Minimising Energy Consumption of Domestic Rainwater Harvesting

Monash University, in partnership with The University of Melbourne and Melbourne Water

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Disclaimer

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Executive summary

Like many cities, Melbourne, along with many other Victorian towns, is facing the need to find supplementary water supplies, as population growth and climate change and variability reduce the reliability of the current potable supply. Domestic rainwater harvesting has the potential to significantly augment Melbourne's supply. However, it is important that all alternative water supplies are evaluated not only in terms of their water conservation benefits, but also in terms of their impacts on energy use.

This project monitored the energy use of a range of domestic rainwater harvesting systems, installed within the Little Stringybark Creek project, which is aiming to retrofit a 450 ha catchment using a range of stormwater management technologies (rainwater and stormwater harvesting, infiltration systems and raingardens) to remove the impact of stormwater runoff on the creek.

The project installed rainwater tanks as part of the "Stormwater Tender". A subset of 12 systems was selected for monitoring. Each had an Odyssey capacitance water level logger installed to measure water demand, along with a Dent Instruments MAGlogger Time of Use meter to measure times when the pumps were on. The energy use when on was measured and validated with a nano-second capable current, volt and amp-meter. All work was undertaken by a qualified electrician. Data were downloaded on an approximately monthly basis and analysed. Water demands were calculated using specific code written in R (www.r-project.org).

The monitored tanks systems covered a range of tank and pump sizes and types, as well as a wide range of water uses (including toilet flushing, hot water, clothes washing, outdoor irrigation).

The mean energy use intensity of the monitored rainwater tank systems is 2.3 kWh/kL (median = 2.00 kWh/kL), as shown in Table ES1. Assuming an emission intensity of 1.1 kg/kWh, this equates to an average of 2.55 kg/kL (with a median of 2.20 kg/kL).

Table ES1. Summary of energy use and CO_2 emission intensity of monitored rainwater tanks.

Statistic	Energy use intensity (kWh/kL)	CO_2 emissions (kg/kL)[1]
Mean	**2.31**	**2.55**
Median	**2.00**	**2.20**
Min	**1.2**	**1.32**
Max	**3.6**	**3.96**
Std. Dev.	**0.86**	**0.94**

[1]. Source: (Sustainability Victoria, 2010)

The mean water use of 2.3 kWh/kL is considerably more than the energy intensity of Melbourne's gravity-fed and largely untreated water supply (0.1 kWh/kL), which is unusual by both Australian and international standards. However, the Wonthaggi desalination plant is expected to require between 5.2 and 7.0 kWh/kL. Importantly, if the most efficient pumps are selected (the most efficient in this study used only 1.2 kWh/kL), the use of rainwater harvesting could save around 645 kWh/year per household compared with that of desalinated water.

We found that the most important determinant of energy use was in the sizing of systems, with many pumps being oversized for their application.

Given these observations, there are a number of important steps that specifiers of rainwater harvesting systems can take to maximise energy efficiency:

1. The most important is to ensure that pumps are appropriately sized for their application. Undersized pumps will be work above their recommended loading, resulting in decreased efficiency. However, the most common situation is for pumps to be oversized. Minimising head losses through the use of large transfer pipes to the point of reticulation (e.g. to the house) can allow small pumps to be used.

2. Reducing the number of starts required by the pump. This can be done using either a pressure tank or a pressure control switch that is programmable to allow a wider range of variation in pressure.

3. Specify pumps which have low power consumption relative to performance. Whilst the P1 and P2 power consumption figures provided by manufacturers may not provide a complete indication of likely energy efficiency, they do provide a valuable starting basis.

These steps should be incorporated into policy and we believe that Sustainability Victoria could play an important part in this, by:

1. Advocating for the development of a 5 star standard to be applied to rainwater pumps sold in Australia. The 5 star standard could be developed based on standard laboratory testing (with a given upstream and downstream head, a given flow rate and pressure, and a given number of starts), reflective of typical household conditions.

2. Advocating that the Living Victoria Water Rebate Program require a minimum energy efficiency standard be met by pump systems installed as part of rainwater harvesting installed under the rebate program.

There are clearly significant savings to be made in water through the use of rainwater harvesting as a supplementary water supply to Melbourne’s potable system. The evaluation of the energy use costs or benefits of rainwater harvesting is system-specific, as it depends on the energy intensity of the existing system. In the case of Melbourne, the existing gravity-fed system has very low energy costs both for transport and treatment. However, the alternative supplementary supply of desalinated water comes at a very high energy cost, meaning that for Melbourne, rainwater and stormwater harvesting is a very attractive option. Sustainability Victoria should consider advocating that the energy cost of alternative water supplies be included in the per kL usage charge for water (rather than embedded in the fixed supply charge), so that there is a clear economic incentive to use energy-efficient sources.

This study will be used to build integrated scenarios of alternative water supply options for Melbourne, so that future decisions about supplementary water supply options can be made with a proper understanding of the implications for consumption of potable water and energy.

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Introduction

Project background

Many years of drought in Victoria (and elsewhere in Australia) led to a rapid increase in the number of rainwater harvesting systems being installed by households. Whilst in many cases, such systems are used for outdoor irrigation purposes only, a large number are used for internal uses, such as toilet flushing; connection to such internal uses has been a requirement for both State and Commonwealth rebates for tank connection.

The installation of rainwater tanks has had a significant impact on water conservation, with rainwater tanks now estimated to supply 1.4% of Melbourne's water supply (source: Department of Sustainability and Environment, Living Melbourne, Living Victoria Roadmap, Ministerial Advisory Council, 2011). However, the installation of household rainwater harvesting systems has the potential to reduce the energy efficiency of the water supply system, because of the requirement of a pump for each household.

With this nexus between water and energy conservation in mind, the objective of this project was to assess the energy consumption of a range of household water harvesting systems, with different end uses (e.g. toilet flushing only, laundry, hot water and toilet, etc) and pump configurations. In doing so, we aim to compare this to the energy intensity of the water distribution system for Melbourne and thus to assess the extent to which the water savings of household rainwater harvesting systems impose an extra energy demand (and carbon dioxide emission).

The project has been undertaken within the broader framework of the Little Stringybark Creek project, which is attempting to retrofit the stormwater management of an entire catchment (made up of approximately 1000 households), with the aim of restoring the health of the creek, as well as reducing potable demand (to date the project has achieved a reduction in potable water demand of 20.1 ML/year across the 450 ha catchment). This project goes beyond rainwater and stormwater harvesting, aiming to restore the entire catchment water balance back towards the natural level (by enhancing infiltration and evapotranspiration, as well as reducing the volume of stormwater runoff). The overall goal is thus to provide guidelines on the management of stormwater – including stormwater harvesting – which minimises the degradation of receiving waters, whilst maximising potable water savings and minimising energy use (Bos et al., 2009; Fletcher et al., 2011).

Project objectives

The project has both local and broader objectives.

Local objectives

To date, the Little Stringybark Creek project has installed rainwater harvesting systems in 170 households. Given this large number, our first objective was to ensure that systems being installed were as energy-efficient as possible, by providing guidance to the project's contract plumbers on pump selection.

Broader objectives

The overall aims of this project were to:

1. Assess the (i) energy use and (ii) CO_2 emissions of a range of rainwater harvesting systems
2. To compare this energy use to the energy intensity of the Melbourne water supply system (in order the relative energy benefit/cost of household-scale rainwater harvesting).
3. To identify factors influencing energy efficiency (e.g. pump specifications, number of pump starts, etc.) of rainwater harvesting systems.
4. Provide recommendations on the specification and pump selection of household scale rainwater harvesting systems.

Project partners

The project was undertaken as a partnership between Monash University, The University of Melbourne and Melbourne Water, within the broader partnership of the Little Stringybark Creek project (see www.urbanstreams.unimelb.edu.au for more details). The research and monitoring was led by the two universities. Monitoring of the tank water use was undertaken by Matthew Burns (Monash University), while energy monitoring was undertaken by Robert James (University of Melbourne), with the project being led by Tim Fletcher (formerly Monash University and now University of Melbourne) and Chris Walsh (University of Melbourne). The installation of rainwater harvesting systems was overseen by Darren Bos (University of Melbourne), with funding for these systems provided through the Stormwater Tender (see www.urbanstreams.unimelb.edu.au/allotments.htm). Funds for these installations were provided by Melbourne Water, as part of their contribution to the Little Stringybark Creek Project. Toby Prosser and Sharyn RossRakesh have been the principal drivers of the project from within Melbourne Water.

Project activities

Installation of rainwater harvesting systems

Rainwater harvesting systems were installed through three phases of economic instrument. The first – *Stormwater Tender* – sought bids from landholders on their level of funding required to install systems on their property. The tender was a sealed-bid uniform price, reverse auction (for details see: Nemes et al., 2010). Bids were evaluated in terms of their cost per unit of environmental benefit (Table 1). An example of such an evaluation process is provided in Table 2. In the second and third rounds – both called *Stormwater Fund* – householders were provided with a simpler-to-understand approach. The first – a rising clock uniform price auction – offered a set price per unit of environmental benefit. The price was increased each month, until the budget ran out, and all participants were paid the final price (for the full theory regarding these auction models, refer to Nemes et al., 2010). The final round has offered householders the full price of the installation of rainwater harvesting systems. The use of these three approaches was intended to evaluate the relative efficiency of alternative economic incentive models.

Table 1. Summary of sub-indices comprising the Environmental Benefit Index.

Indicator	Weighting	Measure	Rationale
Reduction in runoff frequency	0.5	Proportional reduction in the number of days of runoff	Increased frequency of runoff is biggest impact on urban streams
Reduction in Total Nitrogen load	0.3	Proportional reduction in annual N load exported	Port Phillip Bay is threatened by increases in nitrogen levels.
Water conservation/ volume reduction	0.2	Proportion of harvestable water that is captured for use	Public benefit to conserve water/improved performance of future downslope treatments

Table 2. Uniform price auction example. Given a funding pool of $10 000, the price for all tenders is set at $1100/ unit of EB provided. Only the top three tenders are successful. The payment they receive is calculated as their Environmental Benefit x $1100. (Source: La Nauze *et al.,* 2010).

Tender Ranking	EB	Bid	"Value for money"	Tender Successful	Payment
1	1.5	$1 050	$700 per unit of EB	Yes	**$1 650**
2	2.2	$1 936	$880 per unit of EB	Yes	**$2 420**
3	3.4	$3 100	$912 per unit of EB	Yes	**$3 740**
4	1.7	$1 870	**$1 100 per unit of EB**	No	$0
5	2.1	$2 730	$1 300 per unit of EB	No	$0

At the time of writing, this has resulted in 170 households being treated, with more than 200 rainwater tanks installed to date (a total of 1.71 ML of water storage, capturing around 20 ML of water per year).

A small subset of these tanks was then to be selected for monitoring.

Selection of households to monitor

We initially contacted 46 landowners in the catchment who had installed tanks with the assistance of our restoration project. Each landowner received a letter that outlined a proposal to monitor the performance of their tank configuration. Of the 46 landowners contacted, we received replies from 13 willing to participate. Upon inspection, one of these would have been very difficult to instrument, leaving us with 12 households (Table 3). Willing landowners were sent another letter informing them that data collected would be used on an anonymous basis. It can be seen from Table 1 that a good variety of different systems was obtained, in terms of roof area, tank volume, end-use types etc.

Water Level and Logger Installation and Monitoring

We installed depth loggers in each tank. We used Odyssey capacitance loggers (www.odysseydatarecording.com) to continuously monitor water level. We opted for these loggers because 1) they are precise and accurate (+/- 1 mm), and 2) other types of loggers (i.e. those affixed to tank outlet pipes) may have been seen as intrusive. Each logger was calibrated prior to installation using methods outlined by the manufacturer. We housed each logger in a PVC pipe that protruded from the top of each tank. Each logger was set to record water level every 6 minutes from 20:00:00 on the day it was installed. During logger installation, various characteristics relating to each tank configuration were measured (e.g. tank cross-sectional area, etc.). Other relevant characteristics (e.g. occupancy, connected demands, etc.) were obtained directly from each landowner via mailed surveys and telephone conversations.

Data was downloaded from each logger up until March 2012 approximately every two months, to minimise disturbance to landowners. During each visit, we undertook tank maintenance (e.g. removal of leaves in the tank inlet screen). The data was regularly checked to ensure it was consistent. In September 2011, the loggers were re-calibrated and this second calibration was found to be consistent with that conducted prior to installation. In maintaining our commitment with each landowner, the collection of data ceased in March 2012, at which point we had collected almost two years of data.

Data was analysed using R (version 2.13.0, www.r-project.org) such that it could be used to answer the questions listed in the introduction. For each household, the calibrated depth data was plotted against time and erroneous data was set to missing (or NA). Erroneous data was generally recorded when 1) the loggers were being retrieved; 2) the battery of a logger was flat; or 3) a logger malfunctioned inexplicably. The amount of erroneous data was small across nine household (less than 10% over the monitoring period per household). There was more erroneous data for household 3 (i.e. around 40%) because of a recurring flat battery. Household 7 had a similar level of erroneous data because their tank was not operational for many months. The amount of missing data for household 1 was 24%, primarily because its logger malfunctioned inexplicably over a few months.

We then derived (using cubic spline interpolation) 6-minute time series of calibrated depth data for each household for the entire monitoring period. This was carried out because 1) some erroneous data could be infilled through interpolation, and 2) the timestamps of the recorded time series were not perfect multiples of 6 minutes (e.g. 01/01/2011 12:06:44; DD/MM/YYY HH:MM:SS). The overflow level of each tank was found from the time series by inspection.

Table 3. Properties of monitored households.

Household	**Tank capacity (L)**	**Impervious area draining to tank (m^2) [a]**	**Occupancy[b]**	**Internal demands connected to rainwater tank**	**External demands connected to rainwater tank**	**Garden size[c] (m^2)**	**Reported external demand behaviour over monitoring period**
1*	3,000	35	3	Toilet flushing (TF)	Garden watering (GW)	18	Minimal GW
2*	5,400	71	2	Clothes washing (CW) and TF	GW	200	Minimal GW
3*	5,000	130	2	CW and TF	Car washing (CWS) and GW	600	Minimal CWS and GW
4*	26,000	374	2	CW and TF	CWS, GW and swimming pool top-up	3,500	Minimal CWS and swimming pool top-up. Moderate GW
5	5,500	167	2.0	CW and TF	GW	80	Minimal GW
6*	5,500	91	2	CW, TF and hot water	GW	125	No GW
7*	22,500	466	3.4	All	GW	300	Minimal GW
8	25,000	366	2.5	All (except drinking)	GW	800	Minimal GW
9*	18,000	199	2	All	None	20	No GW
10*	28,000	183	3	All	GW	240	Minimal GW
11*	9,000	316	3	All	GW	216	Minimal GW
12*	18,200	229	4	All (except drinking)	GW	200	Minimal GW

[a] These areas were calculated primarily using satellite imagery (NearMaNop; http://www.nearmap.com/) and ground-truthing.
[b] Over the monitoring period, the occupancy for some households changed. For these cases, the average occupancy, weighted by time, over the monitoring period is reported.
[c] Watered garden area is based on estimates from householders.

Of those households who agreed to have water level monitored, we then sought to install energy monitors. We selected Dent Instruments MAGlogger Time of Use Meters for their robustness and ability to be deployed without requirement to modify electrical circuitry. The meters were installed by a qualified electrician and their accuracy validated with a nano-second capable current, volt and amp-meter. Due to a combination of logistical constraints and privacy concerns by landholders, we were only able to install the MAGloggers on 10 of the 12 sites; these are highlighted with an asterisk in Table 3. However, due to issues such as landholders selling and extended absences of residents within the study area, reliable energy use data could only be obtained for 7 of the 12 sites (Table 4). These sites covered a wide range of end use types as well as pumps. This allowed a more reliable estimate of ‘population-level’ performance. However, because it was not feasible to have a fully replicated study (in other words many households with the same pump but different water end uses, or vice versa), it was not possible to directly relate energy use to the type of end use or to the type of pump.

Instead, we undertook analysis to calculate the (i) mean, median and standard deviation of energy efficiency (expressed in kWh/kL), (ii) mean, median and standard deviation of CO_2 emissions for each household, and thus, the (iii) difference between energy use of household rainwater harvesting systems. Finally, we examine the influence of factors such as the number of pump starts on energy efficiency and identify the likely outcome if pumps were specified according to energy efficiency.

Table 4. Pump energy monitoring details.

Household	Pump Brand	Model	Reliable data*
1	Hyflow	DHJ800	Yes
2	Davey	HP45-05	Yes
3	Davey	HP45-05	No
4	Pentax	CAM 100/00	Yes
6	Pumpmaster	STJN 120	Yes
7	Pentax	MPX 120/5	No
8	-	-	No
9	Pumpmaster	CSS 2-60	Yes
10	Davey	HM 90-13	Yes
11	Grundfos	CH 2-50	Yes
12	Onga	SMH75	No

* As at 30/3/2012 (the project will be extended for another 12 months)

Communications and media

Based on the measured variation, we provide recommendations on the selection and configuration of pumps for household rainwater harvesting. We have used this material in guiding contractors working within the Little Stringybark Creek project and prepared a communiqué for distribution to the Plumbing Industry Commission (part of the Building Commission), along with Green Plumbers. We are including this material in a seminar being run in partnership with Melbourne Water and Clearwater in September 2012.

The Little Stringybark Creek project produces a regular newsletter and the results of this study are being included in the 2012 2nd edition of the newsletter.

Challenges and obstacles

The principal challenge of this project has been the timely collection of data, given the reliance on the willingness of landholders to be available and for the rainwater systems to be fully functional. A number of householders were away over extended periods, preventing us from collecting data for long periods, while others had breakdowns of their system (not of the pumps themselves, but breakdowns due to installations) and chose not to repair them for several months, preventing us from collecting data. As we relied on their voluntary support, we had little power to influence these circumstances.

Key findings

Energy use intensity and emissions

The mean energy use intensity of the monitored rainwater tank systems is 2.3 kWh/kL (median = 2.00 kWh/kL), as shown in Table 5. Assuming an emission intensity of 1.1 kg/kWh, this equates to an average of 2.55 kg/kL (with a median of 2.20 kg/kL).

Table 5. Energy use and CO_2 emission intensity of monitored rainwater tanks.

Household	Pump	Calculated kVA	% loaded	Mean intensity (kWh/kL)	Mean CO_2 emissions (kg/kL)[1]
1	Hyflow DHJ800	0.588	74	3.6	3.96
2	Davey HP45-05			2.6	2.86
3	HP45-05			n/a	n/a
4	Pentax CAM100/00	1.045	141	2.0	2.20
6	Pumpmaster STJN120	1.568	174	3.2	3.52
7	Pentax MPX120/5	0.819	93	n/a	n/a
9	Pumpmaster CSS2-60	0.476	59	1.9	2.09
10	Davey HM90-13	0.823	46	1.7	1.87
11	Grundfos CH2-50	0.480	71	1.2	1.32
12	Onga SMH75	0.703	94	n/a	n/a
Mean		**0.814**	**94**	**2.31**	**2.55**
Median		**0.761**	**83.5**	**2.00**	**2.20**
Min		**0.476**	**46**	**1.20**	**1.32**
Max		**1.568**	**174**	**3.6**	**3.96**
Std. Dev.		**0.835**	**43.2**	**0.86**	**0.94**

[1]. Source: (Sustainability Victoria, 2010)

Comparison with Melbourne reticulated water supply

Melbourne has the lowest energy consumption water supply system of any major city in Australia, equating to 335 GJ/GL (Kenway et al., 2008), or 0.1 kWh/kL (Table 6). This is less than 5% of the energy consumption of Adelaide's water supply system for example. The reason for such a low energy consumption is the fortunate geographic situation of the city relative to its water supply catchments, allowing an almost entirely gravity-fed system. In addition, Melbourne has almost no treatment energy costs, compared to most other cities.

Given this situation, it is not surprising that the median additional energy use of rainwater harvesting is around 1.9 kWh/kL higher than for the reticulated system as at July 2012.

However, the Wonthaggi desalination plant is expected to require between 5.2 and 7.0 kWh/kL for the treatment alone, in addition to pumping costs of moving water from the Wonthaggi plant to Cardinia Reservoir (which were not readily available at the time of writing). Ignoring these pumping costs, it is apparent that there is potentially a very significant energy cost to Melbourne in pursuing alternative water resources to supplement its traditional water supply catchment sources. In the case of desalination, this results in additional energy use per household of around 800 kWh/year, whereas rainwater harvesting imposes an additional 296 kWh. Applied to the entire 150 GL volume to be supplied by the desalination plant, this represents a potential difference in 553000 MWh per year energy consumption.

In the case of the Wonthaggi desalination plant, the extra carbon dioxide emissions are being offset by investments in renewable energy. However, in the case where government had made such investments anyway, the use of rainwater tanks across Melbourne instead of the use of desalinated water could save around 495 kwWh per household, or approximately 0.55 t of CO_2 per household per year.

Table 6. Comparison of energy use and CO2 emission intensity of rainwater harvesting with Melbourne's water supply system. Emissions calculated assume emission rates typical for Victoria (Kenway, et al., 2008) and thus exclude any offset arrangements. This analysis thus shows the emissions before any offsetting takes place. Annual water use is taken from Wilkenfield & Associates (2006), who report an annual water use of 134.54 kL/yr for a combination of toilet flushing, clothes washing, shower and outdoor purposes, for an average house of 2.67 people.

Water source	Energy intensity (kWh/kL)	CO2 emissions (kg/kL)	Annual energy use (kWh)	Annual CO2 emissions (kg)
Rainwater harvesting	2.31	2.541	311	342
Melbourne potable (without desal.)	0.1-0.13	0.11-0.14	13-16.9	15-19.5
Melbourne potable (with desal.)	5-7	5.5-7.7	672-941	740-1036

Factors influencing the energy use intensity of domestic rainwater harvesting systems

In this project we attempted to assess the influence of design factors (e.g. number of starts/kL supplied, size of pump motor, etc). We note that there are of course other factors that may play a role, such as the number of people in the household, but these influence the energy use indirectly, by affecting water use, and are thus taken into account in the calculation of energy intensity.

The size of pump was shown to have a significant impact on energy use intensity (Figure 1), demonstrating that in general domestic rainwater pumps appear to be over-specified for their application. The most efficient of these pumps – from household 10 – consumed only 1.2 kWh/kL.

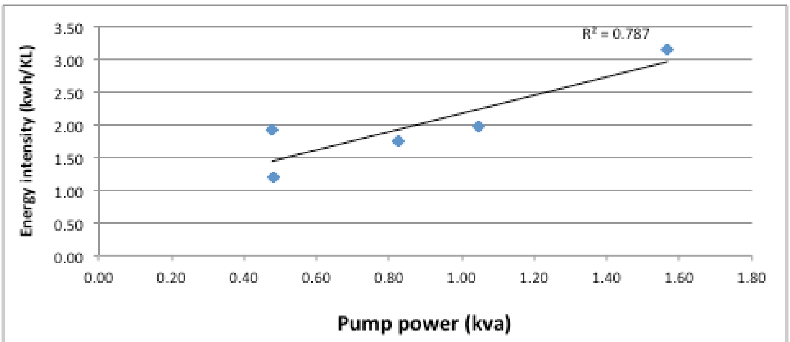

Figure 1. Relationship between pump motor size and energy intensity. Note; this relationship excludes one outlier (property 1), where configuration problems are likely to have influenced the energy efficiency.

Best practice scenario

The energy use intensity of rainwater harvesting systems varies significantly, depending on pump configuration Household 11, using a Grundfos CH2-50, used only 1.2 kWh/kL, being around 50% of the mean. The use of such a system would result in an annual power consumption of only 161 kWh/year, a saving of 150 kWh/year over an 'average' system, and a saving of around 645 kWh/year/household over the energy consumption of desalinated water.

This performance provides clear evidence of the value in specifying high-efficiency rainwater pumps, although it is noted that these typically come at a higher cost than the least efficient pumps.

Project evaluation

The project was undertaken using the methods as planned in development of the proposal and as such, met its primary objectives. The data collected provides a very important information source, one that we are happy to make available to Sustainability Victoria and to other entities who wish to use it (e.g. retail water authorities).

One area we remain disappointed with was the clear relationship between factors driving energy efficiency (e.g. number of pump starts), which we had hoped would provide a more definitive guidance. In part this was due to the difficulty in finding households willing to participate in the project, and having found them, ensuring that their system was functional at all times. This has also placed some qualification on the messages we are communicating to the industry.

For this reason, we have decided to extend the project beyond its original scope, continuing the monitoring for an extra 12 months; this will be funded by The University of Melbourne through its existing resources. This expansion of the project will also allow us to publish the findings in relevant industry and scientific journals, as well as suitable industry conferences. Despite this, the project has provided very clear data on the relative energy cost and benefits of domestic rainwater harvesting systems, and the potential for reducing consumption through careful specification of pump systems.

Recommendations and future directions

There are a number of important steps that specifiers of rainwater harvesting systems can take to maximise energy efficiency:

1. The most important is to ensure that pumps are appropriately sized for their application. Undersized pumps will be work above their recommended loading, resulting in decreased efficiency. However, the most common situation is for pumps to be oversized. Minimising head losses through the use of large transfer pipes to the point of reticulation (e.g. to the house) can allow small pumps to be used.
2. Reducing the number of starts required by the pump. This can be done using either a pressure tank or a pressure control switch that is programmable to allow a wider range of variation in pressure.
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Importantly, these steps should be incorporated into policy and we believe that Sustainability Victoria could play an important part in this, by:

3. Advocating for the development of a 5 star standard to be applied to rainwater pumps sold in Australia. The 5 star standard could be developed based on standard laboratory testing (with a given upstream and downstream head, a given flow rate and pressure, and a given number of starts), reflective of typical household conditions.
4. Advocating that the Living Victoria Water Rebate Program require a minimum energy efficiency standard be met by pump systems installed as part of rainwater harvesting installed under the rebate program.

There are clearly significant savings to be made in water through the use of rainwater harvesting as a supplementary water supply to Melbourne’s potable system. The evaluation of the energy use costs or benefits of rainwater harvesting is system-specific, as it depends on the energy intensity of the existing system. In the case of Melbourne, the existing gravity-fed system has very low energy costs both for transport and treatment. However, the alternative supplementary supply of desalinated water comes at a very high energy cost, meaning that for Melbourne, rainwater and stormwater harvesting is a very attractive option. Sustainability Victoria should consider advocating that the energy cost of alternative water supplies be included in the per kL usage charge for water (rather than embedded in the fixed supply charge), so that there is a clear economic incentive to use energy-efficient sources.

This study will be used to build integrated scenarios of alternative water supply options for Melbourne, so that future decisions about supplementary water supply options can be made with a proper understanding of the implications for consumption of potable water and energy.

Appendix One: Project Financial Report

A financial acquittal of the whole project (this will not be made public)

Appendix Two: References

Bos, D., Walsh, C. J., Fletcher, T. D., & RossRakesh, S. (2009). *Restoring urban streams through the management of stormwater at the catchment scale*. Paper presented at the OzWater.

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