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Background Research Project
Consideration of hot water circulators for inclusion in the WELS Scheme

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Executive Summary

This report has been prepared by Coomes Consulting Group for the Department of the Environment, Water, Heritage and the Arts, to investigate the feasibility of including hot water circulators in the Water Efficiency Labelling and Standards (WELS) scheme and/or other suitable programs.

The WELS scheme currently covers dishwashers, clothes washing machines, showers, taps, toilets, urinals and is optional for flow controllers. WELS labelling provides information to the consumer regarding the water consumption of the product.

Hot water circulators are circulation pumps designed for use in hot water circulation systems, both domestic and commercial. When activated, a circulator draws cooled water out of the hot water line and back to the water heater, either through a dedicated return line or through the cold water line. By ensuring the water in the hot water line is at an optimum temperature before use, circulators reduce or may even eliminate draw off, defined as the water allowed to drain away whilst a user is waiting for hot water to reach the fixture.

The operation of circulators is determined by the circulation system within which they are installed. Three main types of hot water circulation systems exist. In a continuous circulation system, the circulator is in constant operation. In a regulated circulation system, operation of the circulator is governed either by a timer, aquastat or both. In an on-demand system, a manual switch or sensor is used to activate the pump prior to hot water use.

Circulation systems can be created without the use of a circulator, utilising convection to transport the water. Other options may also be considered to reduce or deal with draw off, such as water recovery, heat retention methods, heat trace tape, manifold or smart plumbing, and point-of-use heaters.

Circulation systems can be easily retrofitted in existing dwellings, but work in an optimal manner for new construction. They are particularly useful in buildings with long hot water distribution systems and high hot water demand, such as apartment blocks or multi-storey houses. Circulators are compatible with most hot water distribution systems, but care must be taken in systems with instantaneous or electric water heaters as required flow rates and hours of heater operation may affect the circulation system effectiveness. The energy use of circulators must be considered, as a small saving of water could potentially be accompanied by a significant increase in energy consumption, depending on their design and operation.

As each circulator and circulation system type has the potential to eliminate draw off when in operation, it is considered that hot water circulators are not suitable for inclusion in the WELS scheme as water efficiency differences could not be determined between models. For the same reason, minimum Water Efficiency Standards (WES) would also not be considered suitable. It is suggested, however, that a Minimum Energy Performance Standard may be feasible for a hot water circulation system, should the design and installation of the system be able to be adequately controlled.

It is found that it may be most useful to the consumer if circulators and circulation systems are included in sustainable housing guides and schemes, within the consideration of the entire water distribution system. This would allow consumers to balance other water and energy saving components of a distribution system with the potential benefits of hot water circulation.

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Abbreviations

Term	Definition
3*	3 stars, as rated by the WELS scheme
AS/NZS	Australian Standard / New Zealand Standard
ATS	Australian Technical Standard
AWA	Australian Water Association
BCA	Building Code of Australia
BREEAM	Building Research Establishment Environmental Assessment Method
DEWHA	Department of the Environment, Water, Heritage and the Arts (formerly DEWR)
DEWR	Department of the Environment and Water Resources (now DEWHA)
DSE	Department of Sustainability and Environment (Victoria)
EPA	Environment Protection Authority
EPHC	Environmental Protection and Heritage Council
kL	kilolitres, or 1000 L
L	litres
LEED	Leadership in Energy and Environmental Design
MEPS	Minimum Energy Performance Standards
MP52	Manual of authorisation procedures for plumbing and drainage products
NWI	National Water Initiative
PCA	Plumbing Code of Australia
SAWM	Smart Approved WaterMark
WEL	Water Efficiency Labelling
WELS	Water Efficiency and Labelling Standards
WES	(minimum) Water Efficiency Standard
WSAA	Water Services Association of Australia

Glossary of terms

Aquastat: a common name for a thermostat control that regulates pump operation based on water temperature.

Continuous hot water heater: see Instantaneous hot water heater.

Dead leg: a section of pipe that does not form part of a constant hot water circulation system – water is stagnant until a flow is activated by opening a tap.

Draw off: cooled water that is allowed to drain by the user whilst waiting for optimum temperature hot water during a hot water event.

Fixture: an end use of water within a dwelling, such as a tap, shower, toilet etc.

Hot water circulation system: the components used, including the hot water circulator, to supply immediate hot water at a fixture. This can include timers, valves, manual and/or sensor switches, insulation and additional piping.

Hot water circulator: a pump designed to circulate domestic hot water within the distribution system.

Hot water distribution system: all the components involved in delivering hot water from the water heater to the fixture. This can include the storage tank, temperature control valves, pipes and the fixtures.

Instantaneous hot water heater: a type of hot water heater in which heat energy is added only when water is flowing through the heater.

Manifold plumbing: a water distribution system with a common location from which each fixture is individually supplied.

One-way check valve: a valve that allows fluid to flow in only one direction in a pipe, automatically closing should conditions occur which might lead to flow in the reverse direction. Also known as a **non-return valve**.

Solenoid valve: a valve with a thermostatically-controlled motor that opens or closes a gate or ball in the body of the valve so that the medium flows through. Also known as a **zone valve**.

Smart plumbing: a thoughtfully designed plumbing layout, incorporating adequate insulation, minimising pipe length and diameter, and distance of fixtures from main trunk line in order to minimise water and energy loss.

Storage hot water heater: a water heater incorporating a storage tank such that water can be heated whether or not it is flowing (i.e. under demand).

Tankless hot water heater: see Instantaneous hot water heater.

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1 Introduction

1.1 Purpose of this report

This report has been prepared by Coomes Consulting Group for the Department of the Environment, Water, Heritage and the Arts (DEWHA), which was formerly known as the Department of the Environment and Water Resources (DEWR).

DEWHA is responsible for advising the Australian Government on its policies for protecting the environment and water resources, administering environment and heritage laws, managing the Australian Government's main environment and heritage programmes and representing the Australian Government in international environmental agreements related to the environment and Antarctica.

This report is a summary of technical research undertaken to examine the feasibility of including hot water circulators within the WELS Scheme and/or other suitable programs.

1.2 Objectives and scope

The objective of this project, as detailed in the request for quote document (DEWHA, 2007), is to prepare a background research paper into hot water circulators. It was requested by DEWHA that the report include the following research:

- the range of technologies used by hot water circulating devices which are available in both Australia and overseas
- diagrams of the technologies used by these devices, and details of manufacture and supply
- a review of Australian and international approaches to regulation, installation, use, rebating and effectiveness of these devices
- the extent to which these devices are covered by Australian Standards and/or WaterMark
- an assessment of the suitability of hot water circulators to be included in the WELS Scheme and/or minimum water efficiency standards.

1.3 Report structure

This report is divided into several sections. The earlier sections give an overview of the water losses associated with inefficient hot water distribution systems, as well as the types of hot water circulation systems available to consumers. This is followed by a summary of the Australian and international standards and regulations that control and/or affect the use of hot water circulators and their associated system components. Finally, an assessment of the suitability of hot water circulators for inclusion in the WELS Scheme is made and recommendations provided.

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2 Background

2.1 Why examine hot water circulators?

The potential for hot water circulators to be included in the WELS Scheme was initially raised in a report by George Wilkenfeld and Associates and others (Wilkenfeld *et al.*, 2003). This report was prepared to support and justify the initial introduction of the WELS Scheme. In relation to hot water circulators, the report comments:

> *"A debate has emerged recently concerning the amount of water that is run to waste by users because it is below the required temperature… The only data available so far has been produced by competing manufacturers, and is contradictory.*
>
> *Independent research should be carried out to establish whether there are significant differences between product types or characteristics which are associated with higher efficiency of water use. If so, then an endorsement WEL should be considered."*
> (Wilkenfeld et al, 2003:9)

Information at present regarding hot water circulation systems establishes differences between system types, if not particular hot water circulator models within a particular type. These differences describe significant effects on water and energy efficiency.

The Wilkenfeld report then goes on to recommend further work, including further research into the water use and wastage of both storage and instantaneous water heaters to establish whether there are particular product types or features which are associated with higher water efficiency, before considering the case for inclusion of these products in the WELS Scheme.

Wilkenfeld (2005) also completed an initial feasibility study for the Department to identify those products which may be suitable for addition to the WELS Scheme. Products recommended for further examination included:

- hot water systems and hot water circulators
- evaporative coolers
- clothes washer/dryer combinations
- cooling towers (associated with large air conditioners)
- ice makers and
- commercial dishwashers, glass washers, pre-rinse nozzles and other catering equipment items.

In a separate report prepared for the Victorian Department of Sustainability and Environment (DSE) to examine options for reform of the water component of the 5 Star Standard, Wilkenfeld (2006) examined the potential for hot water circulators to contribute to household water savings. The report indicated there was a lack of data available about the water wasted while waiting for hot water to arrive at a fitting, as the claims made by manufacturers varied widely and had not been independently verified. The wastage of water was estimated as 8.4 kL/household/year, half of which was hot water and thus included energy wastage. The ability of a hot water circulator to negate the vast majority of this loss is the main argument for their inclusion in the WELS Scheme.

2.2 The WELS Scheme

The Water Efficiency Labelling and Standards (WELS) Scheme is administered by DEWHA, with mirror legislation by the State and Territory Governments.

From July 2006, washing machines, dishwashers, taps, showers, urinals and toilets are required to be registered under the WELS Scheme and display a WELS label at point-of-sale. The Scheme is optional for flow controllers. The star rating provides consumers with information on the water consumption of the product – allowing them to take this into account in their purchasing decisions, and save water, energy, greenhouse gas emissions and money. The Scheme also allows industry to showcase their most water efficient products.

Over 10 000 product models are currently registered under the WELS Scheme (Australian Government, 2008).

The WELS label replaced the voluntary National Water Conservation Rating and Labelling Scheme (also known as the 'AAAAA' scheme) developed by the Water Services Association of Australia (WSAA). Both the new and superseded labels are shown below.

Figure 1: AAAAA label, superseded by WELS label (DEWHA 2005, Australian Government 2008)

2.2.1 WELS products

The WELS Scheme currently covers the following products:

- showers
- tap equipment
- toilet (lavatory) equipment
- urinal equipment
- clothes washing machines
- dishwashers and
- flow controllers (optional for registration under the Scheme).

2.2.2 WELS legislation and standard

The Water Efficiency Labelling and Standards Act 2005 (WELS Act), provides the legal framework for the WELS Scheme. The Act is supported by regulations, a determination and a declaration.

The WELS legislation enables:

- the establishment of the WELS Regulator to administer the Scheme
- authority for the Australian Minister for the Environment, Water, Heritage and the Arts to specify the products covered by the WELS Scheme and the standards and other requirements the products must meet
- requirements for the registration and labelling of WELS products
- monitoring and enforcement of the WELS Scheme, including the appointment of inspectors.

National coverage of the WELS Scheme has been enabled by the states and territories enacting complementary legislation to the WELS Act.

The standard that details the criteria for rating the water efficiency and/or performance of each WELS product type is *AS/NZS 6400:2005 Water efficient products – rating and labelling*. Each product type also has Australian Standards specific to that particular product which are inter-referential to AS/NZS6400:2005.

2.2.3 WELS label

The WELS water rating label provides the water efficiency information for the registered products. The label must be attached to the product at the point of supply so it can be used by consumers as part of their purchasing decision making process.

The water rating label shows:

- a zero to six star rating that gives customers a means to quickly assess and compare a product’s water efficiency (i.e. the more stars on the label, the more water efficient the product) and

- a figure showing the water consumption or flow rate of the product based on the laboratory tests specified in AS/NZS 6400.

Some products may be labelled with a 'zero star rated' label to indicate that the product is either not water efficient or does not meet the basic performance requirements of AS/NZS 6400 or other standard.

2.2.4 Expanding the WELS Scheme

For a new product to be considered for inclusion in the WELS Scheme, it must fulfil the following criteria (Australian Government, 2008):

- the product contributes (or is projected to contribute) significantly to the national use of drinking water and/or waste water discharge, because it is either installed in large numbers or consumes a lot of water
- the design of the product significantly contributes to its consumption of water
- a standard test exists (or could be developed) to measure the product's performance, such as water consumption or water flow rate
- the product is mass produced, or assembled from mass produced components, so that all products of a particular model demonstrate the same performance and compliance with a performance standard can be enforced and
- the various models of the product on the market should exhibit a range of water efficiency, so that there are clear differences in performance between models that consumers can use to differentiate between models

For a product to be included in the WELS Scheme, it must first have a performance test, so its efficiency can be assessed. Typical methods of assessing water efficiency include a measure of water use in units such as L/minute, L/kg of clothes washed or L/flush. Where a performance test is developed for hot water circulators, this performance test will be included in an amendment to AS/NZS 6400, the Australian Standard which contains water efficiency performance requirements.

2.3 Minimum Water Efficiency Standards

Minimum Water Efficiency Standards (WES) are various standards which define the minimum water efficiency accepted for certain products. Performance requirements for selected products are outlined in AS/NZS 6400. Australian standards and technical requirements define the conditions of water efficiency tests for these products. Minimum WES are enforced for some products, such as toilets which, to be sold in Australia, must achieve a minimum rating of WELS 3 stars.

WES are used to remove the most water inefficient products from the market (by specifying a minimum efficiency which must be achieved for the product to be sold in Australia), and to encourage innovation amongst manufacturers to improve product water efficiency.

2.4 Other standards

2.4.1 WaterMark Certification Scheme

WaterMark certification ensures that plumbing products meet various quality standards, which have been primarily designed to protect public health. Plumbing products must be WaterMark certified for them to be installed by plumbers, as specified in the Plumbing Code of Australia (PCA) and referenced Australian Standards.

The requirement for a particular plumbing product to be WaterMark certified is related to the risk posed by the plumbing and drainage system, with Level 1 and Level 2 certification available. WaterMark Level 1 certification is for products classified as higher risk, and Level 2 for lower risk products. To be WaterMark certified, a plumbing product must comply with MP52/AS 5200.000, or the Australian Plumbing Code and the manufacturer must have a certified Quality Assurance (QA) system.

Level 1 certified products require a manufacturer to demonstrate ongoing verification of their QA system, including product testing and system auditing.

Currently there are some differences between states in terms of how plumbing products and their installation are regulated. The Plumbing Code of Australia incorporates the WaterMark certification requirements by referencing AS 5200.000:2006. It is anticipated that the PCA (and AS 5200.000) will be progressively introduced into the legislation of each state and territory to replace MP52.

Hot water circulating devices are classified as Level 1, higher risk, plumbing products. Some hot water circulators are able to be certified with WaterMark by compliance with *ATS 5200.464-2004 Hot water manual or sensor activated pumping systems*, and *ATS 5200.472-2006 Heated water system recirculation device*. These Technical Specifications (Standards Australia, 2004) detail the requirements for hot water pumping systems for use in dedicated hot water supply recirculation lines, including the testing required. This testing includes characteristics such as materials, design (including control strategy and cross flow), performance and product documentation (i.e. operating instructions).

2.4.2 Smart Approved WaterMark

The Smart Approved WaterMark (SAWM) is a not-for-profit scheme established by a partnership of four water industry organisations – the Australian Water

Association (AWA), Irrigation Australia Limited, Nursery and Garden Industry Australia and the Water Services Association of Australia (WSAA).

SAWM is an Australian labelling program for previous outdoor water conserving products and services, and is seen as a ‘sister’ to the WELS Scheme. Products which are registered under the WELS Scheme are not currently considered for a Smart Approved WaterMark label.

SAWM claims that a Smart Approved WaterMark label gives consumers confidence they are buying a product or service which will help them reduce their water consumption. Amongst various products and services that SAWM currently registers and labels are hot water circulation devices.

For a product or service to be considered for a Smart Approved WaterMark label it must satisfy the primary criteria of reducing water use and/or using water more efficiently, and where there is a direct correlation between the use of the product and water savings (i.e. regardless of the user). It must also meet the secondary criteria of ‘fit for purpose’, meets applicable regulations and standards and is environmentally sustainable. Claims against these criteria must be independently verified through testing, case studies or comparative reports. Independent assessment of the performance of each product submitted for approval is conducted by Smart Approved WaterMark’s technical expert panel. The products submitted for approval are not measured against published performance criteria (such as a WES or other AS), but on the judgement of the technical expert panel. This means that a Smart Approved WaterMark label does not allow for comparison between products, rather it indicates that a product has been individually judged to effectively reduce water use or improve water efficiency. This differs from the WELS Scheme where the star ratings indicate the relative water efficiency between models and products.

At present, only two manufacturers carry the Smart Approved WaterMark for hot water circulators. Of the Australian manufacturers, one carries a standard hot water circulator as discussed in this report, while the other ‘circulator’ diverts the cooled water for other uses.

2.5 Updating the WELS program

The Australian Government’s National Water Commission’s Raising National Water Standards Program has provided funding for a WELS Phase 2 projects for the possible expansion of the Scheme. The objective of these projects is to investigate the introduction of minimum water efficiency standards (WES) for existing WELS products, and the expansion of the WELS Scheme to include additional products.

The planned programme of work for the WELS Scheme Phase 2 includes:

- identifying and adding extra products to the WELS Scheme

- identifying those products to which minimum water efficiency standards can be applied, and developing the associated technical and minimum performance standards
- preparing any necessary legislative amendments and regulation impact statements and the implementation of regulatory arrangements
- consultating with industry and community about the proposed changes to the WELS scheme, and communication activities and
- product registration, compliance monitoring, testing and enforcement activities for the additional WELS products introduced.

This project is part of the WELS Phase 2 program, and will provide technical research and input into the first and second points listed above in relation to hot water circulators.

3 Hot water distribution

A hot water distribution system in a typical residential home consists of all the components involved in delivering hot water from the water heater to the fixtures at the points of use. A hot water distribution system includes the water heater, storage tank (if applicable), temperature control elements, valves, distribution pipes and fixtures (taps, showerheads, outlets etc.).

The following diagram is an overview of a typical hot water distribution system in a single storey house:

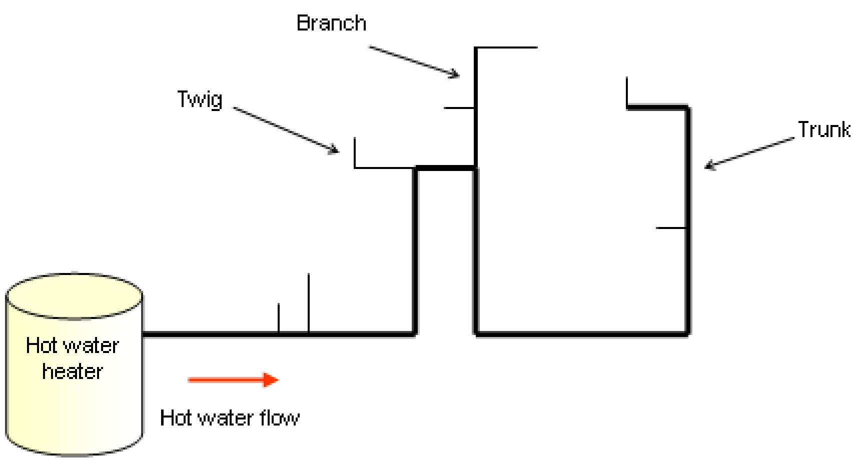

Figure 2: Schematic of typical hot water distribution system

The illustration also shows the typical pipe configuration of a hot water distribution system with a storage tank - a main ‘trunk’ line from the water heater to the furthest hot water usage point, smaller ‘branches’ off the trunk which supply hot water to multiple fixtures, and smaller-still ‘twigs’ that serve an individual fixture.

3.1 Water heater

The water heater used in the hot water distribution system may be either a pressurised storage, instantaneous, or combination (storage with in-line booster) heater. Traditionally, storage water heaters have been most commonly used. In this type of heater, cold water enters the storage tank and is warmed by a primary source of heat such as solid fuel, gas, electricity, oil or other source before being drawn out of the top of the tank when there is a hot water demand.

In an instantaneous water heater, the hot water demand triggers heater operation. Water is heated as it passes through the heater, potentially providing an unlimited supply of hot water (unlike a storage tank). However, instantaneous heaters also tend to have a limited flow rate of heated water they can provide at any one time, dependent on the size of the heater.

3.2 Temperature control

To prevent the growth of Legionella bacteria, the National Plumbing and Drainage Code requires that hot water be stored at a minimum of 60°C. However, to prevent injury, the code also requires that the maximum outlet temperature for sanitary fixtures in all new buildings be 50°C. In nursing homes, schools and facilities for the disabled this maximum temperature is 45°C. This results in a need to mix cold water into the hot water flow before it reaches the outlet. The cooling process can be achieved through the use of various technologies.

3.2.1 Tempering valves

A standard device for delivering safely cooled water to an outlet is a tempering valve. This device mixes the streams of hot and cold water to provide a cooling effect in the situation that the hot water from the water heater exceeds the desired outlet temperature.

3.2.2 Thermostatic Mixing Valves (TMV)

Thermostatic Mixing Valves (TMVs) also mix the streams of hot and cold water to provide safely cooled hot water, but to greater accuracy than a tempering valve. The temperature sensitive element within the valve reacts to water temperature entering the TMW, automatically adjusting the volume of each stream entering the valve to deliver a stable final temperature. With a reliable fail-safe mechanism, TMVs are often used in hospitals, aged care facilities, child care centres and the like. However, under *AS4032 Water supply – Valves for the control of heated water supply temperatures* they require regular maintenance every 12 months and should be replaced at intervals no greater than 5 years. There are also thermoscopic-type TMVs which differ in the function of the element used to control the TMV. These valves should be replaced at intervals no greater than 3 years.

TMVs can provide group control or point of use control. Where incorporated into the water distribution system at or near the water heater, they can provide a uniform distribution temperature for all hot water fixtures. For optimum performance, minimisation of dead legs is required in a TMV installation.

4 Issues in hot water distribution

Water that is allowed to drain whilst waiting for optimal temperature hot water to arrive at a fixture is known as draw-off. The presence of draw-off in a system indicates losses in:

- water – water allowed to drain without use is wasted
- energy – draw off has at some point been previously heated, but the energy has dissipated, necessitating additional heating of new water and
- time – the user must wait for usable hot water to arrive at a fixture.

Gary Klein of the California Energy Commission (CEC) (2005) has examined the reasons for water and energy wastage from hot water distribution systems. He concluded that the main reasons for time, water and energy wastage of hot water were:

- changing house designs, meaning the water heater is located further away from the usage points
- increasing sizes of houses, with more bathrooms, leading to an increase in the number of hot water outlets and longer hot water distribution systems
- lack of insulation and/or correctly installed insulation and
- larger pipe sizes to supply the demands of the additional plumbing fittings, resulting in reduced flow rates in the hot water distribution pipes and increased interface (or volume of warm water in the pipe) between the cooled and hot water creating an increased waiting time before hot water arrives at the outlet and wastage of water during this waiting period. (Klein, 2005a-c).

In essence, the problem of draw-off is being exacerbated by longer pipe runs and larger pipe diameters creating increasing volumes in dead legs, and greater potential for pipe losses. The larger number of fixtures is also increasing total pipe length, exacerbated by the separate piping required for the sanitary (50°C) and non-sanitary fixtures. A further issue has been identified due to the reduced flow rates in water-saving houses.

4.1 Water loss

Draw-off occurs because previously heated water cools in the distribution pipes in between uses. The diagram below shows the changes in hot water temperature experienced by a householder during a typical hot water event, and links them to this draw-off concept.

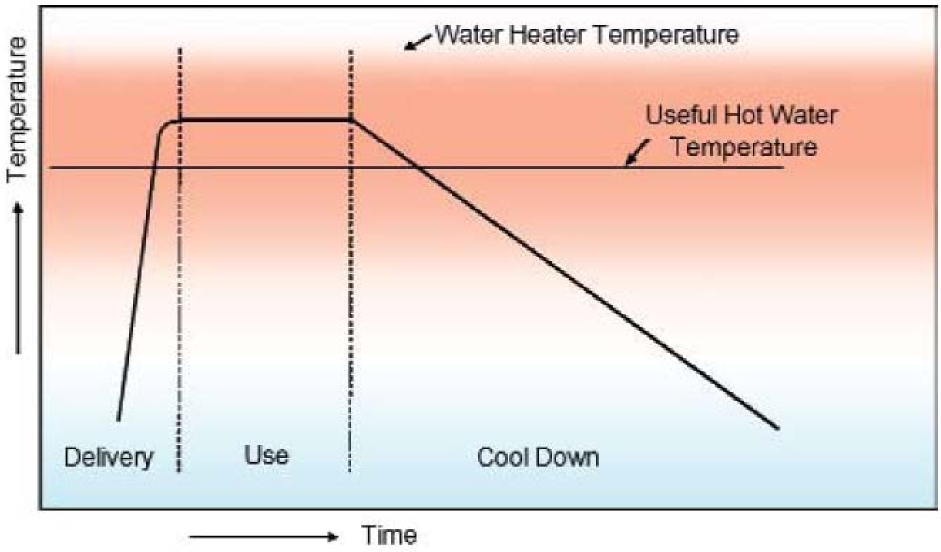

Figure 3: Hot water event schematic (Klein, 2006)

In the case of a storage hot water heater, during the delivery phase, hot water moves through the pipes, pushing the cooled water in the pipe through to the outlet or fitting where it is allowed to run down the drain by the householder. Where an instantaneous hot water heater is used, the delivery phase occurs during the time that the heater is beginning operation and building power. The use phase commences when the user decides the hot water is at an optimum (or useful) temperature and starts their usage, such as a shower. The use phase continues until the use of the hot water is completed (i.e. shower is finished and the tap turned off). The cool down phase starts at the end of the use phase, and continues until the next use of hot water as heat is lost from the distribution system pipes.

The waiting time experienced by householders is the time taken for the water to achieve the desired temperature during the delivery phase. The optimum temperature is somewhat subjective, depending on the user of the hot water and the purpose for which they are using the hot water. For example, some people choose to accept (use) sub-optimal temperature hot water when they are filling baths or sinks (as cold water will be used for temperature adjustment anyway) or in appliances with a capacity to reheat the water (i.e. dishwashers) or where temperature is not critical (i.e. clothes washing machines).

Current research (October, 2007) conducted by Yarra Valley Water shows that an average Victorian household will wait 14 seconds before acceptably hot water flows in when showering, and in some cases up to two minutes. Depending on the flow rate of water in the shower, figures for the volume of water wasted in the shower can be estimated. As actual flow rates vary on a case-by-case basis depending on location and demand, for the purpose of calculation an average flow of 9.5L/m is assumed. In 14 seconds, this sends 2.2L down the drain per shower, or 19L in the extreme case of a two minute wait. With an average household size of 2.48 people, the average flow rate and wait will result in 2kL of water being wasted in the shower every year. The time taken for water to flow to other household fixtures depends on their distance from the hot water heater among other factors, such as water heater type and plumbing design. Depending on the layout of the water distribution system, a household that waits 10 seconds for hot water in the shower may wait 40 seconds for hot water in the kitchen. Wait times for fixtures other than the shower are not available in current studies, but annual draw-off for the entire household may be a significant value.

4.1.1 Dead leg losses

The minimum draw-off loss in a cooled distribution system will be the volume of water stored in the pipes between the water storage tank and the end use fixture. In a non-recirculating system, these inactive water pipes are known as dead legs. The volume of water lost in each dead leg will vary depending on the pipe diameter and length.

The total dead leg losses will be particular to each individual dwelling as a consequence of the method of pipe sizing stipulated by *AS/NZS 3500.1:2003 Plumbing and drainage – Water services*. The final pipe diameter is a function of both the type of fixture served (and thus flow rate required), and the probable simultaneous demand, subject to pipe size limitations.

The table below provides examples of dead leg losses for common pipe diameters:

Table 1: Dead leg volumes

Pipe diameter	10mm plastic	15mm plastic	15mm copper	22mm plastic	22mm copper
Litres per 10m pipe run	0.6	1.1	1.5	2.4	3.1
Max length for 1.5 litre dead leg (m)	25	13	10	6	5

In minimising dead leg losses, the location of the water heater and the design of the piping layout is essential. A centrally-located water heater will decrease the length of pipe required. However, it should be noted that house design and water heater type will affect the locations available – electric storage heaters are generally located inside, while gas and solar-gas heaters are normally located outside the building.

4.1.2 Water and energy efficiency programs

Changes to housing standards to achieve energy and water efficiency have resulted in changes to hot water distribution systems with unintended consequences. For example, increasing numbers of houses with concrete slabs has led to an increase in hot water piping that must run through walls and roof spaces, rather than under the floor. Many concrete slab constructions do run a sub-floor hot water pipe prior to laying the slab, but this is not always the case. When combined with modern houses which are larger and have more plumbing fixtures, more water is being wasted as draw off while waiting for optimal temperature hot water to arrive at the outlets.

Water efficient showerheads and taps improve water efficiency by reducing the flow rate of water through the fixture, thus reducing the total amount of water used. Research by Klein (2005) has shown that reduced flow rates also mean reduced velocity in the hot water lines, which increases the time it takes for the hot water to reach the fitting. This results in an increased waiting time for hot water and loss of water as draw-off.

4.2 Energy loss

As mentioned above, the loss of water through draw-off also indicates a loss of energy. Studies have shown (Belsham, 2005) that as little as 10% of the energy supplied to a storage hot water heater is actually used as useful hot water, with general figures between 25-60%. The remaining energy is lost as standing losses (water which cools down in the pipes between hot water use events and heat losses from tanks and fittings), pipe losses and conversion losses in the heater itself. As the storage water heater is continually working to keep the water in the tank hot, energy is being consumed even when there is no hot water demand. Coupled with the embodied energy involved in the treatment and distribution of potable water, this represents a high embodied energy in water that is being allowed to drain away.

The use of instantaneous water heaters can mitigate some of this energy loss. The energy factor, or portion of the energy going into the water heater that gets turned into usable hot water, is generally greater for instantaneous heaters, in particular the electric models. However, the energy requirements of instantaneous hot water heaters are also much greater than storage water heaters during their times of operation. An electric instantaneous water heater can draw as much as 28 000W compared to 4500W for an electric storage water heater. Similarly, a gas instantaneous heater can use draw up to 50 000W compared to a gas storage heater at 12 000W (Progress Energy, 2008). In these cases, the frequency and distribution of hot water use will determine which method of heating embodies the most energy.

5 Hot water circulators

Hot water circulators are sometimes referred to as recirculators, depending on the country of origin of the literature, and the manufacturer. For the purpose of this report, the term hot water circulator will be used.

A hot water circulator is a pump (or other mechanism) which transfers hot water from the water heater to outlets at the end of the hot water distribution system, sending cooled water back to the water heater, minimising both the time spent waiting and the volume of water wasted while waiting for optimum temperature hot water to arrive. The operation of the pump may be continuous, or regulated in some way. Common forms of regulation include the use of thermostatic controls, pre-programmed timers and manual operation initiation buttons, motion or voice sensors to make up the hot water circulation system. Below are two examples of circulators, both with timers attached.

Figure 4: Hot water circulators (Laing, Grundfos, 2008)

A hot water circulation system minimises water waste by circulating hot water through the distribution pipes and back to the hot water heater's storage tank or cold water inlet line, thus recovering the sub-optimal temperature water for reuse. Because the cooled water is returned to the heater before the fixture is turned on, the user never receives sub-optimal temperature water, and water draw-off losses are minimised or eliminated.

Hot water circulators also recover a portion of the energy used to heat the water (i.e. that energy still in the cooled or warm water) by returning it to the water heater, where it needs less energy to reheat than if cold water were to be used.

Reducing the time spent waiting and the volume of water wasted also assists to increase homeowners' satisfaction with the performance of their hot water system.

5.1 Technologies used for hot water circulation systems

A review of the hot water circulators available in Australia and overseas has revealed there are several technologies being used for the control and operation of water circulation:

- continuous circulation
- regulated circulation
- demand controlled circulation
- temperature regulated differential pressure circulation.

The following sections review each of these technologies, and examine the range of products, their method of operation and control, and other features available.

5.2 Continuous circulation

Continuous circulation systems typically consist of a pump located adjacent to the hot water heater or its storage tank which continually circulates hot water through the hot water distribution system. To return the sub-optimal temperature hot water back to the water heater, the trunk pipe is extended from the last outlet back to the water heater. The following diagram shows a typical layout for a hot water distribution system with continuous circulation:

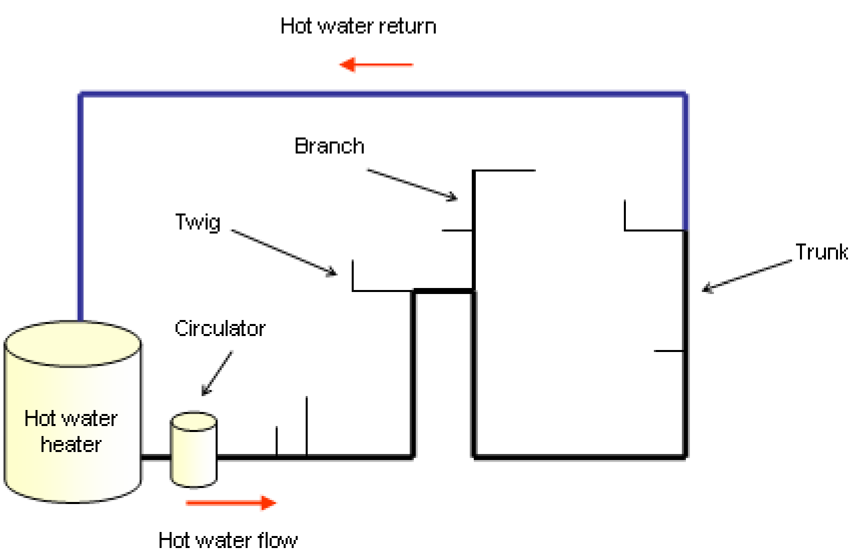

Figure 5: Schematic layout of continuous circulation

A continuous hot water circulation system has the main advantage of having hot water, at the desired temperature, available immediately at all times. As hot water is being constantly circulated through the system, it is truly available 'on demand'.

However, continuous hot water circulation systems are the most wasteful of energy out of the systems to be discussed. In fact, the Davis Energy Group (cited in Chinery 2006) compared the running time of the pump to the volume of hot water used, and found that continuous circulation ran around 70 times longer per litre used than an on-demand system. The pump runs constantly, and therefore does not respond to the two main situations where energy could be saved – 'no use' situations (regular or unscheduled periods where there is no demand on the system), and instances where the water in the pipes is already hot enough, and therefore does not need circulation. This lack of responsiveness leads to high energy inefficiency, wasting energy and increasing running costs.

5.3 Regulated circulation

Regulated hot water circulation systems typically consist of a pump located either adjacent to the hot water heater or its storage tank, or at the furthest hot water outlet, and a return line to allow the water to be returned to the water heater or its cold water inlet pipe. A location at the furthest fixture may be utilised to minimise the pump running time, as the temperature of the water in the return leg is irrelevant.

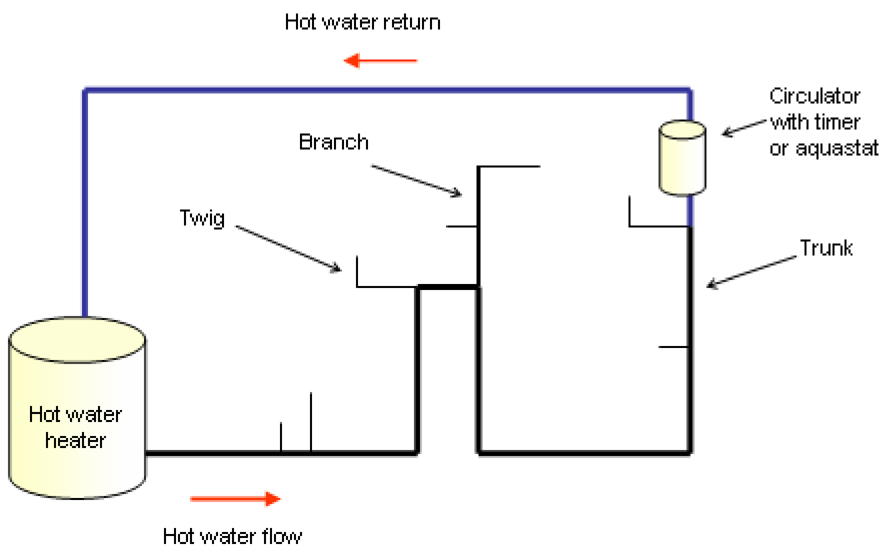

Figure 6: Schematic layout of regulated circulation

The term 'regulated circulation' is used as the operation of the pump is controlled so that it does not run continually. There are three means of control (or regulation) of the pump:

- temperature
- use of a timer
- or temperature and a timer together.

5.3.1 Temperature regulated circulation

This is a circulation system that uses temperature controls to cycle pump operation to maintain circulated water temperatures within certain limits. An installed automatic thermostatic control can respond to the temperature of water returning to the water heater through the recirculation piping, cycling the pump on and off. In a temperature regulated hot water circulation system, the circulator is likely to be located at the furthest fixture, as illustrated in the diagram, to minimise pump operation. A continuous circulation variant of this method also exists, where the temperature of the hot water that is circulated during times of low draw is at least 10°C lower than the standard set point for the water heater.

As with continuous circulation, this method results in hot water at the desired fixtures almost immediately, reducing the water losses generally sustained during the wait for hot water. For the continuous circulation variant, the main disadvantage is once again the waste of energy created by constant use of the circulator. While this is limited somewhat when the circulator is cycled off, the system still does not address the issue of 'no use' situations.

5.3.2 Timer regulated circulation

This is a circulation system that uses a timer control to cycle circulator operation based on time of day. In this system, the timer can be manually set so that the circulator is not in operation during pre-specified times, such as overnight, or perhaps the middle of the day when no one is home. During the hours where the circulator is in operation, it behaves as a continuous circulation system. The circulator will be located at a point on the circulation system that is easily accessible by the user, in order to facilitate use of the timer. (See illustration)

Figure 7: Circulator with timer (Carhil, 2008)

During times of high use, hot water is available immediately at all fixtures. However, energy is conserved by shutting down the system during generalised times of little or no use. This does mean that if there is a demand for hot water during the scheduled 'off' time, the wait for hot water will be equivalent to that of a system without a circulator pump. Also, when the pump is on, it circulates water continuously, potentially wasting energy.

5.3.3 Temperature and timer regulated circulation

This is a circulation system that uses both temperature and timer controls to regulate pump operation. As a combination of the above-discussed methods, this system can be shut down completely when hot water is not required, and will be cycled on and off by an automatic sensor during operating hours.

This is the most energy efficient of the continuous circulation systems, combining shut-down periods with temperature-sensitive operation. During times of high demand, hot water is still available almost immediately at all fixtures. Despite being the most efficient of the continuous systems, a temperature-and timer-regulated system still has the potential to waste energy due to efforts to keep water hot during times where it may not be required. The use of the timer can also cause problems in households where water consumption is altered on a daily basis. In some situations, weekend water use may reach a peak several hours later than on a week day. This could result in timed 'on' periods simply being extended to accommodate the behaviour. Some 7-day timers are available to deal with this issue, although the use of a standard 24-hour timer may result in a relatively efficient timed cycle of perhaps 6-8am and 6-10pm expanding out to 6-11am and 6-12pm, effectively doubling the running time of the circulator.

5.4 Demand controlled circulation

In contrast to continuous circulation systems, demand controlled circulation uses a brief pump operation to circulate hot water to fixtures on demand. This is done via a motion sensor or button (hard wired or remote).

These systems are quite similar to those previously discussed apart from their method of initiation. A hard-wired button system requires an activation button at the point of use, while remote or wireless systems can allow buttons to be located where convenient to the home owner. Such locations can include the laundry, somewhere in the kitchen or near the bed in the master bedroom. Motion sensors can also be used for activation if set to trigger when someone gets near a hot water location.

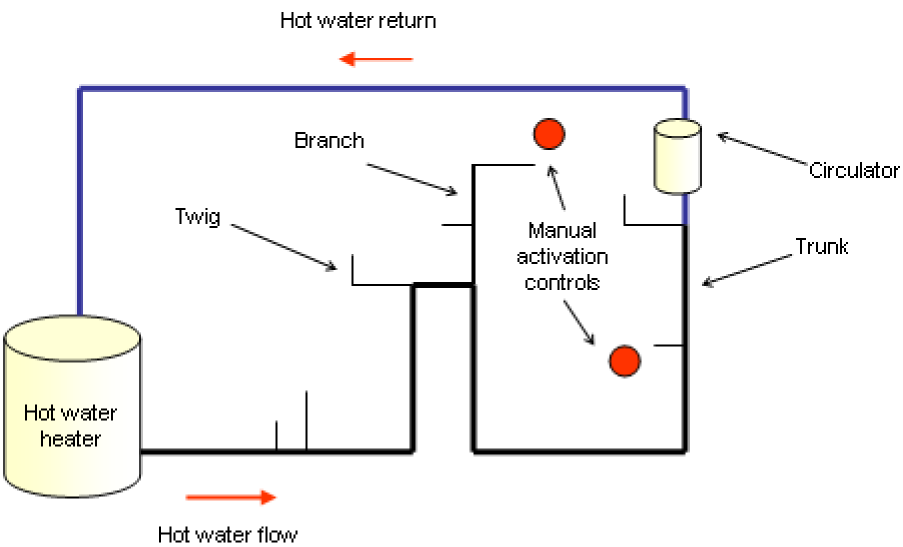

Figure 8: Schematic layout of on-demand circulation

There are two operating principles for on-demand hot water recirculation systems. The simple systems utilise a timed approach, where the circulator is in operation for a set time once activated. Systems which have been recognised (and in some cases recommended in sustainable housing guidelines) in the United States utilise the Delta T principle, which incorporates thermo-sensitive electronics in the system, meaning that once hot water is in the line, the circulator will not reactivate.

On demand systems are traditionally seen as the most efficient of the pumped systems because of their brief operation time. In fact, the Davis Energy Group (cited in Chinery 2006) found that a demand controlled system was the only energy efficient system, in that 'all recirculation systems except demand recirculation systems use more energy than is associated with the water running down the drain'. However, a separate study for Laing (2005) found a time- and temperature regulated system to be energy efficient using this definition. One particular problem has been associated with on-demand systems. This is false signals, where activation of the system occurs incorrectly. False signals occur where sensors rather than manual buttons are used, and in the experiment referred to above, accounted for 70% of the total number of activation signals. This does indicate, however, that manually-activated on-demand systems will be even more efficient than the figures calculated by Davis Energy Group.

5.5 Differential pressure and temperature

A hot water circulation system can be achieved without the use of circulator pumps. In these systems, convection circulation is utilised. Convection systems can use either the cold and hot water lines of the distribution system, or a dedicated return line to the water heater.

In an existing dwelling convection system, a thermo-sensitive control valve is used to separate the hot and cold water lines. When the water in the hot water line cools to a specified temperature, the control valve contracts, allowing the cooled water into the cold water line. Through thermal convection, this warmed water is drawn back through the line to the hot water tank, forcing hot water into the hot line. As a purely mechanical process, convection systems operate continuously.

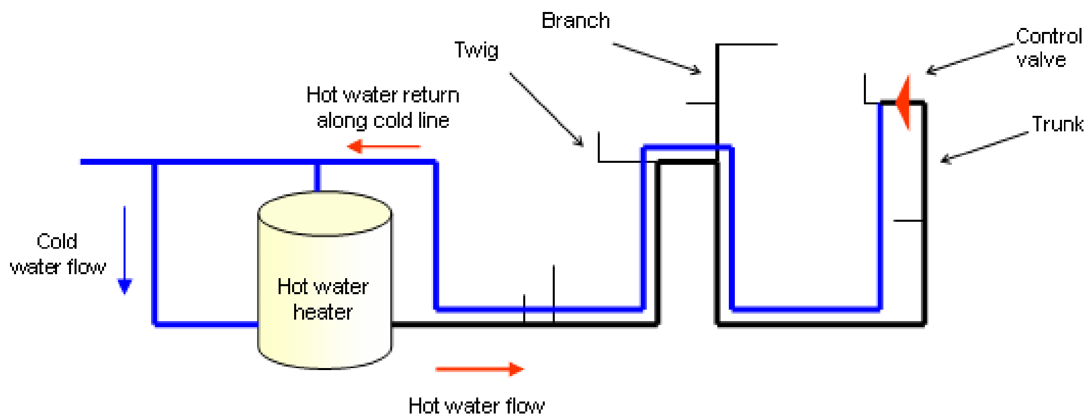

Figure 9: Schematic layout of convection system

Gravity controlled convection circulation makes use of convection and an appropriately laid out water distribution system. This is an effective system for houses with basement water heaters, and for two-storey houses. In gravity controlled convection, a dedicated return line creates a looped hot water system. Heated water rises through the main and, as it cools, is thermo-syphoned back into the water heater. This creates a slow, but constant, flow of water.

Convection systems have the potential to provide hot water immediately at all fixtures within a dwelling. As they do not utilise a pump, they have lower energy costs than other continuous circulation systems. Convection systems have the added advantage of also being silent, in contrast to the possible noise of circulation pumps. However, the constant flow of water means that the water heater will need to be in operation more often than without a looped main. Also, the presence of warmed water in the cold water line can affect the temperature of the cold water immediately available when cold water is required. The warm water added to the cold water line can produce an outcome the reverse of the current problem – wasted water while waiting for cool enough temperatures.

5.6 Issues in circulation systems

As emphasised in the preceding sections, the reduction in draw-off volume created by the use of a circulation system will potentially be negatively offset by the increase in energy use required for operation. In the case of a storage water heater, small energy savings may be created through a reduction in some standby losses, as the water returning to the storage tank will have a higher ambient temperature than that which would be drawn from the cold line after a hot water event. The reduction in draw-off also indicates a reduction in energy loss, from the energy embodied in the water allowed to drain away. However, as outlined in the description of demand controlled systems, conflicting studies exist relating to the energy efficiency of demand controlled and timer- and temperature-regulated systems.

5.7 Other options to improve hot water distribution

Installing or retrofitting a hot water circulation system is not the only way to improve hot water distribution in a domestic setting. Nor is it the only option for increasing efficiency with regards to water losses.

5.7.1 Water recovery

A hot water circulation system reduces water loss by decreasing the time taken for hot water to arrive at a fixture, and therefore reduce the amount of water that is allowed to drain away by the user. This value or volume will vary with the intended use and with individual users. Rather than reducing water being drained, an alternative option is to instigate a water recovery system, diverting drained water from some fixtures to a tank for other uses, or to a grey water system. It must be noted that diverting potable water to a tank means that water restrictions will apply to the use of all water from the tank, i.e. restricted gardening hours and so on will still apply. Where a tank holds only grey- or rainwater, no water restrictions apply to its use. Another practical approach adopted by many Australians under water restrictions is to physically collect draining water in receptacles, for distribution on the garden.

One of the items currently listed as a 'hot water circulation product' under the Smart Approved WaterMark framework is such a water recovery device. The EcoVerta is a diversion product, fitted individually at each fixture to be connected. This product directs the cool water to a storage tank or other chosen application before allowing hot water through to the fixture.

5.7.2 Heat retention

These alternatives for water collection do not address the main problems of reducing the time for hot water to reach fixtures, or reducing the energy wasted in draining heated water. There are several options for addressing this point without the use of circulators.

First, a possible aim is to prevent hot water from cooling in the pipes. If the water in the pipes is already hot to warm, there will be little delay to receive the correct water temperature. Prevention of cooling can be achieved through insulation or the installation of a heat trace system. Good insulation of pipes can prevent energy losses, extending the cooling period for water in the pipes. A heat trace system applies steam, fluid or electric heating (in domestic applications, generally electric) to piping to maintain the water temperature at an appropriate level. This system will result in instantaneous hot water, although energy consumption may be an issue depending on the length and diameter of pipe that is required to be heated as well as the standard of insulation.

5.7.3 Pipe layout

Hot water delays can also be avoided simply through better design of water distribution systems. Shorter pipe lengths, smaller diameter pipes, reduced restrictions to flow and an increased flow rate will all contribute to reducing the time taken for hot water to arrive at a fixture. Designing a water layout to take these factors into account can reduce the waiting time to a point where the need for a circulator is much diminished.

– Manifold plumbing

Manifold plumbing involves the use of multiple water lines. In these distribution systems, a 'control centre' for hot and cold water feeds flexible supply lines to individual fixtures. The flexible piping results in minimal flow restriction, while supply to individual fixtures results in smaller pipe diameters.

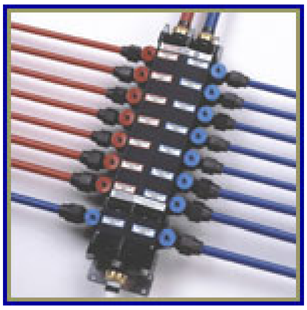

Figure 10: Manifold plumbing control centre (NAHB Research Center, 2008)

– Smart plumbing

Smart plumbing involves the thoughtful design of plumbing layout to minimise pipe length, in particular minimising the distance of all fixtures from the main trunk line. This reduces dead leg volumes, as well as the overall system volume. Restrictions to flow are considered, with wide radius elbows employed to ensure free flow of water. Insulation is provided to reduce pipe and standing losses. Smart plumbing is recommended to be used in conjunction with a hot water circulation system, but even if used in a non-circulating system, care in design and construction can substantially affect draw-off volumes.

5.7.4 Point-of-use heaters

Small instantaneous water heaters located at fixtures, known as point-of-use heaters, can also reduce the volume of draw-off created. Their location at the fixture ensures almost immediate hot water, and they save energy because no hot water is left in the pipes after the water is shut off.

Figure 11: Point-of-use heater at basin (Bosch, 2008)

However, installing sufficient numbers of point-of-use heaters at locations of hot water use can be expensive. As they have limited heating capacities, and it is unlikely that a point-of-use will be installed at every hot water application, they need to be used in conjunction with a central water heater. The energy requirements of the individual units can be very high in comparison to storage type heaters, causing problems during peak times when many households are drawing on their heaters.

Point-of-use heaters are used in different ways. In some cases, a small point-of-use heater may be located at a kitchen sink to provide immediate extremely hot water for cooking and other applications. In houses with long water runs, point-of-use may be used as a booster to reduce draw-off volumes while waiting for hot water from the central heater. Least common would be the application of point-of-use heaters at every source of demand for hot water.

5.8 Supply chain

At present, hot water circulators are not commonly installed in domestic hot water distribution systems in Australia, nor are they commonly recommended by plumbers for retrofitting, largely due to a lack of awareness and knowledge on the part of both the plumber and householder. Those circulators that are used can be found in stock at local plumbing suppliers and some hardware stores, or can be ordered in when requested. Some models can also be ordered online. Products are sourced worldwide, with models coming into Australia from Asia, Europe and the USA as well as those manufactured locally. Appendix A provides a list of some manufacturers and models available.

6 Installation and effectiveness considerations

6.1 Appropriate building types

Circulators and circulation systems incorporated into the water distribution system are appropriate for most building types. In the past, circulation systems have been most commonly used in applications where long pipe lengths, and high hot water demand exists, creating large volumes of draw-off. Hotels, hospitals, office buildings, apartment blocks and multi-storey free-standing homes will benefit most from reduced waiting times for hot water. However, any existing home that currently experiences significant draw-off could improve distribution system performance through a retrofitted circulation system. New dwellings can also avoid the problem of draw-off via a circulation system, although draw-off can also be significantly reduced through approaches discussed earlier, such as adequate pipe insulation and thoughtful system design.

6.2 New dwellings

The hot water distribution systems illustrated in this report have indicated a ‘return line’ or loop closure along which the cooled water travels on its return to the water heater. In a new dwelling, this is a dedicated line, separate to both the hot and cold lines serving the water outlets.

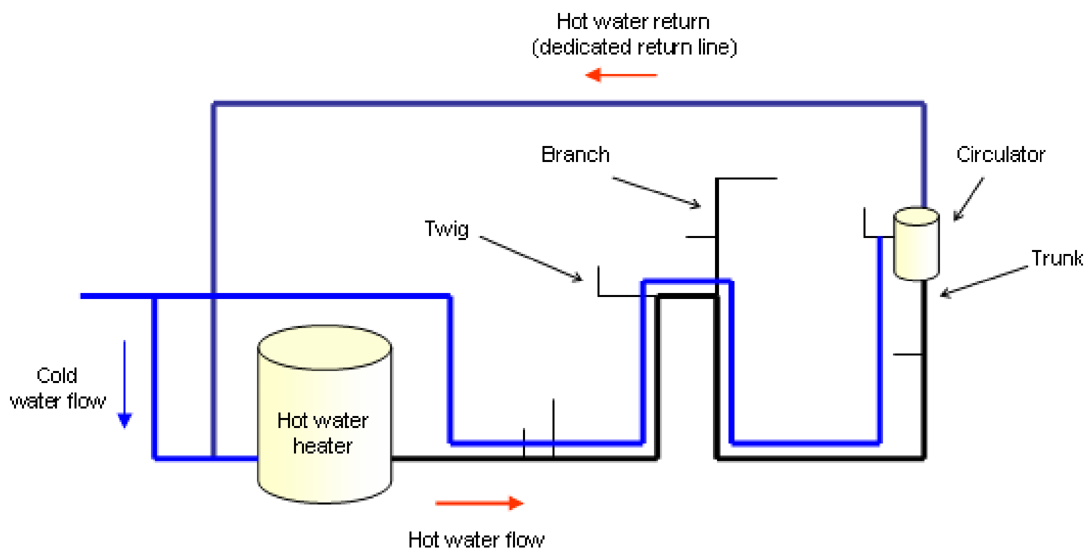

Figure 12: Schematic layout of new construction

It is preferable to have this dedicated line so that there is no crossover of hot and cold water. In this way, alterations to the speed with which hot water reaches the fixtures will have no effect on the delivery of cold water.

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6.3 Existing dwellings

When retrofitting an existing hot water distribution system with a circulating pump, it may not be feasible to install a dedicated return line to the water heater. In this case, the existing cold water line can be used as a return line.

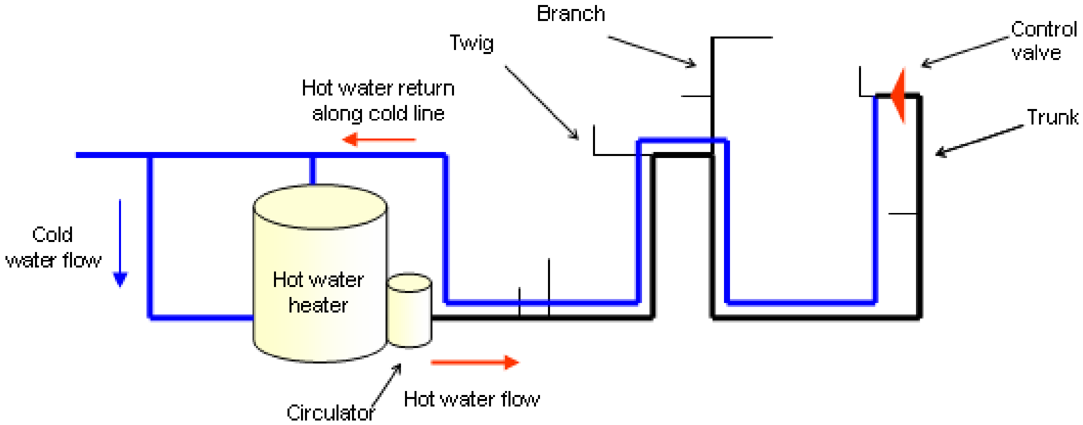

Figure 13: Schematic layout of retrofit

Because of the retrofit and the use of the cold water line, only some circulator pump models are appropriate for use. In these circulation systems, a valve is used to open or close the connection to the cold line as required. These systems can be either normally-open or normally-closed, depending on the behaviour and type of valve used.

– Normally-open system

A normally-open system is created by the use of a passive thermostatic valve. The materials in the valve expand and contract, responding to water temperature changes, to close the connection between the hot and cold lines when the water reaches an optimum temperature. Unless water of this temperature is continuously contacting the valve, the connection will remain open. In this system, the circulator pump will be installed close to the hot water heater, while the control valve will be located at the furthest fixture.

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– Normally-closed system

A normally-closed system may utilise both a one-way check valve and a solenoid valve to ensure that the hot and cold water lines remain disconnected unless active pumping is occurring. This prevents leakage of warmed water into the cold water lines and the subsequent effects on the cold water supply.

There are many types of check valves, all designed to allow flow in one direction only. The diagram below demonstrates the performance of a split-disc type check valve.

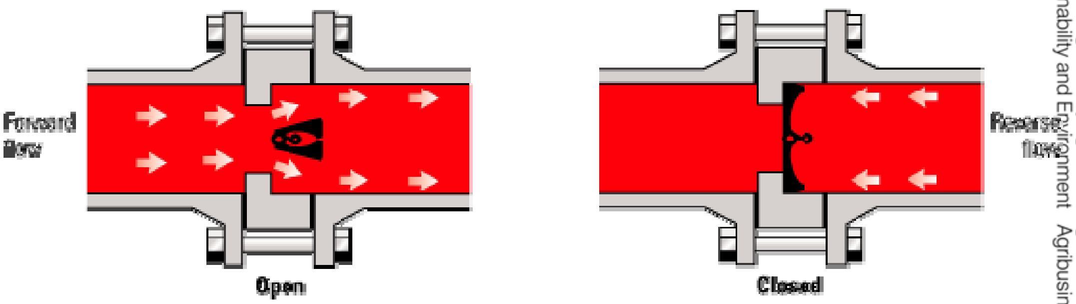

Figure 14: Split disc check valve operation (Spirax-Sarco Ltd, 2008)

In a system such as the one described above, a check valve will ensure that cold or cooled water cannot ever flow into the hot water line, while the solenoid valve will prevent hot water from flowing into the cold water line until the circulation system is actively pumping. A solenoid (or zone) valve is electrically controlled to open and close the valve mechanically. In this case, the valve would be activated to coincide with pump operation, either by aquastat, timer, or manual activation. The diagram below illustrates a typical solenoid valve in the open and closed positions.

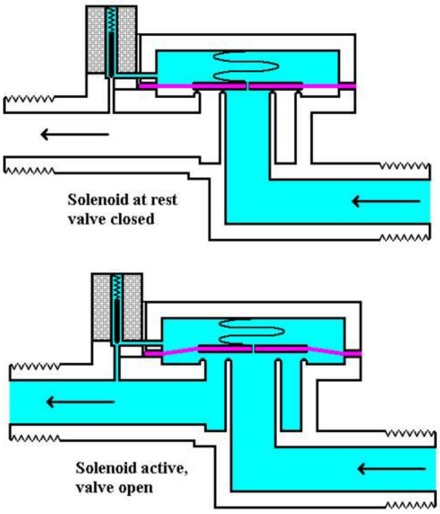

Figure 15: Solenoid valve operation (Gonzalez, 2007)

To ensure adequately heated water at all fixtures, the circulator and aquastat will be located at the furthest fixture from the water heater.

– Issues with retrofitted systems

One concern surrounding using an existing cold water line as a return line is that it can result in an alteration to the cold water temperature. Outcomes in this regard are unclear, with conflicting results from manufacturers. Some claim no temperature change, while others suggest ‘warmed’ water may flow for several seconds.

Another issue in retrofit installations is the temperature of circulated water. For health and safety reasons, Australian Standards require that water heated to temperatures over 38°C may not be returned to the hot water system, yet many of the circulation systems on the international market have temperature cut-off points of up to 50°C. The only approved systems will have maximum operating temperatures of 35°C before the connection to the cold water line is closed off. Circulator models available for use in Australia must be WaterMark certified to demonstrate compliance with these requirements.

6.4 Instantaneous (tankless) water heaters

Not all circulating pumps are suitable to be used with instantaneous water heaters. Circulator pumps that move a low flow of hot water through the system may not produce a high enough flow to actually activate the water heater, resulting simply in the circulation of cooled water before user created demand generates sufficient flow. Minimum flow rates for instantaneous gas water heaters typically vary from less than 2 litres per minute to more than 5 litres per minute to keep the unit operating. (NAEEEC, 2004)

To accommodate this, circulators can be selected on the basis of pump flow rate. Alternatively, circulators specifically designed for instantaneous use can be selected. Some of these circulators are designed to work in conjunction with a specific heater, such as the Rinnai Smartstart, which is designed to be used with the INFINITY water heater, while others such as the SM Laing Tankless Ultracirc is compatible with new dwellings incorporating an instantaneous heater. Appendix A indicates several models compatible with instantaneous heaters.

6.5 Electric water heaters

When hot water circulators are used in homes where an electric storage hot water system is used, issues arise from the return of cooled water back to the hot water system. This is because electric hot water systems generally operate on ‘night rate’, where heating of the water only occurs during the night to avoid expensive electricity costs. If a continuous or semi-regulated circulation system is installed into a household in this situation, the cooled water that is recirculated back to the hot water system will cause the stored hot water to cool down. As the water is only to be heated during the night, by late afternoon/evening, the water within the hot water system may have been cooled and be no longer at a high enough desired temperature for household use. However, an on-demand circulation system should perform well with this type of water heater.

7 Regulatory approaches to hot water distribution

7.1 Australian regulatory approaches

The regulation of hot water distribution, circulation and circulation systems in Australia is covered in the Plumbing Code of Australia, including State and Territory variations, Australian Standards, BASIX (in NSW) and the WaterMark scheme. Guides and incentives available include Smart Approved WaterMark, sustainable housing guidelines, and rebates provided at a State or local level for water efficient fixtures and practices.

There are various regulations and standards for the design of hot water heaters, but no installation standards or guidelines at present for plumbers about how the hot water distribution system should be designed and installed. As such, many plumbers give little or no thought to the design of the hot water distribution system, and do not consider aspects such as the location of the hot water heater relative to outlets, pipe sizes, pipe locations, recirculation systems, location of tempering valves, insulation or draw off volumes. *AS/NZS 3500.4:2003 Plumbing and Drainage – Heated water services* has reserved Section 9 to set out requirements for circulating heated water systems.

7.1.1 Plumbing standards

The Plumbing Code of Australia (PCA), a nationally recognised document, sets out the requirements for the ‘design, construction, installation, replacement, repair, alteration and maintenance’ (NPRF, 2004) of any part of the hot water service connected to the drinking water supply. One of the objectives of the code is to ‘conserve water and energy,’ although it does not directly reference hot water circulation.

The PCA is given legal effect by relevant legislation in each state and territory. For this reason, variations can be found between states as provisions are added or deleted. At present, some states and territories have their own regulations and codes of practice which reference the PCA, AS/NZS 3500 and MP52/AS 5200 with some local variations.

State level documents include:

- Plumbing Regulations 1998 (Victoria)
- NSW Code of Practice for Plumbing and Drainage
- Queensland Plumbing and Wastewater Code and
- Tasmanian Plumbing Code 2006.

The PCA and equivalent state documents contain directives as to the standard of work required for hot water supply. These documents reference Australian Standards regarding plumbing standards, fixtures and performance.

The Australian Standards of relevance to this investigation include:

- *AS/NZS 3500.4:2003 Heated water services*
- *AS/NZS 60335.1Household and similar electrical appliances – Safety - Part 1: General requirements*
- *AS/NZS 3350.2.51:1998 : Safety of household and similar electrical appliances - Particular requirements - Stationary circulation pumps for heating and service water installations (or its equivalent, AS/NZS 60335.2.51:2006)*
- *AS 5200.000-2006 Technical specification for plumbing and drainage products – Part 000: Procedures for certification of plumbing and drainage products*
- *ATS 5200.464-2004 Technical specification for plumbing and drainage products – Part 464: Hot water manual or sensor activated pumping systems*
- *ATS 5200.472-2006: Technical specification for plumbing and drainage products – Part 472: Heated water system recirculation device*
- *AS/NZS 4020 Testing of products for use in contact with drinking water.*

These standards outline the current regulations regarding hot water distribution. They are concerned mainly with safety (OH&S and health risks for drinking water) and technical performance of system components.

7.1.2 Building standards

The Building Code of Australia is a performance-based building code that has been given the status of building regulations by all states and territories (AIB, 2004), although most have variations and additions. The BCA does not regulate plumbing and gas in regards to design and construction. It is administered in conjunction with the PCA, and there is no conflict of contents.

7.1.3 Other supporting standards

- WaterMark

As discussed in section 2.4.1, the WaterMark is used to identify products that meet performance and safety specifications set out by AS 5200.

Figure 16: WaterMark certification mark (Standards Australia Ltd, nd)

AS 5200.464-2004 requires that each pumping system is legibly marked with its licence number and WaterMark. Licensed plumbers will only install WaterMarked products.

– Smart Approved WaterMark

The Smart Approved WaterMark is the current method by which manufacturers of circulating pumps can differentiate themselves in Australia. For approved products, the SAWM label shown below can be placed on the packaging or advertised with the service provided.

Figure 17: Smart Approved WaterMark label (SAWM, nd)

As a voluntary, non-comparative accreditation system, a Smart Approved WaterMark asserts that the product is water saving, fit for purpose, meets standards and regulations and is environmentally sustainable. This mark solely reflects potential water efficiency and savings, and does not consider energy efficiency or waste. Its definition of 'hot water circulation' includes hot water diversion, as evidenced by the products listed as having attained Smart Approved WaterMark status, including the EcoVerta system, designed to divert cooled water to an external tank.

7.1.4 Sustainable housing guidelines

The BCA introduced energy efficiency measures for houses, and mandated a 5-star rating on new construction of building class 1 and 10, which has been adopted nationwide. At a state level, further regulations in regards to water distribution are being put in place. For example, Western Australia has acted to regulate some aspects of hot water distribution design with their new 5 Star Plus building standard. One part of this standard is the 'Water Use in Houses Code' (Department of Housing and Works, 2007), which specifies a performance requirement for hot water use efficiency. The deemed to satisfy provisions provide further details about how to achieve this performance standard:

- the hot water system must be installed in accordance with AS/NZS 3500:2003 (which includes insulation of the pipes)
- the length of pipe between the hot water heater and furthest fitting must not exceed 20 m in length
- or the internal volume of the pipe must not exceed 2 L of internal volume.

No provision exists as yet for the installation of circulation systems.

The Building Sustainability Index (BASIX) is a tool used in NSW to set energy and water reduction targets for all new dwellings, residential alterations and additions throughout the state. Within the Water Details section of BASIX, a check point currently exists to identify if the user intends to install an on-demand hot water recirculation system. Further information supplied by BASIX indicates that this criterion refers only to on-demand (not continuous) systems, and only where they are connected to every hot-water using fixture located within the dwelling.

A voluntary tool available for use is the National Australian Built Environment Rating System (NABERS). This is a performance-based rating system that measures an existing building's overall environmental performance during operation using a set of key impact categories (NABERS, 2006). NABERS relies on energy and water bills for its rating, providing a comparison rating with the average performance for the area in which the dwelling is situated. While NABERS promotes water-saving tips, water circulators are not mentioned.

Other states, such as Queensland, have moved to regulate water heater choice and installation through minimum efficiency standards, rebates and the like, although no specific discussion of hot water circulators has yet been included.

7.1.5 Rebates available

As incentives to install water saving devices, some states and municipalities offer rebates on certain products. These vary in terms of value and conditions attached. Some of the rebates available for water circulators around Australia include:

- Victoria: $150 for a hot water circulator, limit one per property
- Toowoomba City Council (Qld): $200 for a WaterMarked circulator conforming to AS.
- New South Wales: No rebate available for circulators
- Queensland: No rebate available for circulators
- South Australia: No rebate available for circulators
- Western Australia: No rebate available for circulators
- Tasmania: No rebate available for circulators
- ACT: No rebate available for circulators
- Northern Territory: No rebate available for circulators

As in the case of Toowoomba, some city councils offer their own rebate schemes, which may not be captured in this document. At present, the two identified rebate schemes are targeted at residential customers, and do not specify a model or system type to be used.

Most state governments offer rebates on other water-saving and/or WELS labelled products. These rebates are reviewed periodically with some becoming more stringent (for example, requiring 5-star rather than 4-star dishwashers in order to qualify for a rebate). It is likely that if they became WELS labelled or standardised in some way, circulator pumps may attract further rebates.

7.2 International regulatory approaches

Circulator use is widespread internationally, with states and municipalities across the US incorporating requirements for their use into legislation and ordinances, and over 120 million circulators in use in the EU, in both domestic hot water and heating and cooling applications (Grundfos UK, 2007). This section presents a brief selection of standards, guidelines and rebates in use internationally. This does not constitute an all-inclusive list of international regulations.

7.2.1 Plumbing standards

The Plumbing Standards in European countries are generally aligned with the European Standard, with country-to-country variations. The two most relevant standards for hot water circulation systems are:

- *EN 1151.1:2006/AC:2007Pumps - Rotodynamic pumps - Circulation pumps having a rated power input not exceeding 200 W for heating installations and domestic hot water installations - Part 1: Non-automatic circulation pumps, requirements, testing, marking*
- *EN 1151-2:2006/AC:2007 Pumps - Rotodynamic pumps - Circulation pumps having a rated power input not exceeding 200 W for heating installations and domestic hot water installations - Part 2: Noise test code (vibro-acoustics) for measuring structure- and fluid-borne noise.*

These standards outline the testing and performance requirements for circulation pumps. The majority of pumps in use in Europe are for household heating and cooling. These pumps have different usage patterns than hot water circulator pumps; however these standards should still apply.

In the United States, plumbing regulations follow different codes on a state-by-state basis. The majority of the states refer to one of four codes:

- International Plumbing Code (IPC)
- Uniform Plumbing Code (UPC)
- National Standard Plumbing Code (NSPC)
- Standard Plumbing Code (SPC).

Most adopt these codes with some variations, although some states have codes entirely of their own. The IPC and NSPC include a requirement for ‘temperature maintenance’ when the distance from the water heater to the furthest hot water fixture exceeds 100 feet, without specifying conditions on the form this maintenance is to take.

Some cities within the US also have their own plumbing codes. The city of Fontana, California, has amended its plumbing code to require that:

“all dwelling units shall be provided with an approved recirculating hot water system, and all hot water piping connected to that system must be insulated with

a minimum of R-3 [R0.6 in SI units] *insulation around the piping material, throughout the recirculating hot water system."* (Industrial News, 2006)

Other cities have incorporated water recirculation requirements into local building standards and guidelines.

7.2.2 Other standards

There are many and varied energy/environment/water efficiency labelling programs across the globe. Few have been found that currently refer directly to hot water circulators, although some may be able to extend to water circulation systems in the future.

– CE Marking

Similar to the Australian WaterMark, CE marking indicates that a product has met all the essential requirements of the relevant European Directive. At present European Directive 88/378/EEC outlines the efficiency requirements of hot-water boilers, but there is no explicit directive for hot water circulator pumps.

– EU Energy Labelling

This is a Europe-wide labelling system that ‘aims at communicating information about the relative efficiency performance of different appliances to consumers, retailers and manufacturers mainly through the use of a categorical efficiency scale’ (GreenLabelsPurchase, 2006). EU Energy labelling is not yet extended to circulator pumps, but the four main manufacturers (80% of the European market) and Europump (the European pump association) have made a self-commitment to EU-style labelling. This labelling is based on the European Directive 98/11/EC with regard to the energy labelling of household lamps.

The Europump labelling scheme allows for energy classes from A to G, and has been created to focus on energy saving potential in appliances. While it is voluntary, signatories to the agreement are subject to sanctions or exclusion from the scheme upon non-compliance and the scheme is open to all pump manufacturers. This energy efficiency labelling is aimed mainly at circulator pumps used in heating and cooling European houses. These pumps are expected to run continuously, which means that energy efficiency can be determined independently of end use. The Europump labelling is not currently applied to dedicated hot water circulation pump models.

– Japan – Energy Saving Labelling Program and Top Runner

In line with the ‘Law Concerning the Promotion of Procurement of Eco-friendly Goods and Services by the State and Other Entities’, Japan has introduced the Top Runner Program. This program sets efficiency targets within product categories for manufacturers and importers, rather than individual products. The labelling program associated with Top Runner is known as the Energy Saving

Labelling Program (ESLP). ESLP labels inform the consumer as to whether a product has achieved or exceeded the target energy efficiency set for the category. At present this labelling program is voluntary and not applicable to circulator pumps, although certain water heaters are included.

7.2.3 Sustainable housing guidelines

Various countries have introduced voluntary and/or mandatory sustainable housing guidelines, some of which are detailed below.

– LEED

Leadership in Energy and Environmental Design (LEED) is a voluntary rating system initiated by the U.S. Green Building Council, but which has also been adopted in international projects across 41 countries. LEED provides rating systems for new construction for many project types, including commercial, renovation, neighbourhood development and homes. Similar to the NSW BASIX Scheme and the Australia-wide star rating, LEED provides a checklist of 'green' building features available under different areas, such as energy efficiency, health and safety and material resource efficiency. Features provide the building with a certain number of points, with specified levels to achieve ratings such as 'gold' or 'silver'. Options for water heating include pipe insulation, efficient hot water heaters, and smart plumbing incorporating a hot water circulation loop. Water heater efficiency factors (EF) can be enhanced through the use of demand controlled circulation, as detailed in Chinery (2006).

– Energy Efficiency Standards

Oceanside, California, Reno/Sparks, Nevada and the state of Massachusetts are just some of the localities that now require hot water recirculation systems on all new construction. Cambria, California, mandates hot water recirculation pumps for all new construction and existing homes. Other localities across California, Arizona, New Mexico and Texas are in the planning phase of implementing hot water recirculation programs. Changes within California are occurring as a result of that State's Energy Efficiency Standards for Residential and Non-residential Buildings.

The California Energy Commission has, since 1978, produced Energy Efficiency Standards for residential and non-residential buildings. The 2005 Standards incorporate a Residential Compliance Manual, which details requirements on hot water systems incorporating circulator pumps. Such requirements include:

- that recirculating sections of domestic hot water systems must be insulated (the entire length of piping, whether buried or exposed)
- that recirculating systems serving multiple dwelling units must have controls (e.g. timer controls, time and temperature controls) to turn off the pumps when hot water is not needed
- that continuous recirculation systems must be laid out to within 8ft of all hot water fixtures served by the recirculating loop

- that ‘temperature control’ recirculation systems must have an automatic thermostatic control installed to cycle the pump on or off
- that ‘timer control’ systems have a permanently installed timer, permitting the pump to be off for at least eight hours per day and
- that ‘demand control’ systems must have an automatic shut off either by a temperature sensing device or a limited run time. (RCM, 2005)

These definitions allow for clarity in determining compliance with particular energy efficiency ‘packages’ detailed in the document. They do not place restrictions on the performance or efficiency of any one device. The Non-residential Compliance Manual has no requirements regarding hot water circulation.

- BREEAM

In England, the Code for Sustainable Homes and Ecohomes are mandatory environmental assessment methods produced by the Building Research Establishment Environmental Assessment Method (BREEAM) to rate new and refurbished homes respectively. Ecohomes is used for all housing in Scotland and Wales. These codes are designed to calculate the emissions from energy for hot water systems, and focus on the efficiency of fixtures and appliances, with no mention of hot water circulation.

- Sustainable Housing in Europe

The Sustainable Housing in Europe project, run from 2003 until March 2008, has created examples of sustainable housing in four European countries and aims to produce a set of best practices, evaluation procedures and guidelines that can be used anywhere in Europe. At present these guidelines are not complete.

7.2.4 Rebates available

Present research indicates only the United States as offering similar rebate schemes to those available in Australia. From information gathered, rebates appear to be the jurisdiction of individual cities or water authorities. Examples of some available rebates include:

- San Antonio Water System (SAWS): is US$150 rebate on approved on-demand hot water circulator models
- City of Peoria, Arizona: US$100 rebate on hot water circulator models where there is compliance with several conditions, including that the hot water circulator must be a model that includes a built-in timer, so the device runs only when needed and
- City of Scottsdale, Arizona: the lesser of the actual cost (before tax) of the device or US$200 rebate.

These rebates indicate a trend of placing conditions on the type and even model of hot water circulators that will attract a rebate.

8 Admission to schemes

8.1 Suitability for WELS

Products eligible for the WELS scheme are required to have several characteristics. These include:

- that they significantly contribute to national fresh water and/or waste water use
- that the design of the product significantly determines its water use
- that a standard test could be developed to allow for compliance testing
- that the product is mass-produced so that all items of a particular model have the same technical performance
- that models on the market exhibit differences in efficiencies, so that comparisons can be made.

Hot water circulator pumps display some of these characteristics readily, while others require further discussion.

8.1.1 Contribution to water use/waste water discharge

In order to determine their suitability for inclusion in the WELS scheme, it is necessary to determine to what extent water circulators can contribute to the national water use and/or waste water discharge. As circulators do not actually use water, it is necessary to calculate the volume of water wasted without their implementation. Comparing this with the volume wasted once a circulation system is in place will give an estimate of their contribution to water use/waste water discharge and form the basis for testing.

As discussed earlier, the use of a circulation system will significantly reduce or eliminate draw off, which could have volumes in excess of 2kL per year. The use of a hot water circulation system, whether continuous, regulated, or on demand, will effectively remove the majority of losses by providing hot water at the fixture as it is turned on.

8.1.2 Contribution of design to water consumption

As circulator pumps do not use water, the consideration of design as a factor in water consumption must instead be investigated with regard to water conservation. The extent of water loss is determined by the length of time taken for hot water to reach the fixture. As discussed earlier, the different types of circulation system provide varied outcomes, with continuous circulation providing immediate hot water, and on-demand systems requiring a wait period. A study by Wendt et al (2004) indicates identical wait times for hot water for continuous and demand systems, but does not indicate the type of demand system used nor the length of time between system activation and water use.