. The study found the use of a rain harvesting system with a concrete rain tank to be the cheapest option, irrespective of the house size. Depending on consumption (house size), savings could be up to 40% of the life-cycle cost of continued use of reticulated supply.

The study also found that for smaller houses with a floor area of up to 150 m^2, a 50% reduction in the current water consumption alone could be sufficient to gain life-cycle performance from a reticulated system similar to or better than the use of rain harvesting with a concrete tank. In contrast, for new developments with larger houses, were sufficient land area available, use of rain harvesting systems with a concrete rain tank could be cheaper, and have less life-cycle impact than a reticulated system.

However, the impact of the water supply system on the total performance of the houses was found to be negligible, contributing less than 5% of life cycle energy consumption, CO_2 emissions and cost. Composition of life cycle energy for New Zealand houses with varying floor areas is shown in Figure 2.

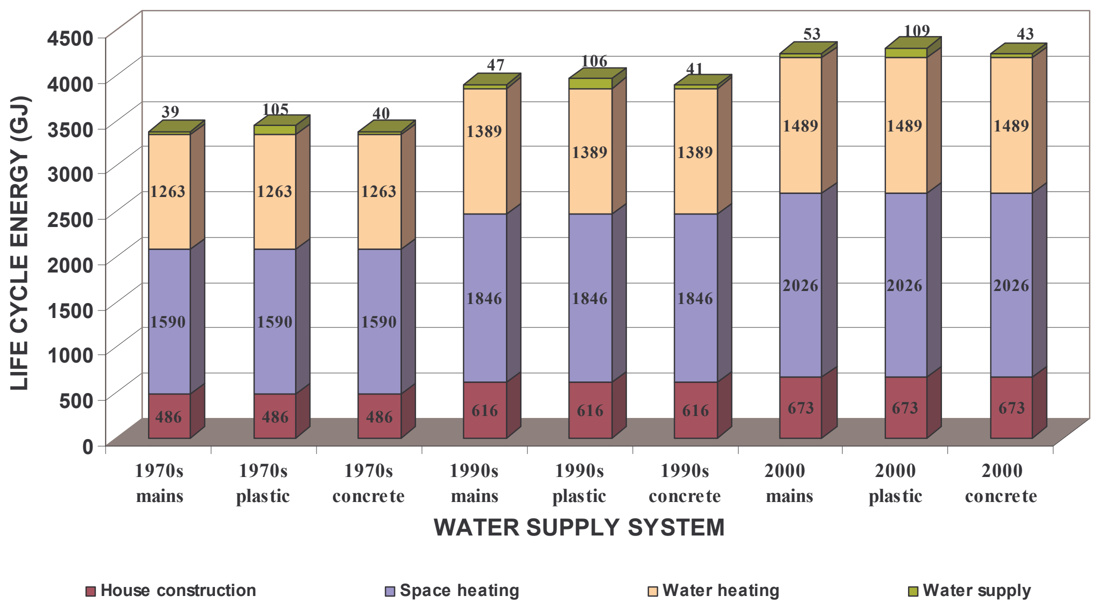

Fig. 2: Composition of life cycle energy for New Zealand houses with varying floor areas

This study, however, did not include lighting, appliances, furniture and cooking, which have been identified as significant in the life-cycle performance (in terms of energy, CO_2 and cost) of an average New Zealand house [21, 22]. The addition of these would further reduce the relative impact of the water supply system. Space and water heating were the main contributors to the life cycle energy consumption, while the initial construction was significant for both the life cycle cost and life cycle CO_2 emissions. For a home owner with limited resources it may therefore be more worthwhile to invest in better insulation to reduce energy required for space heating and water heating, than in a rain harvesting system.

6. CONCLUSIONS

- Reducing the current consumption of water using technical measures is the most environmentally friendly and cost-effective solution for houses of all sizes located in Auckland.
- If it is decided to use rain harvesting in a particular house, the use of a rain harvesting system with a concrete rain tank would be the cheapest option irrespective of the house size.
- The impact of the water supply system is negligible in the total performance of houses.

The above analysis evaluated the relative contribution of the water supply system purely on environmental performance and energy use. However, Aucklanders should not be complacent as the ultimate survival of human beings is not entirely dependent on energy, but on the single variable that is in the least supply [23]. According to UNFPA, in 2004 half a billion of the world population were living in areas identified as water-stressed or water-scarce [2]. It has been estimated this will increase to 3 billion by the year 2025 [24]. Greater use of more efficient household practices such as proposed here can help reduce the current demand for water (and waste water treatment). Even in New Zealand there may be limitations to total water supply, with potential conflicts in the future between household supply and irrigation of crops for home and export.

7. ACKNOWLEDGEMENTS

This research was funded by a grant from the Foundation for Research Science and Technology of New Zealand. The authors wish to thank the New Zealand water industry officials for their support for this research.

8. REFERENCES

1. **United Nations (2000).** *World urbanization prospects: The 1999 revision*. Department of Economic and Social Affairs (ESA/P/WP 161).
2. **United Nations Fund for Population Activities (2004).** *State of World Population 2004*, UNFPA, New York.
3. **Benedict, M. A. and McMahon, E. T. (2002).** Green infrastructure: Smart conversion for the 21st Century. *Renewable Resources Journal* 20(3), 12–17.
4. **Foley, A. J., DeFries, R., Asner, G. P., Barford, C. et al. (2005).** Global consequences of land use. *Science* 309/5734, 570–574.
5. **Ministry for the Environment. (2003).** *Urban sustainability in New Zealand: An information resource for urban practitioners*. MfE, Wellington.
6. **Auckland Regional Council. (2003).** *The demand and supply of housing in the Auckland region 1991–2001*, ARC.
7. **Centre for Housing Research. (2004).** *Changes in the structure of the New Zealand housing market: Executive summary*. (Prepared by DTZ New Zealand).
8. **Ministry for the Environment. (2003).** *Ecological footprints of New Zealand and its regions.* MfE, Wellington.
9. **Satterthwaite, D. (2000).** Will most people live in cities? *BMJ* 321,1143–1145.
10. **Mithraratne, N. and Vale, R. (2007).** Water supply infrastructure and settlement patterns. *3rd Sustainability Conference*, 4–7 January 2007, Chennai, India.

11. **Parliamentary Commissioner for the Environment (2001).** *Ageing pipes and murky waters: Urban water system issues for the 21st Century*. PCE, Wellington..
12. **Mithraratne, N. and Vale, R. (2007).** Conventional and alternative water supply systems: A life-cycle study. *International Journal of Environment and Sustainable Development*, accepted.
13. **Burkhard, R., Deletic, A. and Craig, A. (2000).** Techniques for water and waste water management: A review of techniques and their integration in planning, *Urban Water* 2(3), 197–221.
14. **Abbott, S. E., Douwes, J. and Caughley, B. P. (2006**). A survey of microbiological quality of roof-collected rainwater of private dwellings in New Zealand. *Water 2006 International Conference*, 4 August 2006, Auckland, New Zealand.
15. **Kuczera, G. and Coombes, P. (2001).** A systems perspective of the urban water cycle: New insights, new opportunities. *Stormwater Industry Association 2001 Regional Conference*, 26–28 April 2001, New South Wales, Australia.
16. **Ministry of Health. (2004).** *Household water supplies: The selection, operation and maintenance of individual household water supplies*, MOH, New Zealand.
17. **Vale, B. and Vale, R. (1975).** *The Autonomous House: Design and planning for self-sufficiency*. Thames and Hudson, London.
18. **Mobbs, M. (1998).** *Sustainable house: Living for our future*. University of Otago Press, Dunedin.
19. **Burn, L. S., De Silva, D. and R. J. Shipton. (2002)**. Effect of demand management and system operation on portable water infrastructure costs. *Urban Water* 4/3, 229–236.
20. **Mithraratne, N. and Vale, R. (2006).** Life-cycle impact of water supply system selection on typical New Zealand houses. *5th Australian Conference on Life Cycle Assessment,* 22–24 November 2006, Melbourne, Australia.
21. **Mithraratne, N. and Vale, B. (2004).** Life cycle analysis model for New Zealand Houses. *Building and Environment* 39/4, 483–492.
22. **Isaacs, N., Camilleri, M., French, L. Pollard, A., et al. (2005).** Energy use in New Zealand households, HEEP Year 9 Report, Building Research Association of New Zealand (*BRANZ Study Report No. SR141, 2005*)
23. **Rees, W. E. (1996).** Revisiting carrying capacity: Area-based indicators of sustainability. *Population and Environment: A Journal of Interdisciplinary Studies* 17(3), 195–215.
24. **Postel, S.** L. (1998). Water for food production: Will there be enough in 2025? *BioScience* 48(8), 629–637.