SOLAR HEATING AND COOLING IN AUSTRALIA'S BUILT ENVIRONMENT – AN INDUSTRY ROADMAP

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Abstract

The Australian market is simultaneously small and large – 24 million residents live in a country the size of the USA. It has the highest average solar radiation per square metre of any continent in the world. Despite this, solar energy use in 2014-15 represented 0.6 per cent of Australia's total primary energy consumption and 2.4% of electricity production. The energy used by buildings represents about 20% of total energy consumption in Australia, contributing about 26% of national (anthropogenic) greenhouse emissions. Of that energy, on average 40% are used for space conditioning and domestic hot water. This paper will discuss Australia's market for heating and cooling, and how solar heating and cooling (SHC) can be used in Australia's built environment to augment, replace or improve existing heating and cooling technology solutions. Specific opportunities for improving the market uptake of SHC technologies have been identified in the context of declining political appetite for subsidies.

Keywords: solar heating, solar cooling, regulatory, roadmap

1. Introduction

Australia is in a globally unique position. Most of its landmass boasts an annual average solar radiation of more than 19 MJ/m2 per day, overall 58 million petajoules (PJ) per year, nearly 10,000 times the national annual energy consumption. High energy prices, low PV module and inverter costs over recent years in conjunction with a highly competitive market resulted in the highest penetration of household scale distributed solar PV in the world (Australian Energy Council, 2016) with 23.2% of all households owning home solar electric panels (Roy Morgan, 2017). This contrasts with the weakening growth of rooftop solar thermal domestic hot water systems, installed in 10.29% of Australian households (Australian Bureau of Statistics, 2017; Clean Energy Council, 2017).

Despite local R&D and commercialisation of solar thermal hot water systems dating back to 1950s, installations of larger-scale solar thermal systems, both for heating and cooling, continue to be elusive. Unique national market conditions, a changed legislative situation as well as an uncertain political climate has stunted possible market growth in the recent past. This situation is further exacerbated by Australia's range of local conditions - climate zones ranging from temperate to equatorial and arid to tropically humid provide for special challenges. No single solution fits all requirements.

Rising gas and electricity prices have caused stress on the operating budget of various built environment sectors. Solar generated thermal energy is well suited to replace a large extent of fossil fuel based thermal energy used in various built environment applications. Technically mature solar energy solutions are available for delivering thermal energy in the built environment These solutions provide a viable path forward to minimise both energy use and related cost in the built environment.

In this context, we analyse the current SHC market situation in Australia, discuss market barriers for growth and provide suggestions for market-suitable SHC installation types in the built environment. We then advance recommendations for regulatory support measures, financial market stimulation, research and development activities, pilot projects, skills training for trade and consultants and market education. The motivation for this work is to outline a roadmap for the SHC industry to grow and deliver on positive energy and greenhouse gas emissions outcomes for Australia.

2. The Australian Market

The built environment is one of the largest consumers of energy in Australia. While energy use per household has been steadily decreasing since the early 2000s (Coleman, 2017), the overall residential sector energy consumption increased from 402 PJ in 2008 to 441.1 PJ in 2017 (DEWHA, 2008). A key driver is the growth of occupied residential households and the increasing size of these households. Household numbers increased 6.06 million in 1990 to 9.4 million in 2017, an increase of 55% (DEWHA, 2008). Over the same period, total residential floor area rose from 685 million square metres to 1,564 million square metres, an increase of 128% (DEWHA, 2008).

In comparison, total commercial building energy consumption in Australia grew from 134.6 PJ in 2009 to 159.4 PJ in 2017, a growth of 18.4% principally due to 16% growth in commercial building stock from 135,726,000 m^2 in 2009 to 157,376,000 m^2 in 2020 (Pitt&Sherry, 2012).

In Australia, space conditioning represents the single largest energy user in both the residential and commercial building environment, closely followed by domestic hot water generation (Lecamwasam et al, 2012). In some building types, thermal end use of energy can be even more significant. For example, in hospitals natural gas usage is nearly 50% of total annual energy use, predominantly used for space heating and water heating requirements (Pitt&Sherry, 2012).

Still, the trend of energy use in Australia was more differentiated in the recent past. While overall energy consumption rose, per building energy use in the residential sector declined. Nevertheless, for all buildings the cost of energy increased disproportionally to its use. In the residential sector, per-household consumption of gas grew by only 5.7% from 2008 to 2013, but its expenditure grew by 64% (Coleman, 2017). Similarly, per-household electricity consumption declined by 4.7% and its expenditure grew by 69.3% from 2008 to 2013 (Coleman, 2017). The cost development in the commercial building sector was comparable (Pitt&Sherry, 2012).

From the generation perspective, solar thermal and PV installers have been adding capacities targeting applications in the built environment. The solar PV market grew by 7% in 2016, with small-scale (< 10 kWe) solar PV rooftop systems making up more than 90% of the national installed solar PV generation capacity (Clean Energy Regulator, 2017; Australian PV Institute, 2017). In 2016 the average size of new installed small-scale solar PV rooftop generation surpassed 6 kWe (Australian Energy Council, 2017). Overall, there is more than 5 GW installed Solar PV capacity under the 10 kWe range and 800 MW in the 10 to 100 kWe range.

The domestic Australian solar thermal market also predominantly consists of rooftop solar hot water systems. Spurred by federal and some state subsidies for the installation of solar hot water systems and the national phase-out of electric resistance hot water systems, growth in the solar thermal market was strong through 2010. Despite the marginal growth in installed base, new installations for the domestic solar thermal market declined by more than 60% and continue to shrink (Clean Energy Council, 2017). With an average installed market price of A$4,500, the Australian 2016 rooftop solar hot water market was just under A$223 million p.a. (Table 1 provides annual market figures from Clean Energy Council, 2017).

Table 1: Annual Installations of Solar Hot Water Heaters (Clean Energy Council, 2017)

Year	ACT	NSW	NT	QLD	SA	TAS	VIC	WA	Nat'l	Installed Base
2006										**161,446**
2007	453	8,765	1,414	16,830	2,869	350	9,157	11,139	50,977	**212,423**
2008	1,001	20,203	1,236	23,330	5,103	906	21,208	12,398	85,385	**297,808**
2009	1,974	85,456	1,731	36,659	8,794	2,269	42,120	15,692	194,695	**492,503**
2010	960	38,525	1,303	34,262	6,812	1,433	27,733	16,065	127,093	**619,596**
2011	1,038	25,331	1,267	30,937	5,444	1,725	26,446	12,862	105,050	**724,646**
2012	734	10,810	1,171	18,973	3,473	899	21,594	11,812	69,466	**794,112**
2013	453	9,145	884	13,410	2,983	827	19,608	10,989	58,299	**852,411**
2014	451	9,641	1,026	13,433	1,930	962	20,613	10,672	58,728	**911,139**
2015	572	8,609	1,063	11,799	2,557	803	23,019	10,205	58,627	**969,766**
2016	497	6,963	660	9,793	1,914	822	20,514	8,390	49,553	**1,019,319**

Commercial scale solar hot water systems data (available through clean energy regulator) presents a grim picture. Studies commissioned by the Clean Energy Regulator (CER) indicate the number of Small Scale Technology certificates (STC) created for commercial hot water systems is expected to drop from 131,000 in 2016 to 34,000 in 2019 (Parisot, 2017).

Solar thermal cooling is still a niche in Australian built environment, counting less than 20 active installations. With very few exceptions, these installations are demonstration plants, research and development systems or proof-of-concept installations. Despite the more common use of solar thermal air heating in colder climatic conditions (e.g. North America), space heating with solar thermal collectors has not taken off in Australia, likely due to moderate day time temperature in many parts of the country and lack of market awareness of its benefits.

Large-scale solar thermal systems servicing hot water, heating and cooling needs of a commercial built environment application are very few. Discounting the demonstration projects in this space, Table 2 shows typical examples of operational solar assisted heating, cooling and hot water delivery systems operational in Australia.

Table 2: Representative Solar Heating and Cooling projects

Type of installation	Location	Typical system details	Operational since
Hot water / space heating	University building, Australian National University, Canberra, ACT	392 m2 collector area (140 evacuated tube collectors)	2012
Hot water / space heating / boiler preheat	Monash University, Clayton, VIC	1 MWth collector area (evacuated tube collectors)	2017
Space cooling / hot water	Hospital building – Echuca Regional Hospital, VIC	406 m2 collector area (evacuated tube collectors), 500 kWth single stage absorption chiller	2011
Space heating & cooling / hot water	Educational building – Hamilton, NSW	400 m2 collector area (flat plate collectors)	2013

Use of solar electricity for partially meeting the heating, cooling and hot water needs of residential and commercial buildings is achieved through grid connected solar PV installations. However, these systems are not directly coupled to thermal energy use in the buildings. Theoretical studies of using PV integrated air conditioning systems for Australian climates have been explored, but there are no known demonstration systems that are designed specifically meet the thermal energy needs of a building.

Market Development

The key drivers for continued heating and cooling demand in Australia are overall population and economic growth. Since 2000, Australia's population grew between 1% and 2% annually (Australian Bureau of Statistics, 2017a). Similarly, national GDP growth was always positive and mostly above 2% p.a. in the same timeframe (Reserve Bank of Australia, 2017). With positive economic outlook, this growth is expected to continue. As a result, the overall residential sector energy consumption is forecast to increase to 467 PJ in 2020, the number of occupied households is expected to increase to almost 10 million and aggregate residential floor space to rise to 1,682 million square metres by 2020 (DEWHA 2008). Total commercial building energy consumption is forecast to grow to 169.6 PJ, a growth principally due to an increase in commercial building stock to 165,970,000 square metres in 2020 (Pitt&Sherry, 2012). In both residential and commercial sectors, energy cost is expected to continue to rise disproportionally, outpacing energy use growth significantly (Letts, 2017; Potter and Tillett, 2017; Mountain and Gassem, 2017).

Escalating energy costs will likely continue to be the main driver for end users adopting onsite energy generation options. Declining solar PV system costs will further drive growth in the solar rooftop PV market in Australia. Solar thermal rooftop hot water will face growing competition from alternative technologies.

Heating and Cooling Requirements

Heating and Cooling requirements are substantially different based on building use and the local climate zone of the building. In general, Australian building occupants have a high tolerance for cool buildings in winter and little tolerance for warm buildings in summer. Historically, Australian residential buildings have little insulation and building envelopes that are not air-tight. Minimum energy efficiency standards have been part of the NCC since 2006 and are mandatory for new buildings. Nevertheless, a large proportion of residential and mid-tier commercial building stock uses significant energy for active heating and cooling to reach appropriate occupancy comfort levels. Even new buildings on average have only minimum legally required energy efficiency features, making a functional active heating and cooling system essential for some level of thermal comfort.

The Australian Standard AS5389-2016 *Solar heating and cooling systems— Calculation of energy consumption* nominates 6 climate zones with locations of similar climatic characteristics for the purposes of evaluating the annual energy performance of solar water heaters. Using the modelling from DEWHA, 2008, we derived a representative heating and cooling load range for each zone; the definitions are shown in **Error! Reference source not found.**.

Table 3: Australian Climate Zones, comfort space conditioning requirements and representative annual residential heating/cooling loads (for NatHERS 3 to 5 star buildings estimated per DEWHA, 2008)

Climate Zone	Space Conditioning Requirements	Representative Heating Load (MJ/m2)	Representative Cooling Load (MJ/m2)
SC1: Warm humid summer, mild winter	Little heating requirements, cooling requirements for 3 to 6 months per year.	20 - 40	150 - 300

SC2:	**Hot dry summer, warm winter**	Heating requirements for 1 to 2 months, cooling requirements for 3 to 6 months per year.	50 - 150	150 - 300
SC3:	**Warm temperate**	Heating requirements for 1 to 2 months, cooling requirements for 1 to 2 months per year.	50 - 180	45 - 150
SC4:	**Mild temperate**	Heating requirements for 3 to 5 months, cooling requirements for 1 to 2 months per year.	280 - 360	30 - 50
SC5:	**Cool temperate to Alpine climate**	Predominant heating requirements, with heating needs for 8+ months per year.	450 - 570	15 - 40
SC6:	**High humidity summer, warm winter**	Predominant cooling requirements for most of the year.	0	400 - 570

Note that climate zone SC6 and SC1 have monsoonal weather patterns, with notable overcast and precipitation during the summer months. For climate zones SC1, SC3 and SC6 the average annual latent load is significantly higher than in the other climate zones. Figure 1 depicts the distribution of the climate zones in Australia.

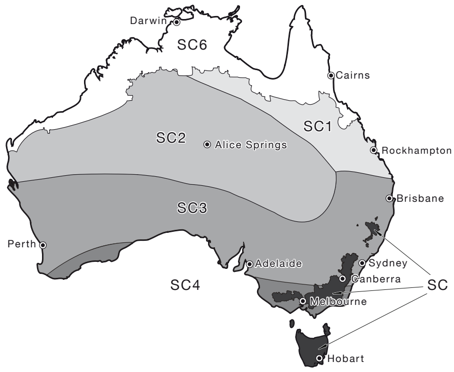

Figure 1: Climate Zones in Australia as per AS5389-2016

Regulatory and other support measures

In line with other countries, Australia introduced several measures to make renewable energy use more affordable. These include state-by-state feed-in tariffs with a subsidised fixed rate for all small-scale renewable energy producers based on the energy fed back to the grid from sources such as solar or wind. All attractive state feed-in tariffs for new installations have been discontinued between 2011 and 2015. There is no current nationalised feed-in tariff, prompting consumers to self-consume onsite generated power.

The federal government also introduced a solar rebate scheme to encourage installation of these systems. The **Renewable Energy Target (RET)** is national government scheme designed to reduce emissions of greenhouse gases in the electricity sector and encourage additional generation of electricity from sustainable and renewable sources. It provides both large-scale generation certificates (LGC) for large-scale power stations and **small-scale technology certificates (STC)** for owners of small-scale systems. Certificates are then purchased by electricity retailers and submitted to the CER to meet the retailers' legal obligations under the Renewable Energy Target. Small-scale technology certificates are created based on the estimated amount of electricity a system produces or replaces (that is, electricity from non-renewable sources) over the life of the renewable energy system.

The **Clean Energy Finance Corporation (CEFC)** is a statutory authority established by the Australian Government under the Clean Energy Finance Corporation Act 2012. It acts as a specialist clean energy financier, investing with commercial rigour to increase the flow of finance into renewable energy, energy efficiency and low emissions technologies. Its investment portfolio ranges from large-scale solar and wind farms to technology-specific research and development activities.

Additionally, there are several national and state programs that encourage energy efficiency in buildings. None of them explicitly nominate the use of renewable energy solutions, but onsite renewable energy generation is an accepted tool to help in improving energy efficiency as per these programs.

On a federal level, the **National Construction Code (NCC) Volume 1, Section J** defines energy efficiency requirements for commercial buildings (class 3 to 9). While it is a national code, it is individually modified and enforced by state law. Section J and the remainder of the NCC mention solar and other renewable energy generation systems only in passing and do not mandate their use. The **National House Energy Ratings Scheme (NatHERS)** is aimed at promoting energy efficiency in residential buildings. A software tool uses defined building characteristics (i.e. climate zone, orientation, building materials etc.) to estimate its annual energy use. Under NCC energy efficiency provisions, every new home or renovation needs to have at least a 6-star NatHERS rating.

The **National Australian Built Environment Rating System (NABERS)** is a national rating system that measures the environmental performance of Australian commercial buildings and tenancies. It rates buildings according to their measured operational performance over the preceding year pertaining to energy and water use, waste handling and indoor environment. Research suggests that offices with high NABERS Energy ratings tend to offer higher investment returns, whilst offices with low NABERS Energy ratings tend to offer lower investment returns (Slow, 2013).

Relying very much on NABERS is the 2010 **Building Energy Efficiency Disclosure (BEED)** Act, which requires anyone selling or leasing office buildings or space greater than 1,000 m2 to obtain a Building Energy Efficiency Certificate (BEEC). BEECs are only valid for 12 months and include a NABERS Energy for offices star rating. The program, called **Commercial Building Disclosure (CBD)**, aims to improve the energy efficiency of Australia's large office buildings and to ensure prospective buyers and tenants are informed. Since inception, more than 72% of the Australian national office market has received an energy rating (McMahon, 2016). Buildings with at least two consecutive NABERS Energy ratings, demonstrated an average reduction in energy use of 8.7% and a reduction in greenhouse gas emissions of 11.5% (Ernst & Young, 2015). A similar program for the federal government is the **Energy Efficiency in Government Operations (EEGO)** Policy, which aims to reduce the energy consumption of government operations with emphasis on building energy efficiency. EEGO mandates the use of Green Lease Schedules (GLS) to form part of lease documentation (or MOUs where the Government owns the building). GLS are designed to ensure that buildings are operated at the required level of energy efficiency, including a required minimum 4.5 stars NABERS Energy for Based Building rating. Contractual language in the GLS is usually coached in “best effort” terms, with little recourse for the tenant in case of a breach of the energy efficiency terms. All state governments in Australia except for Tasmania have similar requirements, at minimum 4.5 stars NABERS Energy for offices rating for all new buildings and fitouts and at minimum 3.5 stars for existing buildings and fitouts.

In addition, some states and municipal governments provide local incentives and funding schemes to drive building energy efficiency and the use of renewable energies. Amongst these are Environmental Upgrade Agreements (EUAs) in New South Wales and in Melbourne – called 1,200 Buildings in Victoria, the Energy Savings Scheme in New South Wales, Victorian Energy Upgrade, ACTSmart Business Energy and Water Program in Canberra, Energy Savers in Queensland and the South Australian Energy Productivity Program. Furthermore, most state electricity utilities have programs with funding for provable peak demand reduction projects, demand management projects and renewable energy buyback schemes. The extent and funding depth varies with each project; Energex offers up to $185 per kW peak demand savings in select supply areas (Energex, 2017).

Outside of government measures, the Green Building Council of Australia (GBCA) manages the **Green Star** rating system, a voluntary sustainability rating system for buildings in Australia. It assesses the sustainability of building projects at all stages of the life cycle. Ratings can be achieved in the planning phase for communities, during design, construction or fit out of buildings, or during the ongoing operational phase and range from one star (minimum practice) to three star (good practice) and six star (world leadership). Energy-efficiency outcomes for Green Star rated buildings are good with 66% less electricity use and 62% fewer greenhouse gas emissions than average Australian buildings (Green Building Council of Australia, 2013), the rated buildings tend to be Premium and Grade A buildings (Ernst & Young, 2015), with limited investment going to the mid-tier market. This market makes up more 50% of the Australian commercial office stock (Ernst & Young, 2015) and is typically comprised predominantly of smaller buildings, often better suited for solar energy use due to a larger proportion of roof space to lettable floor space.

AS5389-2016 (draft) is another initiative to encourage adoption of solar heating and cooling systems in buildings. This draft standard provides an approach for estimating energy consumption of solar heating and cooling systems for receiving government support such as STCs.

Australia ratified the Paris climate agreement committing to achieve 26–28% reduction in greenhouse gas emissions below 2005 levels by 2030. CSIRO’s low emissions technology roadmap advocates fuel switching as one of the options to achieve deep cuts in emissions from the built environment that can help in achieving the 2030 emission reduction targets. In the context of the RET being phased out by 2030, an alternate policy landscape to specifically encourage renewable energy use in the built environment is unclear.

3. Market Barriers / Challenges

The authors of this paper interviewed various stakeholders related to the use of solar heating and cooling technologies in the built environment. This included representatives from the building industry, solar equipment manufacturers, HVAC contractors, consultants and entities dealing with regulatory bodies. A summary of findings from these discussions are provided below.

Initial Cost

Due to Australia's small market size, local production of complex solar heating and cooling components is limited. Importing such equipment results in a relatively large logistics costs due to the distance from the manufacturing countries. This is further exacerbated by limited experience of consulting engineers, contractors and installers with new, custom designed SHC installations. To mitigate potential risks, these projects are often quoted with high risk margins that make them financially nonviable.

A necessary optimisation or retrofit of a heating or cooling delivery system is often fruitful ground for the introduction of renewable energy systems. While a suitable SHC application with attractive payback periods might be a good fit, consultants and system designers often lack the required knowledge and resources (e.g. a design and optimisation tool) to help them identify such introduction opportunities.

Stakeholders are often not aware of appropriate local, regional or federal energy efficiency programs as outlined above. Bureaucratic hurdles to participate in these programs can also be too onerous for the program to be useful, resulting in unused funds which could offset some of the high initial costs.

Lack of awareness of benefits & unrealistic expectations

While there is strong general interest in renewable energy technologies, most of the stakeholders including architects, engineers and building owners do not have sufficient information on capabilities and benefits of solar generated thermal energy and its use in the built environment. Consequently, SHC solutions are either not considered for a project, or poorly planned and designed. These badly designed and commissioned systems bring a negative reputation to the technology, further limiting market growth.

Unrealistic expectations also bring negative reputation to the technology. These expectations range from an expected payback of less than two years, delivery of complete comfort during all periods of the day to maintenance free operation and more. Oftentimes the end-users would not have had similar expectations on the incumbent technology and may be more forgiving for any performance deficiencies of the incumbent technology.

Inexperienced and untrained consultants and trade

SHC systems are not covered in the standard training repertoire of architects, engineers and installers. As a result, a commercial building may be designed such that any inclusion of SHC technologies may result in expensive variations or site preparation costs. This is compounded by the limited number of component suppliers and installers.

Consultant fee models are often predicated on providing standard systems design with only small variations. The business model does not allow for providing a bespoke solution capable of leveraging SHC technology for the best outcome. In addition, most engineers and installers are unsure of the correct use of the technology and inflate the costing of the project to tackle "unknown" risks.

Technical and financial risks

Project owners are often worried about the risks associated with SHC technology installations. These risks can be related to performance, maintenance or the commercial benefits. Negative risk perception is fueled by the lack of suitable local reference installations and access to historical data. Badly designed and underperforming SHC deployments add to this perception. Finally, specialized international SHC vendors often approach the Australian market with insufficient focus and funds, partnering with small, local companies for commercial representation. These small companies do not have the reliability of major vendors, resulting in real execution risk with the associated risk of losing warranty and maintenance options if such a small company were to change direction or enter liquidation.

Split Incentives

Not unique to solar generated thermal energy systems, split incentives are a barrier to the high initial deployment cost of any energy efficiency measures in buildings. So far, the additional capital cost of an SHC installation is not always offset by a commensurate increase in sales or lease price. The tenant or final building operator would reap the rewards of the efficiency measure and the entity making the capital investment would have foregone possible higher profits. Given the higher initial cost of SHC systems, split incentives result in landlords often not not motivated to install such systems in their buildings.

Alternative Technology advancements

New technology innovations disrupt the current technology development and diminish the unique benefits provided by solar thermal heating and cooling solutions. An example is the slowdown in the rooftop solar thermal market due to the decline of PV prices. In residential applications, home owners often prefer a single solar energy collection technology meeting their energy needs rather than dealing with two sets of system installers and technologies. The potentially higher installation cost (labour) of a solar thermal system could be the further differentiator between the installed cost of a solar PV system and a solar thermal system. More disruption potential can be expected from the maturing of electrical storage (so that it becomes competitive with thermal storage) and a potential reduction in price of high efficiency heat pump systems.

4. Opportunities

Solar thermal generated energy for active use in the built environment is available in several forms:

- Solar Thermal driven Absorption/Adsorption Chillers – using heat from solar thermal collectors (flat plate, evacuated tube, concentrating) to drive absorption chillers (LiBr/Water, NH_3/Water, Zeolite/Water, Silica Gel/Water etc.)
- Solar Thermal driven Desiccant Chillers – using heat from solar thermal collectors (flat plate, evacuated tube, concentrating) to drive desiccant chillers (solid or liquid)
- Solar Thermal Heating Hot Water and/or Domestic Hot Water – using heat from solar thermal collectors (flat plate, evacuated tube, concentrating) to generate hot water, either for heating hot water (HHW) or for domestic hot water (DHW)
- Solar PV assisted high-efficiency chillers – using electricity generated from solar PV to drive high-efficiency chillers
- Solar PV assisted high-efficiency heat pump – using electricity generated from solar PV to drive high-efficiency heat pumps to generate HHW or DHW

Ongoing research has been conducted into the cost comparison of solar thermal, solar PV assisted thermal energy generation and conventional heating and cooling. The more rapid change in PV pricing as compared to the components of solar thermal cooling systems make PV-assisted cooling systems increasingly viable alternatives to solar thermal cooling and substantially improve the financials of a deployed system (Otanicar et al, 2012; Kohlenbach and Dennis, 2010; Greenaway and Kohlenbach, 2016). As current representative residential electricity prices continue increasing, the financial performance and ROI of both solar thermal and solar PV-assisted cooling systems will also become more attractive.

Small-scale solar thermal HHW and DHW systems compare well financially to gas or standard heat-pump systems. Solar PV-assisted high-efficiency heat pumps (Mayekawa, 2017; Sanden, 2017) provide a very competitive alternative for HHW and DHW systems, even for medium-sized HHW and DHW requirements. In medium-sized and larger deployments, solar thermal HHW and DHW systems are also financially attractive (Witts, 2017).

Not all situations provide a good fit for solar thermal generated energy. Smaller-scale deployments result in a disproportionately expensive solar thermal driven cooling system. For cooling needs of 20 kWth or less and standard residential or commercial office requirements, there are few criteria to make such a system cost-competitive with a small-scale split system air conditioner or a solar PV-assisted split system air conditioner.

Beyond the need for sufficient annual solar radiation, the essential criteria for the fit of solar generated thermal energy to a buildings heating and cooling needs are:

- Appropriately located available roof space
- Diurnal load match (more than 50% of thermal energy used should be during average daytime hours)
- Annual combined thermal needs (heating in winter, cooling in summer) or significant all-year heating or cooling needs, overall more than 200 $MJ/m^2/a$
- Combined domestic hot water and heating/cooling loads to maximise utilisation

For the purposes of this analysis, we used building classifications following those of the Australian National

Construction Code (NCC).

Table 4 summarises the findings, highlighting cost-efficient suitability for solar thermal energy use for providing heating, cooling and domestic hot water by colour; comfort tolerance was classified as the willingness of the building occupants to tolerate building temperatures marginally outside the generally accepted temperature set points of 21°C to 24°C. Green symbolises a good fit, orange an average fit and red highlights a likely bad fit.

Table 4: Australian Built Environment, space conditioning, hot water requirements and market information (estimated as per DEWHA, 2008; Pitt&Sherry, 2012; Goldsworthy and Sethuvenkatraman, 2016)

Application	Residential	School	Universities & VET	Office	Public buildings	Hotel	Restaurant	Retail: Super-market	Retail: Retail strip	Retail: Shopping centres, excl. super-market	Hospital
Typical operating hours	24 hours	9am-3pm	8am-9pm	8am-5pm	9am – 5pm	24 hours	8am-10pm / 24 hours (chain)	7am-10pm	8:30am-6pm	8:30am-6pm	24 hours
Operating days	50 - 100	200	240	240	240	365	310-360	360	310	360	365
Comfort tolerance	Low	High	Medium	Low	Low	Low	Medium	Medium	Medium	Medium	Low
Indicative capacity range	2 to 15kW	5 to 50kW	50 to 500kW	5 to 500kW	30 to 500kW	100kW to 1MW	10 to 50kW	50 to 200kW	10 to 30kW	100kW to 1MW	100kW to 1MW
Relative hot water use	High	Low	Low	Low	Low	High	High	Medium	Low	Low	High
Fresh air requirement	Low	High	High	Low	Medium	Low	High	Low	Low	Low	High
Latent load	Average	Above average	Average	Average	Average	Average	Above average	Average	Average	Average	Above average
National HVAC energy use (PJ/a)	192	0.8	5.5	27.6	1.1	8.3	NA	NA	NA	NA	9.9
HVAC energy intensity (MJ/m²/a)	115	<18	180, 440	380	300-550	690	NA	NA	NA	NA	680
Current stock size (number / '000 m2)	8,452,743 / 1,564,000	9,414 / 44,023	4,585 / 18,571	NA / 43,403	3010	4,445 / 11,787	13,987 / NA	1,891 / NA	346,704 / 22,599		1,322 / 13,984
Incumbent technology	AC, Split	AC, Split	AC, Ducted / Package, Central plant	AC, Ducted / Package, Central plant	AC, Ducted / Package, Central plant	AC, Ducted / Package, Central plant	AC, Split, Ducted / Package	AC, Ducted / Package	AC, Split, Ducted / Package		AC, Ducted / Central plant
Complexity of incumbent technology	Low	Low	Medium	Medium	Medium	Medium	Low to Medium	Medium	Low	Medium to High	High

In a country the size of Australia, climate Zones are a vital decision criteria to deploy a system using solar generated thermal energy, i.e. monsoonal high cloud cover during summer months in SC1 (and parts of SC6) is likely to result in low solar yield. Similarly, solar heat driven desiccant chillers will have limited value in SC2 because of predominantly arid summers.

Every project is different and requires specific adjustment. Nevertheless, in addition to the above essential criteria for deploying solar generated thermal energy systems in Australia we believe sizeable opportunities exist with deployments outlined in Table 5[1].

Table 5: Opportunities for deployment of solar generated thermal energy systems in the built environment in Australia

Climate Zone		Residential	School	Universities & VET	Office	Public buildings	Hotel	Restaurant	Retail	Hospital
SC1	Heat	◆◆ / ■■/ ▲▲	◆ / ▲				▲▲▲ / ◆◆◆	(▲ / ◆)[2]		◆◆◆ / ▲▲▲
	Cool	△△	△ / (◇)[3]	◇◇◇ / (△△)[4]	□□ / (△△)[4]	□□ / ◇◇ / (△△)[4]	□ / ◇ / (△△)[4]	(△)[2]	□□ / (△△)[4]	◇◇◇
SC2	Heat	◆◆ / ■■/ ▲▲	◆ / ■/ ▲	■■	■■	■■	▲▲▲ / ◆◆◆	(▲ / ◆)[2]		◆◆◆ / ▲▲▲

1 Solar generated thermal energy use in SC6 will need to be evaluated on a case-by-case basis and will likely represent marginal cases

2 Not a good diurnal load match; for worthwhile deployments, requires daytime usage.

3 Dependent on fresh air requirements and latent load

4 For smaller deployments

	Cool	△△	△	(△△)[4]	□□ / (△△)[4]	□□ / ◇◇ / (△△)[4]	□ / ◇ / (△△)[4]	(△)[2]		
SC3	Heat	◆◆ / ■■/ ▲▲	◆ / ■/ ▲	(■■)	(■■)	(■■)	▲▲▲ / ◆◆◆ / (■■)[1]	(▲ / ◆ / ■)[2]	(■■)[1]	◆◆◆ / ▲▲▲ / (■■■)[1]
	Cool	△△	△ / (◇)[3]	(◇◇◇)[1] / (△△)[4]	□□ / (△△)[4]	□□ / ◇◇ / (△△)[4]	□ / ◇ / (△△)[4]	(△)[2]	(□□) / (△△)[4]	(◇◇◇)[1]
SC4	Heat	◆◆ / ■■/ ▲▲	◆ / ■/ ▲	■■■	(■■■)	■■■	▲▲▲ / ◆◆◆ / ■■■	(▲ / ◆ / ■)[2]	■■	◆◆◆ / ▲▲▲ / ■■■
	Cool	△△	△	(△△)[4]	(△△)[4]	(△△)[4]	(△△)[4]	(△)[2, 4]		
SC5	Heat	◆◆ / ■■	◆ / ■■	■■	(■■)	■■	◆◆ / ■■	(◆ / ■)[2]	■■	◆◆ / ■■
	Cool			□ / △						□
SC6	Heat	◆◆ / ■■/ ▲▲	◆ / ■/ ▲				▲▲▲ / ◆◆◆	(▲ / ◆)[2]		◆◆◆ / ▲▲▲
	Cool	△△	△ / (◇)[3]	◇◇◇ / (△△)[4]	(△△)[4]	(△△)[4]	(△△)[4]	(△)[2,4]	□□ / (△△)[4]	◇◇

▲: Solar Domestic Hot Water - solar PV, high efficiency heat pump, tank, optionally with reverse cycle air conditioner for space heating

◆: Solar Domestic Hot Water - solar thermal collectors, tank

■: Solar Heating and Domestic Hot Water - solar thermal collectors, tank

□: Solar Thermal Cooling AB - solar thermal collectors, tank, thermal (absorption, adsorption) chiller

◇: Solar Thermal Cooling DES - solar thermal collectors, tank, desiccant systems

△: Solar PV Cooling - solar PV, high efficiency vapour compression chiller

As solar energy is an intermittent energy source, backup and possibly storage will be needed to guarantee the intended service during all periods of the day in a year.

5. Recommendations

To address the market barriers and enable local and international heating and cooling industry to better address the Australian market, we recommend a three-pronged approach:

Regulate	Support	Inform
Standardisation / Best Practice design – extend AS5389	Environment Upgrade Agreements (EUA)	Training/Knowledge dissemination
	On-Bill Finance	Pilot projects
	Energy Performance Contracts (EPCs) / Energy Services Companies (ESCOs)	

Regulate - Standardisation / Best Practice design

We recommend a project for documenting global best practice for a modular design of a solar thermal heating/cooling system for use in Australia. It needs to provide for options for different collector technologies (flat plate, evacuated tube, concentrating), optional different chiller technologies (absorption / adsorption / desiccant / none), optional HHW and optional DHW systems. Integration into existing systems also needs to be addressed (i.e. utilising existing air handling units, providing boiler pre-heat etc.). Standardisation of solar thermal system design for a given application has the potential to address many of the barriers discussed above:

- Has the potential to lower the initial cost of the system by reducing the design and installation time.
- Increases confidence of various stakeholders in the value chain to move ahead with implementing solar thermal projects.
- Supports the development of components and equipment associated with the technology and helps in improving the availability of local components rather than importing.

This activity must be firmly supported by regulatory means that help in estimation of energy savings from the standardized designs. Extension of AS5389 to incorporate various solar heating and cooling technologies is one typical example. Additionally, efforts should be directed towards developing best practice design documents that can be used by installers (e.g. Master Plumbers' and Mechanical Services Association of Australia and Sustainability Victoria, 2009)

Support

We believe there are various renewable energy support mechanisms already available for large scale utilisation.

[1] For parts of climate zone as per requirements

However, some of the following approaches have been largely overlooked or not yet deployed consistently across Australia. We suggest a reinvigorated approach towards these policies.

Environmental Upgrade Agreement (EUA)

An Environmental Upgrade Agreements (EUA) is a contractual agreement between a building owner, a finance provider and a local council. The building owner agrees to undertake environmental upgrades to their building and the finance provider agrees to advance capital to the building owner to fund the works. The money is repaid to the lender through council rates. This environmental upgrade charge is collected quarterly as a line item on top of the normal council rates. Once payments are completed, the building owner owns all capital equipment covered by the agreement, i.e. it is a balance sheet item.

As such it allows a building owner to access capital at a better rate over a longer term than a conventional bank loan. EUAs also allow some of the costs of the upgrade to be shared with tenants, where the tenant also benefits from the cost saving delivered by the upgrade. Furthermore, it minimizes financial risk to the lender, as the loan is attached to the land/property.

EUAs are currently only available in Victoria (Department of Energy, Land, Water and Planning, 2015) and New South Wales (Office of Environment & Heritage, 2016). Extending these agreements and consolidating their contractual structure, commercial and technical prerequisites based on the above best practice design would remove financial risk and at least partially address the problem of split incentives for retrofits of buildings.

Support - On-Bill Finance

On-bill financing is an alternative way of obtaining access to capital to fund building energy efficiency upgrades, where repayments are made through an electricity utility as part of the energy bill. The energy utility will typically aim to make the monthly payments equal to or less than the energy savings achieved through the upgrade works. Here as well, building owners can access capital at a better rate over a longer term than a conventional bank loan and costs can be shared with tenants, lowering financial risk and mitigating split incentives. In Australia, On-bill financing is currently offered by AGL and Origin Energy for medium to large customers only (Office of Environment & Heritage, 2016a). On completion of payments, the building owner owns all capital equipment covered by the contract, i.e. it is a balance sheet item. We recommend extending standard demand-management practices of all electricity utilities to include on-bill financing for solar generated thermal energy projects, adhering to the above standards and leveraging the best practice design to mitigate technical risk.

Support - Energy Performance Contracts (EPCs) / Energy Services Companies (ESCOs)

Already established in Australia, Energy Performance Contracting (EPC) is when an Energy Service Company (ESCO) is engaged to improve the energy efficiency of a facility, with the guaranteed energy savings paying for the capital investment required to implement improvements. Under a performance contract for energy saving, the ESCO implements and operates the project and guarantees cost savings over an agreed term, lowering financial and technical risk. We recommend working with reputable national and international ESCOs to extend their offering to include solar generated thermal energy projects in Australia, leveraging EUAs, On-bill Financing and the best practice design. Quick wins could be had by integrating an ESCO-operated solar thermal component into a district cooling system such as the CitySmart Brisbane project.

Inform - Training/Knowledge dissemination

Solar generated thermal heating and cooling technology and the relevant design and installation criteria need to be integrated into the standard University and Vocational Education and Training (VET) curriculum for architects, engineers and trades. To this end, the best practice design document needs to become part of the respective curricula and a continued professional development training program needs to be instituted in close cooperation with the relevant industry bodies (Australian Institute of Architects, Australian Institute of Refrigeration, Air Conditioning and Heating). Once implemented, it will reduce technical risk and facilitate that solar generated thermal heating and cooling systems can be designed, built, commissioned and operated by anyone in the industry.

Inform – Pilot Projects

Australia is not home to any commercial large-scale solar thermal cooling projects. We recommend using the outlined Regulate, Support and Inform recommendations to initiate showcase commercial solar generated thermal energy projects with the CEFC acting as a cornerstone investor working with proven national or international industry operators with appropriate and demonstrated experience. This includes adding solar thermal generated thermal energy options to district level heating/cooling infrastructure in early or late planning stages, such as the district cooling system to service downtown Brisbane (Citysmart, 2016).

We believe that if acted upon soon, these recommendations will enable Australia to build a thriving local market for solar generated thermal energy systems, saving energy, greenhouse gases and money for all stakeholders in its built environment.

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