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Smart Water Fund

Development and Trial of Smart Shower Meter Demonstration Prototypes

Project Smart1

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21 February 2006

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1. EXECUTIVE SUMMARY

A recently completed trial has demonstrated that, given real time feedback regarding their water usage, shower users could make water savings of 15%, on average, with some participants achieving up to a 30% saving.

The trial was conducted using prototypes of a water and energy metering device developed by Invetech in a project jointly funded with the Smart Water Fund under the Round 2 programme. The Smart Water Fund is an initiative by Melbourne's water businesses Melbourne Water, Yarra Valley Water, South East Water and City West Water, supported by the Victorian Government. The fund supports projects aimed at innovative water conservation, water recycling and sustainable biosolids management projects.

The metering device, referred to as the Smart Shower Meter provided users with flow-rate, accumulated shower volume and other information to assist them to develop an awareness of their water usage in the shower. The device also provided visual and audible prompts to encourage users to gradually reduce their consumption.

Under the project, Invetech developed a concept for the device, producing a design that could be manufactured with a commercial look and feel using rapid prototyping techniques.

Twenty units were deployed across households in the Melbourne regions serviced by Yarra Valley Water, South East Water and City West Water. In a trial over a period of six months the Smart Shower Meters first recorded a baseline of household shower usage whilst operating in a mode where no usage feedback was provided. After one month of baseline recording each unit entered an active mode in which real time usage feedback was provided to users.

A comparison of water usage between active and baseline modes was made to establish the water and energy savings made by households.

2. BACKGROUND

The Victorian State Government has targeted a 15% per capita reduction in the consumption of potable water in Melbourne relative to consumption in the 1990's. This targeted reduction is in response to a trend toward lower storage levels due to the combined effects of lower than average rainfall in the catchment areas and ongoing population growth[1].

Over a period of time Invetech has been involved in the development of a number of products associated with:

- rainwater harvesting
- water quality monitoring and treatment
- water reuse, and
- water metering.

In this context, Invetech recognised an opportunity to develop new products that would enable residents to reduce their water consumption. Such new products would ideally meet the following criteria:

- be suitable for broad application across a large number of households
- have potential for significant household savings
- achieve savings that existing products cannot access
- achieve an attractive payback time through the savings made, and
- exhibit low barriers to purchase including low cost & easy householder installation.

The bathroom stands out as one of the opportunity areas for achieving a significant reduction in water use (refer to Figure 1). Even in homes fitted with low-flow shower heads, the bathroom is a place of dominant indoor water usage[2]. In many homes the shower is where most usage takes place. The shower is also a place of significant discretionary water usage.

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[1] State Government White Paper "Our Water Our Future Together"

[2] Refer to section 5.2 "Component Usage" in the report Loh M, Coghlan P, Domestic Water Use Study, In Perth, Western Australia 1998 – 2001" Water Corporation, March 2003.

However, users lack information about volumetric usage that could assist them to most effectively minimize shower water consumption.

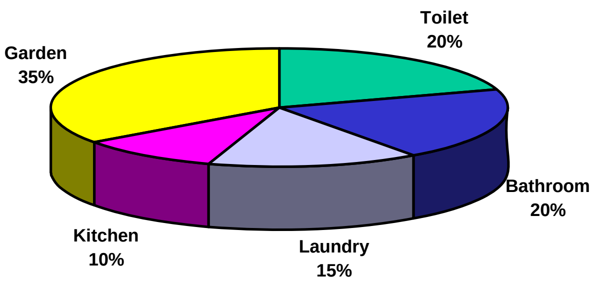

Figure 1 - Domestic water usage - source SE Water

Conserving water usage in the shower also has the potential for significant payback to the householder due to the combination of water supply, water disposal and heating energy savings. In contrast, a reduction in water consumption in the garden nominally only saves the water supply cost.

2.1 Limitations of existing products

A range of commercial products aimed at achieving lower shower water consumption is currently available. Each of these products has its own set of strengths and weaknesses.

Low-flow shower heads achieve water savings compared to less efficient models through a through an efficient head design which limits the flow rate. Being a relatively low-cost product, low-flow shower heads provide a cost effective way to reduce water consumption.

Even when a low-flow shower head has been installed there is scope for further savings by encouraging users to reduce the flow rate to the minimum that still provides an acceptable shower experience. Low-flow shower heads do not address this opportunity or the issue of shower duration.

Flow Cut-off valves that actuate after a settable time or volume can be used to set hard limits. However, if the mechanism is readily resetable, a user may elect to simply reset the time or volume allocation whilst in the shower in order to extend the shower duration.

Where the mechanism is not readily resetable, the user loses the option to extend the shower duration when it would be justified. This may lead to users routinely setting higher limits than necessary in order to avoid having the water cut-off before the end of the shower.

Simple timers are a low cost solution that allows shower users to monitor their shower duration and optionally set an audible alarm. They require users to program in a time interval and start the timer at the beginning of each shower. Timers require a level of engagement from each user that may not be a realistic expectation of all users (especially young children and teenagers).

Whilst a shower timer provides real time awareness of shower duration, it does not encourage users to further reduce their consumption, nor does it provide visibility to the flow rate and total volume used in a shower.

Flow restricters may be inserted into the flow path to the shower head thereby limiting the flow rate from the shower head. These devices provide a very low cost retrofit solution. However, when employed with a high flow-rate shower head, these devices often severely degrade the shower experience in a way that users cannot control. Because of this their appeal in the marketplace is limited. Like low flow shower heads, flow-restrictors do not address the dimension of shower duration.

2.2 A shower meter

Most people have a very poor idea of how much water they use in the shower. For this reason it is difficult for them to improve their shower efficiency. With no direct information about their usage, shower users have no positive feedback to encourage and reinforce water efficient behaviour.

This was the genesis of a concept for a water and energy metering device that provides users with real-time feedback on water consumption for each individual within a household. This meter has been denoted the Smart Shower Meter or Shower Smart.

Figure 2 – Smart Shower Meter Preliminary concept sketch

3. PROJECT OBJECTIVES

Because the Smart Shower Meter is aimed at aiding individuals to modify their behaviour, it is not possible to accurately predict the average household water savings that might be achieved. For this reason Invetech proposed to undertake a trial of the concept in the form of demonstration prototypes.

Invetech and the Smart Water Fund jointly funded a project to evaluate the water savings that might be achieved through the use of a Smart Shower Meter.

In essence, the project aimed to test the hypothesis that, given easy to understand real time feedback, shower users could make significant reductions in the volumes of water that they use.

The execution of the project consisted of two key stages

- Development of a Smart Shower meter demonstration prototype
- User trial of Smart Shower Meters in Metropolitan Melbourne households.

3.1 Demonstration prototype development

Invetech developed a prototype design and produced prototypes for field deployment through a process of:

- Requirements capture, ensuring that requirements key to achieving a successful trial were captured
- Concept development
- Bench testing key technical concepts
- Prototype design including Industrial design as well as the engineering of the electronics, software and mechanical aspects of the device
- Prototype rapid tooling to achieve a product like appearance using low-cost techniques
- Construction and testing.

Key aspects of the design include:

- Achieving a mechanically robust, water resistant enclosure with enough durability to survive the trial
- Development of low power flow and temperature sensing electronics
- Development of an information rich user interface that is easy for the user to understand and operate.
- Integration of a logging function to record shower usage data over the trial period.

3.2 User trial

The objective of the trial was to gauge the level of water savings that individual households could achieve with the assistance of a Shower meter. In order to achieve this, a trial of 20 units over a period of six months duration was undertaken.

For the first month, 16 units were deployed in baseline mode. In this mode the units remained mute, recording a baseline of shower usage without providing any user feedback.

Following the first month of baseline operation each of the sixteen units entered active mode in which visual and audible feedback was provided to shower users in order to encourage more water efficient shower behaviour. These units remained in active mode for the following five months of the trial. Whilst in active mode, each of the units recorded shower usage data in the same way as when in baseline mode.

Four control units remained in baseline mode for the duration of the trial. These units were deployed to detect any strong seasonal variations that might need to be taken into account in the comparison between active and baseline modes for the other sixteen units.

A trial duration of six months was chosen to facilitate identification of any significant seasonal variations in water usage and test whether savings were sustainable.

At the conclusion of the trial units were recovered from the homes of the participating households and the recorded data was harvested from them. A comparison of active mode water usage to baseline mode usage has yielded good estimates of the savings achieved through the usage of the units on a household-by-household basis.

4. SHOWER METER DETAILS

The following features were implemented in the Smart Shower Meter demonstration prototypes

- easy to use user interface
- automatic starting on the commencement of flow
- water flow measurement
- displayed time remaining to an allocated volume
- programmable shower volume alarm
- flashing indicator and audible buzzer
- hold-off time between showers to prevent "cheating"
- water temperature measurement and display
- estimation of the energy used to heat the shower water
- sounding of a scald alarm if the water temperature exceeds 50C
- battery powered – safe to use
- shower information storage to allow water savings to be assessed.

The block diagram of Figure 3 shows the key functional elements of the Smart Shower Meter. Careful software and electronics design achieved a service lifetime in excess of six months from two alkaline AAA cells.

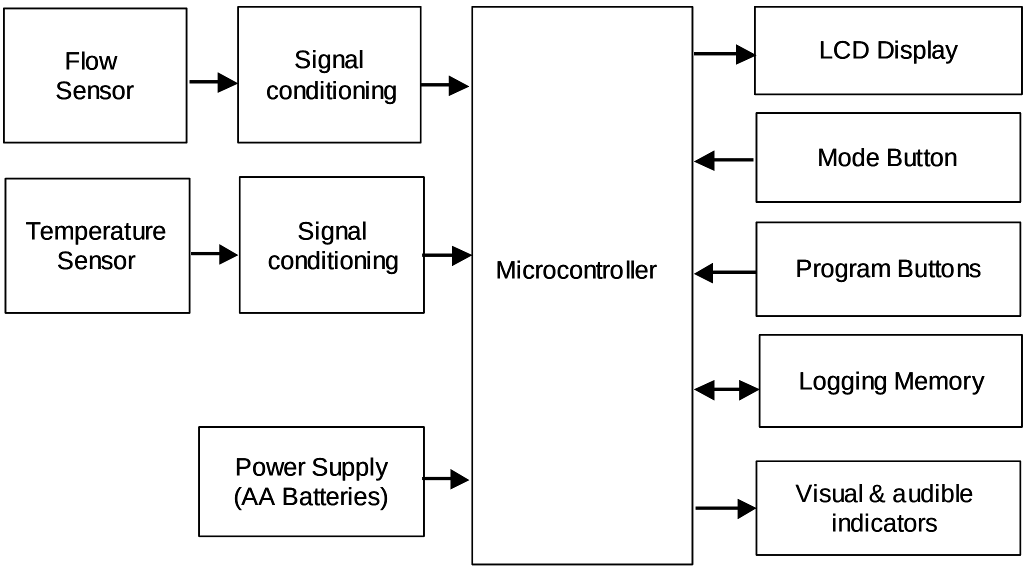

Figure 3 - Smart Shower Meter - Block diagram

4.1 Water flow metering

An integrated in-line flow meter is used to measure the flow rate through the shower head. This flow meter is installed in a short extension tube that connects between the shower head and the water outlet on the wall.

The shower meter automatically registers when a shower begins by sensing the commencement of flow. Thus it does not rely on a shower user to interact with the unit for it to begin monitoring a shower event.

Once a shower begins the device continuously measures the flow and displays both the current flow rate and shower volume to the user in real time.

4.2 Allocated volume and time remaining

The Smart Shower Meter calculates an allocated volume for each shower based on the average usage of the household. Shower users are warned by audible and visual prompts before the allocated volume is reached in order to encourage users to avoid exceeding the allocated volume.

The unit also displays the time remaining before the allocated volume will be reached. This feature allows users to trade-off flow rate against shower duration in order to maintain an acceptable shower experience whilst minimizing water consumption. The time remaining display also provides instant feedback on the effect of reducing shower flow rate.

4.3 Energy estimation

The shower meter estimates the energy used to heat the water for each shower event. This is accomplished by estimating energy associated with raising the temperature of the water to the shower temperature over the volume of the shower. The units for the energy estimate can be user selected as either MJ for a gas heating installation or kWhr for an electric heating installation.

4.4 Installation

The shower meter is easily installed without the need for a plumber. This is important as feedback from trial participants indicates that the need to organize a plumber and coordinate a visit is likely to be a significant barrier to purchase. In fact, the services of a plumber were offered free of charge to participants at the end of the trial. All participants elected to remove the units themselves rather than coordinate a visit by a plumber.

Installation of the shower meter is accomplished by following the following steps

- Unscrew the existing shower head from the outlet pipe
- Fit a short extension pipe to the outlet pipe
- Slide the shower meter over the extension pipe and connect the temperature sensor cable to the rear of the unit
- Place the cushioning nose piece over the extension tube in front of the unit
- Fit the shower head to the extension tube.

5. TRIAL DEPLOYMENT

Shower meters were deployed across the three Melbourne metropolitan water retailing regions serviced by Yarra Valley Water, South East Water and City West Water. Approximately equal numbers were deployed in each of the retailing regions.

The following map shows the approximate placement of units. The location of each baseline unit is indicated by a blue marker and active units by a red marker.

Three registered plumbers were provided with units, which they offered to customers in the course of their house calls. In this way, selection of trial sites was by voluntary response of householders and was conducted at arms length from Invetech.

Units were installed over a three-week period in March 2005. Each unit was installed and checked by the plumber in order to ensure correct operation at the beginning of the trial.

The trial concluded in September 2005 providing approximately 6 months of shower usage data collection.

6. RESULTS

6.1 Household characteristics

The following table summarizes some of the key characteristics of the households where units were deployed. The self-selection process yielded a sample group with between two and four regular shower users per household. The group also included a mix of electrical and gas water heating as well as "normal" higher flow rate shower heads and low flow rate shower heads.

Plumbers were asked to classify the shower head into one of two broad efficiency categories during the installation process. Low-flow shower heads were typically of AAA water efficiency or better.

Household Reference	Install Date	Showerhead type	Heating Gas/Elec	Adults	Children	Active Showers / day	Water saving (kl pa/person)	Water Saving (%)
B1	38416	Normal	Elec	2	3	4.0	1.93	8.4
B14	38422	Normal	Elec	2	2	4.0	2.19	9.0
B16	38429	Normal	Gas	1	1	2.0	1.61	9.5
B7	38433	Low-Flow	Gas	2	1	3.0	2.87	12.0
B5	38429	Low-Flow	Gas	2	2	4.0	2.23	12.2
B12	38417	Low-Flow	Gas	3	0	3.0	1.40	12.6
B2	38419	Low-Flow	Gas	1	1	2.0	1.83	12.6
B19	38403	Low-Flow	Gas	1	2	3.0	1.79	12.8
B10	38419	Low-Flow	Elec	2	2	4.1	2.52	13.9
B11	38422	Normal	Gas	2	0	2.0	2.80	15.5
B21	38426	Low-Flow	Gas	2	2	4.0	4.31	16.5
B13	38420	Normal	Gas	2	2	4.0	4.86	17.5
B8	38427	Normal	Gas	2	0	2.0	5.28	18.7
B18	38424	Normal	Gas	2	2	4.0	6.14	23.7
B4	38423	Low-Flow	Gas	2	2	4.0	6.06	27.3
						Average	**3.2**	**14.8**

Table 1- Characteristics of participating households

In most cases the number of people reported to be regular users of the shower correlated well with the number of showers per day with users taking an average of one shower per day. In the case of household B1 there were five reported users but an average of 4.0 showers per day.

6.2 Baseline control units

Four of the shower meters deployed remained in baseline mode in which they acted as data loggers, recording shower usage over the duration of the trial. The primary purpose of deploying these baseline units was to provide a means to detect major seasonal changes in usage patterns. For example, an increase in water temperature and or total volume used might be expected in the colder winter months as participants attempted to keep warm.

In particular, significant changes in usage patterns between the first month of the trial and the following five months could have a significant impact on the estimation of water savings based on data recorded by the other 16 units. For example, if usage increased in the winter months due to colder temperatures, then a simple usage comparison with the warmer March-April baseline period would not provide an accurate representation of savings achieved by using a Smart Shower Meter. In that case seasonal correction factors would need to be applied to the usage data.

The data from the baseline units did not provide any evidence of significant seasonal variations in water usage over the trial period. The following plot of Baseline Unit #B06 (Figure 4) shower volumes is typical, showing very stable shower volumes over the duration of the trial.

The Baseline units recorded average water consumption in the first month of baseline operation that was 0.9% lower than that for the following five month period. Therefore, if a seasonal correction to Active unit volumes was to be made it would result in a small increase in the estimated savings reported here.

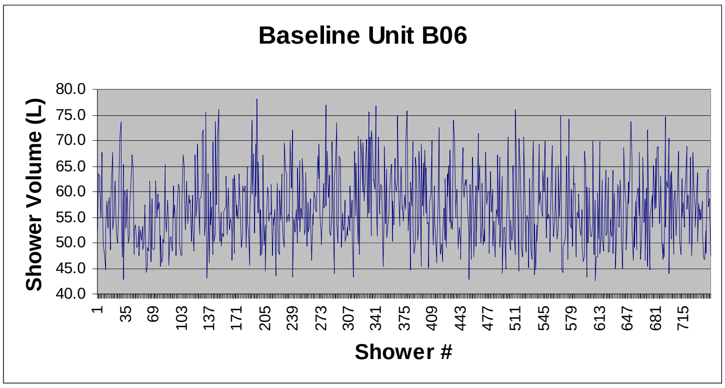

Figure 4 - Baseline Unit Shower Usage

6.3 Active units - baseline usage

Each of the 16 active units deployed, recorded a baseline of usage during the first month of their deployment. Due to a hardware fault in one unit, the data could only be harvested from 15 of the 16 units.

The average shower duration for these units was 7.24 minutes and the average shower volume 55.4 litres. The baseline flow rate averaged 7.4 litres per minute across all 15 units.

In households with a shower head rated as high-flow[3] the average water consumption per shower was 64.2 litres. This compares with 47.7 litres per shower for households with a low-flow shower head.

6.4 Household savings

Following the first month of operation in Baseline mode, each unit automatically entered Active mode. In active mode the unit becomes fully functional, providing users with real time feedback on their water usage as well as visual and audible prompts to encourage more conservative water use.

[3] This equates to a rating of Normal flow rate by the installation plumber.

By way of example of a typical shower volume profile, Figure 5 shows individual shower event volumes for household B10. Note that the usage is relatively stable through the baseline period with typical variability from shower to shower. Some of this variability is due to the different shower usage patterns between individuals within the household.

Once the Shower meter entered active mode, the shower-event volume began to trend downwards as the information and prompts provided by the unit encouraged more water conservative behaviour. Over this period the variability in shower volumes typically decreases as the frequency and magnitude of excessive usage events are reduced.

Finally, the usage pattern stabilized as users reach the minimum shower volume that still provided an acceptable experience. In Figure 5 this is evident after shower number 200. From that point, the information and prompts from the Smart Shower Meter served to maintain water efficient shower behaviour.

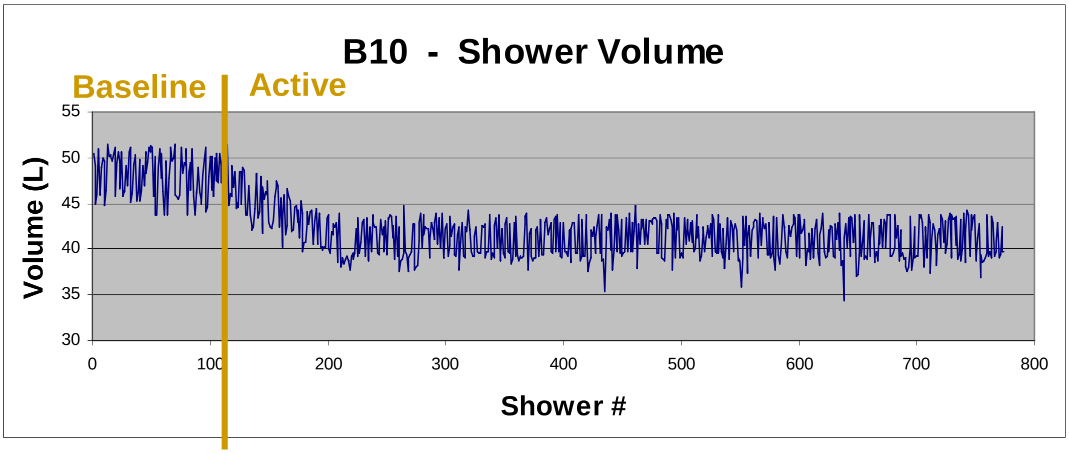

Figure 5 - Shower volume data for household B10

For each household the savings associated with use of the Smart Shower Meter have been estimated by comparing the average shower volume in the Active period of operation to the average volume during the Baseline period. These savings are presented in an annualised form on a per household[4] basis in Figure 6. The top 25% of households achieved savings of 17kl per annum or more. Of course it is expected that those with larger numbers of people using the shower have the potential to achieve larger absolute savings.

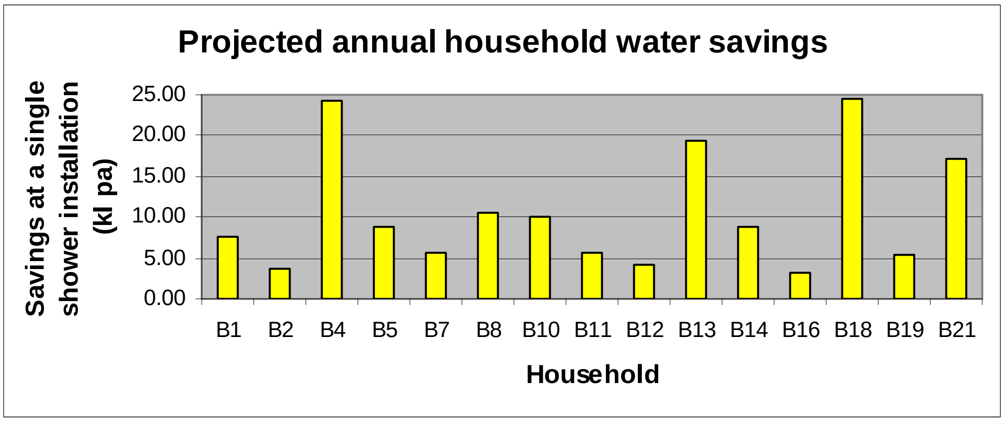

Figure 6 - Annualised household savings

It can be expected that households with high-flow shower heads might save more water than those who have more water efficient low-flow shower heads. Annualised savings per person by shower head type are shown in Figure 7. Whilst the top three water saving households had high-flow rate shower heads, significant savings were also made by a number of households with low-flow shower heads. This demonstrates the applicability of the Smart Shower Meter to both high and low-flow shower head installations.

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[4] Annualised household savings are estimated on the basis of the number of showers per day in the shower where the Smart Shower Meter is installed and the average saving per shower.

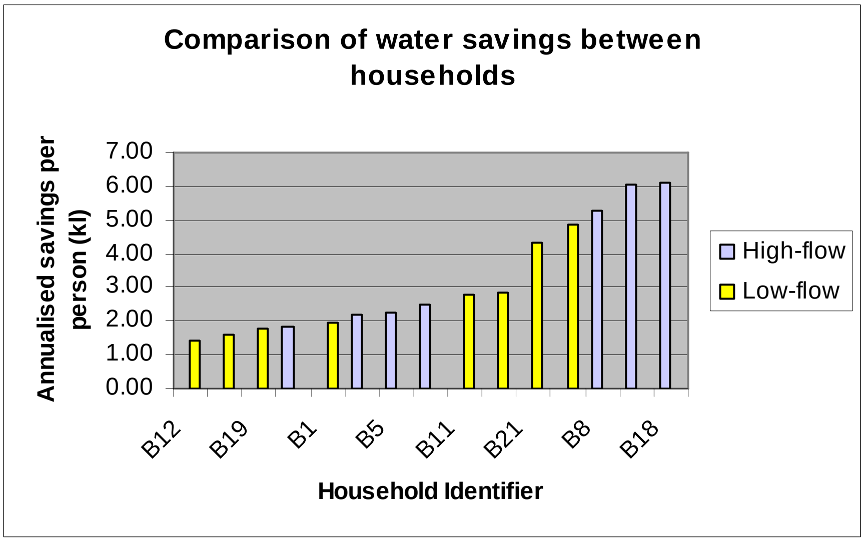

Figure 7 - Annualised savings per person by shower head type

The type of shower head employed was not found to strongly influence the proportion of normal water usage saved when the Smart Shower Meter became active. On average, households with low-flow shower heads achieved a saving of 15% of their baseline water usage whilst households with high-flow shower heads saved 14.6%.

6.5 Individual behaviours

Anecdotal evidence indicates that the Smart Shower Meter often generates a competitive dynamic between shower users that encourages more conservative water use. This dynamic appears to help to reinforce consistent water efficient behaviour.

Typically there are significant differences in the shower usage patterns between residents within a household. This stems from varying perceptions of acceptable minimum flow rates and the time to complete bathing activities. Furthermore, individuals within a household vary their usage patterns depending on need. For example, some people have a longer shower every second day to accommodate hair washing. The Smart Shower Meter allows for these variations.

Within a household, user to user savings were found to vary by an average factor of 3.46 where a low-flow shower head was installed and 3.35 for a high-flow shower head installation. These variations are far greater than the effect of shower head type. This illustrates the reality that when savings are to be made by behaviour change, significant variations should be expected between participants. Some of this variation can be understood by the fact that household members who already undertake water efficient practices have less scope to reduce their water consumption than do household members who are less attentive to the efficient use of water.

Person to person savings are aggregated in the household savings data recorded in Figure 8. Preferences for saving water by reductions in flow rate , shower duration or some combination of the two are evident across the participating households. One of the strengths of the Smart Shower Meter is that it aids users to achieve their lowest acceptable shower volumes by allowing them to choose how they will reduce consumption.

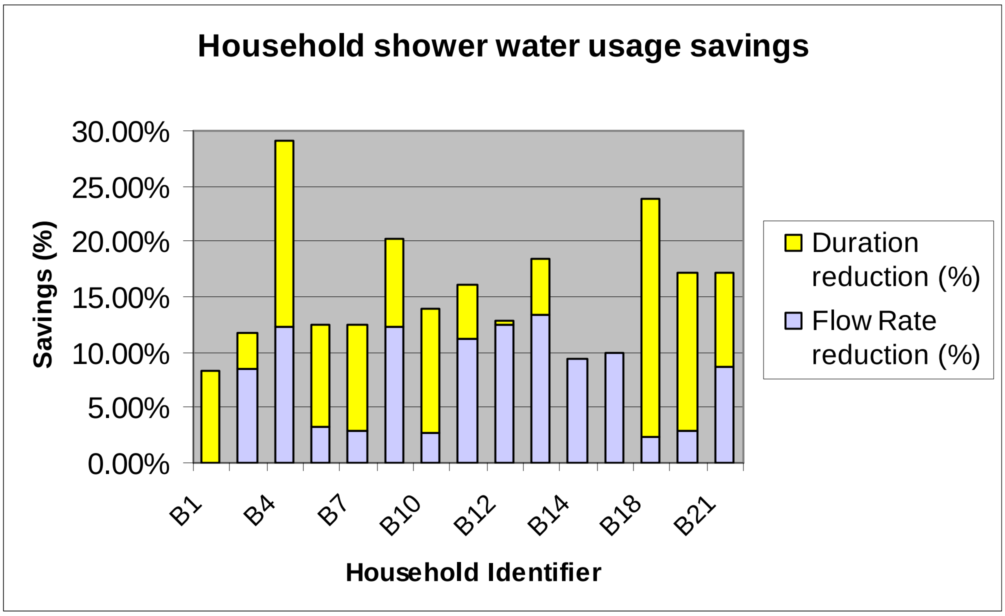

Figure 8 - Household savings by mode of saving

6.6 Survey results

A representative of each participating household was asked to complete a short survey at the conclusion of the trial. The questions were aimed at sampling household attitudes to the shower meter concept. Since the four baseline units provided no user feedback and therefore no user benefit, the survey was limited to the 16 households that had used units in the active mode.

All household respondents indicated that the shower meter was easy to use. Fifty-six percent of respondents indicated that they would consider purchasing a Smart Shower Meter if it were available at a retail outlet.

When offered the services of a plumber, at no cost, to remove the unit at the completion of the trial all participants indicated their preference to do this themselves. This clearly underlines the importance of not requiring a plumber to perform the installation. It also demonstrates the preparedness of householders to remove, and by implication install, a shower meter.

All participants indicated that the device was easy to remove, a procedure that is in practical terms the reverse of the installation process.

7. FINANCIAL PAYBACK

Household financial savings are achieved with the assistance of the shower meter through a reduction in utilities costs as follows

- Reduced water heating costs – either gas or electricity
- Reduced potable water supply costs
- Reduced sewage disposal costs

These savings have been estimated on a per household basis for each of the trial participants and are summarized in the following chart. Savings have been calculated based on the following assumptions

- Block2 water pricing (YVW)
- Average seasonal discharge factor of 0.7
- Off-peak electric heating costs 8.69 cents / kWh (Origin Energy Off-Peak Storage Water Heating Tariff Y8)
- Gas cost of 1.03 cents / MJ (Origin Energy 03 Domestic, average of peak and off-peak, first 6000 MJ)
- Electric storage heater and distribution energy efficiency of 70%. This factor includes estimated water heating, storage and distribution losses
- Gas storage heater and distribution energy efficiency of 60%. This factor includes estimated water heating, storage and distribution losses.

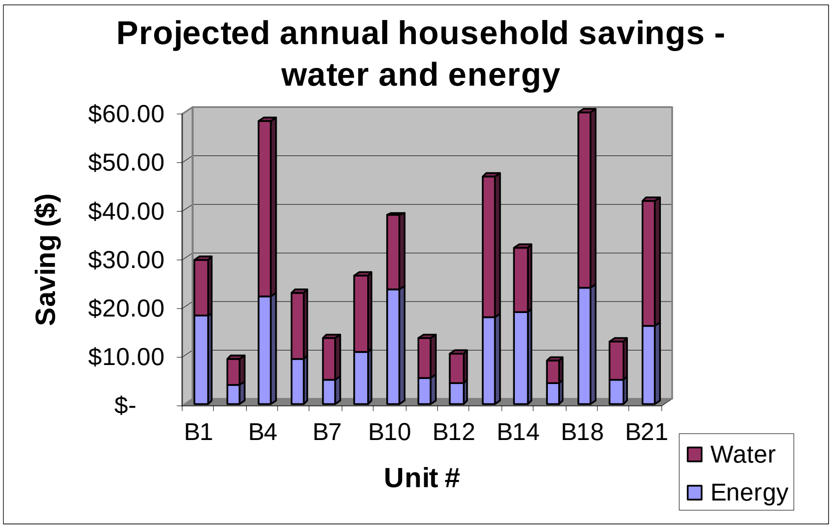

Figure 9 - Household water and energy savings

Note that on average, the energy cost savings made up 44% of the total household savings. This highlights the enhanced value of saving heated water within the home.

Based on these savings a payback period of two to three years is likely for households that effectively used the shower meter to make a significant reduction in their shower water usage. This compares favourably to other water saving products such as rainwater tanks.

8. CONCLUSIONS

The trial of the Smart Shower Meter demonstrated that given real time feedback shower users could make significant savings in the water used. The average savings of 14.8% are in line with the 15% reduction in water usage targeted for 2010 by the Victorian Government.

Users demonstrated their desire to save water in different ways with some doing so by reducing shower duration only. Others retained the same shower periods but substantially reduced their shower flow rate. The bulk of the users achieved savings through a combination of reduced shower duration and flow rate. As expected, those who achieved the highest savings did so by reducing both their shower duration and flow rate.

Savings were consistent and stable over the 5-month duration of the active period of the trial indicating that the concept is robust. Water efficient showering habits once established are reinforced by continued feedback.

A high proportion of users indicated that they would consider purchasing a Smart shower meter if it was commercially available. This is further supported by a rapid payback period compared to other household water saving products.

With significant water savings achieved, a relatively short payback period indicated and a high level of user acceptance, this trial indicates that the Smart Shower Meter would be an attractive water saving option for Victorian householders.

Invetech is currently seeking a partner to commercialise the Smart Shower Meter.