Institute for
Sustainable Futures

LEICHHARDT SOLAR WATER HEATER SURVEY

Performance review and user satisfaction of solar hot water systems in Leichhardt Municipal Council
Sydney, NSW

Prepared for Leichhardt Municipal Council

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SUMMARY

In June 1994 Leichhardt Council adopted *Development Control Plan 17 - Energy Efficient Housing* (DCP17). With this plan and the slogan "Leichhardt goes Solar", Leichhardt Council confirmed their intention to encourage renewable energy systems, in particular regulating for the installation of solar water heater systems (SWH) in most new dwellings and major renovations.

Four years later, in winter 1998, this survey was developed to obtain knowledge about how these systems perform, user satisfaction with the systems, what householders think about DCP17 and, finally, what level of financial and energy savings are possible in the Sydney area. The survey utilised personal interviews and a mail survey. Letters were sent to 182 owners or users of solar hot water heaters, and 33 (20%) of them participated in the survey.

The results are very informative. In general people are satisfied with their systems, and 73% of the participants would buy a solar hot water heater again. In Sydney, the solar contribution can reduce energy required for water heating by between 60 and 75%.

However, the problems of SWH are essentially the high costs of purchase and installation and the low tariffs for off-peak electricity and gas. Because of these factors, solar hot water heaters are often not sufficiently competitive in the financial sense to provide the payback periods expected by many households.

Nevertheless, a household with a solar system can save on average $250 per year compared to a standard continuous tariff storage system, and can reduce the yearly emission of the greenhouse gas carbon dioxide (CO_2) by 2,000 kg.

In general, Leichhardt's Development Control Plan 17 seems to be an effective tool for implementing renewable energy systems like solar hot water heaters. If the lack of user information, which a number of participants in the survey commented upon, can be remedied, the level of acceptance and satisfaction could be much higher.

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Tables and figures

1. INTRODUCTION

This report presents the results of a survey of solar hot water system owners and users in Leichhardt, Sydney, NSW. The survey was designed to collect information about how solar hot water heaters perform under everyday conditions and gauge user satisfaction. The survey was undertaken in winter 1998 as part of a four month student internship at the Institute for Sustainable Futures. The results have been used to assess the environmental outcomes of Leichhardt Municipal Council's *Development Control Plan 17 — Energy Efficient Housing* (DCP 17), which came into operation in June 1994.

Leichhardt Council's solar water heater policy is designed to reduce CO_2 emissions, energy consumption and reliance upon fossil fuels. The Council requires solar hot water systems to be installed in most new residential buildings and all major renovations that require a new hot water system. Consequently, most new houses in the Leichhardt area have a solar hot water system.

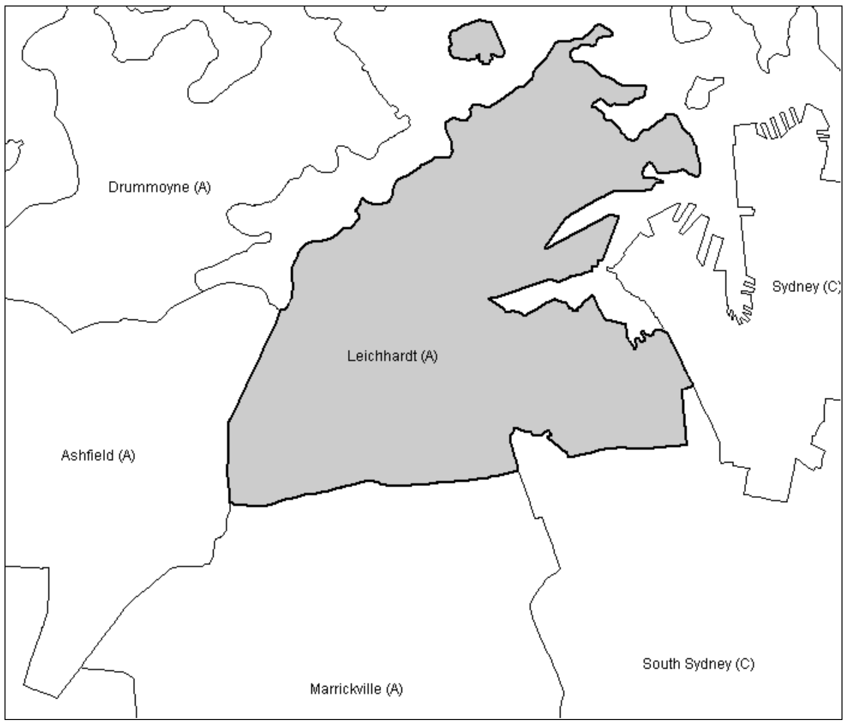
The topic is an important one, as water heating accounts for approximately 35-40% of energy consumption in a typical all electric household in inner Sydney, resulting in the emission of about 3.5 tonnes of CO2 per household each year. Solar water heaters are promoted as an important way of reducing these emissions yet less than 5% of households in NSW currently own one. The NSW Sustainable Energy Development Authority (SEDA) is actively encouraging the installation of solar systems through offering a $500 rebate on the purchase cost, and a number of councils are considering adopting policies to encourage the adoption solar heaters.

The survey included households that had installed solar water heaters for reasons other than DCP17, such as participants in the NSW Sustainable Energy Development Authority's (SEDA) $500 rebate program, Energy Card users and people who installed a solar system for environmental or financial reasons.

2. THE LEICHHARDT AREA

2.1 Geography

The Municipality of Leichhardt is a densely developed, inner-city area with a diverse population and mixture of land uses. It is located in Sydney's inner west and includes the suburbs of Leichhardt, Lilyfield, Balmain, Rozelle, Birchgrove, Annandale, Forest Lodge and Glebe. Leichhardt covers an area of 1225 hectares, bounded by the local government areas of Ashfield to the west, Marrickville and South Sydney to the south and Sydney City to the east. There are 16.8 km of foreshore lands fronting various bays of Sydney Harbour and the Parramatta River.



2.2 Built environment

The Leichhardt municipality is characterised by a diverse range of commercial land uses, including large waterfront industrial sites, strip (high street) shopping centres, small and larger industries, harbourside parkland and private and public recreation facilities. Private and public residential development ranges from small timber workers cottages and three-storey Victorian mansions, through to 1960s blocks of flats, townhouses and warehouse conversions. Leichhardt has been undergoing gentrification since the 1960s, and in the last twenty years older industry has given way to new residential development and some light industry and commercial facilities.

2.3 Demographic profile

Around 60,000 people live and work in the Leichhardt area, which is noted for its cultural and ethnic diversity. The net population density in residential areas is approximately 100 persons per hectare with an average occupancy of 2.2 persons per dwelling. Leichhardt Council's Community Services Department produced a report with a comprehensive population profile in late 1996, which provides a wide range of statistics for the municipality as a whole and individual suburbs. These include: population; age distribution; employment; health; housing; income; religion; journeys to work; family status; and cultural diversity.

The report notes the following trends in Leichhardt:

- the loss of lower priced rental housing;
- an increase in the proportion of owner-occupied dwellings;
- an increase in motor vehicle ownership rates;
- an increase in the number of people with tertiary education qualifications;
- a decline in unskilled employment opportunities;
- a decline in the proportion of people in the 60+ age group;
- an increase in the proportion of people in the 25–59 age group;
- a significant increase in the cost of residential real estate;
- increases in household and individual income levels;
- a decline in household occupancy rates;
- an increase in the number of two-income families;
- an increase in the numbers of single parent families;
- an increase in the amount of public housing; and
- changes in the character and function of local business centres towards more specialised and commercial retail centres.

(Source: Leichhardt Council State of the Environment Report 1996)

2.4 DCP17 — Leichhardt's Sustainable Future

In 1994, Leichhardt Council adopted DCP17. The plan aims to improve energy efficiency so as to reduce greenhouse gas emissions. Its objectives are:

> *'to encourage residential site planning and building design that optimises solar access to land and buildings; to reduce total energy use in residential buildings, by reducing heat loss and energy consumption for heating and cooling purposes; to encourage the use of building materials and techniques that are energy efficient, non-harmful and environmentally sustainable'*

Council's requirement that new residential buildings (except one bedroom dwellings) and major residential renovations where the hot water system is being replaced must install solar water heaters constitutes a major aspect of DCP 17. If the situation is unsuitable for a solar hot water system because of insufficient solar access, or because it may spoil the aesthetic appearance of the building or streetscape, a heat pump or high efficiency gas system is recommended. As a result of this policy, about 90 per cent of all newly built houses in Leichhardt have a solar hot water system on their roof.

3. METHODOLOGY FOR REVIEW OF THE SOLAR WATER HEATER POLICY

3.1 General approach

Interviews and questionnaires were held to collect data from solar hot water system users. In view of the time limit on this study it was decided to use a combination of personal interviews and a mail survey. The questionnaires were accompanied by an introductory letter and a reply paid envelope, which allowed people to decide whether or not they wanted to be interviewed. People who participated in the survey were included in a draw where three prize winners could choose either a water efficient shower head or an energy efficient light bulb. Anyone who did not want to be interviewed was asked to fill in the form and return it in the reply paid envelope to the Institute for Sustainable Futures (ISF).

The research was initially structured around the following questions:

- How is the performance of solar hot water systems affected if they are not optimally installed?
- Are the performance claims made by the manufacturers achievable in Sydney?
- What role does additional boosting play, and do people use their booster switch if one is provided?
- How satisfied are users with their solar hot water system?
- What financial and greenhouse gas savings are possible through the use of SWH in Sydney?

Because quantitative results require a substantial amount of data collection and monitoring it was decided to place less emphasis on the technical aspects of performance and concentrate more upon hot water usage patterns and user satisfaction levels. Both of these factors are important because they can significantly influence performance and affect consumer choice by word-of-mouth recommendation. The questionnaire and face-to-face interview method also offered the opportunity for people to express their opinion about the SWH aspect of DCP17.

The survey questionnaire had to be designed in such a way that everybody would be able to understand and answer the questions. Although most of the SWH were in owner occupied households, sometimes they were installed in rented accommodation. Where posible, a site inspection was be made in the event of any doubt about the accuracy of answers to technical questions concerning pitch or orientation. If an interview was conducted, the interviewer undertook the necessary measurements. Participants were also asked to give their permission for ISF to obtain billing information from energy suppliers so as to calculate financial savings.

The survey covered the following groups of SWH owners:

- people who were required to purchase a system as a result of DCP 17;
- participants in a public program (SEDA $500-rebate, EnergyCard);
- people who installed SWH for environmental reasons; and
- people who want to save money or energy.

Initially the interview questions were developed for home owners who, for one of the above mentioned reasons, had installed a solar hot water system. However, because many of the new town-house type developments in the Leichhardt area are rental properties, tenants also received the questionnaire. This led to some problematic responses, especially for financial questions about money savings, which could not be calculated if, for example, the installation costs were not known. In such instances, more importance was attached to the information about usage patterns and user satisfaction levels.

3.2 Potential Bias and Error Issues

Mistakes and mis-interpretations were bound to occur during self-completion of some of the survey forms, especially considering the technical nature of some of the questions. The data or descriptions from these surveys were carefully checked, and if there was any doubt a site inspection was made or the data was not used.

The interviews took place in winter, which probably influenced the answers to questions about boosting and user satisfaction. July and August 1998 were rainy and cloudy and required longer boosting periods, which people saw as a negative aspect of SWH.

3.3 Response

The first 100 questionnaires were posted on July 30, 1998, another 82 two weeks later (August 13). The first batch was addressed ”to the householder” because names were not known. The second was sent to addresses where the name of the householder was known. Of the 182 questionnaires distributed, nine were returned because they were undeliverable and another four because no SWH was installed. Thus 169 households with SWH received the questionnaire.

The immediate response rate was very low, only seven people answered. An attempt to contact people who had not responded after two weeks began on August 18 and continued until September 4, through a personal visit to a number of households on the list, usually between 3 pm and 6 pm. Forty reminders were distributed to households where nobody was at home.

Eventually, thirty three households participated in the project, 18 filled in the questionnaire and sent it back to ISF, and 15 were interviewed in person. This gives an overall response rate of 20% - an 11% response by mail and 9% from field interviews. Eighteen SWH owners or users who were approached said they had no interest in participating. A further 18 households were considered not suitable because, for example, the people had only just moved in. Two of the questionnaires posted to ISF were only partially completed. There was no response from 40 of the households that received reminders.

Table 1: Survey responses

	Survey number	Percentage
Total letters sent	182	
wrong address	9	
no SWH	4	
Suitable households	**169**	
no response	69	41%
no interest	18	11%
other reason (too new, not found etc.)	18	11%
letter received but not usable	2	1%
reminder distributed	40	24%
Households replying to letter	18	11%
Households interviewed personally	15	9%
Households participating	**33**	**20%**

4. Survey Results

The survey results from the 33 participants are described below in a general summary of responses to each question. A copy of the questionnaire is included in the Appendix. It should be noted that due to the small number of households makes generalisations difficult – for example a 20% response which sounds significant represents only six households.

1. What type of hot water system did you have before you installed your solar system?
This question was answered by both house owners who had installed a SWH and tenants who may have only recently moved into the dwelling.

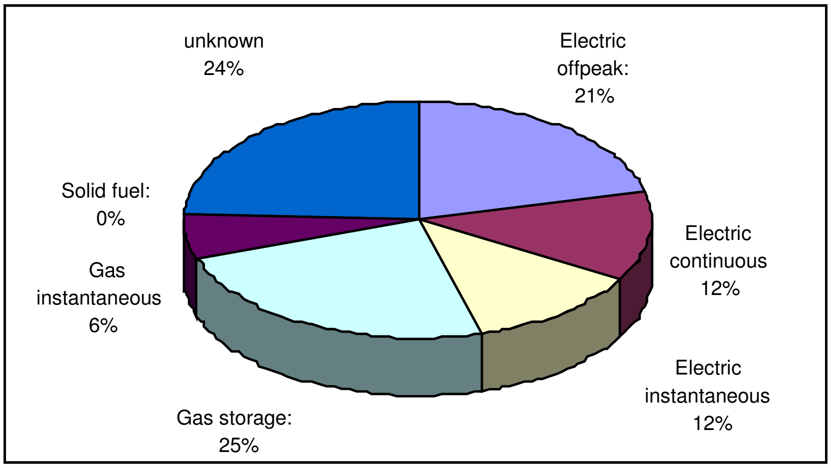


Figure 1: Type of hot water system used before installing SWH

Electric hot water heaters are the most common type of water heater in Sydney, and are owned by about 80% of households compared to 15% gas. According to this survey the local split is 45% electric and 31% gas, reflecting the extensive provision of mains gas in the area. Most of the 24% of people who were unable to answer this question are tenants who moved to their current home 1-3 years ago.

2. What size is the storage tank for your system?
3. How many panels does your system have?
Figure 2 shows the combinations of the system configurations. It indicates that most of the installed systems have a nominal 300 litre capacity tank and two panels, which is the standard size generally recommended for a family of three or four people.

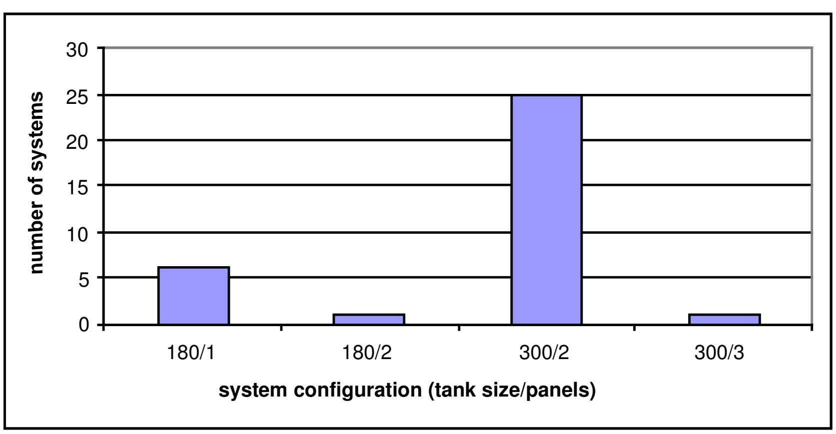


Figure 2: Number of different system configurations by tank size and number of collector panels

4. Year of installation

The responses were grouped according to whether the SWH was installed before 1985, between 1985 and 1994, or after 1994. 1985 was an arbitrary cut-off date, unlike 1994, which was when Council adopted DCP 17. Leichhardt Municipal Council supplied many of the addresses for SWH users, which not only explains the high percentage of recent installations, but also indicates that DCP17 has been successful in increasing the installation of solar water heaters. The average age of the installed solar hot water systems is 5.3 years.

Table 2: Age of systems

Year of installation	Number	Percentage
installed before 1985 (>13 years old)	7	21%
installed between 1985 and 1994	2	6%
installed after 1994	24	73%

5. Direction solar panel is facing

6. Angle of panel(s) inclination

As will be discussed later, the optimal angle of panel inclination in Sydney is approximately 34° from the horizontal, with an acceptable range of ±15° as this is deemed to affect performance only marginally. These responses are grouped according to orientation *and* inclination. Figure 3 shows that 15 out of 33 systems (45%) were installed within the ideal range. It is not known however how accurately some SWH owners determined pitch and orientation in cases where a site visit was not possible.

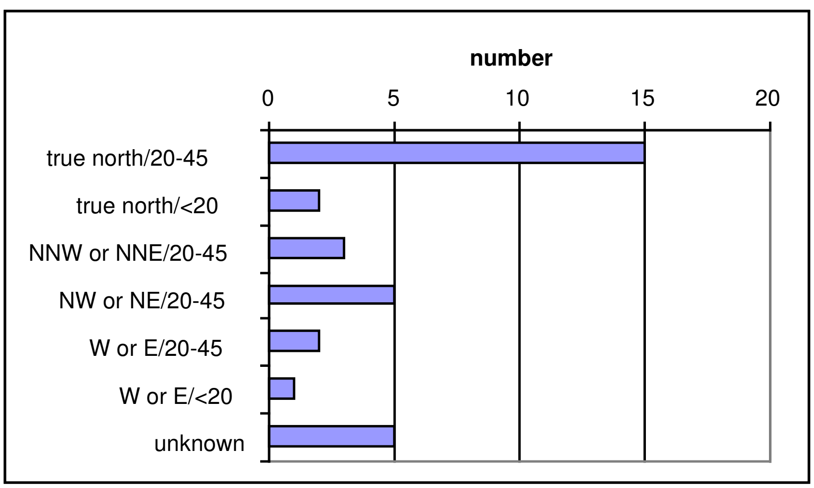


Figure 3: Combination of orientation and inclination

7. Is it a close-coupled system?

Thirty two of the 33 households surveyed households answered ”yes”, and one household couldn’t answer this question. Split systems can be found in Leichhardt, arranged so the panels are on one side of the roof with the tank on the ground or the other side of the roof, usually to reduce the impact on the streetscape. However, such systems did not feature in this survey.

Therefore, question 8: “If split, where is the tank?“ has been omitted.

9. Are the panels shaded?
Most of the households interviewed answered ”no”, 27 not in winter and 26 not in summer. Only a minority said the panels are shaded during the time of highest solar radiation, which is between 10 am and 3 pm (4 pm in summer). Three households couldn’t give any information about the situation in winter, four for the situation in summer.

Although it seems that these are very good figures for the efficiency of solar systems, they may not be very accurate. Because many systems are not entirely visible from the street, it was difficult to check the influence of shade during the field interviews and/or rounds.

10. How many people live in your household?
The average size of the households interviewed is 2.9 people, which is about the same as the average for Sydney but higher than the figure for Leichhardt of 2.2. Two people or less live in 13 households, which are mainly occupied by two adults. Three or four people lived in ten of the houses and there were ten households with families of more than four people.

11. Do you have a water efficient shower head?
Every household answered this question: 45% of households own a water efficient shower head, 55% have a standard shower head. This is a very high ownership level as the figure for Sydney is approximately 20%, but it can be partly explained by the fact that many of the houses with SWH are quite new (built after 1990) and that some SWH owners are more aware of energy and water consumption than the average.

Table 3: Water efficient shower heads

Answer	Number	Percentage
yes	15	45%
no	18	55%

12. When do household members take most showers?
As figure 4 shows, 56% of all showers are taken in the morning. It must borne in mind that some people have two showers per day. In Sydney’s climate zone, peak winter morning hot water use results in slightly lower efficiency than a peak evening use as it is sometimes necessary to boost the temperature due to overnight heat losses. Most of the people interviewed are employed outside the home, with a consequently low proportion of showers taken during the day.

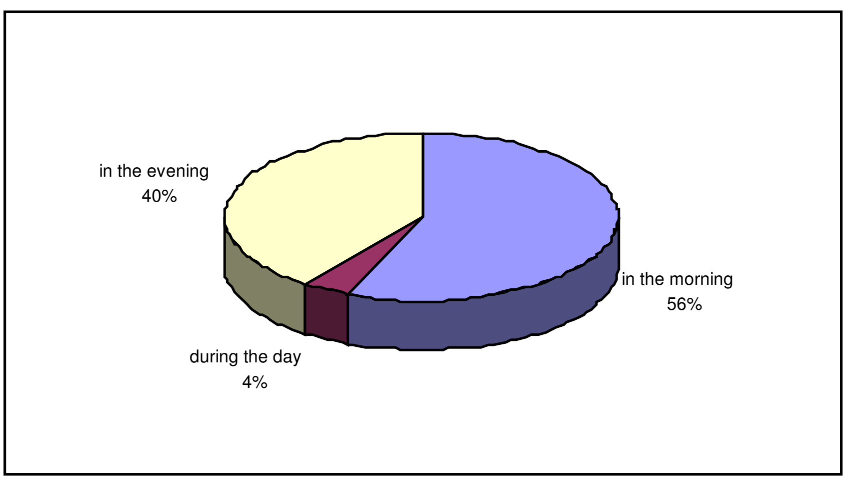


Figure 4: Time of taking a shower

13. Has something changed in your household since installing the solar system that could affect hot water or energy usage? (eg. more or less persons in the house, changeover from electricity to gas for cooking, heating etc.)
This question was designed to help with analysis of the billing data from the energy supplier so as to be able to account for any differences in energy consumption after installing a SWH.

Changes were most notable in those households that had owned a SWH for a long time. People gave examples such as ”the children got older”, and therefore use more or less water/electricity, or more commonly ”over a certain period we had more people in house”.

14. Is there always enough hot water available?
15. Do you think that there is more hot water than you need?
These two questions are designed to find out if a system is correctly sized and used. Question 14 got a 100% response rate, and while it is clearly difficult to say if there is more hot water than needed, 97% answered question 15. The majority thought that SWH could deliver enough hot water without boosting in summer but not in winter or on cloudy days (which is quite normal). It is thus advisable to check factors such as the number of people, type of booster, system size etc. Further investigation is recommended for cases where there is never enough hot water available.

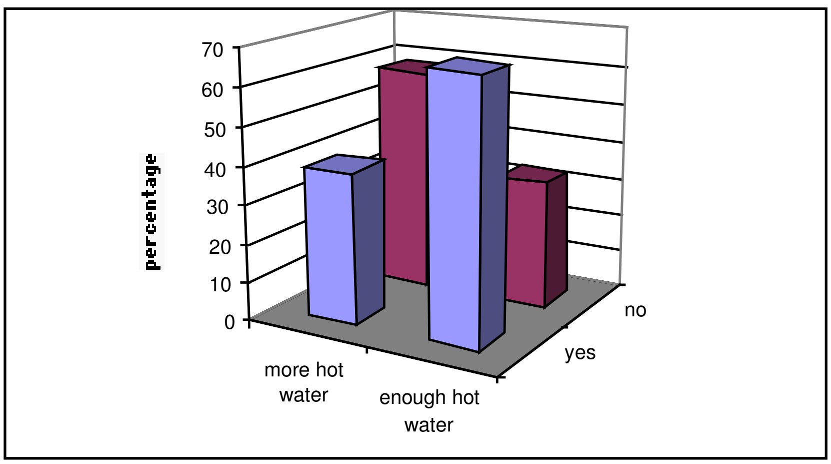


Figure 5: Hot water availability

16. What type of booster do you have?
The booster is used to heat the water on those occasions when there is insufficient sunshine. The responses show an electrical booster is still the most common; gas boosters were only found at one townhouse in the area enclosed by Elizabeth, Quirk and Alfred Streets in Rozelle. All 29 households in this development have a gas-boosted SWH, but only four participated in a face-to-face interview.

As Figure 6 indicates, the continuous electric booster is used more often than either off-peak 1 or 2. Issues relating to boosting will be discussed in the following chapter.

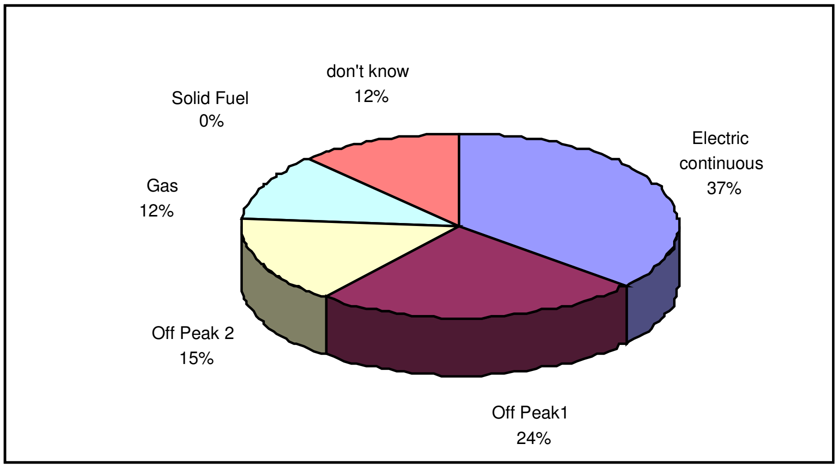


Figure 6: Type of booster

17. Do you have a booster switch?
A booster over-ride switch, usually situated in kitchen or bathroom, is often fitted to electrically boosted systems, particularly continuous and off-peak 2. This allows the user greater control of the water heating with the ability to manually turn the heating element on and off. A booster switch is not a standard fitting on SWH, and according to major manufacturer *Solahart* costs an extra $90. The extra cost and the lack of any advice from SWH manufacturers to fit off-peak systems with a booster switch result in a small number of households who do not have one. Twenty three of the 33 households (70%) said yes they had a booster switch, ten of them (30%) have no booster switch.

Some households with off peak 1 systems used the switch on their electric switchboard to turn the heating element off in summer in order to reduce the overnight electric contribution to water heating and, although not strictly speaking a booster switch, some of these households have answered yes to this question complicating the analysis.

If yes, when do you switch your booster on?
Figure 7 shows the results of this question for the 23 households with a booster switch. Twelve of the 23 (53%) households leave their booster on continuously day and night.

Figure 7: Time of manual boosting

18. How often is your booster on in winter/summer?
As in figure 7, figure 8 is based on the 23 households whose solar hot water systems have a booster switch. The high proportion (78%) of systems that are switched on 24 hours a day in winter is noticeable.

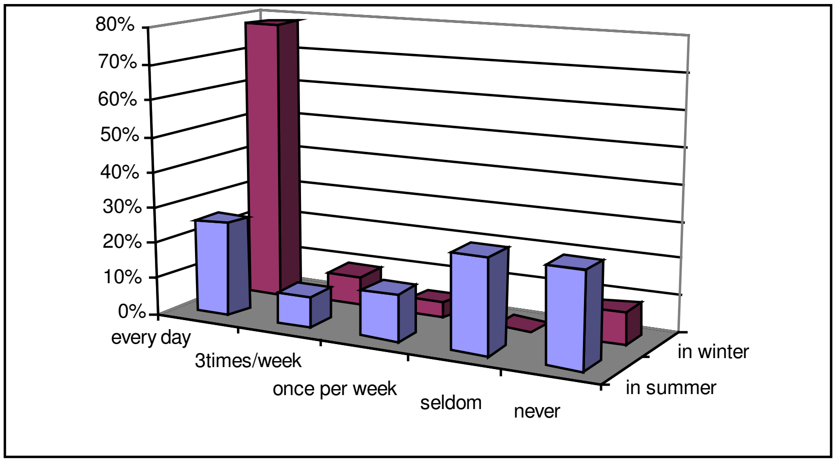


Figure 8: Booster use depending on the seasons

19. Is your booster fitted with a timer?
With a timer it is possible to program the booster to turn on at certain times of the day. For instance, instead of boosting through the night it is possible to set the timer for 5 am and have hot water for the morning shower. However, as figure 9 indicates, only a very small percentage of people knew about and/or used timers.

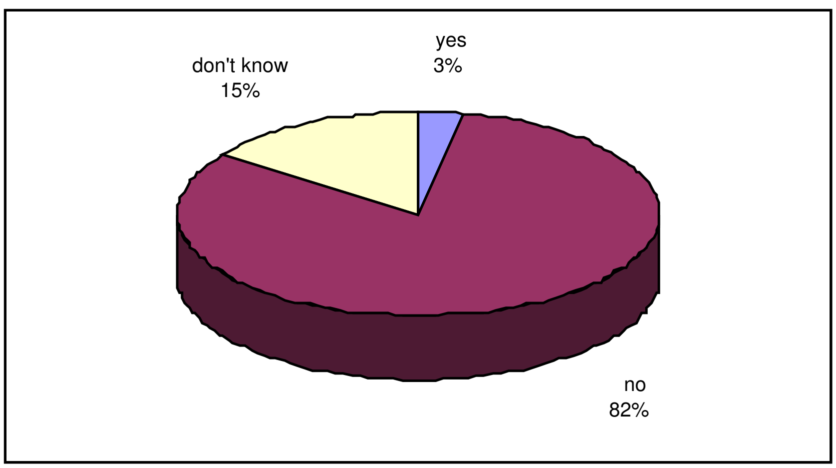


Figure 9: Booster with timer

20. Have you ever had trouble with your SWH?
Two thirds of the households interviewed said they have or had no problems with their systems. This is partly explained by the high percentage (73%) of systems that were installed after 1994, as newer systems are unlikely to have experienced failures.

Of the 10 households with problems, five had trouble with the tank and had to replace it after about 10 years because it leaked. Some of the five had not been informed that in some models the sacrificial anode has to be changed every five years.

In the other five cases people complained about either not having enough hot water, or that the water did not get hot enough. These systems should be checked to see whether the system is too small for the size of the family or is not functioning properly because of thermostat failure, incorrect installation, etc.

In general the responses to this question are positive. If manufacturers can implement measures to avoid disappointing customers, such as a reminder to change the anode, it is highly likely people would be more satisfied with their SWH.

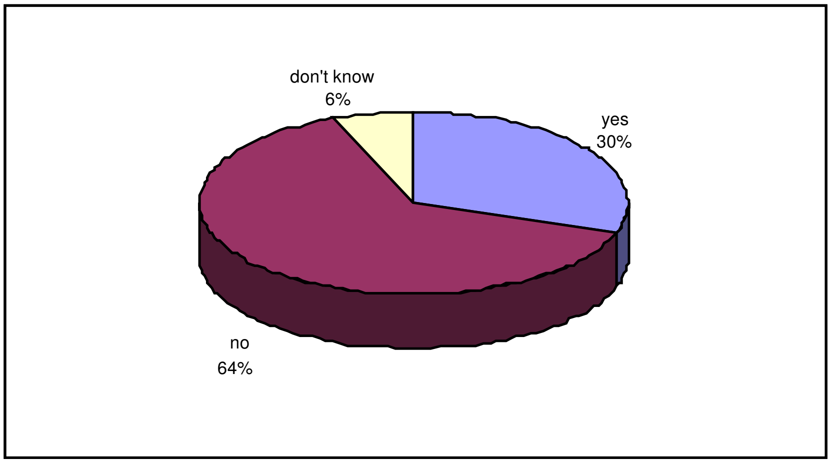


Figure 10: Trouble with SWH

21. Are your panels regularly cleaned?
22. Is your system regularly maintained or inspected?
Only five out of 33 systems are regularly cleaned and/or inspected. Once again this can be explained by the fact that most of the households interviewed have relatively new systems.

On the other hand, many people were astonished by questions 21 and 22. The first question in particular seemed to establish that people are unsure as to whether or not they should clean the panels. A frequent reaction to the second question was to ask who would inspect the SWH and how much it would cost.

The interviewer got the impression that people still have in mind the old advertising slogan "install and forget". This seemed to be supported by SWH manufacturers' responses. The answers to question 20 indicate that this perception exists with regard to changing the sacrificial anode in *Solahart's* systems. When a *Beasley* representative was asked if any maintenance was required, the interviewer was told no maintenance at all is necessary because of the stainless steel tank.

23. Why did you purchase a solar hot water system?
In 10 out of 33 households the system was already installed when the current occupant (tenants or owner) moved to the location. If the house was built after 1994, DCP17 was assumed to be the reason for installation.

In 16 out of 33 households solar hot water systems had been installed because of DCP17. Only four people interviewed decided to install a SWH because of the $500 rebate that SEDA introduced in April 1997. Environmental reasons (17 respondents) followed by "to save energy" (16 respondents) were the most frequently named reasons for installing a SWH. Five out of the 17 people stated both environmental reasons and DCP17. Another reason in at least three cases was that with a solar hot water system the water tank was moved from inside the house, which resulted in more space being available.

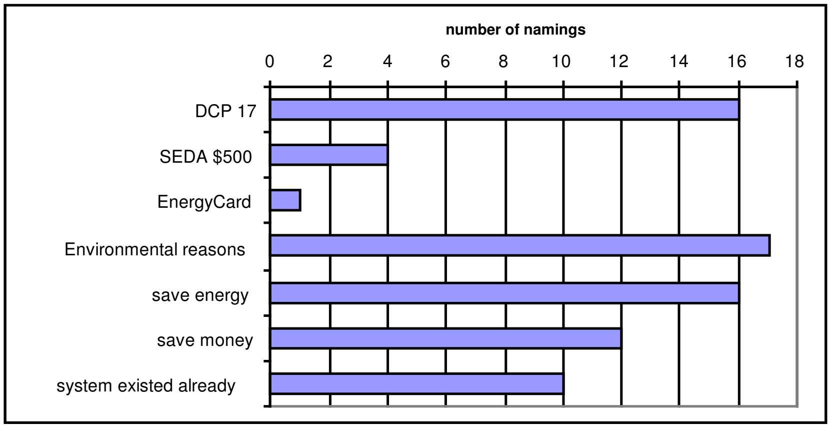


Figure 11: Reasons for purchasing SWH (multiple choices possible)

24. How much did you pay for your SWH (including installation)?

Many people found this question hard to answer. In addition to the 10 households where the solar system was already installed when the current occupiers moved in, two SWH owners were not able to give any price and at least four could only give an approximate answer. Seventeen people interviewed quoted an estimated price.

The following table indicates the rise in prices. In order to take price rises into account the amounts were separated by the age of the system. The year 1985 was chosen because eight systems date from the early or rather mid-1980s. Twenty five of the SWH were installed after 1990. Unfortunately no owners of the older 180 litre systems could be interviewed. However, the difference in price between the two time periods indicates that the price for a 300 litre system with two panels had almost doubled. Even if some inaccuracy is assumed, the price rises are well above the rate of inflation.

Table 4: Average prices of SWH

Prior to 1985	Average cost ($)
180 l	-
300 l	1268
After 1990	
180 l	1733
300 l	2305

25. Do you calculate financial savings from the SWH per year?

As shown in figure 12, 88% of the people interviewed answered ”no”. Only four households (9%) keep or kept an eye on their electricity bills. Of those four households, two calculated the payback-period as approximately six years, one stated annual savings of approximately $200 and one could only say ”it saves money”.

Apart from the one person who couldn’t give any information, 28 of the households had no interest in calculating the benefits (or losses). Of these, 11 households stated ”to save money” as their reason for purchasing a solar hot water system.

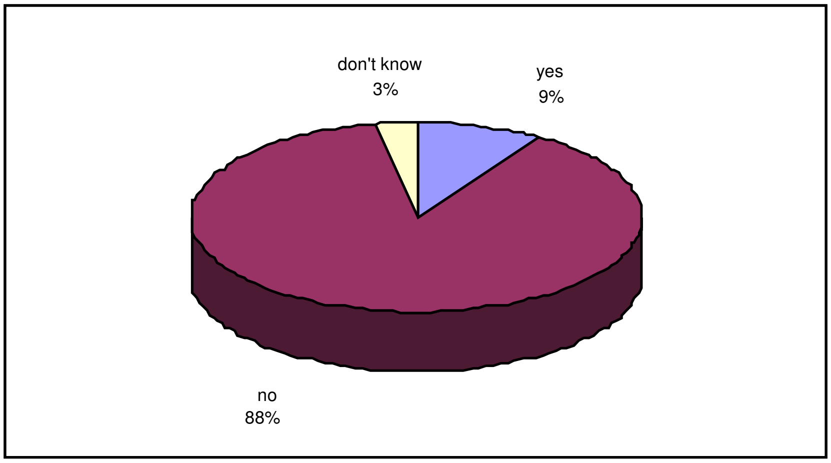


Figure 12: Calculation of financial savings

26. Is there any difference in performance compared with your previous water heater?
With regard to Figure 15, a ”yes” response does not necessarily mean that people are dissatisfied with their SWH. Seventeen households, or 52%, replied ”yes”. Seven of these, or 41%, rated their SWH as better than their previous hot water heater for the following reasons:

- don’t run out of hot water now
- gas was hopeless
- SWH is better because constant hot water
- continuity of supply is better now.

Ten of the households interviewed were not satisfied with their system’s performance, but the extent of dissatisfaction varies. Some people complained that the hot water takes too long to get from tank to tap, which wastes water. Other criticisms of SWH included:

- not nearly as good
- run out of hot water more often
- this one is a lot of trouble
- previous system worked better.

The remaining 30% said there was no difference in performance.

The relation between this question, the reasons for buying a SWH (especially in the case of DCP17), and whether people would buy a SWH again will be analysed and discussed in Chapter 5, User Satisfaction.

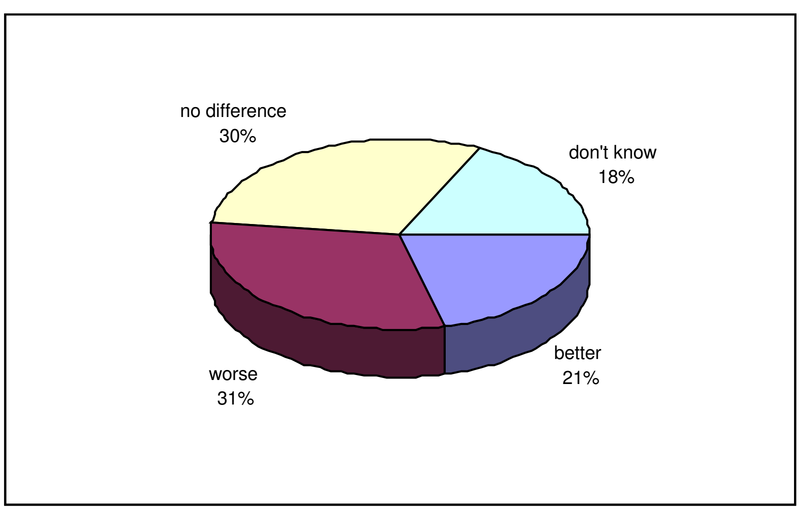


Figure 13: Difference in performance between SWH and previous system

27. Would you buy a SWH again?

Twenty five people 76% would buy a solar hot water system (current tenants) or install a new one (house owner). This is a pleasing result even if it is be assumed that the tenants and some house owners probably don't know how much a SWH costs.

The 18% who won't install a solar hot water system again are, with one exception, current SWH owners. Their reasons included "instant gas is cheaper to buy, to install, to run and always delivers hot water" or "to avoid costly cheques [$230] for maintenance every five years".

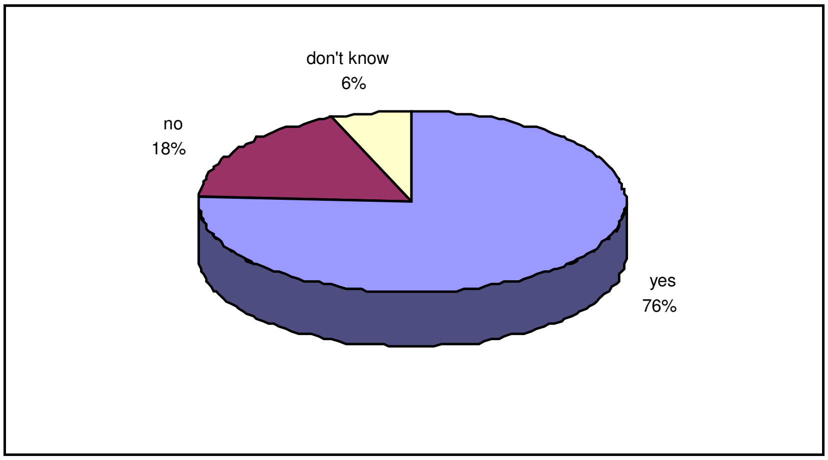


Figure 14: Percentage of people who would buy a SWH again

28. Would you change your hot water usage pattern for a more efficient usage ($ savings) of your SWH? (eg. time of day for showering, laundry etc.)

Two thirds of the people participating would not change their usage pattern at all, even if they could save more money or reduce CO_2 emissions; 30% answered "yes", one person had no opinion.

Many of the people interviewed said they need a warm shower in the morning, otherwise they would feel inconvenienced. A changeover to an evening shower, which would use the hot water heated by the sun during the day, was not acceptable to them. The majority of the people who participated are employed outside the home and therefore usually use hot water in the morning or evening.

Generally speaking, most of the people consider a solar thermal system as a device to produce hot water, not whether it can produce more or less. It is therefore important whether there is sufficient hot water provided at the required time.

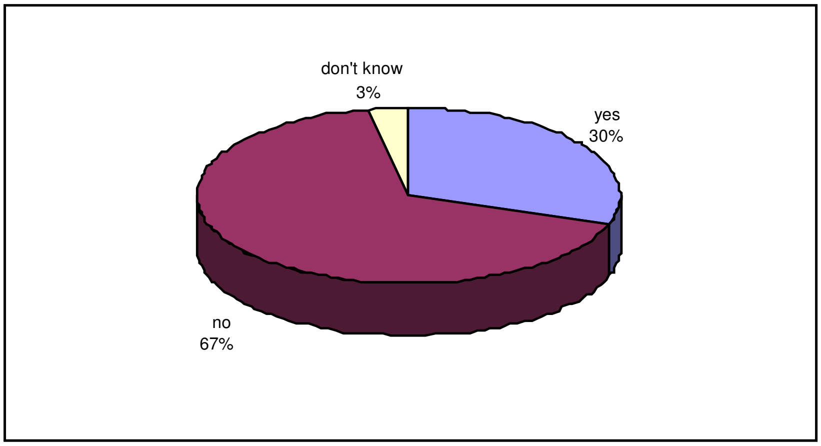


Figure 15: Willingness to change usage patterns

29. Would you give ISF the permission to obtain billing data from your energy supplier?
Almost all people (94%) signed the declaration of consent to allow ISF to obtain their billing data from EnergyAustralia. Only two people objected.

Table 5: Permission to obtain billing data

	Number
Yes	31
No	2

5. PERFORMANCE OF SOLAR HOT WATER SYSTEMS

5.1 Introduction

Solar hot water heater performance depends on many factors. Of these, orientation and inclination of the panels are probably the most important because they determine the amount of solar radiation which can be trapped. However, system configurations and size, usage patterns, the type of tariff used (e.g. continuous or off-peak 1) and, of course, the weather also have considerable influences.

There are, however, a number of different procedures to determine the performance of solar hot water systems exist. One is the solar simulation test (Australian Standard AS2813), which allows performance to be assessed under controlled conditions — an average day and a bad weather day are simulated. Another procedure is the short-term outdoor test method (Australian Standard AS2984). This determines the performance of solar water heaters under natural conditions, which can be transformed from the test's particular climate conditions to the long-term average conditions of the test location or other locations. Other tests exist that require monitoring a system over a longer period.

All methods have the disadvantage of being either expensive or unsuitable because of the long test period, or both. Consequently a decision was made to forgo very detailed performance tests for this project and instead use standardised performance data to estimate efficiency under different conditions, such as the orientation and pitch of panels, and over-shadowing.

5.2 Climate/Geographical data

Sydney lies on 34 degrees of latitude and 151 degrees of longitude. The elevation is approximately 39 metres above sea level.

The Australian Standard AS2984 for solar water heaters (outdoor test for thermal performance) divides Australia into four different climate zones, depending on solar radiation, wind and cloud conditions. Sydney lies in Zone 3, together with Brisbane, Canberra, Adelaide and Perth. Zone 1 is the Queensland coastal region from the Sunshine coast to Darwin in the Northern Territory, Zone 2 is Alice Springs and Central Australia and Zone 4 contains Melbourne and Hobart. A map showing the zones is included in the appendix.

Table 6: Selected long-term climate data for Sydney

Month	Mean daily Max Temp (deg C)	Mean Rainfall (mm)	Mean Daily Sunshine(hrs)
Jan	25.8	103.0	7.2
Feb	25.6	117.1	6.7
Mar	24.6	133.7	6.4
Apr	22.3	126.6	6.3
May	19.3	120.4	5.9
Jun	16.8	131.7	5.4
Jul	16.1	98.2	6.3
Aug	17.6	79.8	7.0
Sep	19.8	69.9	7.2
Oct	21.9	77.5	7.3
Nov	23.6	83.1	7.7
Dec	25.1	79.6	7.6

Source: Bureau of Meteorology

The following table gives the long-term mean (1983 till 1988) of Sydney global radiation as measured by satellites [8].

Table 7: Global Radiation in Sydney [8]:

month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
mean	24.2	20.6	16.8	12.3	9.5	8.7	9.1	12.0	16.4	20.0	22.0	24.2

all in $MJm^{-2}d^{-1}$

5.3 Determination of performance

5.3.1 How inclination and orientation affect system performance

The Australian Standard AS3500.4-1994 was used to investigate the effects of inclination and orientation on system performance. A generalised graph, produced with the simulation program 'Sunbear', allows the anticipated solar fraction to be estimated, which is the assessment basis of this review. A copy of this graph can be found in the appendix. Because 'Sunbear' is a correlation model the results are less accurate than if detailed simulation calculations were used.

The degree of latitude of the location is usually selected to achieve maximum year round heat collection, which in Sydney is 34º. Because of the low sun altitude in winter, the optimum inclination of a solar hot water system in Sydney is between 34º and 46º [1].

The following graph [1] was used to assess the effect of collector orientation only.

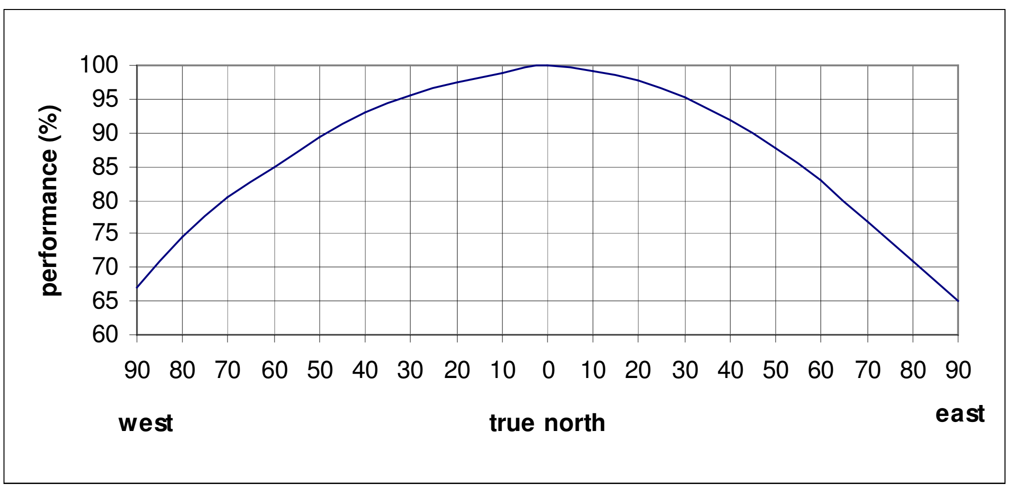


Figure 16: Effect of collector orientation on annual heating contribution

The graph shows the percentage drop from the maximum possible as the orientation of the panel installed with the optimal pitch changes. The solar contribution can drop significantly if the system orientation is not within the prescribed range. If for any reason a system cannot be installed facing true north, it is possible to improve its efficiency by changing the angle of inclination, or pitch, of the collector panels. The bigger the angle from true north, the smaller the angle of inclination must be. According to Australian Standard AS3500.4-1994, the deviation from the 34º inclination should be not more than 20º for Sydney. The winter performance will be improved by a steeper angle, the summer performance by a flatter angle.

The following table gives an impression of how the performance can change according to different inclinations and orientations in Sydney [2].

Table 8: Anticipated solar percentage contribution [2]

orientation / inclination	0°	30°	45°	60°	90°
0°	64	64	64	64	64
10°	71	70	69	67	64
20°	74	73	71	69	63
30°	75	74	72	70	62
34° (optimum)	76	74	72	69	61
40°	75	74	71	68	60
50°	73	71	69	66	57
60°	69	67	66	63	54
70°	63	62	60	58	48
80°	56	56	54	52	44
90°	48	48	48	46	40

Table 8 demonstrates that an optimally installed solar water heater, which means facing true north with a pitch of 34º, can achieve a 76% solar contribution in Sydney. The solar contribution will decrease further if other factors like hot water usage or the electricity tariff are taken into account. Systems are typically designed to provide 70% of hot water requirements on an annual average (Wilkenfeld, 1990).

Modelling of solar hot water heater performance has been undertaken by the University of NSW. The results are contained in the 1994 ERDC report *Solar and Heat Pump Hot Water Systems* [9]. Different loads, draw-off regimes, tariffs and water heaters were assessed using the TRNSYS solar simulation program. This report suggests that a SWH in Sydney which provides a standard household of three to four people with hot water will have a solar contribution of between 56% and 75%. Generally speaking, 63% is a good average for a standard household in Sydney (pers comm. David Mills, Sydney University). It is possible to reach higher efficiencies if the household is more aware of its hot water usage and use of the booster.

An additional point is the temperature of the auxiliary booster, which is normally set at 60ºC. If this temperature is raised the overall efficiency of the system will fall due to greater standing losses and supplementary energy required to heat the water.

5.3.2 Comparative figures

Table 9 shows the calculated performance of an optimally installed solar system in Sydney with an average hot water load of 36MJ per day. The data is derived from Morrison and Tran [7].

Table 9: Typical load cycle performance of a solar water heater (climate zone 3)

Month	Radiation MJ/m^2	Ambient temp °C	Load MJ/d	Volume L/d	Tank loss MJ/d	Aux MJ/d	T_{out} °C	CO_2 produced kg/d
Jan	21.4	23.1	28.0	138	11.8	4.3	68.8	1.6
Feb	20.6	22.3	32.0	169	10.7	6.3	66.3	2.3
Mar	18.8	22.4	34.0	186	10.1	9.4	64.8	3.4
Apr	16.7	19.0	36.0	208	9.7	14.4	61.8	5.2
May	13.4	14.6	38.0	223	9.8	24.7	59.6	9.0
Jun	12.9	12.6	40.0	221	10.2	27.6	59.7	10.0
Jul	15.7	11.3	40.0	214	11.1	23.1	59.9	8.4

Aug	17.2	13.6	40.0	207	10.7	18.9	60.8	6.9
Sep	19.4	16.7	40.0	203	10.7	14.2	62.3	5.2
Oct	21.9	16.8	38.0	189	11.7	9.8	64.6	3.6
Nov	20.5	19.8	36.0	186	10.6	8.4	64.4	3.0
Dec	23.5	22.3	32.0	154	12.1	2.9	68.7	1.1

Radiation = Irradiation on the collector slope
Ambient temp = Ambient temperature (24 hours average)
Load = Useful energy delivered
Volume = Volume of water delivered
Tank loss = Heat loss from solar components of the system
Aux = Auxiliary energy used by boost system (includes booster efficiency)
T_{out} = Average hot water outlet temperature

The annual booster energy input is 6,000 MJ, and CO_2 emissions approximately 1,600 kg. This compares to a standard electric storage system which would use approximately 16,000MJ and produce about 4,300 kg of CO_2 .

Table 10: Performance of a solar water heater in % [7]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
P in %	89	85	79	68	48	45	55	63	72	80	82	93

The average performance of this system is 72%.

5.3.3 How the size of the system affects performance

Advice from experts in the field at the University of NSW and Sydney University suggests the following aspects need to be taken into account:

• 300 litre systems with two panels have a higher performance than 180 litre systems with one panel;

• 180 litre, two panel-systems have a higher performance than 300 litre, two panel-systems because heat losses are lower. They are also cheaper. The main problem for this configuration is the risk of boiling in the tank, which is dangerous for users and the system (material fatigue);

• a booster mirror can increase the winter efficiency by about 10%, resulting in a more even distribution of solar contribution over the whole year; and

• better insulated tank and pipes will increase efficiency by about 10%

Additional factors that need to be taken into account according to the 1994 ERDC report [9] include:

• for the same model and hot water draw-off pattern the solar contribution is higher on continuous and off peak 2 tariffs than on off-peak 1, particularly in the case of lower hot water usage; and

• solar contribution falls as daily hot water demand increases even though the total energy contribution from solar imcreases.

5.3.4 The use of a panel mounting bracket

The inclination of a system depends in part on the roof inclination. If the roof is too flat a bracket will generally be used to obtain the optimum ptich. The brackets used by *Beasley* have a pitch of 22º (source: *Australian Hot Water Service*). *Solahart* use a slightly different pitch of between 17º and 24º. It can be assumed that the mounted systems have an inclination of between 20º and 30º, which will result in a solar contribution of 74-75% if facing true north, derived from Table 8.

One of the solar systems inspected has an inclination of 8º and faces west. According to Table 8 the maximum solar efficiency that this system can reach is 64%. The water heater is used by one person and delivers enough hot water (without boosting) between mid-September and mid-May. This configuration is sufficient for one person. The very small angle is a good solution for an inappropriate orientation — a steeper pitch would result in a loss of radiation from the midday sun. It is unknown whether the thermosiphoning system will work well enough at such low angles so as to supply sufficient hot water. According to the Australian Standard AS3500.4-1994, the angle of inclination must be at least 10º to enable the system to work well.

5.3.5 Additional boosting

All solar hot water systems manufactured by *Solahart, Edwards, Rheem* and *Beasley* have a standard booster to guarantee hot water on cloudy and/or winter days. Most of the systems investigated have an electrical booster connected to continuous or OP electricity tariffs. Gas-boosted solar systems were only found on one townhouse complex. Boosting is often necessary in Sydney in winter and on cloudy summer days.

A manual booster over-ride switch is not a standard fitting on many solar hot water systems. If not fitted the user has no simple method of controlling the operation of the system booster. They are generally only fitted to continuous or OP2 systems and can be installed for approximately $90 in either the kitchen, laundry or bathroom. Some OP1 systems can have dual elements so that one can be used on continuous tariff for boosting if needed, but none were found in the survey sample. If used correctly, booster switches can significantly increase the efficiency of SWH by reducing the electric contribution to water heating.

There was considerable confusion from respondents about what what constituted a booster switch. A number of households with OP1 and gas systems replied in the questionnaire that they used booster switches even though none would have been fitted. It transpired from the interviews that a number of people used the power switch for the system in their electric switchboard as a booster over-ride switch to avoid heating the water unecessarily. This has led to some difficulty in analysing this issue as the question was actually aimed at systems fitted with a booster switch.

What role does additional boosting play, and do people use their booster switch?

Booster over-ride switch usage varies greatly from winter to summer. Nearly 80% of all the systems fitted with a booster switch are left on 24 hours a day in winter to ensure sufficient hot water. In a few cases, particularly in one person households, the booster was only turned on in the evening a few times a week.

Boosting in summer is generally only required on cloudy days. Only 25% of households said they used the booster all the time. Six people stated they never use their booster switch in summer, another six said they ”seldom” used it. Five people said they used the booster about three times per week or less.

Several of the people interviewed, especially those who had moved into a house with an existing solar water heater, complained there was no information available about using the booster switch or the solar hot water system. Many of these houses were newly built but neither the estate agent nor the landlord provided any information or brochures. If booster switches were labelled, it was generally with 'Solar HWS', with no indication as to the function of the switch or how it could be used.

Some participants considered that the booster could be left on all the time, since the thermostat will prevent additional boosting if the temperature in the tank is above the thermostat setting. While true, and actually recommended by manufacturers, informed use of the booster can greatly increase system efficiency. It is not known if these people switch the booster off even when they are away from home for a few days or more.

5.3.6 Water Usage Patterns

A solar hot water system's performance is related to the pattern of hot water usage. The relationship between the size of the family and the tank is the main factor that influences whether there will be sufficient hot water, but it is also useful to take a closer look at occupancy and user behaviour. Thus a family with small children will need more hot water during the day than in the evening, while a family of the same size whose members are all employed outside the home will have peak consumption in the morning or evening.

The following table gives the daily water usage of average families [5].

Table 11: Average family water usage per day

Occupancy (No of people)	Behaviour	Average family water usage per day (Litre)
2	both at work	136
2	one at home	341
3	both at work	341
3	one at home	455
4	both at work	455
4	one at home	568
5	both at work	568
5	one at home	796
6	both at work	682
6	one at home	910

Two standard values are generally used for hot water consumption when assessing system performance: 120 litres a day for 2-3 persons and 200 litres for a household of four to five members. These amounts of water are equivalent to an energy requirement of 24 and 38 MJ (load) per day respectively assuming the water is heated from 20 to 65°C.

The load can be calculated by using the formula:

$L = V \times 0.19$

where L: Load in MJ
V: volume of hot water per day in litres
0.19: MJ required to raise 1 litre from 20°C to 65°C

In practice the required energy is higher due to the fact that all hot water system are less than 100% efficient due to heat losses and inefficiency in the fuel conversion process.

Showers use approximately half of all residential hot water consumption, or about 25,000 litres each year for the average household. Thus reducing water consumption will improve the solar hot water system's efficiency and also save money and greenhouse gas emissions. One very easy way to do this is to use water efficient shower heads, which can reduce the flow rate from approximately 18 litres per minute to 9 litres or less. The questionnaire included questions about the type of shower head and the time of showering.

As previously mentioned in chapter 4, 45% of all households interviewed said they had a water-efficient shower head. As this is a much higher than average usage rate it indicates that the promotion of water saving equipment could usefully be targeted at this group.

Another aspect that affects the SWH efficiency is when people shower. It is convenient for many people to shower in the morning, but it may mean they have to use their booster overnight in order to have hot water in the morning in winter when overnight heat losses from the tank will be higher, which will result in increased energy consumption.

During the survey it became apparent that water consumption with a SWH will often be higher than with a standard water heater. In summer for instance, people may tend to use all hot water they can get thinking it is free. There is also the additional problem mentioned of the time the hot water takes "to come down" from the tank, and which leads to a situation whereby water is wasted in order to save energy. Manufacturers also need to investigate ways to better insulate the pipes. Further research in this area should also consider water consumption as this is an issue for some of the people interviewed.

5.4 'Real' performance versus manufacturer's claims

One of the central questions of this research project was whether the manufacturers' performance claims were achievable in Sydney, as manufacturers often promise more than their products can deliver. Although unrealistically high performance claims may attract new customers, if the systems do not bring the savings that are promised the user's subsequent disappointment and anger can backfire on the solar hot water industry.

It is very difficult to estimate or calculate the performance in real conditions. As shown above, the performance depends on many different factors and taking all of them into account results in different efficiencies for different scenarios.

Consequently the project only compared manufacturer's descriptions with the values calculated by the simulation program *Sunbear* (see Table 8).

The *Edwards Energy Systems*' web page (www.edwardsenergysystems.com.au) stated that an *Edwards* solar system can save "Hundreds of dollars" each year and reduce hot water bills by as much as 95%. During a telephone conversation a solar contribution of 65% was quoted for Sydney.

Beasley Solar Systems' web page (www.beasley.com.au) also claimed its system "can save you as much as 95% on your electricity bills (depending on your location)". *Beasley Hot Water NSW* stated that the solar contribution factor for Sydney is between 70% and 75% for a 300 litre system.

Rheem Australia Ltd's brochures (now *Southcorp Water Heaters*) state an efficiency of 70% regardless of system size. In response to a telephone inquiry a Rheem employee said 40%

efficiency was the true value. It is not known how *Rheem* arrived at this extremely low efficiency. The company's candour may be connected to the fact that in addition to solar water systems it also manufactures gas and electric hot water heaters.

On the *Solahart* web site (www.solahart.com.au) the company states that "up to 80% of your heating costs are free" with a *Solahart* system (L series). According to *Solahart* this depends on location and water usage. A program to calculate the solar contribution factor, which is equivalent to measuring efficiency, is available on the *Solahart* web page. The program makes it possible to estimate different locations, system sizes, orientations and inclinations and water consumption.

Some solar contribution factors for different system configurations were calculated using the *Solahart* program. The results are shown in Table 12:

Table 12: solar contribution factors for Sydney

System type	Inclination	Orientation	Water usage (MJ/day)	Solar contribution %
180/1	34°	true north	15	77
300/2	34°	true north	25	86
300/2	34°	true north	40	65
300/2	34°	true north	50	54
300/2	34°	45° off north	40	58
300/2	20°	45° off north	40	62

Annotation: 300/2 means 300 litres tank with two panels

The calculations are based on *Solahart's* L series, which is widely used in Leichhardt (Source: *Solahart*). The table indicates that only an oversized system with a proportionately lower water draw off can achieve an efficiency above 80%. The 65% efficiency for a 300 litre, two panel system with 40MJ per day is approximately what the SWH specialists who were interviewed had predicted (63%). Even if the *Solahart* program is not as accurate as TRNSYS or Sunbear, it gives an indication of possible changes in solar contribution and also clearly shows how the efficiency will drop if the orientation changes.

When the aforementioned efficiency statements, especially those found in official promotional material, are compared with the figures for performance presented in this report (Table 8), the claims of SWH manufacturers can be shown to be exaggerated. *Beasley* and *Edwards*, unlike *Solahart*, give no information as to which system, or under which conditions, can reach such a high performance. The values that were quoted for Sydney during telephone conversations are more realistic but still show noticeable differences.

5.6 Maintenance

As data on the maintenance costs of solar systems in Australia is not available, information obtained from the manufacturers was used.

Solahart and *Beasley* supplied the most systems in the Leichhardt area. The difference in the construction of each system results in different maintenance advice. While Solahart's tank is made from vitreous enamel lined mild steel the *Beasley* tank consists of stainless steel. To prevent corrosion on any bare metal surface, *Solahart* and *Beasley* tanks are fitted with a sacrificial magnesium anode.

Solahart gives a five year warranty and recommends an inspection every five years, which includes the exchange of the sacrificial anode and panel cleaning and currently costs about $200. According to information from the *Australian Hot Water Service* company, which installs

Beasley systems, no maintenance of *Beasley* systems is required. The warranty here is seven years, the same as *Edwards* Systems.

6. User satisfaction

One of the main purposes of this survey was to find out whether users were satisfied with their solar systems. The answer to this question can partly be obtained by examining in detail the answers to the following survey questions:

14. Is there always enough hot water available?
20. Have you ever had trouble with your SWH?
27. Would you buy a SWH again?

Because it is very difficult to give a clear picture by looking only at the answers to the above mentioned three questions, an attempt was made to explain the negative or positive answers by considering other factors which may influence these responese such as household size.

I. Is there always enough hot water available?

Eleven participants, or 33%, answered that the SWH doesn't provide enough hot water. All types of boosted systems were represented. With one exception, all the systems are installed within the specified parameters (orientation within 45º of true north, panel inclination between 20º and 45º) and correctly sized. The exception is a 180 litre, 1 panel system, facing west with an inclination of 8º, installed in a one person household.

Four out of the 11 households consist of 5 people which might be a reason for the shortage of hot water, particularly if the booster is not used correctly and a water efficient shower is not fitted. Another explanation might be that some of the participants related this question only to water which is heated by the sun. Some people ticked "no" on the questionnaire but stated that enough hot water is available if the booster is used when subsequentially questioned.

In one case where a woman and her seven year-old son occupied the house, the lack of hot water was due to incorrect installation. A 300 litre, two panel system was installed facing true north with an angle of inclination of about 30º. The water, however, was always only lukewarm. The owner was very disappointed and annoyed about the poor performance, and the fact that she was forced to buy this system as a result of DCP17 exacerbated her dissatisfaction. The interviewer recommended a closer investigation by the manufacturer, which revealed that the cold and hot water pipes were swapped over, with the hot water take-off point at the bottom of the tank. Once this had been rectified, the system worked correctly.

In the other cases the hot water shortage might be explained by the time of showering or the use of a standard shower head rather than an efficient model.

II. Have you ever had trouble with your SWH?

Ten households stated they have had trouble with their system. As was discussed in Chapter 4: "Survey Results", in five cases the tank had been replaced after 10 years because of corrosion/leakage. These five solar hot water systems were manufactured by *Solahart* and had a sacrificial anode in the tank to prevent corrosion. After 5 years the anode should be replaced (recommendation of *Solahart*). Three participants stated that they had no information or knowledge about the necessity of replacement. It should be noted that these systems are now between 16 and 18 years old but have never been inspected or maintained.

From the other five participants who stated they have had trouble with their SWH, four gave "not enough hot water" as the reason, one the wastage of water because the SWH is located too far away from the hot water taps. Ideally a hot water storage tank should be located as close as possible to the draw-off points, particularly the kitchen where draw-off events are more frequent.

It can be concluded that the lack of information and maintenance was the major cause of the trouble people experienced with their systems. In general, the systems work correctly, but it should be noted that 24 of them are less than three years old. Installing a new tank can be postponed by periodic maintenance and by replacing the sacrificial anode (three different systems 13, 15 and 16 years old are working without any problem). Reminders from the manufacturers to change the anode could probably solve this problem and result in a better reputation and improved performance of SWH.

III. Would you buy a SWH again?

This question is probably the best indication of user satisfaction although not all the people actually paid for their solar hot water system (e.g. tenants) and therefore may have little idea about the purchase or maintenance costs or possible problems when systems get older.

Three quarters (76%) answered “yes”, they would buy a SWH again, only 18% (6 participants) rated their current system worse than the previous one. First of all this is explainable with the difference in performance.

Five of the people who named differences in performance compared with the previous water heater won’t buy a SWH again. Four out of the five rated the old system better (see Chapter 4: “Survey results”, question 26). One of them gave a contradictory answer: the “performance” is better because hot water is “free” but $230 for maintenance every five years was considered to be too expensive and the reason for the negative answer.

The sixth participant who stated they would not buy a SWH again replied “no” on question 26 (difference in performance) but gave no indications for his/her choice.

A connection between dissatisfaction and DCP17 could not be found. People accept a solar hot water system if it performs well and delivers enough hot water. Only in the case of the incorrectly installed system mentioned above, where the poor perfromance of the system created a great deal of negativity, and the fact that a new electricity meter and cables were required at a cost of about $800, was there any animosity expressed towards the policy.

The answers to the above mentioned questions make clear that user satisfaction is in general high. DCP17 was accepted by many people and clearly stimulated the installation of SWH. The fact that sometimes water is wasted because of the long way it needs “to come down” indicates a reason to develop better installation practices.

As a conclusion the dissatisfaction of SWH-users can be avoided by:

- providing more information about solar hot water systems;
- providing information about the booster and the use of the booster switch;
- inform the SWH-owners when the sacrificial anode must be replaced.

(See also Chapter 8: Recommendations for further details)

7. ECONOMICS OF SOLAR HOT WATER SYSTEMS

7.1 Financial savings

All households in Leichhardt are within the EnergyAustralia franchise area. Gas is supplied by the Australian Gas Light Company (AGL). Table 13 gives an overview of the electricity and gas tariffs in Sydney in 1998.

Table 13: Electricity tariffs

Continuous c/kWh	Off Peak 1 c/kWh	Off Peak 2 c/kWh	Gas c/MJ
10.15	3.72	6.76	1

Off Peak 1 or 'Restricted hours Off-peak' means that electricity is only available between 10 pm and 7 am. Off Peak 2 or 'Extended hours Off-peak' electricity is available for 16 hours, normally between 10 am and 5 pm and 10 pm to 7 am.

Assumptions used as the basis for the calculations of the financial savings are derived from Saddler (9) for a hot water usage of 125 litres (25MJ) per day. A solar contribution of 70% is used, with continuous tariff system overall efficiencies, due to standing and pipe losses, of 72% and OP1 of 66% for both solar and standard. Table 14 shows the calculated annual running costs for the different systems.

Table 14 Calculated financial savings

System type	Annual energy cost ($)
Continuous tariff	
Standard	340
Solar	110
Difference	**230**
OP1	
Standard	135
Solar	45
Difference	**90**

Assuming a purchase cost differential of $1500, these figures show a payback of approximately 6 to 7 years for continuous tariff systems and 15 years plus for OP1. Including maintenance costs fo SWH will increase the payback period. On the other hand, higher levels of hot water usage, solar contribution or electricity prices will reduce the payback period.

7.2 Analysis of actual billing data

As an important part of the survey it was planned to calculate financial savings of SWH-users based on actual billing data. EnergyAustralia was asked to provide the necessary billing data for the interviewed households who consented. The data from 29 participants was supplied but it was not possible to analyse them in a meaningful way for a number of reasons:

- only the billing data from 1995 onwards could be easily obtained from computer records. Thus, not enough data points were available to make a reliable estimate of energy and financial savings;

- this problem was exacerbated by the fact that the exact date of installation is not known by many of the households;
- in some of the rented properties the tenants had changed in that time which greatly complicates any analysis.

In order to undertake a meaningful analysis it would be necessary to have a longer time series of data and be able to correct it for variations due to the weather etc., or to establish a control group of similar households without SWH. There was insufficient time and resources to undertake either of these approaches in the context of this project. Given the importance of this aspect and the large number of consents given by participants to obtain billing data, it would be desirable to carry out additional research in this area.

8 GREENHOUSE GAS SAVINGS

The greenhouse effect is probably the most frequently discussed environmental topic of the day. Originally a natural process that enabled the development of life on earth, global warming is possibly becoming a threat to the ecosystem. The phenomenon is predominantly caused by a range of human activities that emit greenhouse gases such as carbon dioxide, nitrous oxide, methane, chlorofluorocarbons (CFCs) and others. Carbon dioxide is probably the major contributor to the greenhouse effect and its atmospheric concentration has increased significantly since the industrial revolution.

Approximately 8,000 kg of greenhouse gas is emitted per household per year in Australia by non-transport related energy use. Most of the hot water is heated by burning gas or using electricity. In NSW about 95% of electricity is produced by burning coal).

Emissions can be calculated using the following conversion factors [11]:

Electricity:	940 t/GWh	(ie. 0.94 kg/kWh or 0.26 kg/MJ)
Gas:	250 t/GWh	(ie. 0.25 kg/kWh or 0.07 kg/MJ)

Table 15 shows energy use and carbon dioxide emissions for a typical household for both a standard electric and solar electric storage hot water system based on an average hot water usage of 125 litres per day, a solar contribution of 70% and an efficiency of 72% for continuous tariff systems and 66% for OP1.

Table 15: Typical CO_2 emissions from household electric storage water heaters

	Annual kWh	Annual MJ	CO_2-emission in kg (electrical) [5]	CO_2 saved per annum (kg)
Standard systems				
continuous tariff	3340	12030	3176	
OP1	3650	13128	3464	
Solar systems				
continuous	1103	3971	1048	2128
OP1	1240	4463	1178	2286

A SWH can save approximately 2000 kg of CO_2 emissions per annum compared to standard electric storage water heaters if fitted with an electrical booster.

Obviously electric water heaters play an important role in producing CO_2 emissions. More sparing use of hot water and a change to a solar thermal or heat pump water heater could help substantially decrease CO_2 emissions. The annual avoided emissions per household could be between 1300 and 2500 kg of CO_2, depending on the type of water heater and booster.

9. Recommendations and Conclusion

This research project was the first of its kind undertaken in Sydney. Although the results are quite positive, there are some aspects that need to be acted upon to give solar hot water heaters a better reputation and wider acceptance amongst the public.

9.1 Manufacturers

The survey indicated that customers do not feel sufficiently informed about their solar hot water system. A widely held opinion is that a SWH has to provide largely free hot water and perform nearly as well as anstandard storage water heater without boosting. Because some people were not well-informed about how to best use their systems they left their boosters on all the time, potentially resulting in unecessary energy consumption. In at least two cases where people had bought houses with pre-installed systems, neither the manufacturer nor the real estate agent or manager provided information about the SWH.

As mentioned above, some manufacturers and installation companies claim that no maintenance is necessary, which is not the case. Indeed, manufacturers need to expand their range of customer service. They could, for example, set up a customer information service. This would then be able to notify Solahart or Rheem system owners when the sacrificial anode needs to be replaced, or an inspection made.

A performance evaluation should be made after a solar system has been installed. This could be done using a reply paid postcard, where people can give their opinion about their system to find out if it works properly. This could reduce the number of disgruntled customers such as the househoild where the system had been incorrectly installed.

The labelling of booster switches is currently inappropriate. A sticker needs to be designed, with small but clear illustrations and instructions which explain how to use the booster. These stickers could be distributed with a brochure that explains the basics of a solar hot water system and ways to save energy and money.

An energy labelling system for solar hot water heaters should be considered. This could be similar to the voluntary system used for gas appliances administered by the Australian Gas Association. It would help customers compare different models more easily and could improve the acceptance of such environmentally friendly water heaters.

9.2 Leichhardt Municipal Council

After evaluating the questionnaires and the answers to interview questions, DCP17 can be considered to be a success. A large number of new systems were installed after 1994 and seem to be performing well with a relatively high degree of user satisfaction. In the cases of user dissatisfaction, the circumstances were examined where possible to determine the reasons for it, and recommendations to avoid repetition of some of the problems are given below.

Leichhardt Municipal Council, in concert with manufacturers and government agencies such as SEDA, should develop a brochure that describes how SWH work; how to use a booster switch; the different energy tariffs and their effects as well as possible energy, money and CO_2 savings. The brochure could be part of an information campaign for greenhouse gas savings.

The following problems were described during the survey and are examples of the kind of difficulties that could possibly be avoided if Council devised a suitable control system.

One household of only two people had to install a SWH as a result of DCP17, which required new cables and a new meter as well as the SWH, which resulted in an additional $800 on top of the cost of the system. In such cases the financial burden must be considered in determining whether the SWH requirement is reasonable. This is a difficult problem to resolve as the house could be occupied by more people which would make the SWH morefinancially feasible. Providing the option of gas instantaneous water heaters in household of two or less may be an option.

An example of incorrectly sized solar hot water heaters can be found in Rozelle. Here the requirement of DCP17 was fulfilled but the performance of the systems is poor. The builder of three single dwellings installed 180 litre single panel systems in dwellings large enough to be occupied by three or four people for which such a system would be undersized.

It is suggested that more consideration is given to the location of SWH in relation to the most frequently used hot water outlets and insulation of the pipes that connect tank and taps, particularly in cases where the tank is far away from kitchen and/or bathroom. The time for hot water to reach taps was a common complaint.

One family who purchased one house and moved in could not/cannot receive enough hot water and is very dissatisfied. Leichhardt Council should therefore take the size of the dwelling and of the thermal system into consideration when giving the permission for construction.

In another case, an SWH owner complained that a building which will be erected nearby could overshadow the panels of the system. People who are required to invest in SWH need to be reassured that overshadowing will not be permitted.

9.3 Performance and savings

The annual average solar contribution a solar water heater can achieve in Sydney lies in the range of 60 to 75 %. Based on these figures, the financial savings achievable are insufficient alone to convince many people that they are a worthwhile financial investment due to the availibility of cheap electricity tariffs and the high capital costs of SWH – most householders expect a payback of 3 to 5 years at the most. The pay back period for a 300 litres, 2 panel system is approximately 7 years for a continuous tariff system, taking only the initial price into consideration and excluding maintenance costs. To make solar hot water systems competitive the purchase price must be lowered or the cost of electricity, particularly off peak, must be increased.

Another very important aspect of a SWH is the saving of the greenhouse gas CO_2. Greenhouse gases and other environmental externalities are currently not factored into energy costs. According to George Wilkenfeld, between 1300 and 2500 kg of CO_2 can be avoided per household per year[11].

9.4 Suggestions For Further Research

The research produced interesting and helpful outcomes. However, the number of households interviewed is not a large enough or sufficiently independent to be representative of Leichhardt or even whole Sydney. Further research should add here and enclose a bigger test group.

The technical part of this project yielded only estimates and inexact results. This was caused by, among other things, the style of interview in which the owner made the statements. As it is very difficult to investigate private systems over a long period it is recommended that data from research institutions are used for efficiency predictions. The University of New South Wales and the Sydney University have considerable experience of testing thermal solar systems. The obvious thing to do would be to analyse the billing data from SWH owners, particularly as a high proportion of the households interviewed had no objections to signing the declaration of consent for obtaining the data.

Any further research must take water consumption into account. However, it will be necessary to find out whether the household has appliances such as a dishwasher or a washing machine and water saving equipment. This would establish if the water consumption will change with a SWH.

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APPENDIX 1

Questionnaire form

APPENDIX 2

Australian Standard graph for estimation of solar contribution