DEVELOPING THE AUSTRALIAN SOLAR COOLING MARKET: STATUS UPDATE AND LESSONS FROM THE SOLAR THERMAL INDUSTRY

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ABSTRACT

Australia's solar thermal industry has seen significant growth over the last decade, having doubled the number of domestic solar hot water systems. In 2010 Australia installed the most solar thermal capacity, per-capita, of any country. This growth has been driven by government support for domestic solar hot water systems, and industry compliance with strong standards, which have ensured high quality systems. The domestic solar cooling market is very small in comparison to solar hot water, with a total of nine installed systems. Several lessons learned in the development of the solar hot water market should be applied to the solar cooling market to encourage growth in this industry.

Standards Australia has developed a solar heating and cooling performance assessment standard, AS 5389, which is set to be released in 2013. This standard should give stakeholders a better tool to measure and rate the performance of systems. This standard will also provide policymakers with an important tool for developing more support mechanisms to promote solar cooling systems, or incorporate them in to existing renewable energy programs such as the Renewable Energy Target (RET).

High-quality demonstration systems will also play an important role in industry development over the next few years. This paper describes two recent projects of this nature: a 233kW$_r$ system at the Charlestown Shopping Centre and a solar driven tri-generation system planned for the University of Technology, Sydney.

THE AUSTRALIAN SOLAR THERMAL MARKET

MARKET GROWTH TO 2013

Over the last 13 years Australia has seen a rapid increase in the solar thermal industry, driven by the uptake of domestic solar hot water systems. The proportion of the current building stock incorporating some form of solar thermal hot water system has risen from 4.4% in 2005 to 8.5% in 2011 (1). The percentage of new water heating installations that are solar has risen from 5% in 2004 to 27% in 2010 (2). In absolute terms, this represents the sale of approximately 400,000 m^2 of new collector area in 2010 (3). Figure 1 shows the annual sale of systems, by collector area, since 1970.

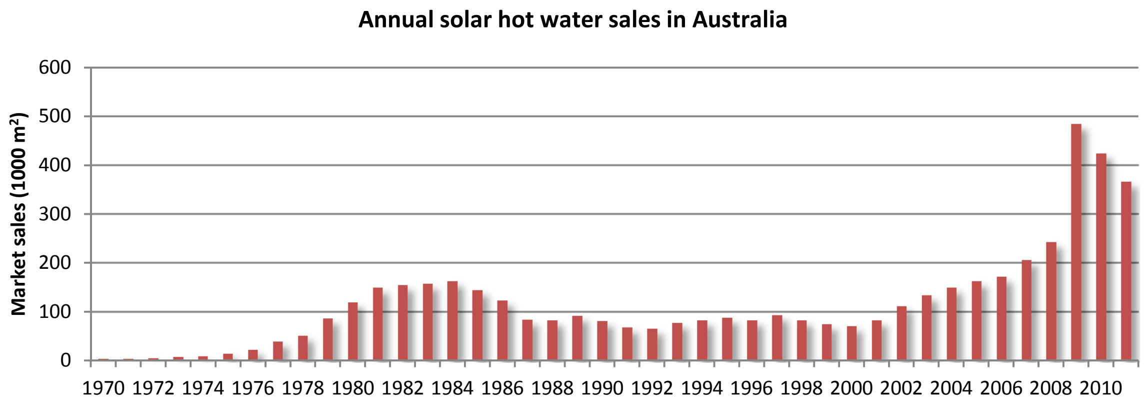

Figure 1 Solar hot water sales on an installed collector area 1000 m^2 since 1970 (3)

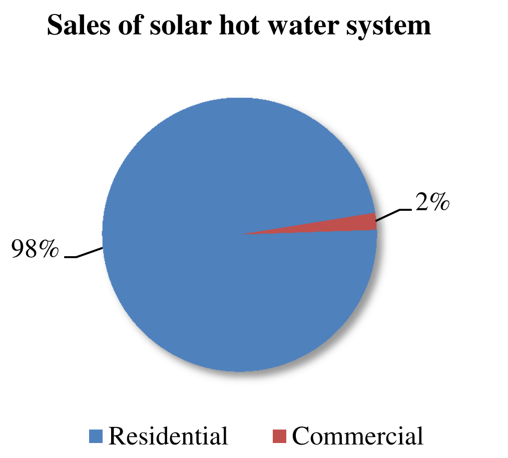

Figure 2 Breakdown of residential to commercial systems (4)

Commercial systems make up approximately 2% of the cumulative solar hot water installations in Australia (4). According to the International Energy Agency's (IEA) Solar Heat Worldwide report, in 2010, Australia had the fifth greatest installed capacity of solar thermal (per capita) at 271 W_{th} per one thousand inhabitants[i]. Australia also led the world for newly installed capacity in 2010 with 35kW_{th} per 1000 inhabitants installed. (5).

GOVERNMENT SUPPORT FOR MARKET DEVELOPMENT

A range of government policies and regulations have been used to support the development of the Australian solar thermal market. These have included federal and state government financial incentives, and building regulations which have provided businesses and individuals with both '*carrots and sticks'* for the uptake of solar thermal technologies.

The NSW Government introduced a rebate program supporting solar hot water systems with $500-700 rebate in 1996 (6). A solar hot water rebate program was established in 2000 by Sustainability Victoria, an environmental agency within the Victorian State Government (2). The rebate provided by this program depends on the calculated 'deemed' energy savings of each packaged solar hot water system using AS/NZS 4234 (7). This incentive is still available in 2013 and has been used as a model for other jurisdictions for policy design.
In addition to the rebate program, Sustainability Victoria also set up a 'Green Plumbers' training program. This program was important for the industry's development, as they are often the first point of call when a hot water system experiences issues. Plumbers' perceptions of solar systems and their ability to safely service them have been important for the reputation of the technology among consumers. Solar hot water systems were also supported through Victoria's *6 star new homes*

[i] This is total capacity at peak rated all solar thermal products including glazed collectors, and unglazed (pool heaters) , concentrators for all applications including domestic hot water, solar process heat, solar cooling, solar heating.

regulation (8; 2). Under this program, all new homes must install either a rainwater tank, or a solar hot water system.

In 2001, the Australian Federal Government introduced the Mandatory Renewable Energy Target (RET) scheme with the aim of increasing renewable energy generation in Australia. This scheme was implemented through the former Office of the Renewable Energy Regulator, now called the Clean Energy Regulator. Under the RET solar hot water systems receive tradable certificates called STCs[ii]. The number of STCs provided is based on an upfront calculation of the energy savings from each system over 10 years. Manufacturers calculate energy savings using the method contained in AS/NZS 4234:2010 'Water heater systems - calculation of Energy Consumption'.

The RET has led to a large increase in demand for solar hot water systems, by reducing their cost in the following two ways:

- The 10 years of STCs were provided at the time of system installation, allowing installers to use them as an upfront rebate for purchasers.
- The STC calculation method promoted improved system performance as a means of reducing the upfront cost of system, with associated benefits accruing to consumers over the lifetime of the system.

In addition to the policies mentioned, state and federal governments have introduced several other support mechanisms for solar how water since 2000. See (2) for more details.

DEVELOPMENT OF INDUSTRY STANDARDS

Australia has a strong set of standards for solar thermal products and systems that has been developed over the last 25 years. These have helped to ensure high quality systems are being installed in Australia. In particular, AS/NZS 4234 has driven major improvements to system performance by providing a consistent and auditable method for calculating the energy consumption of solar hot water and heat pump systems.

AS/NZS 4234 was first developed in 1994. The energy consumption calculations are based on a transient simulation using the TRNSYS software package (9). TRNSYS has become a powerful tool for manufacturers to rate their own systems and pursue improvements in design. The standard has also provided a tool for governments to consistently incorporate quality requirements for solar hot water to be integrated in to other renewable energy policies and programs, as seen with the programs mentioned above.

[ii] From 2001-2010 the certificates where call Renewable Energy Certificates (RECs). In 2010, this was split into Large-scale Generation Certificates (LTCs) and Small-scale Technology Certificates (STCs) (16). One STC is equal to 1MWh of displaced electricity by the solar hot water system over its lifetime.

LESSONS FOR THE SOLAR COOLING INDUSTRY

MARKET PENETRATION CHALLENGES FOR NEW SOLAR TECHNOLOGIES

Solar cooling represents a tiny fraction of the current Australian solar thermal market. At present, there are nine known systems installed in Australia, with another three planned. These systems and their specifications are listed in Table 1.

Location	Cooling capacity	Solar field size	Collector type	In operation since	Application	Type
Ipswich, QLD	300 kW_r	570 m^2	Parabolic Trough	2007	Air-conditioning	2E AB
Blackall, QLD	10kW_r	22m^2	Evacuated tube	2011	Air-conditioning	AD
Padstow, NSW	175 kW_r	165 m^2	Parabolic Trough	2007	Air-conditioning	2E AB
Wyong, NSW	7 kW_r	20 m^2	Evacuated tube	2009	Air-conditioning	AD
Newcastle, NSW	18 kW_r	58 m^2	Parabolic Trough	2010	Demonstration	
Newcastle, NSW	233 kW_r	350 m^2	Parabolic Trough	2011	Air-conditioning	2E AB
Newcastle, NSW	80 kW_r	400 m^2	Flat plate	2011	Air-conditioning, hot water	DEC
Echuca, VIC	200 kW_r	400m^2	Evacuated tube	2010	Air-conditioning	2E AB
Sydney, NSW	250kW_r	500m^2	Evacuated tube	2011	Air-conditioning	1E AB
Echuca, VIC			Micro linear Fresnel	Planned	Air-conditioning	
Sydney, NSW	19 kW_r (+5kW_e ORC, and 60 kW_{th} hot water)	116m^2	Parabolic Trough	Planned	Air conditioning, (+ Electricity, and domestic hot water)	1E
Wendouree, VIC	15 kW_r	148 m^2	Parabolic Trough	Planned	Air conditioning (+ hot water)	2E DEC

Table 1 Solar Cooling system's installed in Australia with details of capacity, field size, collector type, operational period, application, type of system. TYPE: 2E = double effect, 1E = single effect, AD = Adsorption, AB=Absorption, DEC = desiccant evaporative cooling

The Australian government is generally supportive of projects and activities to promote research, development and deployment of new solar technologies. There are opportunities for companies to obtain grants for these activities through the Australian Solar Institute and other incentive programs. The government agencies and staff administering these programs tend to collaborate with project developers to navigate the existing standards and regulations for solar thermal systems.

In typical projects involving new technologies, regulations have been adapted so that projects can obtain development approval. However, the conditions for obtaining grants are often tied to standards and regulations in a less flexible way. This has meant that whilst projects are usually able to obtain approval for construction, they are often excluded from existing incentive programs, which is a significant barrier to entry for solar cooling and new solar thermal technologies.

As an example, the solar thermal design standard AS/NZS 2712:2007[iii] is a voluntary standard which has been vital for supporting the sustainable development of the industry. However, systems applying for government incentives must comply with the standard, so there is a pseudo-compulsory

[iii] AS/NZS 2712:2007 (13)

enforcement of the standard in practice. For projects using new solar thermal technologies that are not suited to this particular standard, the opportunities for government support are limited.

This specific issue affects several Hybrid Photovoltaic Thermal (PV-T) solar collector manufacturers who are currently trying to enter the Australian market[iv]. PV-T solar panels convert sunlight to hear and electricity, using photovoltaic (PV) cells as their absorber surface. There is no Australian Standard giving a detailed method for testing the performance of PV-T collectors and the certifiers and laboratories in Australia have been struggling to incorporate them into existing standards.

To be more specific, some PV-T collectors are considered unglazed because the cell has no covering over its photovoltaic (PV) surface. This causes difficulty because there is no unglazed Australian Standard, and the international standard[v] for unglazed performance does not provide sufficient detail for application with PV-T collectors. Solimpeks Australia recently went through a costly process with the Clean Energy Regulator to obtain certification for their unglazed flat plate PV-T collectors and their product can now be included in systems eligible for STCs and rebates[vi]. For the concentrating PV-T industry as a whole, there are still significant challenges of this nature to overcome.

Concentrating PV (electrical only) has also encountered problems entering the Australian market. The Australian safety standard for concentrating PV is yet to be published (as of February 2013), which is preventing the Clean Energy Council from assessing the product to be acceptable under their accreditation scheme[vii].

Concentrating thermal collectors (non-electrical) are encountering fewer problems, because the Clean Energy Council and the Clean Energy Regulator have accepted the European standards for certifying quality and performance.[viii]

PROJECT DESIGN AND DEVLIVERY CHALLENGES: SOLAR COOLING SYSTEM CASE STUDIES

The Australian solar cooling industry has encountered a variety of challenges in the projects planned and delivered to date. The case studies below highlight some of the issues involved in designing and delivering systems in such a young industry. The first case also highlights an instance of successful project delivery, and both show considerable forward-thinking from the stakeholders in developing innovative solutions.

Charlestown Square Solar Cooling System

The Charlestown Square solar thermal cooling system is a 230kW$_r$ absorption cooling system that provides chilled water to a shopping centre in Charlestown (near Newcastle), NSW. GPT are the building owners, and co-funded 50% of the project cost with support from the NSW Government's Renewable Energy Development Program (10). The system was delivered by Lend Lease, which began operating in 2011.

[iv] Solimpeks, Chromasun, Bosch, and Cogenra are four companies with intentions of bringing PV-T to Australia.
[v] ISO 9806.3 1994 (14)
[vi] AS/NZS 2712:2007 (13)
[vii] prIEC 62688 Concentrator photovoltaic (CPV) module and assembly safety qualification
[viii] EN 12975:2011 Thermal solar systems and components - Solar collectors (15)

The solar field consists of 12 PolyTrough 1200 concentrating trough collectors that were manufactured, supplied, and installed by NEP solar. The total aperture area is 350 m^2, supplying 180°C pressurized hot water to a BROAD double-effect absorption chiller. Condenser heat is rejected using a hybrid cooling tower. The system components are listed in Table 2.

Component	Model
Collectors	NEP Solar PolyTrough 1200 (12 troughs) – 350m^2 aperture area
Absorption chiller	BROAD BH20 233kW_r double effect Water LiBr

Table 2 Charlestown Square Solar Cooling System Components

Figure 3 Picture of the installation at Charlestown Square

Several design issues were identified with the Charlestown system during and after commissioning, demonstrating the industry's current lack of experience with designing commercial-scale systems. These issues were mainly concerned with the high operating temperatures and pressures of the system, including the following:

The insulation was underspecified for the system size and temperature of operation, causing substantial heat loss.

- The pipe work insulation became waterlogged in some sections. This led to hot spots where the outside of the cladding exceed 100°C. This issue was resolved by replacing the insulation with high temperature closed cell insulation (11).
- Leaks were identified in several pump seals, leading to the replacement of all seals on all pumps. This delayed the commissioning process substantially.

Solar-driven Tri-generation system at University of Technology, Sydney (UTS)

The roof of the new Engineering Building at the University of Technology, Sydney will feature an advanced solar field that will provide all of the input heat for a demonstration tri-generation plant generating electricity, chilled water and hot water. The system is expected to begin operation in mid-2014.

The system will be used as a research and teaching tool for engineering and research students, who will be able to run the system in different operational modes and fully monitor the system and its individual components.

The system will produce:

- electrical output using an Organic Rankine Cycle (ORC) turbine,
- chilled water from an absorption chiller, and
- hot water using the waste heat from the above two processes, as well as directly from the solar field.

The concept design flow chart is shown in Figure 4.

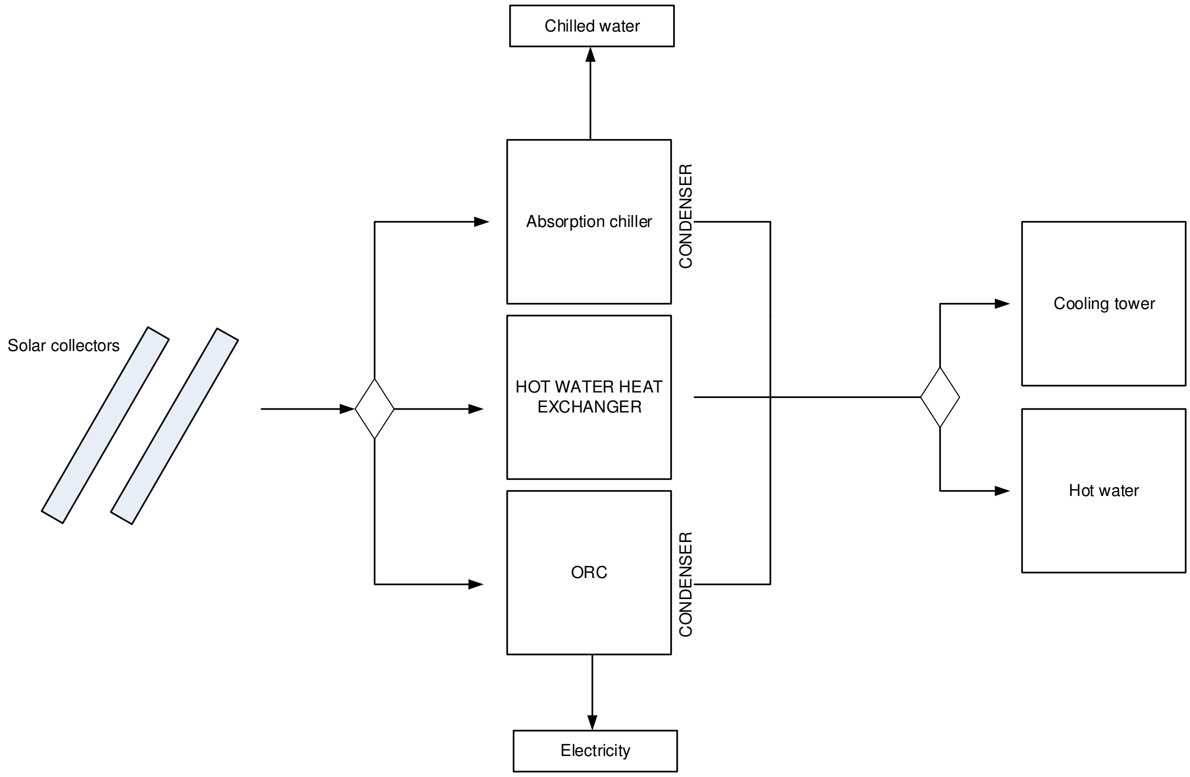

Figure 4 Concept design of the solar tri-generation plant.

The system components are listed in Table 3. The solar field consists of four NEP Solar PolyTrough 1200 collectors with a total aperture area of 116 m^2. This has a thermal power of approximately $56kW_{th}$ [ix] which is delivered by pressurized water at up to 150°C for the ORC and up to 100°C for the absorption chiller.

The selected ORC is a $5kW_e$ model from Eneftech in Switzerland, and the absorption chiller is one PC-19 $19kW_r$ ammonia-water absorption chiller from Pink in Germany. Provision has been made for the addition of a second chiller in the future.

Component	Model
Collectors	NEP Solar PolyTrough 1200 (4 troughs) – 116 m^2 aperture area
ORC	Eneftech Enefcogen Green $5kW_e$
Absorption chiller	Pink PC-19 $19kW_r$ single effect ammonia water (provision for a second future chiller made).

Table 3 UTS Tri-generation System Components

The design process for this system highlighted the fact that Australia has only a very limited selection of equipment suppliers for this type of system. There were a small number of available ORC units but none of the existing Australian suppliers had the necessary experience with this type of system. As a result the University was more confident purchasing the ORC turbine from a manufacturer from Switzerland. There were also no market-ready chiller units available from Australian manufacturers. There are only a small number of suppliers who import these units and provide product support.

[ix] Design conditions of solar radiation level 800W/m2 at 25°C ambient.

POLICY PRIORITIES FOR SOLAR COOLING MARKET DEVELOPMENT

Despite growing demand for air conditioning products in Australia, there has not been significant penetration of solar cooling systems. The high upfront cost of systems and lack of major subsidies for them have been the main barriers to market growth. However, the low uptake has led to a general lack of awareness of the technology among consumers, government and business. This has manifested in a lack of experience with the technology among designers, installers and suppliers, which will be a significant barrier to industry expansion in the near term. To address this limited industry experience and increase awareness of the technology among consumers, government support for the development of the solar cooling industry should emphasise high-quality demonstration projects, development of standards, and training programs.

Demonstration Projects

Demonstration and research projects should be undertaken with cooperation of solar cooling companies from the more experienced European market. In this early period there should be an emphasis on designing and installing high-quality systems with extensive performance monitoring. This process has begun slowly over the last 6 years- most of the projects that have been installed in this time have been financed through government support. The systems at Charlestown Square Shopping Centre and the University of Technology, Sydney, show the value of demonstration projects as case studies for industry learning.

Development of new standards

The solar thermal industry standard AS/NZS 4234 has demonstrated the potential effectiveness of standards for driving improvements in system performance for a developing industry. The process of developing solar cooling standards is already underway. A new standard, currently titled DR AS 5389: 'Solar cooling and heating systems –Calculation of energy consumption', has been under development by the Australian Standards committee CS-28 since June 2011. A draft version is expected for release in mid-2013, with an extended two-year public comment period. Over this period the standard will be revised based on international developments and feedback from local industry experience.

The scope of the standard is limited to desiccant wheel technology, which can be incorporated in to air cooling, air heating, and domestic hot water systems. It has been written in a way to allow additional technologies, such as absorption and adsorption chillers, to be added at a future stage. While the system size is not limited in the standard, it is focused on domestic-scale systems. The reason for this limited scope was due to the large number of possible technologies and a limited timeframe for the standard development.

The new standard will also use the TRNSYS simulation software package (9). The performance calculation approach is based on Component Testing System Simulation (CTSS), which means that the major components of a complete system are performance-tested individually, under pre-specified conditions. A rating for a complete system can then be calculated by simulating the interaction between the individual components, using the methods outlined in the standard.

This calculation method will allow many system design parameters to be simulated from the same test data. For example, if the components of a particular system have already been tested, modifications such as increasing the size of the collector field will not require additional physical testing. The draft standard includes a document explaining the simulation method and an example TRNSYS simulation studio file.

Standards such as AS 5389 will play a vital role in developing the solar cooling industry through the following mechanisms:

- Highlighting design simplifications and improvements for future projects.
- Increasing industry and consumer confidence, which should promote long-term investments in research and development.
- Identifying which products, designs and components are most suitable for use in the Australian market.

Additional standards for component and system design and construction will also be required. The International Energy Agency's "Solar Heating and Cooling Programme: Task 48 Quality Assurance and Support Measures for Solar Cooling Systems" (12) is a mechanism that is available to Australian organisations, for sharing experience gained from around the world in the development of these standards. This is important as there is limited experience in solar cooling standards globally, and continual the improvement of these documents will be required as the industry grows.

Training programs for new technologies

Training programs such as Sustainability Victoria's *Green Plumbers* (2) program, are required to foster the skills required to safely install and maintain these systems. Training programs will also be important for capturing and disseminating the knowledge gained through demonstration systems, and for implementing newly developed standards.

CONCLUSIONS

Australia's solar thermal industry has seen healthy growth over the last 13 years. Demand has being concentrated in domestic solar hot water systems. The industry growth that has occurred, was made possible by both government financial incentives to reduce the upfront cost of systems, and the development of standards that improved the quality and safety of systems, and laid the foundations for long-term improvements in design and performance.

The solar PV and solar hot water industries have experienced sustainable long-term growth in Australia due to policies that have emphasised the use of standards and certification for quality and safety. Unfortunately, this focus has also created a barrier to entry for new innovative products such as PV-T, concentrating collectors, and concentrating PV-T find it very difficult if not impossible to obtain accreditation. These barriers can be resolved by renewing the industry's focus on developing new standards, and through better collaboration with government regulators to adapt existing incentives to accommodate new technologies.

The solar cooling industry needs to follow a similar path in quality assurance and market development. Australia is leading this charge with the development of a solar heating and cooling performance assessment standard, which will lay the framework for a performance-oriented solar cooling industry. The Australian solar cooling industry is currently very small, with project experience limited to a handful of government-financed, commercial-scale systems. Through the installation of these eight systems, many lessons have been already been learnt and will be built upon through the construction of the three new systems planned for 2013. As the number of systems increases and standards continue to be developed, consumer awareness and financial support for solar cooling systems must also be increased so that a viable import or manufacturing industry in solar cooling technologies develops in Australia.

ACKNOWLEDGEMENT

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REFERENCES

1. **ABS.** *Environmental Issues: Energy Use and Conservation,.* s.l. : Australian Bureau of Statistics, Mar 2011.

2. *Learning from interventions aimed at mainstreaming solar hot water in the Australian market* . **Ferrari, David.** San Francisco : Elsevier Energy Procedia, 2012. SHC 2012. pp. 1401 – 1410 .

3. **Sustainability Victoria.** *internal recording keeping.* 2013.

4. **CEC.** *Solar Hot Water & Heat Pump Study.* s.l. : Clean Energy Council , 2011.

5. **Weiss, Werner and Mauthner, Franz.** *Solar Heat Worldwide* . s.l. : International Energy Agency - Solar Heating and Cooling Programme, 2012.

6. **SUSTAINABLE ENERGY DEVELOPMENT AUTHORITY OF NSW (SEDA).** *03–04 ANNUAL REPORT.* Sydney : SEDA, 2004.

7. **Standards Australia.** *AS/NZS 4234:2008 Heated Water Systems - Calcuation of energy consumption.* s.l. : SAI Global, 2008.

8. **Building Commission.** 6 Star for new homes, home renovations, alterations, additions and relocations. [Online] 2011. [Cited: 2013 03 27.] http://www.buildingcommission.com.au/resources/documents/6Star_consumer_brochure_(web)2.pdf.

9. **University of Wisconsin Madison.** TRNSYS. [Online] 2013. http://sel.me.wisc.edu/trnsys/index.html.

10. **NSW Government.** Renewable Energy Development Program. *NSW Government Environment and Heritage.* [Online] 14 November 2012. [Cited: 27 March 2013.] http://www.environment.nsw.gov.au/grants/ccfred.htm.

11. **NEP Solar.** Personal communication. 2013.

12. **International Energy Agency.** Quality Assurance & Support Measures for Solar Cooling Systems. [Online] [Cited: 03 27 2013.] http://task48.iea-shc.org/.

13. **Standards Australia.** *AS/NZS 2712:2007 Solar and heat pump water heaters - Design and construction.* s.l. : SAI Global, 2007.

14. **International Organization for Standardization (ISO).** *Test methods for solar collectors -- Part 3: Thermal performance of unglazed liquid heating collectors* . s.l. : ISO, 1995. ISO 9806-3:1995.

15. **European Committee for Standardization (CEN).** *Thermal Solar Systems And Components - Solar Collectors.* s.l. : CEN, 2006. EN 12975:2006.

16. **Clean Energy Regulator.** About the Renewable Energy Target. [Online] April 2012. [Cited: 27 03 2013.] http://ret.cleanenergyregulator.gov.au/ArticleDocuments/205/About%20the%20RET%20booklet.pdf.aspx.