# STUDY REPORT

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# An Inspection of Solar Water Heater Installations

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# REPORT ON SOLAR WATER HEATING INSTALLATIONS

Findings from an independent research project on Solar Water Heating (SWH) support the emphasis the Government is placing on working with industry to improve information and quality of SWH installations, says the Energy Efficiency and Conservation Authority (EECA).

EECA and Building Research commissioned BRANZ to undertake the research project to provide independent evidence of the energy performance, installation quality, and durability of solar water heating systems in New Zealand.

The three year research project began in October 2006. The purpose of the first stage of the project was to inspect solar water heating systems and assess their current condition including installation. The second stage will measure the amount of energy that the units capture at each site over a one year period. The inspections for the first stage of the project were completed in February 2007. The systems inspected were all installed before work on a draft Acceptable Solution for the installation of SWH was prepared by the Department of Building and Housing.

The report on the first stage of the three year project shows that:

- The quality of SWH installations is uneven. Industry is not yet consistent in its application of standard practices.

- Many systems do not have building consents, as required by law

The findings are being released so that the industry can be aware of any issues they need to consider, including health and safety issues and other factors to take into account to improve customer satisfaction with SWH installations.

EECA is working with the solar water heating industry in a number of areas to improve the way SWH systems are installed. These areas include:

- Subsidising training for installers, to broaden the knowledge base about how to install solar water heating systems to achieve the best results. The first subsidised course was held in late March at Wintec and the programme is being rolled out to other centres.

- Developing guidelines on how to meet Building Code requirements for solar water heating, known as an "Acceptable Solution", in association with the Department of Building and Housing (DBH). EECA will be working with DBH and local councils to put this in to practice consistently nationwide.

- Targeting government finance assistance to the purchase and installation of systems from suppliers who have accreditation with the Solar Industries Association including the requirement to use approved installers. Approved installers need to complete a Short Course Certificate in Solar Water Heating.

## Solar Industries Association Comment

The Solar Industries Association welcomes the research that has been undertaken by BRANZ into the installation of solar water heating systems. This is the first in-depth study of installation practices in over two decades and it highlights the necessity for development of technical standards and installer training that the Association has been working on in conjunction with EECA. The Association hopes that EECA will continue to fund such surveys so that solar water heating suppliers can continue to monitor where further installation training is required.

Many of the systems studied were installed before the current standards and training programmes had been developed so the report provides a good learning resource which many of the members of the Association will be using in training of their installers.

It is also encouraging to see that many of the issues identified in the report have already been addressed in the recent revision of the technical standards and the preparation of an Acceptable Solution for meeting the requirements of the Building Code.

If homeowners have any concerns or questions about existing solar water heating installations, they should contact their installer/supplier, or the Executive Officer of the Solar Industries Association.

# AN INSPECTION OF SOLAR WATER HEATER INSTALLATIONS

**BRANZ Study Report SR 184 (2007)** **C D Kane, A R Pollard and J Zhao**

## Reference

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# 1. EXECUTIVE SUMMARY

This report covers the first stage of the EECA/Building Research funded solar water heating (SWH) project, comprising inspections of a number of SWH installations, and monitoring equipment installation at the same houses. Results of the performance monitoring will be presented in later reports.

Thirty-six installations in Auckland, Christchurch, Dunedin and Wellington were visited. At each installation, the system was evaluated using the Inspection Protocol presented in Appendix 1. At the same time, monitoring equipment was installed to capture the energy performance of each installation, and the occupants were interviewed to understand their experiences of the systems.

As this work was being completed, a draft Acceptable Solution for the installation of SWH (G12/AS2) was in preparation by the Department of Building and Housing. The systems inspected were all installed before the work on the Acceptable Solution began, and therefore provide a contrast between industry practices of the past and the future.

The results of the field inspections have provided some insight into the areas which will require focus for the industry as SWH becomes more mainstream, the majority of which have been addressed in the draft Acceptable Solution. The key issues are:

Safety – two main issues are apparent. First, the installation of over-temperature pressure relief valves is not consistent. Some installations appear to rely on a roof-top air admittance valve, whilst others depend on the temperature/pressure relief valve (TPR) valve on the storage cylinder itself. Although the majority of installations were protected, a large number were not. From the systems inspected, there is no certainty that the solar loop is mechanically protected against an over-temperature incident. As an example, in one system the controller shut down the circulation to the collector when the temperature exceeded the over-temperature threshold. The stagnant collector was then unable to dump heat or pressure as there was no pressure relief at the collector or elsewhere in the solar loop.

The second safety issue is the apparent ignorance of the recommended 60° anti-Legionella temperature boost: although all of the systems inspected are theoretically capable of regularly achieving the required temperature, the combination of the system's configuration, owner's operation, and even some manufacturer's recommendations all make it difficult to rely on this happening as a planned event.

Expected Performance – most systems met the recommended (G12/AS2) inclination of within 20° of latitude. None of the systems inspected had collectors installed at an inclination angle greater than the site latitude which would favour winter time performance. There was an apparent bias towards the western aspect when orientation was assessed. This would appear to be due to the approximate 20° difference between geographic and magnetic north, and may be inherent in the orientation of the houses themselves.

Owner Information – few of the owners were able to claim that they fully understood how to operate their solar systems. Most were unaware of the need for a building consent when installing a system. Only one manufacturer provided clear instructions and an owner’s manual, left where the owners could find it.

Installation Durability – most of the problems seen here are typical of the issues that arise when retrofitting items to the roof of a house. TV aerials and satellite dishes are commonly found to be poorly installed, and less durable as a result of inattention to small details. In contrast most of the SWH installations seen were generally well thought through but small details still require attention, primarily related to workmanship – metal from hole drilling remains on several roofs, rusting into small spots; feed and return pipes are often not secured, either on the roof or in the house. Many of the installations inspected had at least one inappropriate material selection, either for the durability of the material itself (UV attack on pipe lagging outdoors) or for the combinations of materials used (collector mounts in direct contact with roofing). As pointed out this is not uncommon in the building industry at large and does not represent a major concern. However, the SWH industry will please more customers by consistently getting the “small things” right. The draft G12/AS2 provides clear guidance on how to do this.

In conclusion, the industry is not yet consistent in its application of standard practices, with a variety of proprietary configurations employed alongside bespoke (“bitsa”) solutions. An increasing number of ready-made solutions are now available for problems such as adapting SWH to an existing storage cylinder. However the application of these solutions is not yet up to the individual installer’s preferences. Awareness of the need for a building consent is evidently low amongst installers and missing among owners. Owners do not appear to be sufficiently informed to run their systems as efficiently as possible, with due regard for their own safety.

The introduction of an Acceptable Solution for SWH will help to standardise the approaches employed, bringing the uniformity needed to the installation process and mechanics. Providing clear guidance to the Territorial Authorities to enable them to issue Code Compliance Certificates will give homeowners the additional confidence needed to specify SWH as a mainstream choice.

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# 2. INTRODUCTION

This report covers the first stage of the EECA/Building Research funded SWH project, comprising inspections of a number of SWH installations, and monitoring equipment installation at the same houses. Results of the performance monitoring will be presented in later reports.

The inspections are focussed on understanding:

1. The quality of each installation – how the installer has handled the unique variables of each site, specifying and installing appropriate materials and systems to deliver the optimum possible energy performance.
2. The durability of the components used – as seen during the inspection and as expected to perform in coming years.
3. The interaction between the supplier/installer and the owner/purchaser, both in terms of the purchase and the information passed on to ensure a satisfactory ownership experience.

## 2.1 Worldwide trends in SWH

Perusal of the latest International Energy Agency report (Murphy 2005) on international uptake of SWH by country shows that for the last five years the energy capture capacity of domestic SWH installations has increased dramatically in many of the reporting countries.

In many cases, this can be tracked through to high-level governmental initiatives to drive the uptake of renewable energy technologies – for example in Australia, Germany, Denmark, Netherlands and Austria the building codes cap the permitted energy use of new buildings, and include solar energy as one of the sources in the energy balancing calculations to prove compliance with the code. In many countries, the introduction of an incentives scheme has driven increased uptake. In the Netherlands, there was a drop in systems installed when the local subsidy scheme ended in 2003 – illustrating the effect of such schemes on market dynamics.

Only the French report makes explicit mention of the need to ensure that the quality of installations is maintained, by ensuring work is done by “right-skilled” firms. Their report also specifically mentions the need for greater harmony of standards across Europe.

A visit to China late in 2005 by one of the authors gave some insight into this market; export revenue from low-cost high-quality evacuated tube manufacture is around 10% of the total sales. One manufacturer produces around 25 million tubes each year, and exports almost solely to Europe, at around the level of 10% of total production. The main driver for the relatively low export volumes is the domestic demand within China. The physical size of China ensures that there are a number of natural barriers to infrastructure growth (mountains into which it is difficult to run the electricity grid), but also strong regional demand for the services offered by electricity, owing to the large population. The response of the central government has been a number of incentive schemes to ensure that people in remote communities have access to SWH systems. The sheer size of the country and population, coupled with substantial local manufacturing capability, has meant that China has the fastest growing SWH market in the world at 25%.

Australia and New Zealand are also mentioned specifically as high-growth areas. Australia provides possibly the best comparison for New Zealand at this time, having a larger market and a more suitable regulatory structure (Federal/State) in which to develop and trial new regulations governing the building sector. The New Zealand

Government has signalled its intent to harmonise standards and regulations as far as possible with Australia, and work has been underway on this in the area of building energy consumption for some time. A number of initiatives such as MEPS, WELS and numerous joint standards are now well-embedded. The Australian SWH is at a greater level of maturity than the New Zealand market, largely due to the greater market size leading to more opportunities to learn by doing. Australian regulatory structures governing the installations of SWH units also differ from those in New Zealand – in Australia a separate Plumbing Code exists in parallel to the Building Code of Australia, whereas in New Zealand this is covered as one of the clauses of the New Zealand Building Code (NZBC). Established Australian SWH manufacturers Solahart and Edwards are well-represented in the New Zealand market; as mentioned above their installation experience in Australia may not translate well into this country.

## 2.2 New Zealand trends in SWH

Over the last five years in New Zealand, the number of domestic SWH installations has followed similar trends to those observed overseas, increasing dramatically. However, the New Zealand market is less mature than many overseas ones, and as a result there are fewer experienced installers and "standard" installations are much less common.

To date, the most comprehensive overview of the New Zealand SWH industry is that compiled by East Harbour Management Services for EECA in mid-2006 (EECA June 2006). The key points can be summarised as:

- Significant growth in absolute numbers of units installed each year, from less than 1000 in 2001 to about 3800 in 2005.
- In total, around 28,400 systems were believed to have been installed across New Zealand up until the end of 2005.
- The majority of the systems installed in the last five years were in the northern part of the North Island, with the South Island being the fastest growing region.
- There is a strong trend away from thermosiphon (tank-on-roof) systems towards pumped systems, where the storage tank is hidden within the building.
- Strong potential exists for significant growth due to a combination of factors including government "push", industry capacity increases and energy price increases.

In a later discussion paper (EECA September 2006), further thought is given to the barriers which exist to wider uptake of SWH. Four "core elements" have been identified as the main barriers:

1. Information
2. Quality assurance
3. Installation capacity
4. Reducing costs.

The study reported on in this paper addresses primarily item 2 – Quality Assurance, as detailed inspections are carried out on more than 30 installations. By monitoring the delivered energy performance of the systems it will be possible to relate quality of installation to level of performance, and hence to financial payback and national energy benefits.

As part of the inspection survey (also used for EECA's audits of those systems installed as part of the grants scheme) homeowners have been asked about the quality of information available with their systems, so this work will also provide feedback to item 1.

## 2.3 Performance monitoring

SWH performance can be examined at a variety of levels of detail.

The most detailed and reliable means of capturing the real-world performance of any technology is to measure its effectiveness in use.

The solar energy contribution to a hot water system cannot be measured directly, instead many heat flows are required to be measured and the solar contribution determined by balancing the heat flows.

The broader use of computer simulations and models using tools such as TRNSYS (Solar Energy Laboratory 2007) or RETScreen (Renewable-Energy and Energy-Efficient Technologies screening tool, CETC-Varennes) can allow variations in system configurations to be examined. These simulation and modelling techniques are strengthened when the influences of differing building techniques, climate and user behaviours are examined with measured real-world data.

# 3. EXPERIMENTAL DESIGN

Solar water heater performance is dependent on a number of factors which can be grouped into three broad categories; climate, system design and user interactions.

In order to explore these influences on solar water heater performance a number of different types of solar water heaters from a range of climates will be examined.

The climates examined were taken as the four major population centres: Auckland (including Manukau, North Shore, and Waitakere), Wellington (including Lower Hutt, Porirua and Upper Hutt), Christchurch and Dunedin.

The technology classes chosen to be examined were integrated flat plate thermosiphon systems, pumped flat plate systems and pumped evacuated tube systems. Examples of these types of systems are shown in Figure 1.

In order to ensure that a particular technology or climate was not heavily biased by the specific characteristics of one individual household, the experimental design called for three systems of each climate / technology combination to be measured. Consequently 4 (climates) x 3 (technologies) x 3 (households) = 36 systems were to be investigated.

Systems to be examined would be new systems (within the last three years) so that the current rather than historic performance and practice was being examined.

This report captures the set-up of the systems which would later be used to determine the solar energy performance of the installations.

The Inspection Protocol (Appendix 1) was jointly developed by BRANZ, EECA and the Solar Industries Association (SIA). It is intended to capture as much information as possible from a passive inspection of the system installed and an interview with the occupants. The information captured is of a “lead indicator” nature, intended to provide insight into whether the system will perform well in energy terms, and will last as long as possible. Indicators of the ability of the owners to manage their systems effectively are also captured.

The photographs presented below are from neutral sources and not from this study, in order to ensure the privacy of the participants in the study.

A flat plate thermosiphon system

A flat plate collector (cylinder is within building)

An evacuated tube system (collector installed on roof or exterior, cylinder is installed within building)

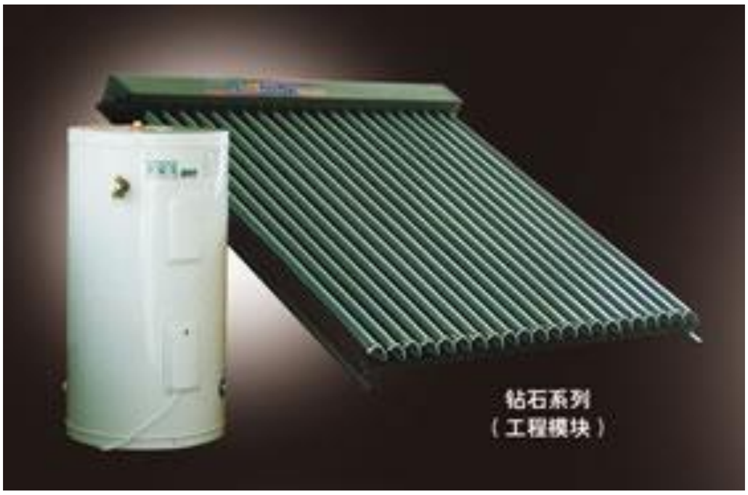


**Figure 1. Examples of solar water heating technologies.**

## 3.1 Determination of solar performance

Many different measurements can be made on each of the components of a solar water heater. It is important to cover the full range of influences on performance such as system design, climate and user behaviour. In order that comparisons can be made for each different type of system, the broadest measure would be the most useful. This essentially becomes a system measurement (i.e. collector, pumps, pipes, cylinder and controller) and involves calculating a heat balance on the hot water cylinder the solar collectors are feeding heat into. As the system performance is dependent on the user behaviour and the amount of solar radiation at that site, it is important to measure the performance for a full year to see the full range of performance from the SWH system.

There are a range of international standards dealing with testing of solar water heating components and systems. ISO 9459-3 is one such standard which relates to this system type monitoring and it provides a useful framework upon which to base a measurement plan.

In order to calculate the solar contribution into the cylinder it is necessary to measure the supplementary (usually only an electric element) heating into the cylinder. It is also necessary to determine the losses of energy from the cylinder; from the water drawn off from cylinder and via conduction through cylinder walls (the 'standing losses' of the cylinder).

## 3.2 Determination of product and installation durability

Durability can be defined in a number of ways. Instinctively, most people understand it to mean how long an item lasts and inevitably this brings with it the colouring of personal expectation – from a consumer's perspective.

The NZBC (DBH 2004) contains explicit expectations for the durability of parts of buildings – called building elements. These are parts of the building which have a function under the NZBC – for example the hidden fasteners which hold the building together (thereby complying with Clause B1 – Structure) are required to last a minimum of 50 years. The cladding which keeps the water out of the building (thereby ensuring compliance with Clause E2 – External Moisture) is required to last a minimum of 15 years.

Clause B2 (Durability) allows for routine maintenance of the particular building element concerned to achieve the required durability period. This means scheduled maintenance as specified by the manufacturer – replacement of parts, monitoring of condition – as well as expected behaviour from the owner, usually in the form of cleaning and periodic inspection.

Two main factors influence the durability of an item on a building: the materials the item is made from, and the exposure environment.

### 3.2.1 Factors determining durability

#### 3.2.1.1 Materials

Materials selection for a solar water heater is not simply a matter of choosing the most durable metals and plastics. Given that the primary requirement of a solar water heater is to heat water using the sun as an energy source, the materials selection should first be geared towards that goal.

Many flat plate collectors are manufactured from copper, for its superior heat transfer properties. Copper can be finished in a number of ways, from a polished mirror-like surface, to a patinated finish such as would be found on a well-weathered (green) copper roof. Neither would be useful for heat capture and retention; the former's high-emissivity surface would reflect much of the incident energy, and the thick corrosion product of the latter would function as an insulator. For this reason, most copper plate collectors are coated with a very dark or black surface finish. The dark surface is thus optimised for the collection of incident solar radiation. This can either be a chemical treatment of the copper itself, or can take the form of an applied plating, such as nickel or chromium. In either case, the coating is chemically different from the base metal, and as such creates the potential for a corrosion reaction to occur under some environmental conditions. In some units selectively coated steel was used for the collector surface.

The flat plate collectors examined in this study were all covered with glass, which whilst not truly “inert” in chemical terms, is extremely unreactive in normal atmospheric exposure. Because of this lack of reactivity, rainwater which runs from the glass surface tends to be extremely pure, having dissolved little from the surface. This can cause a phenomenon known as the inert catchment effect for unpainted galvanised roofing below the glass plate – the zinc dissolves more readily into the very pure water than into water which already has zinc dissolved in it.

The glazing of a flat plate collector is commonly held into the unit itself using rubber (polymeric) gaskets. A variety of rubber compounds are available for atmospheric exposure, normally based around an EPDM backbone. The formulation of these rubber gaskets varies, to maintain an appropriate balance between performance, cost and manufacturability.

Each flat plate collector has a frame, glazed on the top, containing the collector plates. For those collectors examined, these frames were all metal. The vast majority were extruded aluminium, the remainder being folded from sheet aluminium. All of the metal frames were painted or anodised.

The evacuated tube collectors are made from selectively-coated glass, with the coatings being inside the outer tube, in the vacuum area. Each tube is plugged into a rubber seal, itself housed in an aluminium header (manifold). These headers are either anodised or painted.

Both tube and plate of collectors are held to the roof with a variety of brackets and fasteners. The most common hold-down arrangement is an aluminium channel across the bottom of the collector array, either screwed directly through the roofing to the purlins beneath, with the top of the array either secured by this arrangement or hung via two stainless steel straps, again screwed through the roofing to the purlins beneath. A second common method, most commonly employed for tube systems, is an inverted stainless steel channel held to the roof by screws, onto which is bolted the tube array.

Some collectors are held on frames above the roof at a more appropriate angle for solar access – the most common material for this is galvanised steel, although stainless steel was found on one tube installation near the sea, and on a plate system attached to an aluminium roof. Again, these frames are screwed through the roofing to the purlins.

All screws used are either galvanised steel or stainless steel “Tek” screws – self-drilling, self-tapping wood screws designed to secure metal roofing to timber framing.

#### 3.2.1.2 Exposure environment

In general, the exposure factors most damaging to solar water heaters can be broken into two categories: those that damage metallic items, and those that damage polymeric items.

Water must be present for metals to corrode (excepting a few very exotic circumstances), and corrosion reactions are usually speeded up when there are dissolved salts in the water because the water becomes more conductive. Increasing the temperature will increase the speed of the reaction. All corrosion reactions are driven by a small voltage difference – coupling dissimilar metals together will often create a larger driving voltage, causing one of the metals to corrode in preference to the other. In atmospheric exposure, some metals such as stainless steel, copper (and to a lesser extent galvanised steel) will form a stable corrosion product at the surface which slows down further corrosion reactions.

Applied to SWH units, this can be distilled down to mean the following:

- The closer the unit/house is to the sea, the more likelihood there will be sea salt present. Sea salt is problematic for three reasons:
    - it increases the conductivity of any water present on the surface, increasing the corrosion rate (good electrolyte)
    - it will absorb moisture from the atmosphere once the relative humidity increases above about 65%, leading to concentrated electrolyte on the metal surface (deliquescence)
    - it breaks down the stable corrosion products on the surface of many metals, accelerating the corrosion reaction compared to areas where sea salt is absent (depassivation).
- Coupling dissimilar metals together will normally cause one of the metals to corrode rapidly if they get wet – especially in the presence of salt. This is known as galvanic corrosion. Hence, stainless steel bolts through aluminium or galvanised steel brackets (which are themselves held onto a galvanised or zinc/aluminium-coated roof) can cause problems if the metals are not electrically isolated. The descending order of corrodibility in flowing seawater is known as a Galvanic Series. Metals which are higher on the series will cause metals lower than them to corrode when coupled together in the presence of an electrolyte. The more concentrated the electrolyte, the more rapid the reaction. Common SWH metals encountered in the survey (listed from the least to most corrodible) are:
    - Stainless steel
    - Copper
    - Steel
    - Aluminium
    - Zinc (galvanised steel).

  A second galvanic corrosion issue arises where copper dissolved in water (such as would be expected from a hot water cylinder overflow/header pipe) runs across a galvanised steel roof. The dissolved copper will cause the zinc to corrode extremely rapidly. This will be visible as highly localised rusting, where the overflow water runs.
- It is possible to visually represent the corrosion risk to metals in the atmosphere. Maps were drawn by BRANZ in the mid-1990s outlining this hazard. These were later adopted, with some slight modifications, by Standards New Zealand to form the corrosion hazard maps in Section 4 of NZS 3604:1999. These maps refer to the macroclimate – the general atmospheric corrosion hazard area in which buildings are sited.
- For a SWH unit, the microclimatic effects are also important. An excellent example of this is the area under a flat plate collector which has been mounted on a roof with a small or nonexistent difference in angle between the roof and the collector. Figure 2 shows this situation. The area under the collector is seldom, if ever,

washed by the rain. As explained above, the accumulation of salt and dirt can cause a highly corrosive electrolyte to form on the roof surface, breaking down any protective corrosion products and leading to rapid degradation. The solution here is to regularly wash the area with fresh water. Similar microclimatic conditions can occur inside a flat plate collector if open to the elements. Figure 3 shows a situation where water is trapped inside a collector – whilst no apparent damage had been done at the time of the inspection, the trapped moisture and high temperatures will cause accelerated corrosion attack compared with a hot, dry environment.


**Figure 2. Unwashed area under collector can accelerate corrosion of roofing.**

**Figure 3. Water trapped inside collector.**

The breakdown of polymeric materials in atmospheric exposure depends on three main environmental influences. Polymers (plastics, rubbers, paints, sealants) are built from repeating “blocks”, or monomers. In the case of PVC – polyvinylchloride – the plastic is built from multiple vinyl chloride monomers. Each common polymer has advantages and disadvantages in use – some are easy to manufacture but not very durable in the atmosphere. Others are extremely durable, but difficult to manufacture and hence very expensive. Most of the common building plastics are therefore a compromise, usually achieved with a blend of polymeric base material and additives such as UV stabilisers, heat stabilisers and plasticisers (for flexibility). Most of these chemicals are based on carbon backbones, as are the polymers themselves.

Whilst it is a generalisation to classify such a wide range of materials together, for the purposes of this explanation it is a sensible approach. Polymeric materials used in SWH units are susceptible to breakdown by:

- UV radiation – the sun. Work nearing completion at BRANZ at the time of writing has correlated UV exposure intensity to external plastics durability, with plastics exposed in Kaitaia degrading more quickly than those exposed in Bluff. UV radiation breaks the carbon backbones of many of the polymers, causing loss of structural integrity, flaking and chalking. The most common problem seen from this on the SWH units inspected is the degradation of the pipe lagging, which is not designed to be used in the sun without additional protection.
- Heat – from the sun directly, and indirectly from the SWH unit. Heat can break carbon backbones, and can also break molecules off the carbon chain – known to chemists as loss of functional groups. In the case of PVC, one of the chloride ions and one of the hydrogen ions breaks off the chain. This causes the PVC to become brittle and also creates hydrochloric acid when it gets wet – which can attack other building materials such as galvanised steel roofing. On SWH units,

heat attack will become apparent in brittle seals and even melting of plastics in some areas.

- Water – not usually the primary cause of the degradation. However, water is necessary to carry away both the broken-down polymers and also any pigment particles which have been liberated, exposing fresh polymer surfaces to weathering, and hastening the gradual erosion process.

# 4. DATA COLLECTION

## 4.1 Sample selection

Data was collected for all of the distinct analysis requirements outlined in Section 4 by making use of the same sample. The means of selecting this sample is discussed here.

Presently only 2% of households in New Zealand have a SWH system, so selecting the 36 houses by approaching randomly selected houses was not practical as it would require a very large number of households to be contacted.

While the SIA collects some details of the numbers of systems installed by its members, the selection of the 36 systems from industry sources would be potentially biased as some screening may occur.

The sampling frame chosen for this project was the EECA solar water heating financing database. EECA has been running a scheme since 2005 whereby government funding is provided to assist with loan repayments for the purchase of new SWH systems. At August 2006 the database contained 1560 addresses of SWH purchases and this list was broken down for city and type of solar water heater.

There were some variations in the selection process. The final number of each system used (city by technology) is shown in Table 1.

**Table 1. Surveyed houses by each technology at each defined region.**

| City/Technology | Evacuate Pumped | Flat Pumped | Flat Thermosiphon |
|---|---|---|---|
| Auckland | 3* | 5 | 1 |
| Wellington | 3 | 3 | 3§ |
| Christchurch | 3 | 3 | 3 |
| Dunedin | 4† | 2‡ | 3 |

* *Two inspections could not be undertaken at the time of equipment installation due to poor weather making roof access impossible.*
† *The owner of one system was unavailable for answering the occupant-related questions of the survey.*
‡ *The owner of one system was unavailable for the installation of the monitoring equipment at the time of the other installations in this area.*
§ *The owner of one system was unavailable for answering the occupant-related questions of the survey.*

The database recorded only the name of the supplier of the system, and as some suppliers provided more than one type of technology, there were some misclassifications of systems as part of the selection process. Two systems in Auckland (which were thought to be thermosiphon systems) turned out to be pumped flat plate systems on arrival at the house for installation of monitoring equipment. For the later installations in Christchurch and Dunedin the reply forms were modified to confirm the type of systems more carefully.

Not all brands of solar water heaters appear in the financing scheme. As it was important to EECA to have a broad range of manufacturers represented, a local manufacturer whose products did not appear in the financing scheme database was asked to provide of a list of 12 systems installed in the last two years in Christchurch and three of these systems were selected in place of the flat plate systems for Christchurch.

As the sampling for Dunedin was underway the number of a particular brand of thermosiphon systems selected for the other centres was low. Two of these systems were selected in Dunedin to ensure that this brand was represented in the database.

Owing to the small number of systems in Dunedin once the different technologies were considered, only two pumped flat plate systems could be selected so an additional evacuated tube system was chosen.

## 4.2 Inspection

The Inspection Protocol in Appendix 1 was the instrument used to capture the physical characteristics of each installation., Whilst preliminary discussions were underway between the monitoring installation experts and the owner at each house, a durability expert began the assessment of the condition of the installation.

This began with a detailed inspection of the equipment on the roof (or deck in one case), starting with the collector. This was measured for size using an uncalibrated tape measure and recorded to the nearest mm: the size was determined by measuring between the glazing rubbers, giving the aperture area – the maximum possible size the panels could be. In the case of evacuated tube systems, the number of tubes was counted. Where the information was visible, the brand of collector, specific type, serial number and date of manufacture were recorded.

The collector itself was inspected for signs of dust and dirt build-up, and any deterioration of the plates, fins, pipes or tubes which could be determined without dismantling the system. The exterior of the collector was also assessed for degradation of the collector casing, its fastenings or coatings.

The inclination angle of the collector was measured using a simple uncalibrated spirit level inclinometer, and the orientation towards north measured using a compass, later corrected to true north,

The method by which the collector was attached to the roof was recorded, and its condition assessed. The condition of the roof as a result of the installation (damage to roofing by scratching, footprints or corrosion) was assessed.

If there were pipes on the roof (or deck) feeding the collector, these were inspected to determine the material they were made from (plastic or copper), whether they were lagged, what type of lagging was used, and the condition and quality of installation of the lagging. The condition of any visible valves or pipework was also assessed. Any obvious leaks were investigated and made good before monitoring commenced.

The penetrations through the roofing (for piping and/or electrical services) were assessed for number, type, workmanship and condition.

The existence of any relief valves was noted.

If the tank was with the collector (thermosiphon system) this was inspected to determine its size, the location of the heating element and thermostat, and generic operation type (was it a direct water-filled thermosiphon or indirect monoethylene glycol filled heat exchanger?).

Inside the house, the pipework runs to the collector were inspected where they could be seen without dismantling any parts of the building – note that this means uncertainty in some cases as to whether entire pipe runs have been lagged. In some cases it was not possible to find out definitively.

If the hot water cylinder was in the house, the piping to it was inspected for “sense”, condition and workmanship. The materials used were noted, and the layout of the system sketched and photographed. Again the size, type, thermostat and element positions were recorded.

If a pump was fitted, the make and settings were recorded, and an inspection made to determine whether the unit could be removed for repair without draining the system. If a controller was fitted, the brand and general layout was determined, and if the settings could be ascertained readily, they were recorded. Timers were similarly noted.

## 4.3 Interview

Whilst the installation of the monitoring equipment was underway, the owner was interviewed to determine their experiences to date with the system, how easy it was to choose and have installed, and whether they were happy with it.

The questions naturally formed three groups:

*How easy was it to purchase a system* – what was the range available when looking, what detailed information was available to assist the choice, how helpful were the sales people, whether the existence of EECA’s finance scheme was a deciding factor in the purchasing decision, why did you decide to buy a SWH?

*How easy was it to have a system installed* – was the installer/agent (and their technicians) helpful and professional, were inspections carried out prior to installation, were key performance variables (inclination/orientation) discussed, how long did the installation process take, was any other work done on the house at the same time, were you given information on how to run and look after the system, what you should expect from it, did the installer obtain a building consent?

*How good is the system installed* – is it delivering the amount of hot water expected, have you had to carry out maintenance on it, do you know who to contact if it fails, are you happy with the system?

These questions provided an opportunity to understand the owners’ motivations, the nature of the work that was done, any frustrations experienced, and any unexpected findings. It was also a chance for the installation team to feed back any concerns over the system as configured – for example to notify the owner of any leaks or non-functional components (this was only needed twice).

An in-depth owner’s survey will be carried out by CRESA mid-way through 2007, to provide input necessary to conduct sensible analyses of the performance data captured by the monitoring system.

## 4.4 Monitoring

The monitoring system installed at each site was kept as simple as possible, for reasons of cost and reliability. The key factors mentioned in Section 3.1 – *Determination of solar performance* were measured, as well as the total electricity usage for the house.

With a need to measure a number of systems in four centres, and with no need for user feedback or system control, a data logger based data collection system is the most effective way of collecting the appropriate data.

Modifications were made to the existing loggers used by BRANZ for the HEEP project (Isaacs et al 2006) so that they could be used for this project and overall, similar data collection processes have been used.

Generally each system was instrumented at the same time the inspection was undertaken.

An electricity tariff meter with a pulsed output was installed to determine the amount of electricity consumed by the auxiliary hot water heater. Similarly, a second meter was installed to determine the total electricity usage of the house. The outputs from both of these were captured by a BRANZ pulse logger.

If a pump and/or controller were installed, a meter was installed to capture the energy consumption of these, and again the outputs were sent to a BRANZ pulse logger.

The thermal energy balance of the cylinder was determined by measuring water flows and temperatures.

A water logger with a pulsed output was installed in the cold water feed line to the hot water system, to determine the volume of water which was to be heated. Care was taken to ensure that only the water which was going to the hot water system was measured. A situation frequently encountered was where the cold water feed for the tempering valve was taken off the cold feed close to the cylinder: it was important to ensure that the water meter is placed after this take-off. Where a combined valve groupset was involved, or space was limited, the installation of the water meter proved difficult. An example of a complicated cold feed into a cylinder is shown in Figure 4. The pulsed output from the water meter was sent to a BRANZ pulse logger, which was installed near the water meter in a place accessible to the download person. For a few of the roof-top thermosiphon systems which had tempering valves alongside the system, it was necessary to place the water meter on the roof and run cabling down alongside the pipework back into the interior of the house.

The water temperatures were measured by T-type thermocouples taped to the pipes. The thermocouple locations were lagged with closed-cell foam, and the thermocouples wired into a BRANZ microvolt logger.

The water temperatures measured were the inlet and outlet temperatures of the hot water system. Frequently these corresponded to the inlet and outlet water temperatures to the hot water cylinder.

Note that for thermosiphon systems, where the tank was installed on the roof, it was necessary to run the thermocouple wires up one of the feed pipes, via the flashing boot. The logger was then placed in a handy place within the house for the download person to access it.

**Figure 4. Complicated valve arrangement – the cylinder is within the blue cover to the right.**

Currently the data is being collected with a local BRANZ representative visiting each installation each month. The data is sent back to BRANZ by email for cleaning up, checking and analysis. Reporting and analysis of this data will be the subject of a later report. Data collection will end in February 2008.

# 5. RESULTS

## 5.1 Detailed results by category

In this section, results are presented arranged by specific question from the inspection. Because there are approximately 100 questions in total, only those considered useful to the industry (for performance, economic or safety reasons) are presented here.

### 5.1.1 Have any of the sealants, rubbers, insulation or plastics perished or started to crack?

Many of the systems inspected are beginning to show signs of perished insulation. The degradation is caused by UV radiation in atmospheric exposure, however the root cause is that the closed-cell foam used is not appropriate for outdoor exposure without additional protection. Acrylic paint (roof paint) or PVC tape are suitable barriers to prevent this degradation. The following photographs illustrate this clearly, with two examples of painted lagging of the same age in good condition presented for contrast.

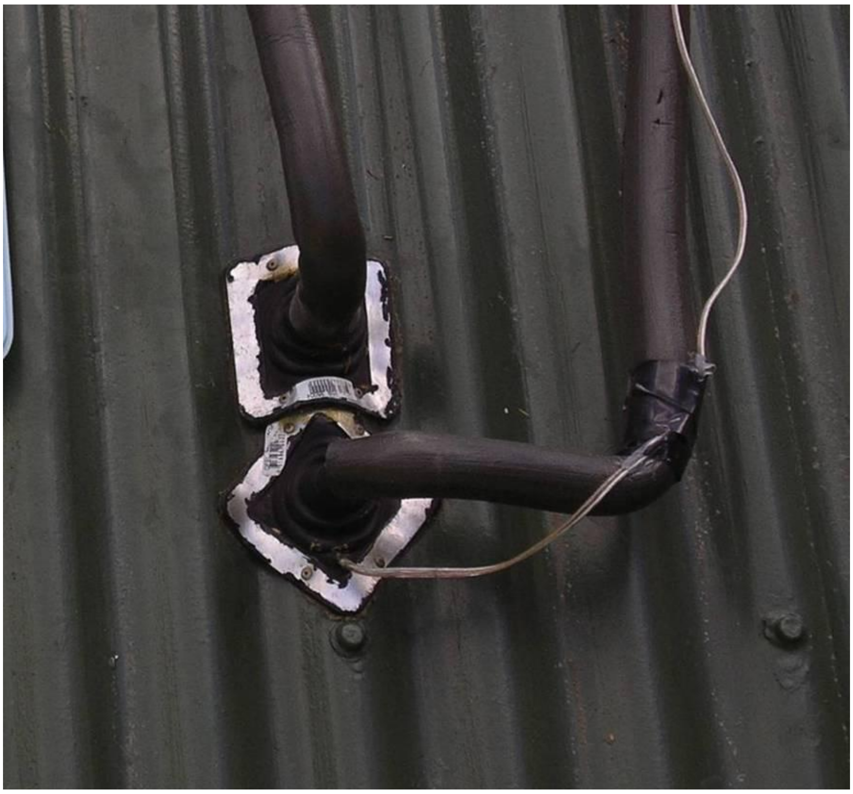

**Figure 5. The lagging has been painted to match the roof – no UV damage.**

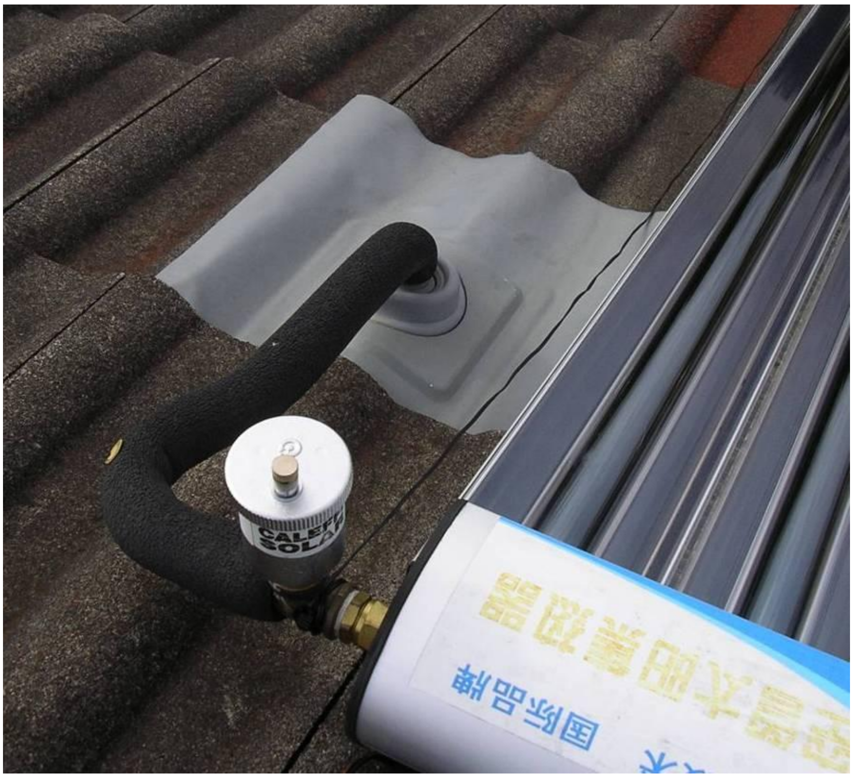


**Figure 6. The lagging follows the bends nicely, but has begun degrading.**

**Figure 7. Note the checking of the surface of the lagging.**

**Figure 8. This lagging (north wall) has been painted – no UV damage.**

**Figure 9. This is a very tidy job, but needs UV protection.**


**Figure 10. Surface checking,**

### 5.1.2 Is corrosion visible on any surfaces adjacent to or connected to the collector panels?

This question was intended to capture any incidences of inert catchment effect, of which nothing was found – possibly due to the relatively young age of the installations, and the increased use of pre-painted metal roofing. A number of instances were identified where corrosion adjacent to the panels was a concern. There were two primary reasons for this: overflow/leaks from copper pipes and rusty swarf from drilling operations. The following photographs show examples of both of these instances.

**Figure 11. Note rusty swarf. See also Figures 19 & 42**

**Figure 12. The edge of the collector frame has corroded due to the leaky washer.**

**Figure 13.Cold water expansion valve in copper pipe has caused corrosion lower on roof.**

**Figure 14. Leaky washer has caused corrosion of roof.**

### 5.1.3 Has the collector been adequately attached to the roof?

This is an issue of some concern, as there are no instances of collectors being held down with the recommended (according to the draft G12/AS2) 10 mm coach screws. Instead, the preferred method of attachment is via “Tek” screws, of various number but never less than four, supporting the array (including the tank if it is a thermosiphon system). In one notable case (Figure 22), the collector (and tank) sat on a frame for better inclination, which was in turn attached to the building by four self-tapping screws inserted into the upstand ribs of the roofing. This particular installation also resulted in ponding on the low-pitched roof, and had rusty swarf near each hold-down screw.

**Figure 15. This tank frame is not mechanically held down at all.**

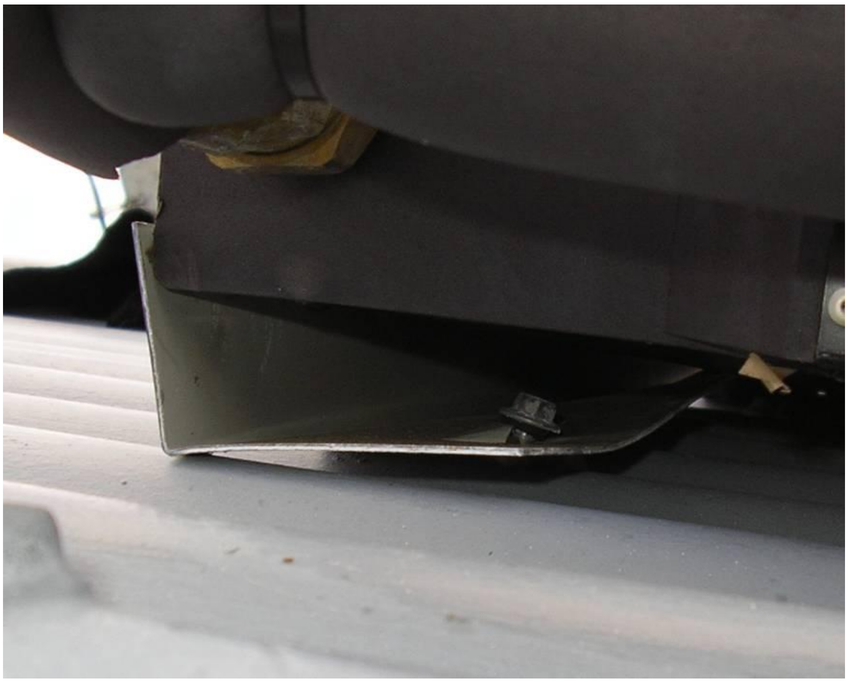

**Figure 16. This screw is neither tight nor well-aimed.**

**Figure 17. Good to see connect pipe lagged – but needs UV protection**

**Figure 18. It is not clear whether the left fastener is tight.**

**Figure 19. Four screws hold this tank/frame/collector onto the roof – each like this.**

**Figure 20. It is uncertain whether this bracket is tight on the stack of isolating washers.**

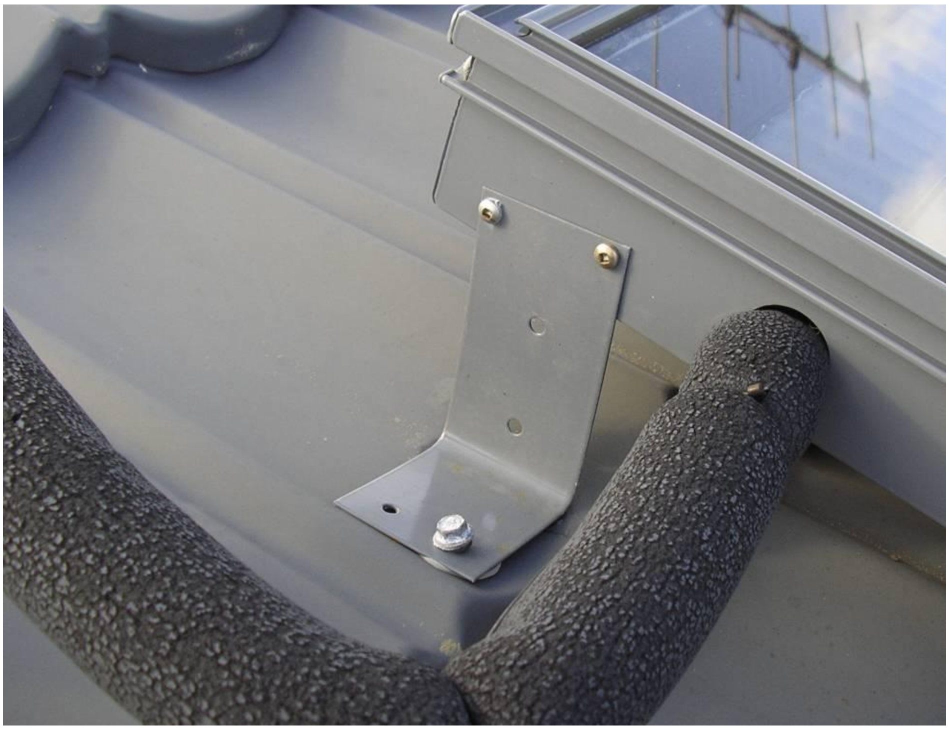

**Figure 21. This collector has one screw at each top corner. The sharp bracket is touching the roof, despite the isolating washer.**

**Figure 22. Fibrous board will swell further and bend bracket/break tiles.**

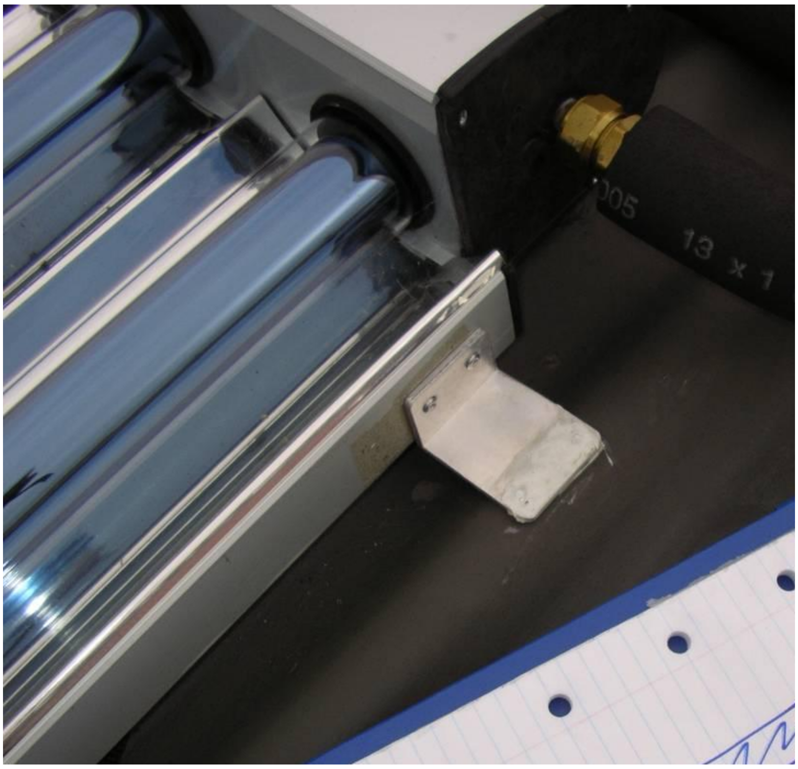

**Figure 23. Aluminium angle held to roof with pop rivets.**

### 5.1.4 Incompatible materials

This topic is addressed retrospectively by a number of questions in the Inspection Protocol (“Is corrosion visible on any of the surfaces adjacent to or connected to the collector panels”, “Any signs of staining / discolouring from runoff on the surfaces below the collector panels” and most obviously “Any signs of corrosion…”. Because of the relatively young age of the systems inspected, the degradation visible is mild. However, the draft G12/AS2 contains guidance on which materials are compatible and which are not, referring to Tables 20, 21 and 22 of E2/AS1. Photographs and short descriptions are included below for clarity.

**Figure 24. Stainless steel straps, sharp edges, galvanised screws, in contact with damaged roof.**

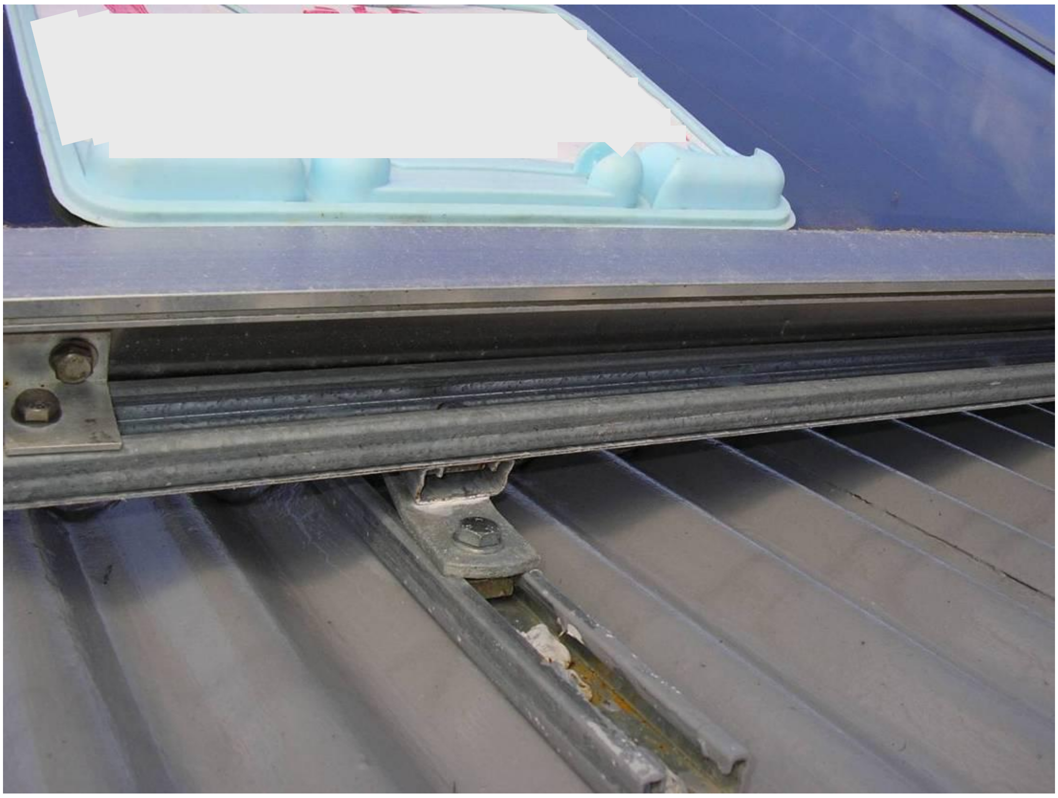

**Figure 25. Galvanised brackets and stainless steel screws – channel not separated from roof.**

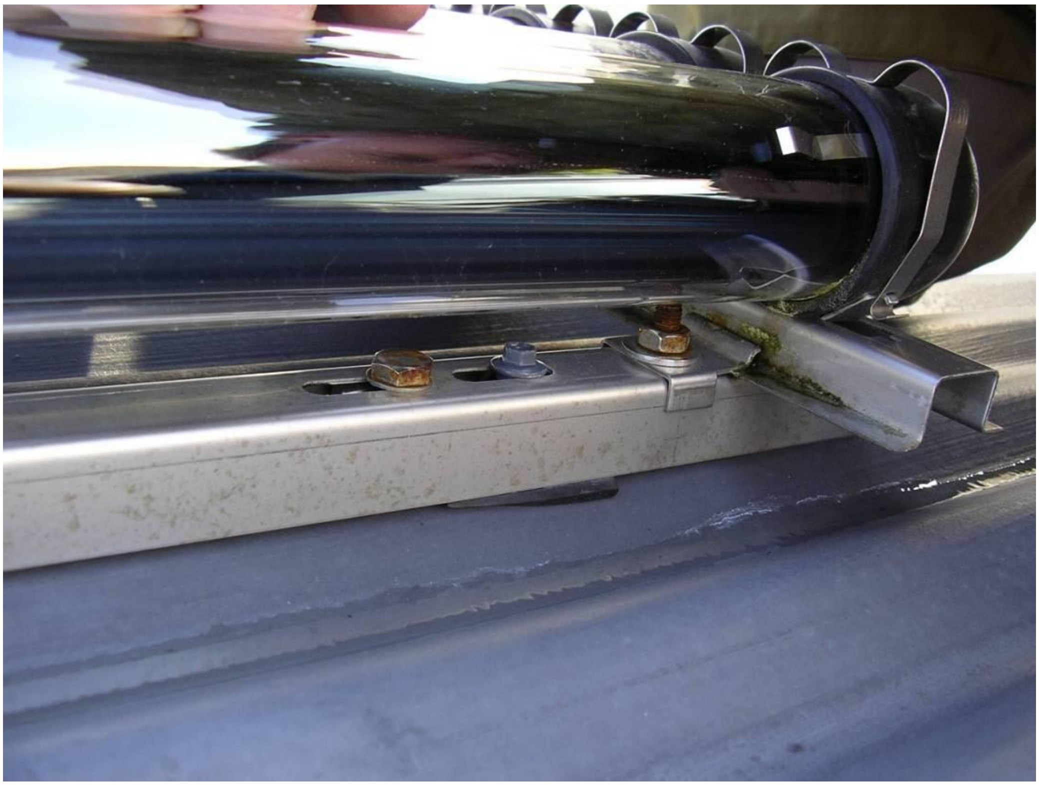

**Figure 26. Separator under stainless steel channel – rust on stainless steel bolts is manufacturing fault.**

**Figure 27. Stainless steel brackets with galvanised screws and separators.**

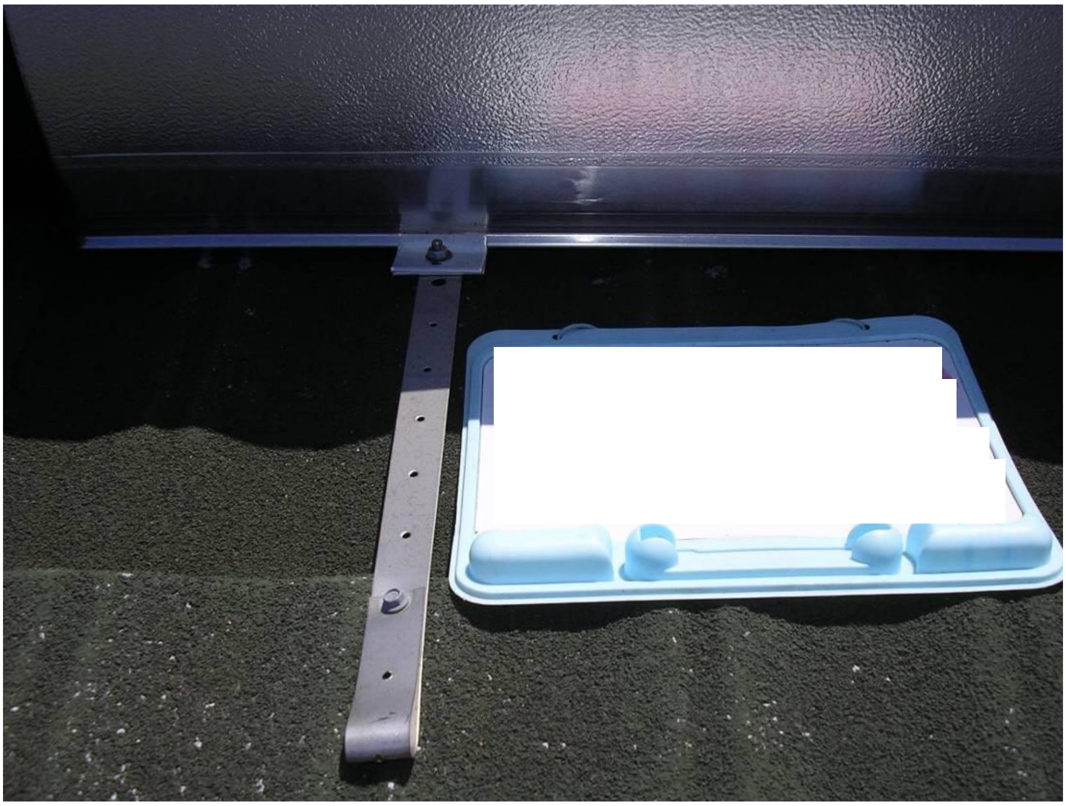

**Figure 28. Stainless steel strap, galvanised screws, zinc and chip-coated roof, no separator.**

**Figure 29. Painted steel bracket, with sharp edges touching roof despite separator.**

**Figure 30. Painted galvanised screws, stainless steel strap, painted roofing, no separators.**

**Figure 31. Stainless steel strap, galvanised screws, treated timber (holds moisture).**

**Figure 32. Stainless steel bolts, galvanised steel roof and brackets, no separators.**

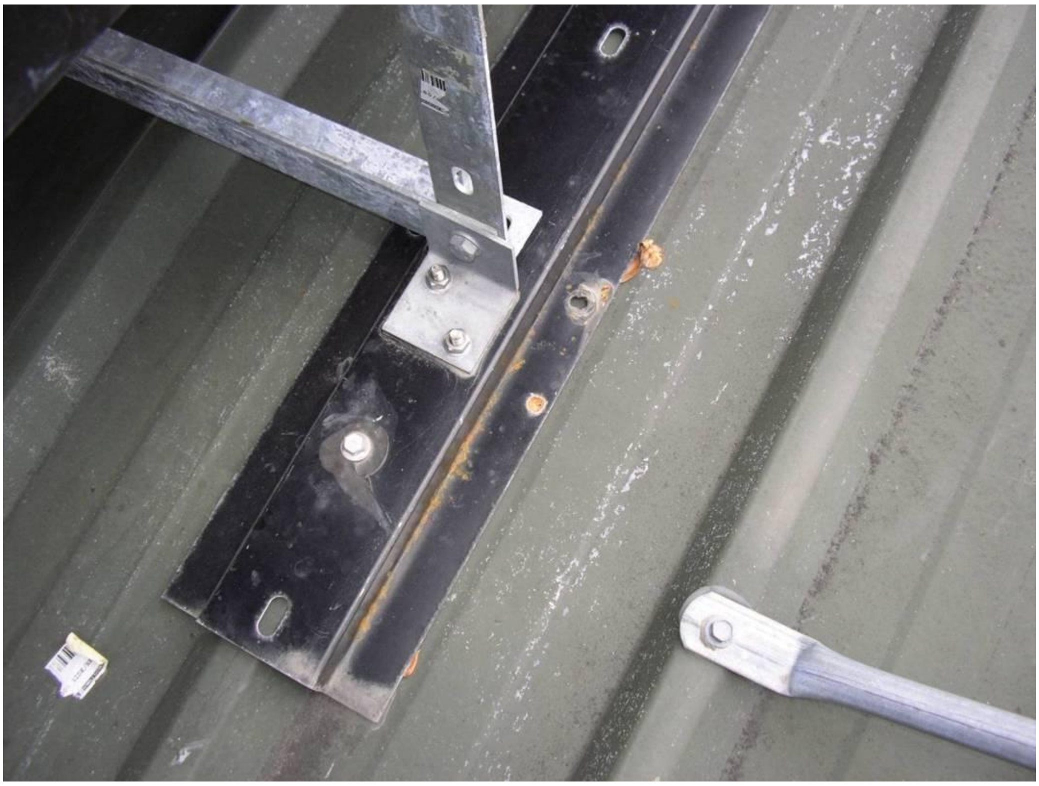

**Figure 33. Stainless steel bolts, galvanised steel roof and brackets, no separators.**

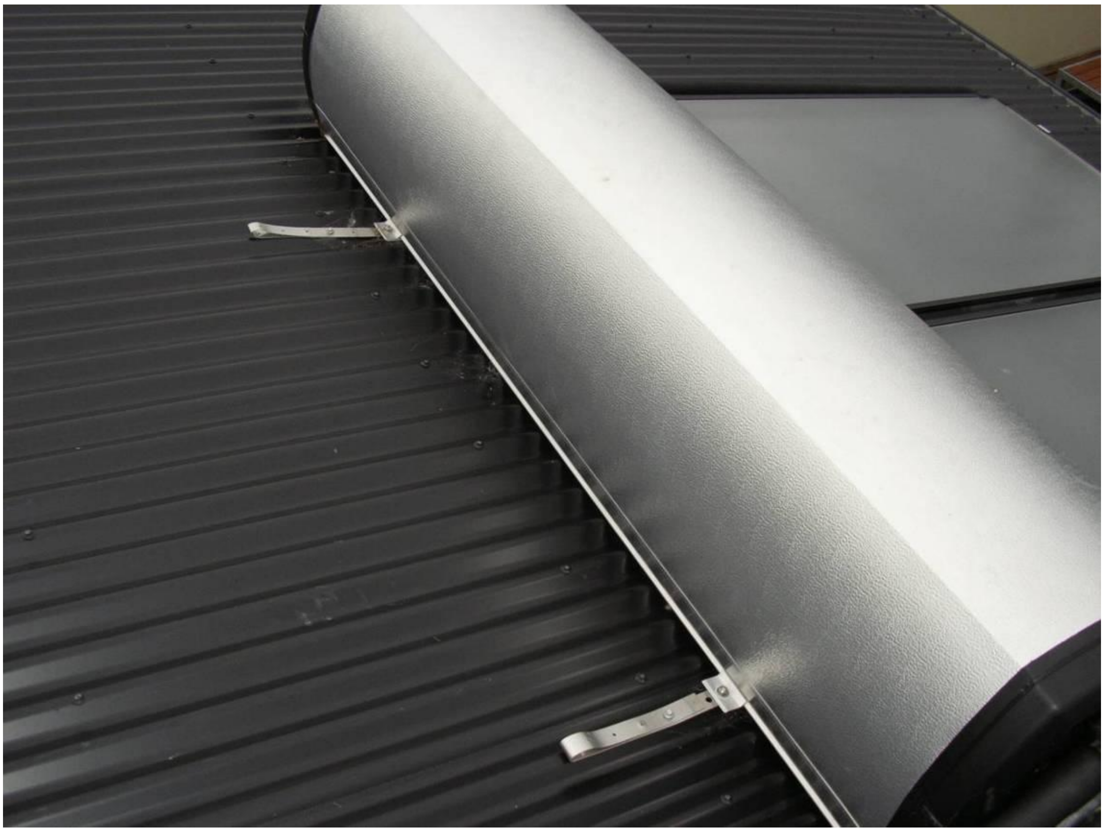

**Figure 34. Stainless steel straps with zinc-coated screws used unseparated from a coated zinc-aluminium alloy roof – if the paint coating is broken, corrosion of the roofing will occur.**

### 5.1.5 Overheating safety events

Eighteen of the 31 houses captured had an apparent means of avoiding overheating danger should the system stagnate. Predominantly this was via a relief valve, often at the collector (and often not strictly a relief valve but an air admittance valve) – but also in some cases at the cylinder. In some installations both were fitted – and were arranged in line with the recommendations in the draft Acceptable Solution G12/AS2 (DBH 2007). More noteworthy were the 10 houses which had no apparent over-temperature relief system fitted. In these cases, should the system stagnate (for example because of an electricity failure causing the pump to stop) the pressure in the system will build uncontrollably, contained only by the physical strength of the system. This is tested when new, but for a 15 year old system the same safety margins may not apply.

### 5.1.6 Solar orientation

The draft Acceptable Solution G12/AS2 calls for solar collector panels to be orientated within 45° of geographic north (NW to NE) and inclined at an angle within 20° of latitude.

In a similar fashion to Figure 1 in the draft G12/AS2, Figure 35 gives a plot of the solar collector orientations and inclinations for the 31 systems examined. The ‘Good’, ‘Moderate’ and ‘Poor’ classifications approximate those given in the draft G12/AS2.

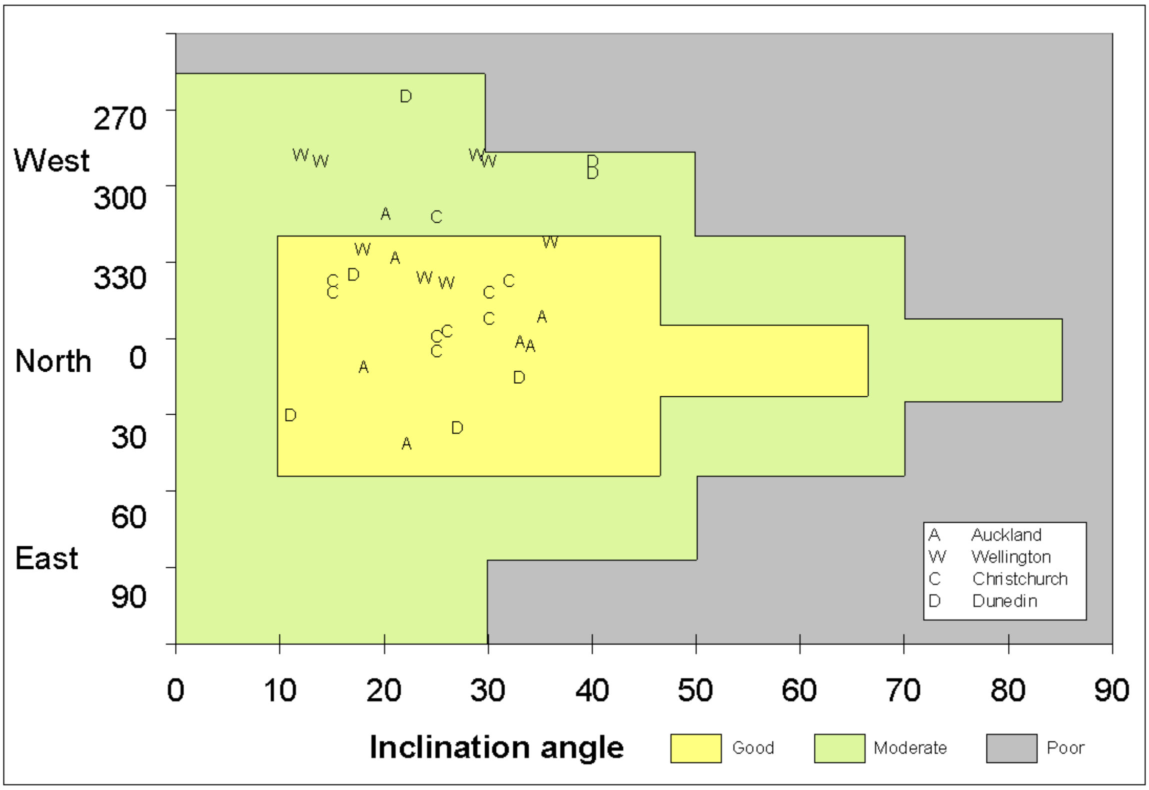


**Figure 35. Orientation and inclination of solar collectors.**

Many of the sample data points lie on the west side of north with an average direction 24° west of north (336°). The size and direction of this variation is similar to the magnetic correction (taken as 19° for Auckland, 22° for Wellington, 23° for Christchurch and 25° for Dunedin). A possible reason for this bias could be that many of the systems have been aligned using magnetic directions rather than grid (geographic) directions. For practical reasons, systems generally follow roofing directions so this may reflect than many of the houses have been aligned magnetically.

For the sample of 31 systems, 71% were installed within 45° of grid north (between NE and NW). The eight remaining systems were all located between NW and SW.

Again for practical reasons, many of the systems were inclined at the same angle as the roofing material. The draft G12/AS2 requires that systems be installed within 20° of the sites latitude and 74% of the same were installed at an acceptable angle. Figure 36 provides a plot of excess of the inclination angle over the site latitude as well as the orientation of the panels. All of the systems inspected had inclination angles less than the latitude. The advantage of installing a system at an inclination angle greater than the latitude is that the winter performance of the solar water heater is improved. As SWH is very seasonal, improving the winter time performance will even out the supplementary heating requirements (and therefore running costs) for the occupants.

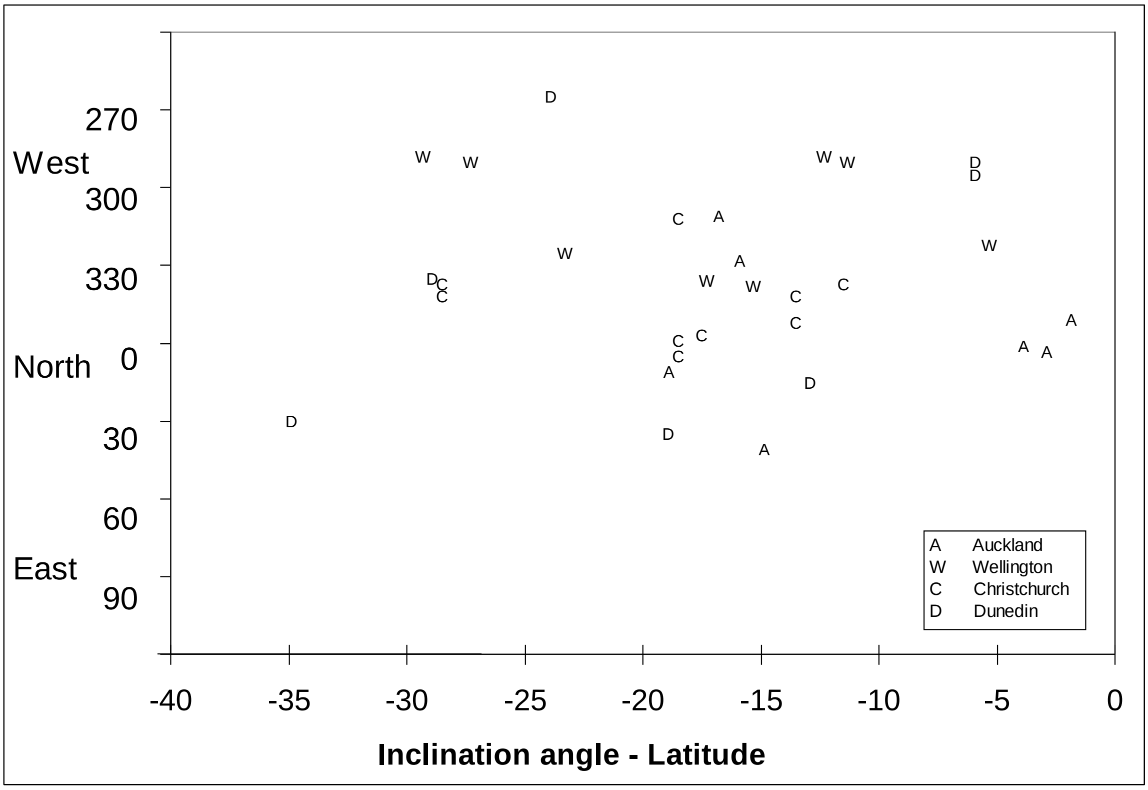


**Figure 36. Excess of inclination angle over the site latitude (all numbers are negative).**

### 5.1.7 Sizing of systems

The draft Acceptable Solution G12/AS2 states that the capacity of the storage tank should be not less than one day of expected use and goes on to give an expected use of 40–60 L per person for water at 60°C.

The use of consumption per person as a design parameter is problematic as the number of people per house is not a fixed quantity. While a cylinder size may be selected for the number of occupants when the system is installed, when the house is sold or the household size changes, the cylinder sizing for the new situation may be inappropriate.

Figure 37 gives the cylinder size for the inspected sample along with the number of occupants. The size of the collectors is indicated by the size of the square. Jittering has been applied to the number of occupants so that data is not plotted over the top of one another. Lines have also be added for the 40 L per person and 60 L per person. There are six cases (19%) below the 60 L per person line, with all of the remaining cases above this line.

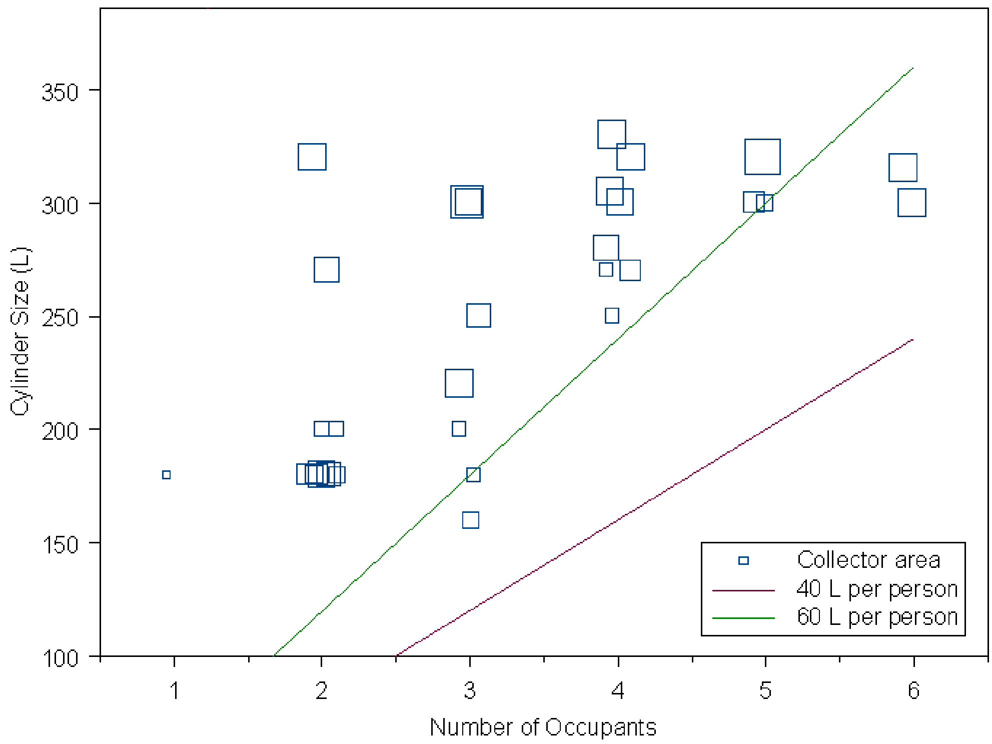


**Figure 37. Cylinder size by number of occupants.**

The draft standard goes on to say that the ratio of the cylinder volume to the collector area should be greater than 50 $Lm^{-2}$. Figure 38 gives a plot of cylinder size by the collector area as well as the line for 50 L of storage volume per square meter of collector area. The size of the circles this time reflects the number of household occupants.

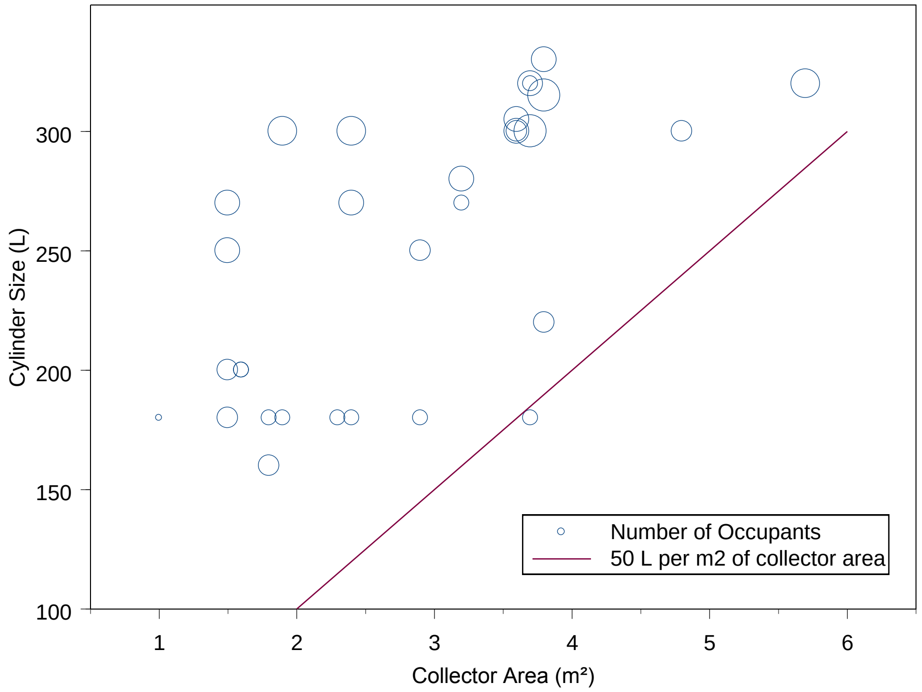


**Figure 38. Cylinder size by collector area.**

Only one case (3%) was below the line with the average ratio of cylinder volume to collector area being 99 $Lm^{-2}$. Collector efficiencies vary by technology and it may be appropriate to assign different cylinder volumes depending on the technology used. Figure 39 gives the cylinder size and collector area shown in Figure 38, but this time displays a code for the technology used.

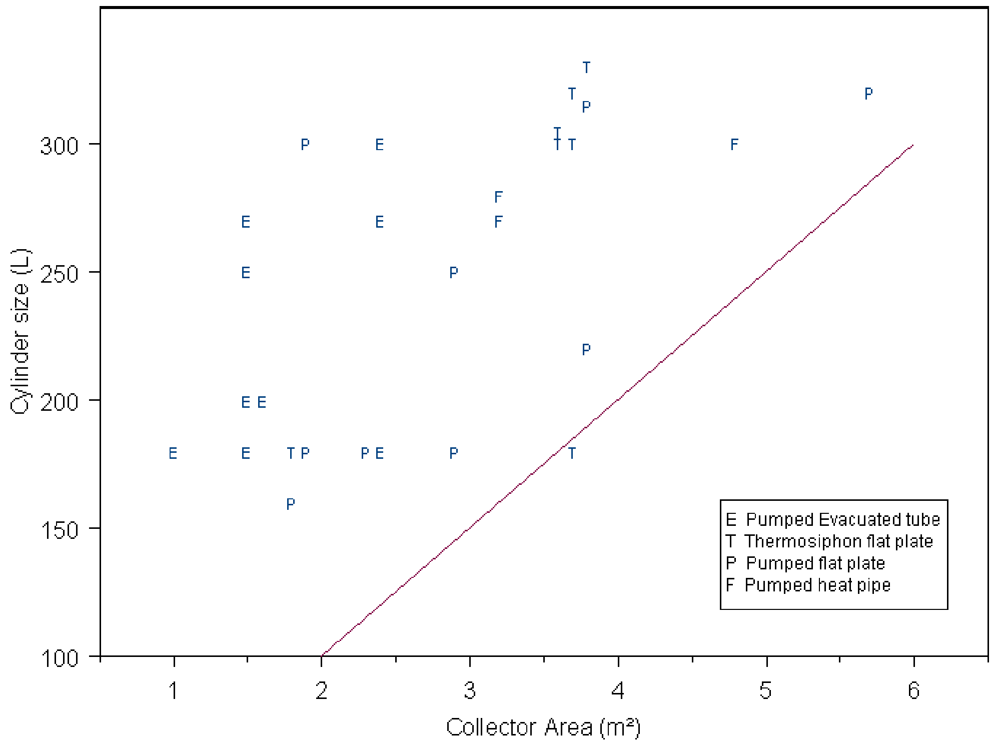


**Figure 39. Cylinder size by the collector area with the technology used shown.**

# 6. DISCUSSION

## 6.1 Key safety issues

There are a number of hazards with hot water systems, and solar water heaters introduce some additional risks that have to be managed.

Hot water can cause serious burns in a short length of time – as the temperature of the water increases the length of time to cause serious burns reduces exponentially (Williamson and Clark 2001).

The heating effect of the solar radiation can be quite strong and the temperature of the fluid within the solar collector can get hot quickly. How this collector-heated water is managed within the overall water heating system is important. Many systems inspected included additional pressure relief valves.

Many of the controllers will shut down circulation of the collector fluid to the hot water cylinder when the temperature of that water exceeds certain pre-set temperatures (in many cases 70°C, presumably to protect the cylinder, especially enamel lined ones, from overheating). While working on such a system as part of this experiment, the circulation pump was not operating for a while and the evacuated tube collector fluid got over this temperature. As this system did not have a temperature relief on the collector circuit, when the pump was re-engaged the controller prevented the system from circulating and so the water in the collector kept getting hotter until it reached the stagnation temperature.

In one case inspected (see Figure 40) an air intake valve was located on the collector pipework in the roofspace. The insulation below the valve was melted, indicating that the valve has discharged at some point.

This air intake valve poses a risk to people working in the roofspace. However, there is a shut-off valve immediately before the air intake valve, presumably so that it would not discharge steam while working in the roofspace. There was a second air intake valve for this system immediately adjacent to the collector on the roof. No signage on any of the pipework for this installation was present.

Another hazard partly visible in Figure 40 is the electrical outlet pointing upwards immediately to the left of the red pump. When the air intake valve is discharging steam this can cause water to come into contact with the outlet.

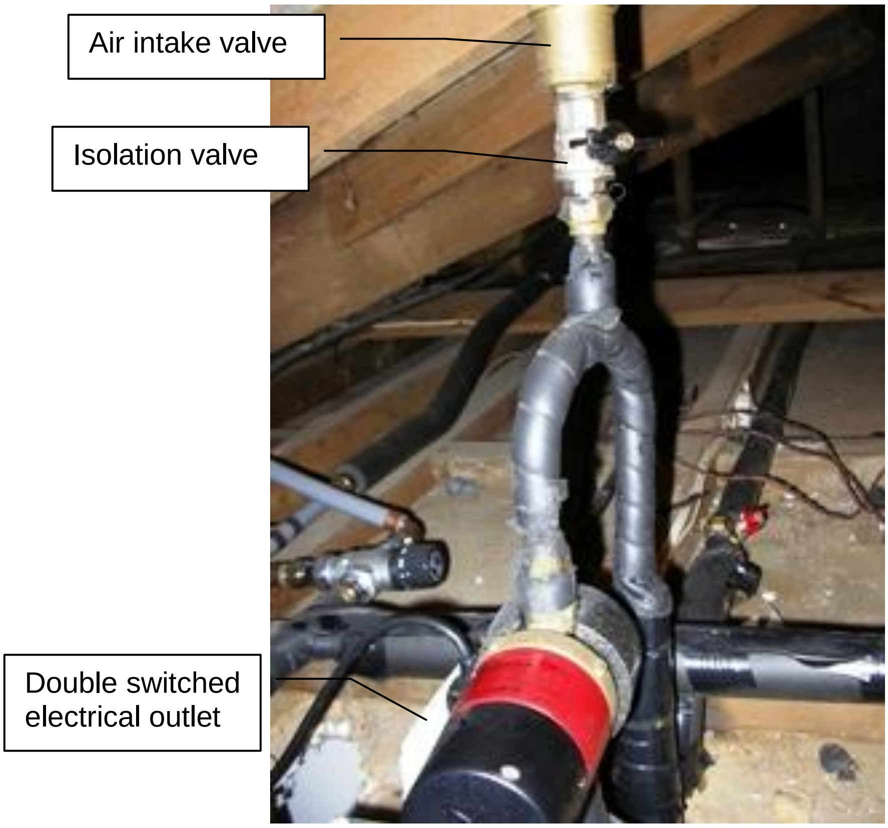


**Figure 40. Air intake valve located in roofspace.**

It is important to ensure that the inclusion of the solar water heater does not compromise any existing systems, for example in one inspected case a roof-mounted thermosiphon system was installed as a pre-heater to an existing hot water cylinder. The existing cylinder had a pre-existing tempering valve to limit the distribution of hot water to the house to 55°C by mixing the storage water (at say 60°C) with the incoming cold water (taken from the inlet into the cylinder at say 15°C). When the solar water heater was added as a pre-heater to this system the pipework for the tempering valve was not altered. The 'cold' feed to the tempering valve was now the outlet temperature of the solar water heater which could be at temperatures exceeding 55°C, thereby comprising the operation of the tempering valve.

The use of roof-mounted hot water cylinders also poses electrical hazards, especially when work is required to be undertaken on the roof. Many of the roof-mounted hot water cylinders inspected did not have a separate isolation switch on the roof adjacent to the system. The use of a roof-top isolation switch provides a level of safety to workers that the isolation at the meter board has not been compromised while they are away from the meter board working on the roof. An example is shown in Figure 41.

**Figure 41. Good use of an electrical isolation switch glued to the exterior of a roof-top cylinder. Note, however, the poor flashing for the conduit passing through the roof.**

Hot water cylinders, when filled with sometimes up to 340 L of water, can be very heavy. The security of hot water cylinders in the home is important in New Zealand due to our risk of earthquakes, and appropriate strapping should be used. In many cases inspected an insufficient number of straps were used or the straps were loose. Attaching roof-mounted cylinders securely is important and some inspections revealed poor attachments to the roof of the solar water heater. An example of a poorly attached system is shown in Figure 42 where a system is installed on a pan and rib flat roof using a frame which is only held down by four screws through the ribs of the roof. The weight of the system can be seen to be distorting the bottom left hand rib (where the sign is) and water was pooling around this location.

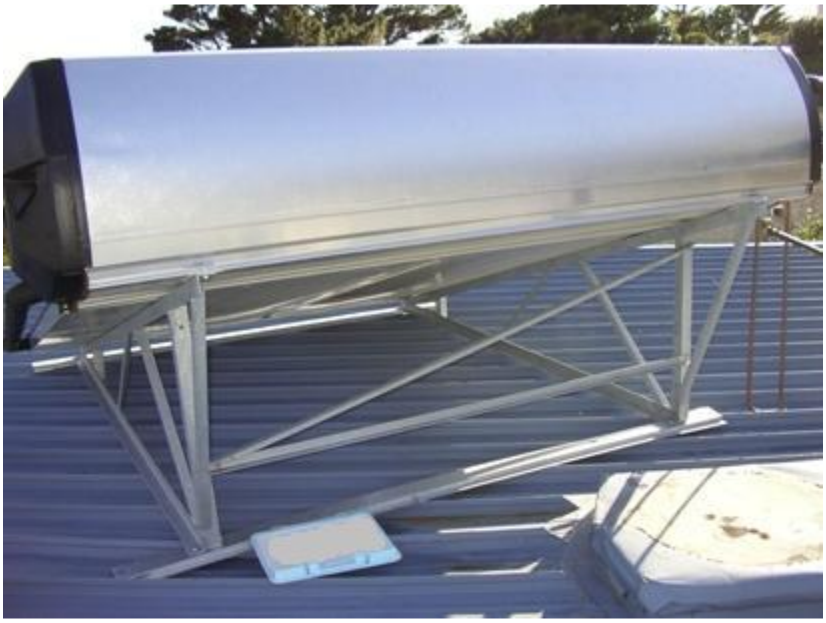

**Figure 42. Poorly secured roof-top system.**

## 6.2 Key durability issues

Overall, at the time of the inspections, the majority of the units seen were in good condition. It must be noted, however, that the oldest unit seen was less than three years old, and that if durability problems exist with the products (collectors, controllers, pumps and tanks) they may not yet be apparent. At three years old a SWH system might only have reached 20% of its lifespan, which may not be sufficient time to discover problems – especially in more benign environments. However, a number of issues have arisen which can be confidently predicted to cause problems within the lifetime of the system.

The most visually obvious problem is the use of closed-cell foam insulation products such as Armaflex and Centurylon outdoors without protection from UV. In only two installations was this material painted, and it was still undamaged after two years. The paint coating also helped to hide the pipework against the building as it was the same colour. On a small number of installations the lagging had been wrapped with vinyl tape, which has protected it well to date. However, the tape is beginning to degrade on some installations, which will eventually lead to the lagging being exposed and beginning to degrade itself. Figure 43 shows the degree of surface breakdown on the normally smooth insulation.

Dissimilar metals used in holding the collector units (and collector/tank units) to the roof will cause accelerated corrosion. Figure 44 shows this in some detail, with a stainless steel strap held directly to coil-coated zinc/aluminium-coated roofing with a galvanised “Tek” screw. Note the white area around the screw, which is caused by zinc corrosion products. There is no separating strip under the strap, so the point at which the screw penetrates the roofing will corrode more rapidly due to the presence of the stainless steel. There is a secondary issue here, which is that the timber on the roof will hold water against the roofing, accelerating the corrosion.

**Figure 43. Degradation of lagging, unprofessional penetration sealing.**

**Figure 44. Dissimilar metals in contact, unprofessional penetration sealing.**

Run-off from plumbing fittings containing copper, in addition to that from the collector elements themselves via leaks, will cause corrosion of galvanised, zinc/aluminium-coated and aluminium roofs. Figure 45 demonstrates this quite graphically. The leak was due to a degraded fibre washer behind the blanking plug. The owner was notified and the leak fixed before the installation of monitoring equipment commenced.

**Figure 45. A leak has directed copper containing water onto the roof, corroding it.**

Sheltering from rainwashing will cause a build-up of salt and debris on the roof under the collector. If left unwashed, this can double the corrosion rate of the roofing. Figure 2 shows a large unwashed area under this panel. It will take several years for the corrosion damage to become apparent through a coil-coated or painted roof – by this stage significant remedial work will be necessary to the roofing. The solution is to wash the sheltered areas regularly with fresh water and a soft brush. Note also the hole in the foreground – this is a pipe penetration from the original installation of the unit – facing almost due east. The owners demanded a change of orientation and the unit was moved. The hole remains.

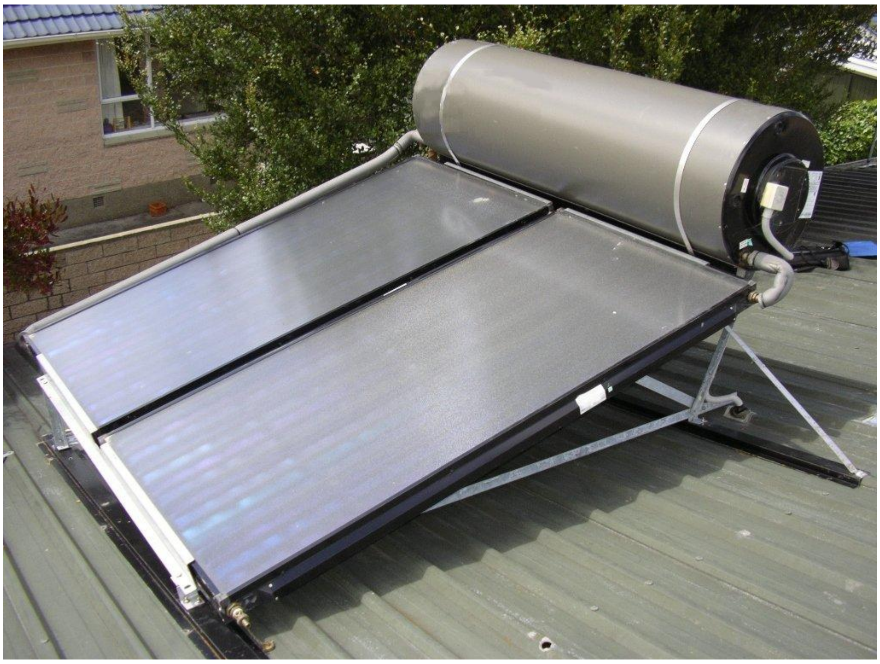

**Figure 49. A large sheltered area exists under this collector.**

### 6.2.1 Collector condition

One unit was inspected which exhibited the discolouration of the collector surface seen in Figure 46. This did not appear to be corrosion *per se*, but rather a colour change, back to the natural copper colour. This collector is of the type which is cast into its insulating foam surround, the latter forming the rear part of the panel. This collector was actually loose in its frame and could be moved with the fingers. It is doubtful in this case that a still air gap would exist between the collector and the glass face, which would lead to efficiency losses. This collector is 11 months old. Another nearby unit of the same type and 16 months old did not show this discolouration or loose collector.

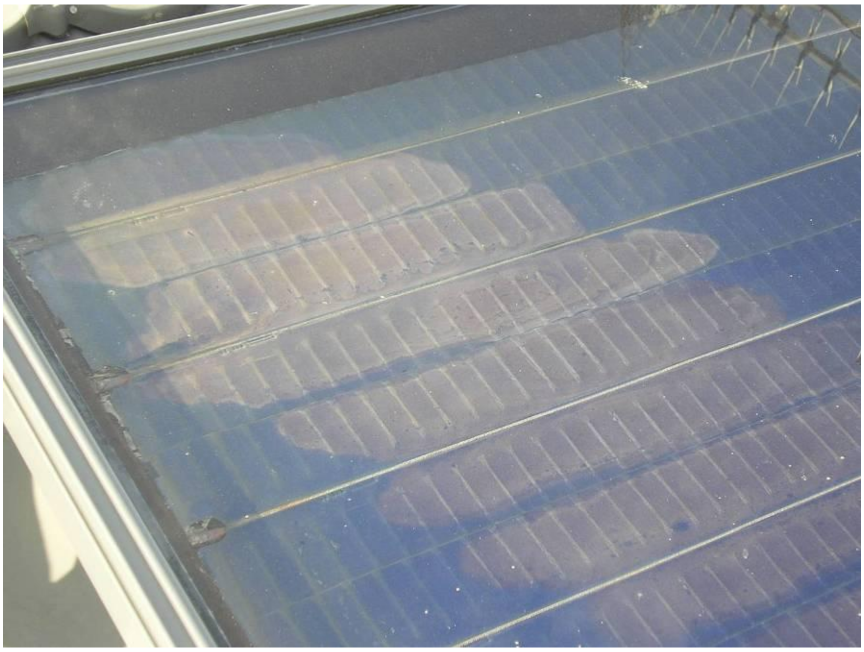

**Figure 46. Discoloured collector.**

**Figure 47. Condensation inside glass.**

Condensation in collectors was noticed on two installations, as shown above in Figure 3 and Figure 47. The collector array is not clearly visible due to the condensation. Figure 48 below gives a close-up shot of the collector surface from Figure 3. The collector array can be seen indistinctly through the glass. No discolouration is visible on the collector.

**Figure 48. Condensation in collector.**

Incorrect lagging choice has led to this material melting in service. Foamed polyolefin lagging of this sort is not suitable for piping temperatures above 80°, although it is more durable when exposed to UV.

**Figure 49. Melted lagging.**

# 7. CONCLUSIONS

- The installations seen fell predominantly into two camps – those following a proprietary “recipe” for installation (with some variations, although generally minor), typical of a packaged system; and those which combined widely available parts with individually available collectors to produce bespoke systems. It is apparent that the market has not yet reached the point where “standard” systems are offered, although some of the packaged systems are nearing this point. Whilst some degree of difference is expected (and necessary) between systems, more uniformity will assist greatly with troubleshooting and general parts availability as the systems age. Figure 53 shows the result of a “non-standard” installation at its worst.

**Figure 50. The tempering valve is fed from two hot supplies – the HWC and the SWH.**

- Most of the installations inspected had at least one inappropriate material selection, either for the durability of the material itself (for example UV attack on pipe lagging outdoors) or for the combinations of materials used (e.g. collector mounts in direct contact with roofing made from a different metal).

- Workmanship is still erratic – swarf from drillings remains on several roofs, rusting into small spots; three installations had pop rivet shanks scattered around the collectors; feed and return pipes are often not secured, either on the roof or in the house. Damage to the roof is often not made good (Figure 54).

**Figure 51. Hole left after reorienting collector by 90° – it is 25 mm in diameter.**

- The installation of over-temperature pressure and TPR valves is not consistent. Some installations appear to rely on a roof-top air admittance valve, whilst others depend on the TPR valve on the storage cylinder itself. There is no certainty that the solar loop is mechanically protected against an over-temperature incident – as an example, in one system the controller shut down the circulation to the collector when the temperature exceeded the over-temperature threshold. The stagnant collector was then unable to dump heat or pressure as there was no pressure relief at the collector or elsewhere in the solar loop.

**Figure 52. Collector at 120°C – note the lack of relief valve.**

- The second safety issue is the apparent ignorance of the 60° anti-Legionella temperature boost: although all of the systems inspected are theoretically capable of regularly achieving the required temperature, the system configuration, owner's operation, and some manufacturer's recommendations can combine to prevent this from happening as a regularly scheduled event (see Figure 55).


**Figure 53. Thermostat set at 56°C as owner's manual recommends.**

- None of the systems inspected had collectors installed at an inclination angle greater than the site latitude which would favour winter time performance. Most systems met the recommended (G12/AS2) inclination of within 20° of latitude, although all were below. There was an apparent bias towards the western aspect when orientation was assessed. This would appear to be due to the approximate 20° difference between geographic and magnetic north, and may be inherent in the orientation of the houses themselves.

- Few of the owners were able to claim that they fully understood how to operate their solar systems. Most were unaware of the need for a building consent when installing a system. Only one manufacturer consistently provided clear instructions and an owner's manual, and left this where the owners could find it.

In conclusion, the industry is not yet consistent in its application of standard practices, with a variety of proprietary configurations employed alongside bespoke ("bitsa") solutions. An increasing number of ready-made solutions are now available for problems such as adapting SWH to an existing storage cylinder. However, the application of these solutions is as yet up to the individual installer's preferences. Awareness of the need for a building consent is evidently low amongst installers and missing among owners. Owners are not sufficiently informed to run their systems as efficiently as possible, and with due regard for their own safety.

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# 9. APPENDIX 1. INSPECTION PROTOCOL

The inspection protocol used for this project is shown on the following pages.

| 1.INSPECTOR'S OBSERVATIONS ON ARRIVAL | Question # |
|---|---|
| **Installation address:** | **1.1** |
| **Town/City/Suburb:** | **1.2** |
| **Latitude:** | |
| **Environment:**<br>( ) Industrial<br>( ) Urban<br>( ) Rural<br>( ) Commercial/CBD | **1.4** |
| **Distance from shore:**<br>( ) Within 500m<br>( ) between 500 and 1km<br>( ) 1km -10 km<br>( ) More than 10km | **1.5** |
| **Frost Table Zone?** | **1.6** |
| **2. BUILDING DESCRIPTION** | |
| How high is the building:<br>( ) Single storey<br>( ) Double storey<br>( ) Multiple storeys | **2.1** |
| The solar collector panels are located on the:<br>( ) Roof<br>( ) Ground<br>( ) Other | **2.3** |

| | |
|---|---|
| What kind of hot water system is in place:<br>( ) Low pressure<br>( ) Mains pressure | **2.4** |
| What type of SWH is installed:<br>( ) Flat thermo<br>( ) Flat pumped<br>( ) Evac thermo<br>( ) Evac pumped<br>( ) Other: | **2.5** |
| **3. ROOF-TOP INSPECTION DETAILS (and inside, if split system)** | |
| Manufacturer's name: | **3.1** |
| Supplier's name: | **3.2** |
| Size of single panel (mm x mm): | **3.3** |
| Number of panels: | |
| Date of manufacture (if known): | **3.4** |
| Model number: | **3.5** |
| Serial number: | **3.6** |
| Size of cylinder: | **3.7** |
| What type of frost protection:<br>( ) Frost plugs<br>( ) Expansion vessel<br>( ) Pump circulation<br>( ) Glycol in collector<br>( ) Other: | **3.8** |

| **4. DURABILITY AND DEGRADATION Components inside and outside** | |
|---|---|
| Any signs of corrosion:<br>( ) Pipes<br>( ) Solar collector panels<br>( ) Components<br>( ) Fittings | **4.1** |
| Further detail: | |
| Appearance: Any fading or discolouring of paint or coatings<br>( ) Yes<br>( ) No | **4.2** |
| Further detail: | |
| Have any of the sealants, rubbers, insulation, or plastics perished or started to crack:<br>( ) Yes<br>( ) No | **4.3** |
| Further detail: | |
| Is there a build-up of dust and material on the glass surfaces?<br>( ) Yes<br>( ) No | **4.4** |
| Any signs of staining / discolouring from the runoff on the surfaces below the collector panels?<br>( ) Yes<br>( ) No | **4.5** |
| Is corrosion visible on any of the surfaces adjacent to or connected to the collector panels?<br>( ) Yes<br>( ) No | **4.6** |
| Other observations:<br>( ) Footprints<br>( ) Scratches<br>( ) Bird pecking<br>( ) Birds nests | **4.7** |

| 5. INSTALLATION | |
|---|---|
| If the system has a tank on the roof, has it been installed with regard to safe structural loadings (ref; “Manual for Structural Assessment for Installation of SWH in Domestic Dwellings”)<br>( ) Yes<br>( ) No | **5.1** |
| Has the collector been adequately attached to the roof?<br>( ) Yes<br>( ) No | **5.2** |
| Has a building permit been obtained?<br>( ) Yes<br>( ) No | **5.3** |
| Consenting authority for this location: | **5.4** |
| Which direction do the solar panels face:<br>( ) North<br>( ) North East<br>( ) East<br>( ) South East<br>( ) South<br>( ) South West<br>( ) West<br>( ) North West | **5.5** |
| Are the solar panels:<br>( ) Fixed to the roof angle<br>( ) Mounted so as to be away from the angle of the roof | **5.6** |
| What is the inclination angle of the panels? If measured actual angle º | **5.7** |
| Are pipes in the ceiling cavity lagged:<br>( ) Yes<br>( ) No | **5.8** |
| What sort of lagging has been used? | **5.9** |

| | |
|---|---|
| Are pipes outside of the building lagged:<br>( ) Yes<br>( ) No | **5.10** |
| Are the bends lagged properly:<br>( ) Yes<br>( ) No | **5.11** |
| If visible, what sort of lagging has been used? | **5.12** |
| Are all holes in the roof sealed with the appropriate sealant:<br>( ) Yes<br>( ) No | **5.13** |
| Are penetrations flashed properly:<br>( ) Yes<br>( ) No | **5.14** |
| Is there any damage (including scratches or buckling) to the roof, guttering or any other parts of the building that have been used during the installation?<br>( ) Yes<br>( ) No<br>Further detail: | **5.15** |
| Has the system been designed and installed to meet:<br>( ) Electricity supply interruptions<br>( ) Overheating safety events | **5.16** |
| How many roof or wall penetrations are required to feed the collector? | **5.17** |
| In summer will the panels be in the shade at any time of day:<br>( ) Morning<br>( ) Noon<br>( ) Afternoon<br>( ) Never | **5.18** |
| In the winter will the panels be in the shade at any time of day:<br>( ) Morning<br>( ) Noon<br>( ) Afternoon<br>( ) Never | **5.19** |

| | |
|---|---|
| What type of plumbing is used:<br>( ) Copper<br>( ) Plastic<br>( ) Steel<br>( ) Other: | **5.20** |
| What source of energy is used for boosting the cylinder:<br>( ) Electricity<br>( ) Gas<br>( ) Wetback<br>( ) Other: | **5.21** |
| Are there any indicators inside the house that the supplementary heating is on, for example a warning light:<br>( ) Yes<br>( ) No | **5.22** |
| Is the solar panel independent of the roof (does not replace roofing material):<br>( ) Yes<br>( ) No | **5.23** |
| Can the pump be isolated for repair without draining the system:<br>( ) Yes<br>( ) No | **5.24** |
| Make of pump if fitted: | **5.25** |
| Type of pump:<br>( ) Diaphragm<br>( ) Impeller<br>( ) Other | |
| Flow capacity of pump: | **5.26** |
| Power consumption of pump (measured in watts): | **5.27** |
| How often can the system deliver a 60° legionella boost:<br>( ) Every 24 hours<br>( ) Twice a week<br>( ) Once a week<br>( ) Never | **5.28** |

| | |
|---|---|
| Does the cylinder have any additional inputs (ie top element):<br>( ) Yes<br>( ) No<br>Further detail: | **5.29** |
| | |
| **6. REMEDIAL ACTION** | **6** |
| **7. QUESTIONS TO OWNER / RESIDENT** | |
| How many people live in this house? | **7.1** |
| Do you experience:<br>( ) Ice<br>( ) Snow<br>( ) Sub-zero temperatures | **7.3** |
| How old is the building? | **7.5** |
| When was the SWH system installed? | **7.6** |
| At the time of installation of the SHW system did you:<br>( ) Replace the hot water cylinder<br>( ) Replace more than 50% of the plumbing<br>( ) Replace taps and other fittings | **7.7** |
| Was the tank moved to another location:<br>( ) Yes<br>( ) No | **7.8** |
| Who installed the system? | **7.9** |
| How long did installation take:<br>( ) Less than 3 hours<br>( ) 3-6 hours<br>( ) 1 day<br>( ) 1-2 days<br>( ) More than 2 days | **7.10** |

| | |
|---|---|
| Was there an inspection of the structure (ie roof) to determine if it could take the additional load, before a quotation for installation, or the installation was started:<br>( ) Yes<br>( ) No | **7.11** |
| What were your main reasons for purchasing a solar water heater (SWH):<br>( ) To save money<br>( ) Environmental concerns<br>( ) Been thinking about it / great idea.<br>( ) Other | **7.12** |
| *FINANCE SCHEME(only relevant if part of EECA's audits of finance scheme installations)* | |
| Would you have bought a SWH if finance assistance wasn't available?<br>( ) Yes<br>( ) No<br>( ) Maybe<br>Further comment: | **7.13** |
| How would you describe the finance process?<br>( ) Very easy (user friendly)<br>( ) Easy<br>( ) Difficult<br>( ) Very difficult<br>Further Comment: | **7.14** |
| *SOLAR WATER HEATING SYSTEM* | |
| How did you decide which type of SWH to buy? | **7.15** |
| When you decided to purchase a unit, did you have much choice:<br>( ) Little<br>( ) Some<br>( ) A lot | **7.16** |
| How many brands did you consider? | **7.17** |

| | |
|---|---|
| What was your impression of the people you contacted? | **7.18** |
| Are you happy with the SWH unit:<br>( ) Yes<br>( ) No<br>Reason, if not: | **7.19** |
| Are all parts of the system fully installed and operational to the best of your knowledge:<br>( ) Yes<br>( ) No | **7.20** |
| Is the system producing the quantities of hot water expected:<br>( ) Yes<br>( ) No | **7.21** |
| *INSTALLATION AND INFORMATION* | |
| Are you satisfied with the way the system was installed:<br>( ) Yes<br>( ) No | **7.22** |
| Was the installer/plumber:<br>( ) Friendly<br>( ) Respectful<br>( ) Helpful | **7.23** |
| Did the installer discuss orientation/inclination with you?<br>( ) Yes<br>( ) No | **7.24** |
| Has good clear documentation been supplied of what performance you can expect from the system:<br>( ) For your specific house design<br>( ) Location<br>( ) House direction<br>( ) And for each of the seasons | **7.25** |
| Have you been provided with an owner’s manual outlining ongoing operation and maintenance requirements:<br>( ) Yes<br>( ) No | **7.26** |
| Have you been advised who is responsible if anything goes wrong with the system:<br>( ) Yes<br>( ) No | **7.27** |

| | |
|---|---|
| Is there appropriate signage/instruction on switches and/or controls:<br>( ) Yes<br>( ) No | **7.28** |
| *MAINTAINANCE* | |
| Have you ever had to do any maintenance on the unit:<br>( ) Yes<br>( ) No | **7.29** |
| Detail of maintenance:<br>*eg Top-up of Glycol* | **7.30** |
| If you've had to do maintenance, how much did it cost each time? | **7.31** |
| How many times have you had to do maintenance ? | **7.32** |
| *CONTROLLERS* | |
| Were you offered a controller for the supplementary energy?<br>( ) Yes<br>( ) No | **7.33** |
| Is a supplementary energy controller being used?<br>( ) Yes<br>( ) No | **7.34** |
| If yes, is it a controller that responds to a minimum cylinder temp:<br><br>( ) Yes At what temp does it turn on? ………….degrees C<br>( ) No | **7.35** |
| Or is it a time-based controller:<br><br>( ) Yes<br>( ) No<br><br>What are the time settings for the supplementary energy boost to turn on:<br>From______ until _______<br>From ______until _______<br>From ______until _______ | **7.36** |

| | |
|---|---|
| Is the supplementary energy on a ripple control tariff:<br>( ) Yes<br>( ) No | **7.37** |
| Do you manually turn off the cylinder:<br>( ) Yes<br>( ) No | **7.38** |
| If so, at what times of the day? | |
| If so, what time of year do you turn it off? | |
| If so, what time of year do you turn it back on? | |
| If a pumped circulation system, what temp differential triggers the circulation pump?<br>Turn on at ____ $^{o}$C difference<br>Turn off at ____ $^{o}$C difference | **7.39** |
| *CYLINDER* | |
| What is the size of your cylinder? (in litres) | **7.40** |
| Is your cylinder:<br>( ) A specialised solar container<br>( ) A conventional hot water cylinder | **7.41** |
| What is the position of the thermostat:<br>( ) Lower<br>( ) Middle<br>( ) Top | **7.42** |
| What is the position of the supplementary energy boost:<br>( ) Lower<br>( ) Middle<br>( ) Top | **7.43** |

| *COST EFFECTIVENESS* | |
|---|---|
| Do you agree to allow EECA staff and/or EECA contractors to access my power bill records solely for use in the solar water heating project?<br><br>( ) Yes If yes, please sign disclaimer below<br>( ) No | **7.44** |
| What was the total installed cost of the solar water heating system (includes installation costs, building consent costs, all equipment) | **7.45** |
| | |
| ***Complete after power bill information obtained.*** | |
| kWh for water heating, before system installed<br>_______kWh in ________months | **7.46** |
| kWh for water heating, after installation<br>_______kWh in ________months | **7.47** |
| Energy company | **7.48** |
| Tariff name | **7.49** |
| Tariff cost (water heating) _______c/kWh | **7.50** |
| If ripple control, what rules (when on, when off, how many hours guaranteed etc) | **7.51** |