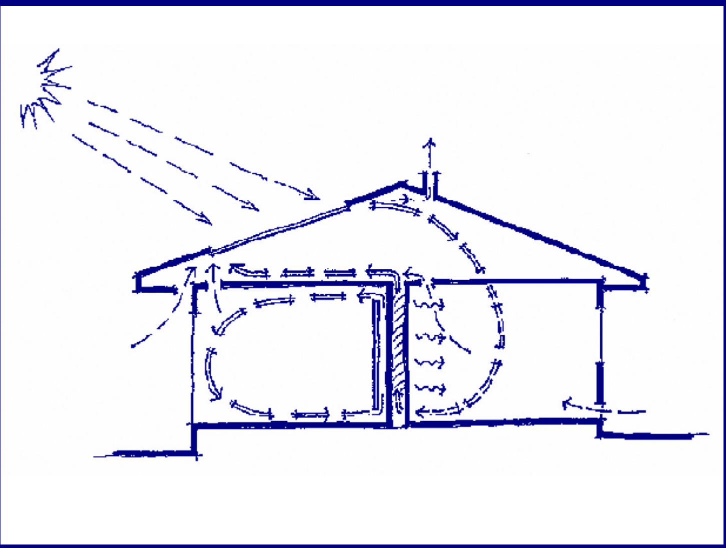
International
Specialised
Skills
Institute Inc

Australian Government
Department of Education, Science and Training

SOLAR AIR HEATING AND COOLING



Robert Moore

ISS Institute Overseas Fellowship

Fellowship supported by the
Department of Education, Science and Training,
Commonwealth of Australia

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1. International Specialised Skills Institute (ISS Institute)

Since 1990, ISS Institute, an independent, national, innovative organisation, has provided opportunities for Australian industry and commerce, learning institutions and public authorities to gain best-in-the-world skills and experience in traditional and leading-edge technology, design, innovation and management.

ISS Institute offers a broad array of services to upgrade Australia's capabilities in areas that lead to commercial and industrial capacity and, in turn, return direct benefits to Australia's metropolitan, rural and regional businesses and communities.

Our core service lines are identifying capabilities (knowledge, skills and insights) to fill skill gaps (skill deficiencies), which are not available in accredited university or TAFE courses; acquiring those capabilities from overseas (Overseas Skills Acquisition Plan - Fellowship Program); then placing those capabilities into firms, industry and commerce, learning institutions and public authorities through the ISS Research Institute.

Skill Deficiency
This is where a demand for labour has not been recognised and where accredited courses are not available through Australian higher education institutions. This demand is met where skills and knowledge are acquired on-the-job, gleaned from published material, or from working and/or study overseas. This is the key area targeted by ISS Institute.

Overseas Skills Acquisition Plan - Fellowship Program

Importantly, fellows must pass on what they have learnt through a report and ISS Institute education and training activities and events such as workshops, lectures, seminars, forums, demonstrations, showcases and conferences. The activities place these capabilities, plus insights (attitudinal change), into the minds and hands of those that use them - trades and professional people alike - the multiplier effect.

ISS Research Institute
At ISS Institute we have significant human capital resources. We draw upon our staff, industry partners, specialists in their field and Fellows, here and around the world.

Based on our experience and acute insights gained over the past fifteen years, we have demonstrated our capabilities in identifying and filling skill deficiencies and delivering practical solutions.

Our holistic approach takes us to working across occupations and industry sectors and building bridges along the way:

- Filling skill deficiencies and skill shortages,
- Valuing the trades as equal, but different to professional disciplines,
- Using 'design' as a critical factor in all aspects of work.
- Working in collaboration and enhancing communication (trades and professional),
- Learning from the past and other contemporary cultures, then transposing those skills, knowledge and insights, where appropriate, into today's businesses.

The result has been highly effective in the creation of new business, the development of existing business and the return of lost skills and knowledge to our workforce, thus creating jobs.

We have no vested interest other that to see Australian talent flourish and, in turn, business succeed in local and global markets.

Carolynne Bourne AM, ISS Institute's CEO formula is "skills + knowledge + good design + innovation + collaboration = competitive edge • good business".

Individuals gain; industry and business gain; the Australian community gains economically, educationally and culturally.

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2 Acknowledgments

2.1 International Specialised Skills (ISS) Institute

This section acknowledges the assistance/support/mentoring from my initial enquiry to date given by ISS Institute and its staff.

2.2 Fellowship Sponsor

Department of Education, Science and Training (DEST), Commonwealth Government

In November of 2004 I was the recipient of the International Specialised Skills (ISS) Institute / Department of Education, Science and Training (DEST) fellowship for the ACT to undertake a research program in Solar Air Heating and Cooling

2.3 The Master Builders Association

I would also like to thank my employer The Master Builders Association who encouraged me, provided financial assistance and the time to research and write this report.

2.4 Participating overseas organisations and individuals

To obtain an international perspective on the topic I arranged consultations with and discussed Solar Air Heating and Cooling with the following overseas personnel who I wish to thank for their time and insight on this topic. Without their direct assistance and that of their associates this report would not be as comprehensive as I have provided.

- Professor David Strong
  Managing Director of the Building Research Establishment (BRE)
  Garston, Watford
  United Kingdom

- Professor Saffa Riffat
  Head of School & Director of the Institute of Building Technology
  Nottingham
  United Kingdom

- Professor Brian Norton
  President of the Dublin Institute of Technology
  Ireland

- Professor Jan-Olof Dalenback
  Building Services Engineering
  Department of Energy and Environment
  Chalmers University of Technology
  Gothenburg
  Sweden

- Dr Robert Hastings
  Managing Director
  Architecture, Energy and the Environment
  Wallisellen, Zurich
  Switzerland

3. Introduction

3.1 The Master Builders Association of the ACT

The Master Builders Association (MBA) is a National member based organisation representing up to 30,000 building industry practitioners, encompassing trades and design professionals engaged in commercial, residential, and civil construction works. The MBA has a strong commitment to sustainable construction, being very pro-active to bring about change both within our industry and to raise the general public awareness on the broad range of environmental issues related to building construction that have emerged over the last two proceeding decades.

The MBA has the foresight to see the direction that the industry must be encouraged to embrace, and how to instigate and apply new concepts to achieve the goals towards best practice in sustainable construction.

As part of the MBA's' environmental commitment they are embarking on a long term continuing professional development program for its members under the tag line of 'Green Living'. Green Living builders will take the Building Code of Australia (BCA) as the minimum performance standard then aim their practice at a higher level. The competencies that 'Green Living' builders develop through the training provided by the MBA will eventually lead to a course with full accreditation.

The MBA's 'Green Living' training program was developed for Master Builders Australia, under contract by the University of Technology Sydney (UTS), with all contents of the program remaining the property of the MBA.

The MBA fully support the concept of 'Solar Air Heating and Cooling' because it has the potential to change the way we build in Australia today. As with many good ideas in the past this won't just happen overnight the construction industry needs to develop, test and prove it is a viable and economical energy system for integration into residential buildings. Hence, the MBA believe the training program is only the start of this process and intend to explore all the possibilities to move all forms of sustainability into mainstream construction.

This report for the ISS Institute is a key component in this program. The institute is an excellent organisation to raise the profile of 'Solar Air Heating and Cooling' outside that of the construction industry. Not just promoting the system within Australia but acknowledging that Australia is also at the cutting edge in this new field working alongside leaders in International organisations.

3.2 The skills and knowledge Gap

Solar Air Heating and Cooling - PLAN B*

This report and training workshop/seminar are designed to up-skill builders. Encourage them to start using 'forms of construction' in new houses *that can be used* ** as alternative energy heating and cooling systems to help offset their clients dependency on fossil fuels, especially in temperate Australia.

In conjunction with standard building practice these 'forms of construction' will use traditional heavy building materials as thermal mass in new innovative ways to help

- Heat our houses in winter, by circulating solar heated air through ducts formed in the thermal mass, and to
- Cool our houses in summer, by using these same ducts for night-time ventilation (purging the accumulated hot, day-time air from the house).

Outcome:

Based on the research, the training workshop/seminars will draw on natural, heating and cooling systems that were traditionally used by builders to make homes more comfortable. Then integrate these new concepts into today's housing using current technology. In addition to the sustainable and cost benefits associated with the reduction of energy in the running of the homes, they will also be healthier places to live and the occupants will have total control over their indoor environment.

The training workshop/seminars will use a combination of explanatory text and illustrations to assist builders to adopt more sustainable forms of construction. It is not the intension to develop one form of construction or a single system, but rather a broad collection of related systems, ideas and methods that builders can choose to adopt appropriate to the design and construction of the houses they propose to build.

Such a training workshop/seminar does not exist in our construction industry.

* This implies that there was a plan 'A' - there still is. It is the National House Energy Rating System (NatHERS), this is not to say Plan 'A' didn't work, quite the contrary it is and will continue to be very successful. But even with all its recent refinements it is and will always be, basically restricted to the building's orientation and the design of the building's envelope. Think of it as 'Passive Solar Design'.

'Solar Air Heating and Cooling' - Plan 'B' is the natural progression of taking this form of building efficiency to the next level of sustainability i.e. the reduction of energy consumption used by the occupants, not covered by NatHERS. Technically it is part of 'Passive Solar Design' i.e. Slab on ground, but in the manner that I am proposing it is almost non-existent in mainstream housing today.

** There is an implied uncertainty as to when and who would do the 'Fit off' for an alternative energy system, this is intentional; this report proposes that there are two stages in the concept of these systems.

Firstly, the construction of ducts concealed within a building can have a 'Passive Solar' application, somewhat limited but they do have an immediate use value, without any further building involvement. Secondly, the incorporation of mechanical equipment into the ducts (now 'Active Solar') will create a system that will achieve its full potential but this equipment adds to the cost, which the owners may not be able to afford when the house is initially built.

In the building design and construction industry this is referred to as 'Adaptability' or 'Flexibility', - the ability for the building to be easily modified, completed or extended to suit the changing needs of the occupants (or other influences i.e. environmental), at minimum cost and disruption. In the bigger picture of sustainability, 'adaptive use and reuse' includes the installation / replacement of services, which has a considerable influence on the longevity of buildings.

The main issue here is, to encourage builders (and designers) to move on to this next phase of sustainable construction by at least preparing the structure of the building with a system of ducts in it's construction so that it can be adapted at a latter stage. Having said that, I am confident, that there are builders who will just embrace the whole concept and construct and install total packages for their clients.

3.3 Organisations that have influenced me and should benefit from my findings

The Master Builders Association of the ACT
Master Builders Inc Australia
Building Design Professional's 'Environment Design Guide'
University of Canberra
ACT Government Department - Environment ACT
Federal Government Department - Environment and Heritage
Australia and New Zealand Solar Energy Society (ANZSES)
Building Science Forum of Australia - ACT Regional Division

3.4 Aim of the Fellowship.

Was to investigate the skills/knowledge gaps I identified, and to produce this report to show how we can apply what is practiced in Europe into the Australian construction industry. To demonstrate the practicality of 'Solar Air heating and Cooling' training workshop/seminars will be delivered by the Master Builders Association Australia.

This report is intended to give the readers a concise snapshot in time, from an Australian perspective, outlining some of the foreseen problems, solutions to these problems and the opportunities that exist in this field.

4 Solar Air Heating

4.1 A brief history on Solar Air Heating

Some references claim that there were numerous inventions in America since the 1700s on how one could harness the sun's energy for heating a home. But the first accredited solar air heater was designed and produced by an American E Morse in 1881. It was a simple wall hung timber-framed cabinet for a black sheet of metal covered with a sheet of glass (what we now refer to as a solar collector). It functioned purely by convection, facing the sun hot air would be emitted from the solar heated steel plate within the cabinet, this would rise and enter the building via an opening in the wall behind the cabinet. The rising hot air was displaced with cooler air from the building entering at the bottom of the cabinet. This system attracted very little attention, variations were developed but it is not known if any of this type were even factory produced.

It was in the 1920s when the term 'solar house' was first used by a Chicago newspaper in articles to describe their large south facing windows (in the northern hemisphere) to obtain heat directly from the sun. Pioneered by architects G & W Keck in their 1932 House of Tomorrow and then in the 1933 Crystal House at the Chicago World Fair. Their designs featured specific overhangs to shade against overheating in summer and internal masonry walls and floors to help absorb the heat on sunny winter days for later release in the cooler evenings (the principal benefit of what we now refer to as *Thermal Mass*).

The next major development came during the 1940s, when another American K Miller patented a system using solar collectors to heat air that was then pumped into a storage container filled with granulated rock. The rock stored the heat that could be released later in the evening when the outside air temperature fell. This system proved itself as a reliable supplementary heat source offsetting a portion of the homeowner's energy consumption. These systems were automated with fans and thermostats.

Between 1946 and 1949 two residences in Massachusetts explored new ground with solar air heating with the use of chemical compounds that absorb and give off heat as needed by being changed from a solid to a liquid state. Today we refer to this technology as *Phase Change Materials (PCM)* which has unlimited applications in various industries

In the late 1940s and during the 1950s Americans developed a number of variations to the earlier designed solar collectors that further validated their true potential. Then in the mid 1970s came the industries biggest boost with America and Canada funding the research and development of solar energy systems (both water and air) with considerable monetary incentives for manufacturing and the homeowner to invest in these products. All activated by the energy shortages and their increasing cost at that time, of course. Unfortunately, this came to an abrupt end some 10 years later when the monetary incentives were removed.

European architects then took up the challenge designing site specific solar air systems for their projects. An industry for the manufacturing of solar air collectors was revived using technically advanced materials in a variety of systems for use to meet the designer's needs.

Internationally, there are now manufacturers who have developed patented solar air handling systems that can be either attached onto a building or, to varying degrees, integration into the building's design and construction.

4.2 Australian contributions to Solar Air Heating

As outlined above 'Solar Air Heating' is not a new discovery. But in Australia the research and application of this technology has been very small in comparison to solar hot water heating in which we are recognised as one of the leading authorities on the subject.

Unfortunately, in the past our mainstream architects, building professionals and developers were not that interested in the use of the recent innovative Solar Air Heating systems because they were considered too 'alternative' and were generally associated with radical fringe groups of designers, builders and owners. Even when the engineering and the scientific data available fully embraced and proved that it was a most logical direction that the building industry should take.

I have divided our existing solar air heating technology in Australia into two distinct groups:

1. Integrated: when the system is constructed into the buildings fabric during the building of the home, and

2. Retrofitted: when it is fitted onto the home after the buildings construction is completed.

Integrated Systems
Some of our past/present 'Integrated' solar air systems vary considerably in their levels of acceptance/usage in construction. In order of their popularity they are:

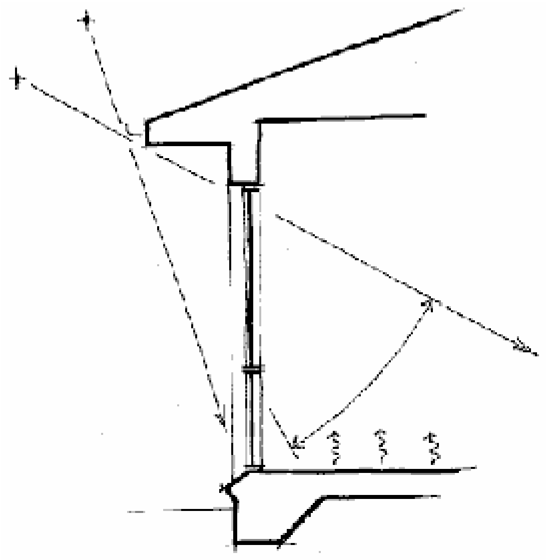
(a) Slab on Ground
(b) Trombe Walls
(c) Rock Storage Beds

(a) Slab on Ground - is a component of passive solar design. It is a storage medium *(thermal mass)* collecting the solar radiation entering the building through the building's windows. Generally it is not thought of as an air-based system but slabs do warm the surrounding air within the building via its *emittance* of *long wave radiation* and its effect on the natural convection of air within the room. With this capacity to store heat they can be also used to assist in the comfort of the occupants in summer, as a heat sink during the day then releasing this heat in the evening by 'night purging' the home.

It popularity today is not because everybody involved in the building industry thought it was an excellent way we should use to help heat and cool our homes. It popularity grew in the 1980's because builders found it quicker and easier to construct slabs over constructing a timber framed floor, with the added benefit of providing an instant working platform on which to build.

<u>SLAB ON GROUND</u>

Solar energy penetrating into the home during the heating season to heat the thermal mass of the slab
Angle of the mid winter sun
Angle of the mid summer sun
Energy released at night when the air temperature in the house falls below that of the slab

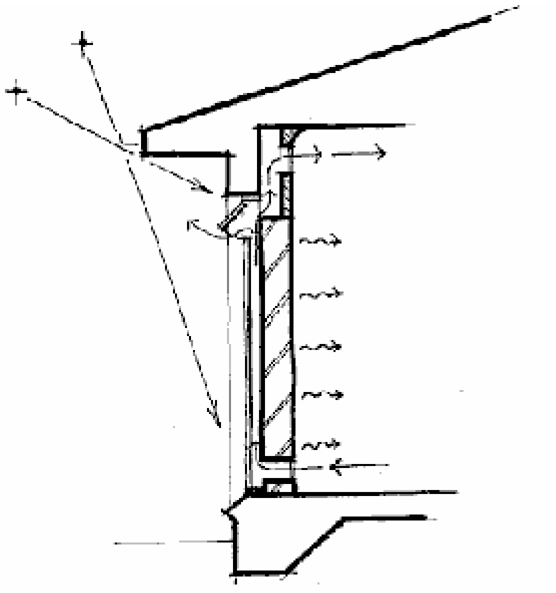


(b) Trombe Walls and (c) Rock Storage Beds   Unfortunately, these systems and variations on them, are all but non-existent in temperate Australia.

Trombe Walls - are in fact a vertical solar hot air collector that can be a very efficient system to heat and cool a room. On the down side they can restrict an occupant's view to our sunny north, they are not cheep to construct and maintenance issues do exist: on cleaning the inside of the glass and removing our Aussie blowflies from the enclosed space. But most of all for these systems to work effectively they require the owners to manually control their day and night time modes. Collectively, the disadvantages seem to outweigh the benefit of free solar heating, discouraging their use today.

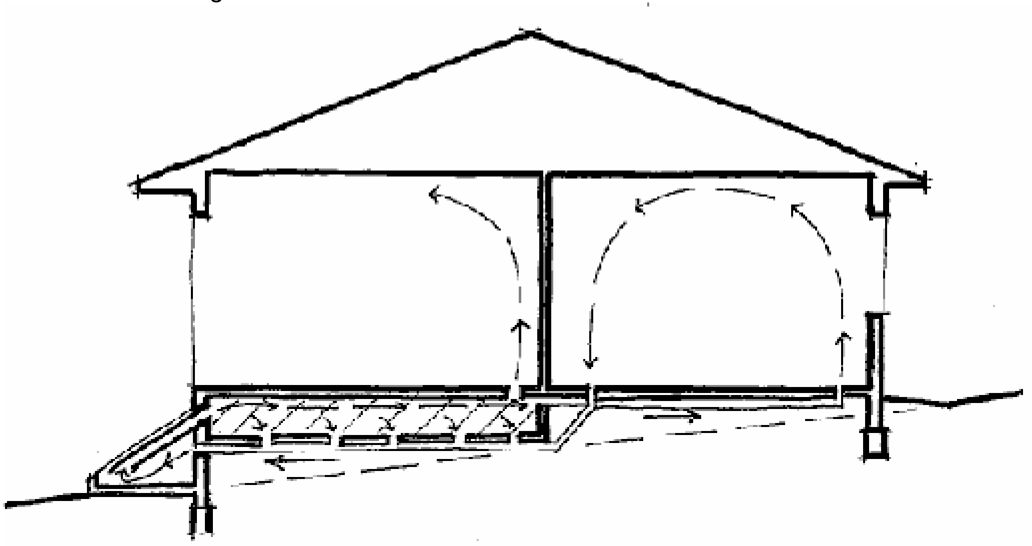
Below is just one method (of many) how a 'Trombe Wall' can be constructed.

Openable vent to prevent overheating in mid seasons and for summer ventilation
<u>TROMBE WALL CONSTRUCTION</u>
Double glazed window to limit heat loss on cold nights
Heated air in winter circulated into room during the day
Radiant energy released from the thermal mass into the room during winter evenings
Cool air intake from room



Rock Storage Beds were never quite accepted as a solar air heating system in Australia. This was and may still be because (apart from being very expensive to construct building designers were confronted with quite complex designs and a mountain of technical data) in Australia we just don't build the way Americans do, where all the designs and data was coming from.

Solar air panel/s
Natural convection (thermosiphoning) to circulate heated air
Heated air supply to southern side of home
Cooled air return back to solar panel collector/s
Graded rocks in storage beds under



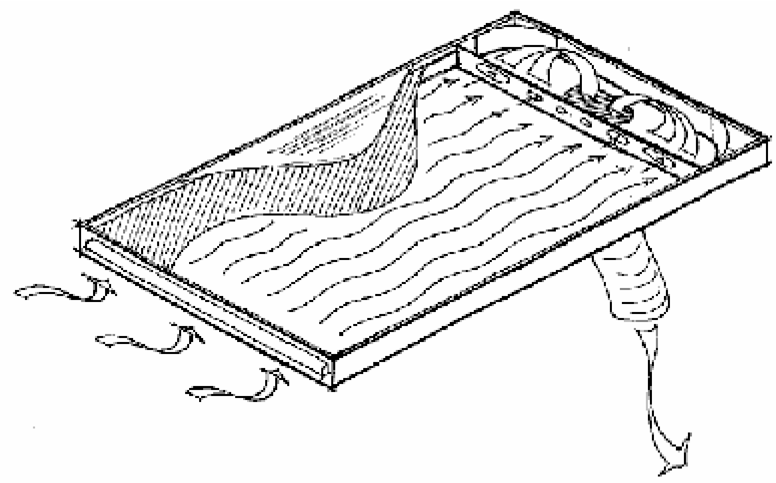
slab ROCK STORAGE BEDS

Retrofitted Systems

These systems are generally factory produced 'solar air collectors'

Pre-manufactured metal box insulated on sides and bottom
Glass cover

A TYPICAL MANUFACTURED SOLAR AIR COLLECTOR
Heat collector with selective surface coating
Fresh air intake
Rising hot air on the underside of the collector
Fan assisted hot air blown into room



A very small number of manufacturers took up the challenge in Australia back in the 1970s and produced solar-air panels that were simply attached onto residential roofs with the solar heated air ducted directly into selected rooms via a ceiling vent. These manufactured units also doubled as hot air extraction (cooling) systems when the accumulated hot air pooled against the ceiling on hot summer nights. Unfortunately, to the best of my knowledge they ceased manufacturing these units back in the late 1980s?

But there is now a growing interest to resurrect the development, production and use of these solar panels for the housing industry but progress for their wider acceptance is slow. I suspect that the difficulties they experienced are;

- The reluctance by designers to use unknown products,
- The high cost for their supply and installation,
- Because they are limited (cost wise) to a 1 or 2 panel assembly their winter efficiency value is also limited,
- They are a stand alone system without any heat storage capacity, and
- They can be a bulky attachment (some 150 to 200 mm thick) on your home that many people dislike.

But on the positive side they did and still do produce solar heated air that was / is pumped into homes thus minimising the occupants reliance on fossil fuels and the fact that they can be fitted onto a home after it is constructed is a plus.

4.3 Recent advances overseas in Solar Air Heating

Speaking generally, in Europe over the last two decades the integration of solar air heating systems into the architecture of commercial and residential buildings was not and is still not actively practiced in any large numbers. Which then results in the insignificant numbers seen on its use in the construction industry. These statements are relative when they are considered within the context of comparing this type of design/construction with the amount of the other 'standard' development/changes that have occurred in these countries in that period.

On the positive side, over the last decade especially in the last 2-3 years this field of sustainability is now starting to receive the recognition it duly deserves encouraging design practitioners into this field of sustainability. The industry received its largest boost when in 1993 the International Energy Agency (IEA) under their Solar Heating & Cooling (SHC) program was assigned a new Task (No 19) to research and develop information on Solar Air Systems. They produced three books around 1999/2000 that dealt with: the design of solar air systems, built examples and a range of standard products (in Europe), that architects could use when designing a system.

This set of books established beyond any doubt that Solar Air Heating and Cooling had come of age, well at least 'in theory' at this stage because there are few completed projects in the field based on this knowledge. This soon became apparent, as it was extremely difficult for me to find built examples show casing this latest research or better still examples currently under construction. The excellent examples that do exist (in Europe), were designed for clients who now occupy these homes and are reluctant to permit ongoing visits by interested parties. As more projects are designed and built using the IEA's well founded information it is expected that Solar Air Heating and Cooling will become more widely known.

Design and technical information contained in the IEA's book on Solar Air Systems 'A Design Handbook' edited by S. Robert Hastings and Ove MØrck is used in part throughout this report, some of which will be used in the associated builders training workshop / seminar. This book is an excellent publication and is considered to be an essential reference for every serious solar air practitioner. Learning and keeping abreast of the IEA's recent research would prove to be of benefit to the building industry but it is only part of the challenge we face in Australia. That is, we have to adapt the concepts physically into our buildings and raise the awareness of the public of this emerging sustainable technology.

5 The Fellowship program

The nature of the overseas program was to meet with the leading edge UK and European practitioners in the field of solar air heating and cooling to discuss traditional systems and the new emerging systems coming onto the market. And to find out who are the main motivators/ drivers/ consumers in their country, their marketing strategies, restraints they face and, the trends and opportunities they foresee.

Also to investigate and document any traditional solar air heating systems that builders once used to thermally improve their indoor, home environment along with the examination of the new and emerging systems being used in the UK and Europe today.

The countries visited were the U.K. Ireland, Sweden and Switzerland.

6 Solar Air Heating Systems

6.1 The Fundamentals

In writing this report I have made an assumption that the reader has a basic understanding on the following: solar energy, heat, conduction, radiation, convection, insulation and emittance. And that such a person would also be familiar with residential building construction in Australia along with the terminology in use in this industry.

A basic solar air heating system consists of the following:

- Solar collectors
- A air handling system (ducts, fans, dampers and diffusers),
- A control system, and
- Thermal mass (although not essential).

Generally solar collectors, that is the component of the system exposed to the sun, are quite efficient. They collect the suns radiant heat that is either extract or fan forced away from the internal absorber panel into the internal parts of the building. An issue associated with them is that air is not a very good conductor of heat, with air temperatures only in the order of 100^0C - 120^0 C being obtainable, but this is simply compensated by increasing the volume of air circulated through the system.

What is considered beneficial is to include a storage system, where the heat energy in the air can be transferred (stored) into another medium for later use. There are a number of materials that can achieve this, they are: water, heavy construction materials *(thermal mass)* and *Phase Change Materials (PCM)*. This fellowship report only discusses thermal mass in detail as the storage medium.

6.2 System classifications

The IEA under their Solar Heating and Cooling (SHC) program, Task 19 (referred earlier) classified Solar Air Heating Systems into 6 distinct types.

They are:

Type 1	Solar heating of ventilated air
Type 2	Collector/room/collector
Type 3	Collector-heated air circulated through the cavity of the building envelope
Type 4	Closed loop collector/storage and radiant discharge to building spaces
Type 5	Open single loop collector to the building spaces
Type 6	Collector-heated air transferred to water via an air/water heat exchanger

Each of the above systems serves a range of functions, along with their inherent efficiencies, advantages, disadvantages and of course challenges. It is the designer who must evaluate which of these systems is most suitable for the project in hand and of course to meet the expressed needs of his / her client/s.

It is not my intension to describe how each of these work and how one would choose the one that best suits their building design and client, for that I recommend that one would need to purchase the IEA 'Design Handbook' referred to in the Bibliography.

6.3 Recommended systems

From the assessments of the technical information available, from discussions and site evaluations made available to me overseas I have selected from the above, types 1, 4 and 5 as the systems most suitable for their integration into the Australian residential building industry.

This is not saying that the others are unsuitable, they are just more suitable in Australia to a commercial building application because of the manner how these systems would need to be incorporated into the construction systems in use in commercial buildings today.

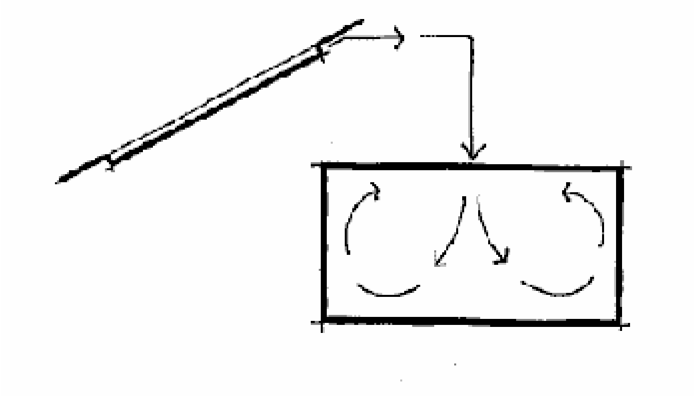
Types 1, 4 and 5 can be reasonably accommodated into residential construction however there needs to be a change in the current mindset of how we build some of the components of our houses in Australia today. Hence the need for the Master Builder's training workshop/seminar which introduces the builder to possible alternative construction practices.

Type 6 does require a special mention, although outside the scope of this report it has a very good potential for use in the residential building industry. Basically the solar heated air from the collector/s is circulated through an air-to-water heat exchanger thus raising the temperature of the water such that it can then be circulated through radiators, in-slab heating and/or as the homes domestic hot water system.

Type 1 Solar heating of ventilated air

In brief - this type is believed to be the most economical, most widely used system worldwide, least complex and is considered quite efficient. In the cooler months a fan simply draws fresh outside air through the collector, then via roof ducts the heated air is pumped directly into the residence through diffusers in the ceiling. In the warmer months the heated air in the collector is diverted to the outside all by natural convection.

Fresh air drawn in from outside
Heated air fan forced into room
Solar collector integrated into roof



The notable advantages of this system are:

- Low installation costs because they are usually retrofitted onto roofs, what the solar hot water industry refers to as 'plonk ons'.
- The solar heated air can be delivered directly into a selected room or zone of the home that has little or no solar gain,
- In larger installations the ducting delivering the heated air can be connected up to a central mechanical ventilation system, and
- By using outside fresh air the building is pressurised limiting, if not eliminating while the system is running, the infiltration of cold drafts into the home.

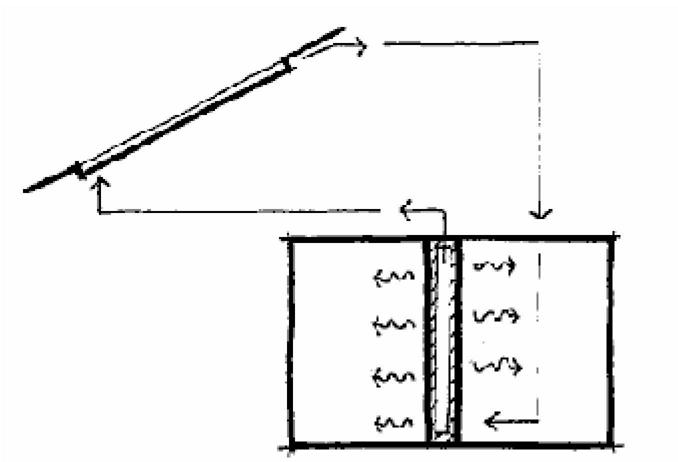
The disadvantages are:

- Although fresh outside air is beneficial under most circumstances it can be contaminated with pollutants, dust, etc. Care must be taken to position the intakes away from any undesirable polluted air sources. Apart from the associated health risks when outside air is used, the inside of the collectors would require periodical cleaning to maintain their efficiency, and
- In the context of this fellowship report, this system, in its simplest form as described above, is not connected to a thermal mass storage system. But this can be turned into a positive by developing variations within this system in conjunction with adaptations to the construction of the home.

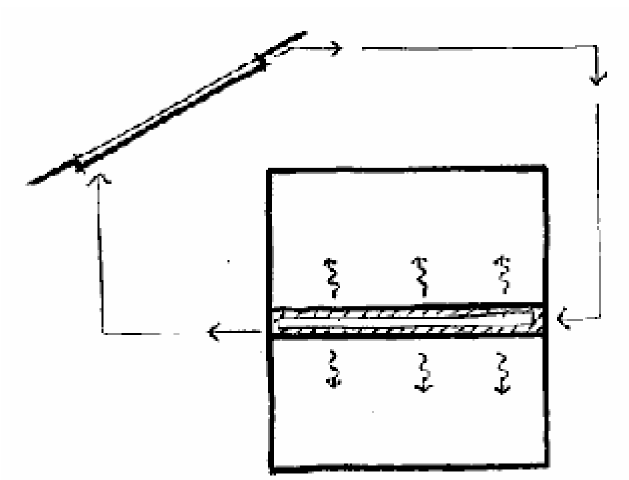
Type 4 Closed loop collector/storage and radiant discharge to building spaces

In brief - this type has been successfully integrated into homes across Europe contributing to a considerable reduction to their annual energy consumption. The solar collectors in this system are coupled directly to a thermal mass storage system by a 'closed loop' arrangement of ducts to reticulate the air via a fan. This is primarily considered a fan forced system although a *thermosiphon* system, unaided with mechanical equipment can easily be achieved.

Fan assisted air into base of cavity
Radiant energy released from the walls thermal mass into the room during winter
WALL CONSTRUCTION WITH CAVITY DUCTING
Solar collector integrated into roof



Fan assisted air into the edge of the slab
Radiant energy released from the slabs thermal mass to both levels of the unit
Solar collector integrated into roof
FLOOR CONSTRUCTION WITH DUCTS INCORPORATED



The notable advantages of this system are:

- The 'closed loop' prevent contaminates from entering the system drastically reducing the collector maintenance and eliminating introduced pollutants into the home,

- The home is heated by the radiant heat discharge from the thermal mass and by natural convection as opposed to fan forced air into the occupied rooms, that many people dislike,
- Internally the system is integrated into the building's construction, you don't see it, you just receive the benefits, and
- On summer nights when the diurnal temperature is lower than in the home the system can be reversed to cool down the homes internal thermal mass in readiness for the next hot day.

The challenges in using this type of system are:

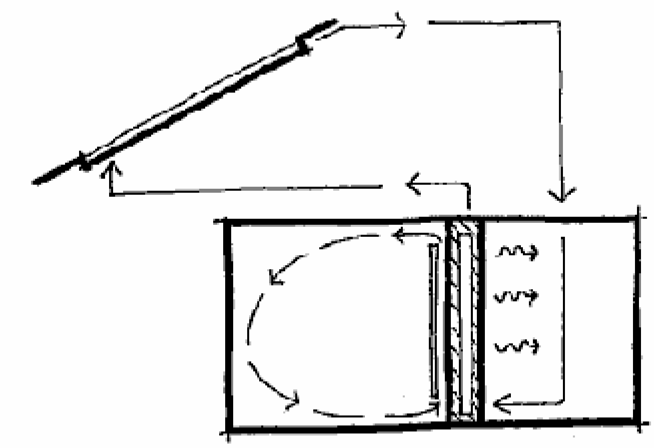
- The design of the building has to accommodate supply and return ducts and a thermal mass storage system both come at an unavoidable cost, and
- The system should be a balanced design with predictable outcomes. Over designed systems increase the building costs unnecessary, but as solar air heating becomes more popular professionals will develop an expertise in its design.

Type 5 Open single loop collector to the building spaces

Similar in principal to system 4 along with its merits and challenges, except that this system incorporates an 'open discharge loop'. This builds on the benefits of having a thermal mass storage system within the home but then gives the occupants the ability to operate the heat discharge when or if they required it.

OPENABLE DISCHARGE LOOP
Open discharge loop to selective north or south facing rooms with openable vents
Radiant energy released from the walls thermal mass into the room during winter

Fan assisted air into base of cavity
Solar collector integrated into roof



The notable advantages of this system are:

- That the discharge loop raises the efficiency of the system, and
- The loop prevents occupants in areas of the room adjacent to the *thermal mass* from overheating.

6.4 Integrating solar air systems into houses

Before we continue it must be understood that there are many factors that determine the design and construction of buildings, these factors vary no just between countries, but even within a country, as they do in Australia. The obvious ones being climate, availability of local materials and available skills, but there are many others, for example: culture, cost, terrain, marketing, trends, trade agreements in raw materials, building regulations, Government incentive programs and education to name a few.

This report focuses in on our existing construction practices in our temperate climates. Broadly speaking, I refer here to the Building Code of Australia's (BCA) climate zones 4 through to 8, with the home occupiers in climate zones 4 and 5 also benefiting from the cooling advantages of these systems in summer.

However this 'focusing in' should not restrict one from collecting further knowledge from other countries overseas with climates outside this range because it's the application of that knowledge into our construction practices that counts.

As previously described the main components of a system are:

- The solar collector/s
- The air handling system
- The control system, and for the purpose of this report
- Thermal mass

Each of the above (except *thermal mass*) need not necessarily be incorporated into the homes original construction. But for them to be successfully incorporated as an integrated system at a later date it is recommended that some provision be provided, complete with the details of the designer's and/or the builder's intensions. This concept is often referred to as *adaptability*.

6.4.1 Roof collectors

As previously discussed solar air systems can be divided into two groups integrated and retrofitted. From this point the report will now only discuss the integrated type in detail, specifically roof integrated models. In this context pre manufactured collectors are almost eliminated, this is intentional because the number of collectors required to offset a significant proportion of the energy heating bill would be very costly. To make solar air heating more affordable the best way is to use our existing roofing materials in new innovative ways. Having said that it is possible to retrofit an integrated system under a roof covering however it would be difficult working in such a confined space and not very cost effective unless the owner carried out the majority of the work.

As most homeowners know roof cavities can become excessively hot in summer and surprising warm in winter. The object is to harness this heat in both seasons and use it to our advantage. Now, all roofing materials absorb heat in varying amounts from the radiant energy of the sun, the extent of which is dependent on the materials *conductance* value, the texture of its surface and its colour. This heat is then *emitted* from its surfaces in *long wave radiation* that effectively heats other surrounding materials and the air by convection.

In Australia we build our roofs with either, prefabricated trusses (the majority of new homes) or with pieces of timber, i.e. rafters, purlins, ridges, struts, etc. With both systems we are actually creating spaces that are perfect for airways to be formed running up the underside of the roof covering. I propose that, all we have to do is to enclose these spaces between the top chords of the trusses, or the rafters as the case may be, insulate and seal them and we have our solar hot air collectors on the underside of the roof covering. Yes they would work but unfortunately their efficiency in winter would be very dependent on the roof being a dark colour. As trendy as it is today for a roof to be specified black or a dark grey or blue, the performance of the house to maintain a comfortable indoor environment in summer is difficult, the roof cavities would and do get too hot.

So to enhance a standard roof that has a light to medium roof colour we would need to cover the roof ducts with glass just above the surface of the roof. The glass traps the long wave radiation on top of the roof covering thus raising the temperature and forcing the roofing material to emit the majority of its heat downwards into the duct/s. It is not intended to cover an entire north facing roof surface with glass, or to run sheets of glass over the ducts from the ridge to the gutter. What is practical and economical is to enhance the ducts performance by only covering the say ¼ of the duct's length down from the ridge. These glass panels would also be more acceptable in appearance, not that much different to an array of photovoltaic panels.

<u>6.4.2   The air handling system</u>

By providing a vent at the bottom and the top of these ducts, as described above, a current of hot air by natural convection would quickly develop whenever the collectors are exposed to the sun.

For summer cooling it would be very easy to install an openable vent at the bottom of the collectors drawing warm air, at high level from inside the house and another openable vent at the top effectively expelling this air unassisted through the roof to the outside. An instant cooling system.

For the cooler months the rising warm air in the collectors would be ducted generally with the aid of fans down into the homes thermal mass where it would be stored and used to help heat the home.

The types of ducts used to transport the heated air away from the collectors would be the same as those already in use in the residential air conditioning industry, complete with all the readily available junctions, diverters, dampers and diffusers.

<u>6.4.3   The control System</u>

Whenever indoor thermal comfort is required there is a need for an operating system to maintain the occupants personal comfort level. These systems can be either fully automated or manual fully reliant on the occupant to operate as they require a change in their indoor environment. Hybrids systems between the two obviously exist.

Sadly, the general trend in heating and cooling a house today is to install a fully automated reverse cycle air conditioner, which we are accepting usually without question and thus becoming reliance on an artificial indoor environment, not to mention the green house gas emissions they produce.

So in following this trend, for solar air systems to be successful it would be prudent to integrate them into homes with the potential for them to be fully automated at a later date, if required. This can be done very simply, by just providing conduits with draw wires, so that thermostats and time clocks can be all added later.

The different forms of control (automation) systems are continuous operation, thermostat controlled or by a time clock.   But don't forget the simplest one of all the 'owner operate mode', turning the fan on or off when required and seasonally opening or shutting the vents and windows etc. is very cost effective.

6.4.4   Thermal mass

Fundamental to the success of using solar air to heat a home, is the use of *thermal mass* as both a building material for a construction element and as an efficient heat storage system. By having this double value its cost for the latter can be greatly reduced if not almost eliminated. *Thermal mass* can be any heavy building material we find on the construction site today, i.e. brick, concrete, stone. As a general rule of thumb the heaver the material the higher the thermal mass.

It basically works like this. The hot air is pumped via ducts from the solar collectors to enter the construction element (for the sake of visualising an element think of it as an internal wall) through preformed passageways formed during the construction of the wall.   Before the air returns to the collectors, as in system No 4, the heat in the air is transferred to the walls mass where it is stored, the air continues on its cycle and is reheated again and again repeating the cycle continually and raising the temperature of the wall.

In winter when the sun can no longer radiate heat onto the collectors, as in the later part of the day or on cloudy days, the system is simply switched off. When this occurs, the indoor air temperature falls, when it falls below that of the wall, the wall releases it stored heat to the room in order to maintain equilibrium. Remember that fundamental law of physics - 'heat always moves from a hot to cold'.

In summer the system is switched to the open ventilation mode during the day, that is as with the type 1 system, the heated air in the collectors is diverted to the outside all by natural convection. But now at nighttime the thermal mass is put to use. In temperate Australia we generally get the hot summer days (in the mid 30s) followed by cooler night temperatures sometimes 20^{0}C lower. So what we can do is to draw in this cooler nighttime air and circulate it through the thermal mass to cool it down for the following hot day. Then as the day heats up so does the house but with the cooler thermal mass it absorbs this heat delaying the process and making the house more comfortable for its occupants.

6.4.4.1 The location of thermal mass

Generally there are three places where ducts that transport solar heated air can be built into construction mass within residential homes:

- Within the floor slabs (or below them),
- Within ceiling slabs (multi residential) and
- Within the walls and supporting structures.

6.4.4.2 Slabs

In southern Australia the majority of residential homes built today are slab on ground. Being the majority of the market, of course I had my sights on this group but to provide air transport ducts within a slab on ground in Australia is just not feasible, if fact it is impractical. We encounters ground water problems, it can be extremely difficult and costly to construct termite barriers, they are expensive to form up for the concrete pour and it would be extremely difficult (if not impossible) to change our current trade practices when it comes to slabs on ground.

On sloping sites suspended slabs are sometimes used in part above the lower level rooms and less frequently as the entire upper level floor structure. The upper floors in two storey homes are generally constructed in timber irrespective of the slope of the ground because it is cheaper. Again, without changing the way we build and because of the low volume of suspended slabs, mostly in parts of the house only, I cannot recommend that solar air heating be applied to this form of housing construction.

But in multi residential construction where slabs are the norm it is feasible. Therefore there is a huge potential for these slabs to have some form of air transmission ducts incorporated especially when precast hollow cored slabs are used in their construction. This is not uncharted territory for Australia, this concept is overseas but it has some inherent problems.

- In the larger developments over say three stories there would not be enough roof area for the solar collectors to deliver enough hot air to each occupancy,
- The ducts would require fire dampers to meet the mandatory fire ratings, and similarly,
- Dampers would be required to be fitted to the ducts to meet the sound transmission / insulation requirements.

To summarise, in 'standard residential' construction the use of slabs as a construction element through which solar heated air could be transported cannot be justified as a practical approach for mainstream construction in Australia.

6.4.4.3 Ceilings

Our most common construction practice in Australia is to construct our ceiling on timber framing finished with sheet plasterboard, insulated of course. And as stated above on sloping sites we do build floors using suspended concrete slabs that act as a ceiling to the rooms below but these usually have a secondary framed structure below the concrete for the buildings services. These voids could be used for locating ducts, or even as ducts, but again they are the minority, my target is mainstream construction. Other systems like 'Hebel' ceiling panels do exist but they are in comparison lightweight insulated products and do not perform well as a thermal mass storage system.

Without radical changes to our construction practices in 'standard residential' housing I cannot foresee how we can use ceilings as thermal mass to store solar heated air. But they are ideal voids within the construction for installing the air ducts to shift the solar heated air to more appropriately located thermal mass.

6.4.4.4 Walls and supporting structures

It is in the construction of the walls, specifically the internal walls and other elements like columns within the central core of the house that are evaluated as the best structures to incorporate the solar air ducts. When constructed in a high thermal mass material these walls have the greatest potential to work as part of an integrated solar air thermal system. Effectively, when in use they will heat the rooms on both sides of the walls via *radiation* and *convection*. The internal skin of an external wall could be used but it would need to be well insulated from the colder air in the ventilated cavity, adding to the cost of that system.

The following construction systems are all readily available for their integration into the building as a solar air thermal system as well as their primary function - being an internal wall.

- Clay brick,
- Concrete block, and
- Precast concrete panels.

All of the above can be used to construct internal walls with passageways along which air can be pumped through. However, because of their weight they will require either a footing or a thickened portion of the slab beneath them for building construction compliance.

In construction, clay bricks (solid is preferred, remember the heaver the higher the thermal mass) could be used to build the standard double skin 'cavity brick wall', where the whole cavity is the air passageway.

Concrete blocks are similar to bricks but have large ready-made airways formed in their manufacture that can be used to duct the air through. When these blocks are used it would be necessary to construct the majority of the wall using the solid form of these blocks to ensure that there is a sufficient amount of mass is provided.

Precast concrete wall panels are mainly used in commercial buildings but why not use them as heat storage in residential? They also come complete with in-built ducts, come in a variety of sizes and thicknesses, all they require is to be lifted into position.

There are also other building materials of high mass like precast concrete and hollow steel columns, which can be used in conjunction with these walls acting as vertical ducts at the end of the walls.

The possibilities are endless a good builder equipped with an understanding on solar air heating has the potential to provide a home with multiple possibilities for solar air heating.

6.5 The technical complexities

To try to explain all the technical complexities on why and how to design a solar air system would be a daunting task for anybody, there is just so much to cover and it cannot be covered in this report. I would recommend that if you wish to further your education in this field beyond that in this report that you source the information contained in the publications referenced in the Bibliography.

This ISS fellowship report does have one principal I applied throughout, that is 'simplicity', over complex, infinitely detailed explanations with a high level of technical information, eg *thermodynamics* and mathematics, will not assist in moving the concept of Solar Air Heating and Cooling into mainstream housing construction. Quite often in the search for a basic solution we have the tendency to make it over complicated, why? Because we can.

So to assist the average reader to obtain a basic understanding on the technical part of the subject this next section makes use of the simple Questions and Answers approach. The majority of the questions are those that I initially listed when I first started my research, then I expanded them as I discussed the subject with my colleagues within the construction industry.

The ISS Institute overseas study program made it possible for me to be able to answers them all.

1 What does a system cost?

To some this is the most important question of all and rightfully so, but the answer is divided. The first cost being relative to the form of the construction provided, so that the future operational part of the system can be simply attached or connected as the case may be, bearing in mind that it may never be done at all but the owners have that option. The thermal mass wall and its support system would account for the majority of this cost that is estimated in the order of $2,000 - $3,000. The second cost is the installation of the collectors and the running equipment. This can vary considerably depending on the area of the collectors, the quality, the complexity and the efficiency of the system. An estimated range is between $3,000 - $5,000.

2 What is their payback period?

Firstly why is it that when it comes to energy efficient appliances and systems i.e. solar hot water, people want to know their payback period? The fact is that they are better than a system that has no payback at all, i.e. electric hot water storage heaters. Do people ask if their refrigerator, washing machine, dishwasher or their family car has a payback? No, they can only compare its operational efficiency, so why do they need convincing in payback figures that use the sun's free energy? Its because their initial cost is usually higher than the more polluting conventional systems on the market.

Yes, there is a payback period, but because a system needs to be designed for its incorporation into a particular house the following variables would need to be factored in:

- The specific 'star' rating of the house (new and old),
- In which climate zones would it be installed,
- The efficiency of the collectors,
- The cost of the fossil fuels its displacing, and
- Most importantly, the occupants expectations for personal comfort,

It is extremely difficult to give a payback figure in years. Until a computer modelling program is developed or case studies are built and monitored in temperate Australia a number would or could be misleading.

3 If I install a system will it supply all my heating needs?

In temperate Australia, no. A solar air system will provide free supplementary energy, reducing the cost and shortening the heating period you require to be totally dependant of fossil fuels as your energy source. However it can create a more comfortable summer indoor environment and eliminate the need for airconditioning in many areas of temperate Australia.

4 Can you use any roof material as a solar collector?

Yes, no matter what type of roofing material you have, be it concrete or terracotta tiles, slate or metal sheeting on your home it has a value as a heat absorber/collector. Of course, the darker and rougher the texture of the material the better, highly reflective surfaces like 'Zincalume' will work but their efficiency is reduced. An issue here is that the underside of the roof covering must be sealed to (and forming the top surface of) the ducts that run up the roof pitch, a problem that is easily solved when using metal sheet roofing.

5 Do you need to use glass over the solar collector absorber?

A system will work without glass covering the absorber but that application (at least in Europe) was usually confined to commercial applications using purpose made perforated absorbers. Domestically and in the Australian context, to obtain maximum efficiency from each collector glass is recommended at least towards the top of the collectors.

6 Do solar collectors need be of a certain size or have a width to Height ratio?

There is no recommended ratio, it would be determined by the construction of the roof and the size of manageable pieces of glass covering the collectors. But a 100 mm minimum depth of the collector/duct is recommended. This depth is measured from the back of the absorber to the inside face of the insulation behind the absorber forming the collector/duct. The issue here is, you need large volumes of air to move through the ducts for the system to be efficient because air unlike water does not have a high specific heat capacity.

7 Do solar collectors need to be sealed and insulated?

Yes, it is very important that the collectors are sealed. This does not just prevent hot air leakage decreasing the systems efficiency but prevents any contaminates in the roof cavity from entering the house via an 'open' type system. It also reduces if not eliminates cleaning maintenance on the glass when a 'closed' type system is used.

8 Will condensation form in the solar collectors?

Condensation can become an issue in summer when the system is being used to ventilate the home but only when the temperature in any part of the system falls below 18^0C. Having said that, if by poor design, the location of the air intake vents draws in outside moisture laden air i.e. from a sprinkler system, into the collectors late in a winters day it could also form condensation within the collectors overnight but it would be exhausted on the next sunny day. Well designed collectors should allow for the event of condensation or rainwater entering into the collectors and the discharge of that water.

9 Can a system overheat and cause a house fire?

All system must be designed so that if in the event of a power failure or when the temperature exceeds a determined limit the system would revert back to an open ventilation mode. This would then divert any hot summer air out of the collector through one or more roof vents via natural convection/ventilation. And of course all the components of the system must be constructed of non-combustible materials in accordance with the Building Code of Australia.

10 Are they safe in bush fires?

Yes, as long as the owner closes down the air intake if one is installed as in the Type 1 system - 'Solar heating of ventilated air'. Because it draws its fresh air supply from the outside, generally from the underside of the eaves through the collector then it is fan forced directly into the living spaces of the home. As with all the other pollutants around the home i.e. car emissions, the inlet vents should be carefully placed as to not create a potential problem. If a house is in a bushfire prone area diversion valves should be fitted that shut down the external vent and supply the collector with the air from within the home effectively closing the air supply loop to inside the home.

11 What type of glass should I use?

Any glass used on or in conjunction with an integrated roof solar air collector should be safety glass of the required thickness and installed in accordance with the Australian Standard, AS 1288 - 1994 'Glass in Buildings" incorporating amendments 1 & 2. As far as which glass is best for solar transmission, keep it simple just use clear glass.

12 How should the glass be fixed?

Glass must be firmly secured so than it cannot become displaced by any unforeseen means so that it cannot cause danger to anybody in the vicinity. It must also be fixed to enable cleaning maintenance and easy replacement if damaged. A certified glazing bar system is recommended.

13 Is the orientation and the tilt of the collector critical for its performance?

No, one can use similar siting criteria as used for the solar hot water systems, i.e. tilted at an angle equal to that of the latitude of your home +/- 10^0 and preferably facing true north but quite acceptable facing up to 45^0 east or west of true north. This tilt angle is a general figure that works reasonably well all year round in latitudes higher than 25^0. If one requires optimum performance in winter this figure can be increased up to 20^0. If summer venting is an important issue due to either the poor initial siting of the house or its design consider favouring a more westerly aspect for the collectors to assist in exhausting the late afternoon internal heat gains.

Of course the tilt angle is relevant if you are designing a new home because the angle of tilt is the same as the roof pitch for integrated collectors. And as far as a minimum roof pitch is concerned one should not be incorporated at less than 15^0, in fact the steeper the better for an efficient *thermosiphon* effect.

14 Is there a simple rule of thumb formula for how many collectors I need?

Yes, it is 0.08 m^2 of collectors for each m^2 of the residence's floor area. When this figure is increased a higher total yield is achieved with higher temperatures exiting of the collectors but the performance of the collectors per m^2 is reduced and the system becomes more expensive. The above figure is generally considered optimal for the majority of installations.

15 How much thermal mass do I need?

Meaning the volume of the storage system made from brick, concrete or stone. The optimum volume is expressed as a ratio between the storage volume to the collector area that ranges from 0.1 to 0.2 m^3 per m^2. The principal here is that it is a balance between, that the storage system can be cooled down sufficiently but also achieve sufficiently high temperatures i.e. if too small it could overheat and if too large it may never reach optimum operating temperature.

Associated with this issue is the length of the 'heat charging' ducts in the thermal mass. They should be of such a length (a minimum of 10 m) that all the ducted hot air is cooled down by the heat being transferred into the *thermal mass*.

16 How do you stop the system from reversing the heat flow on a winters night?

As the temperature drops in late afternoon there is a natural tendency for the heat collected in the thermal mass to rise up through the ducts of the air transport system to the highest point of the system, back into the collectors. If this occurs any heat will quickly dissipate out to the colder night sky, effectively draining the system. To prevent this, temperature sensors are placed within the ducts to close the damper/s that reopen when the given temperature is reached the next day. Of course in the simplest system the damper/s could by manually operated by closing a valve, flap or the like.

17 What type of fan should be used and where should it be placed?

An axial (in-line) fan has the advantage that any heat (energy) produced by the fans operation contributes to the heating of the thermal mass, but the selection of such a fan must be able to withstand the temperatures produced by the collectors up to 120^0 C. Alternatively to avoid the heat issue you can use a radial fan where the fan body/motor is outside the duct. The fan/s should be installed on the outlet side of the collector within close proximity and coupled to the temperature sensor (if installed).

18 How does the system work in winter?

Without automation the operational phases of the system would need to be manually controlled by the occupants, this is not complex issue. When the day time outside temperature is warmer than the inside temperature (open the door to find out) you turn on the fan to, depending on the type of the system, blow the warm air directly into your living areas or through the home's thermal mass. When the temperature outside drops below that inside simply turn the fan off. The fan can be coupled to an adjacent damper so that the direction of the heat flow at night does not reverse or, as described above, the owner can manually stop this occurring but shutting a valve, flap or the like.

In an automated system the fan and damper are controlled by an electronic differential thermostat, with one sensor located within the outlet duct just outside the collector and the other within the space of the home to be heated or within the ducting of the thermal mass itself. When the temperature at the collector exceeds the predetermined amount above that of the room or the air in the duct of the thermal mass, the fan is operational and then turns off when it falls below the predetermined amount. These thermostats generally come with an on/off switch that overrides the system if required.

19 How does the system work in summer?

Again, without automation its operation is not complex. If the home did not overheat during the day but you wish to cool it down in preparation for the following hot day you can 'purge' the accumulated warm air by simply opening a ceiling vent that is connected to inlet duct of the collector. By natural convection the hot air will rise unassisted and dissipate through both the cooler surface of the collector and the collectors roof vent. To work effectively open low level windows preferably on the southern side of the home where the cooler denser air will enter to displace the vented air until equilibrium is maintained.

If your home is overheating during the day turn on the same fan that you use to heat your home. But now because the fan is installed with a summer mode the damper will open and the hot air will be extracted through the ceiling vents and out through the collectors roof vent. As above to work effectively windows need to be opened but now the actual location of the ceiling vents (or high-level wall vents) and the openings on the south are important. With correctly located vents and openings, a breeze will enhance the cooling effect on people within the room.

20 Can a photovoltaic (PV) panel be used as a solar collector?

Yes, because the panels radiate in all directions when they are operational, but it is the only the heat produced from their underside that is used in solar air heating. The panel effectively becomes the glass cover to the collector. In fact these panels become less efficient if they overheat and it is for this reason if PV panels are used in a solar air system they should only be placed towards the lower end of a roof integrated collector.

21 Does a solar air system require maintenance?

Yes, but the extent varies with the type of system installed. First the collectors, for maximum performance the glass should be kept clean, this is generally not a problem if the gutter height is only one storey high, one can use sponges/blades on extendable rods. If an open system is selected the air circulated through the collectors can contain contaminates that could adhere to the underside of the glass. Depending on the severity of the polluted air the glass would need to be cleaned, how often - who knows? But the design of the glass fixing should allow for this to be done simply with the least amount of skill and specialised equipment.

With the air handling and the control system the maintenance is no different to that of a gas fired central heating systems commonly installed today. The fans, dampers and ducts should be checked and serviced to prevent any possible operational malfunctioning.

22 Can I design a Solar Air System myself?

Yes you can, if you have a good understanding of building construction, the principals of heat transfer, control systems and the fundamentals of air transport systems. If you do not or are in doubt you should seek the advice of a specialist in one or more of the above fields. The information provided in this report is by no means a complete reference guide on the subject nor was it ever intended. It is purely an introduction to an emerging practice that has huge opportunities and benefits if designed and constructed correctly.

7 Outcomes

7.1 The challenges

At present there are three major challenges to order to move 'Solar Air Heating and Cooling' into mainstream Australian housing construction, they are:

1 The business as usual approach, that is designers and builders are reluctant to move out of their comfort zone to detail and specify or use a system they are not unfamiliar with.

2 Almost all of our existing Heating and cooling systems are manufactured products (reliant on fossil fuels), complete with specialised installers, warranties, maintenance companies etc. altogether as an industry directly promoting their products as a lifestyle. They are also indirectly promoted by the energy utilities.

3 Clients are unaware that 'Solar Air Heating and Cooling' exists, let alone that they can be incorporated into residential buildings. In Australia 'Solar Air Heating and Cooling' does exist (in principal) in commercial buildings in varying forms, however examples of such are few and far between.

7.2 The solutions

Each of the above challenges can be overcome. Items 1 and 3 are related but at the opposite ends of the spectrum. It is just as common to hear from the builder/designer (when explained) that there is no demand for such systems by their clients, as to hear from the clients 'nobody knows anything about it'. The answer is education and this report is a good starting point in Australia.

In the past decade or two with have seen energy efficiency/sustainability issues of the public raised to new heights but progress is very slow. Instigated mainly by their own 'to be green' involvement, when extending or buying a new home. Usually coupled with some Government incentives i.e. water saving devices like shower heads, if you are lucky, but usually by their encounter with the upgraded buildings regulations and the house star rating systems or the like.

A far more effective method, in tandem with the owners self education is to educate the builders and the designers so that they can move the concepts of 'Solar Air Heating and Cooling' forward into mainstream construction. This is about being competitive, which is further discussed under 'Opportunities' below.

In respect to item number 2 above 'manufactured products', there is a whole range of issues that the owner should consider prior to the purchase or installation of such items. These include but are not limited to:

- Do you actually need one or would another smaller/ cheaper appliance do?
- Is it over designed or more complex than what you actually need?
- What is the predicted life of the unit?
- What is the length of the warranty period?

- Can it be easily replaced? (some are enclosed in roof cavities)
- Can all or any part of the unit be recycled?
- How long will spare parts be available?
- What is the most common spare part required, how often is it replaced and what is its present day cost?
- Can you service / maintain the unit yourself?
- Will the distributor and the service company still be operating in your area in 10 years?
- What happens if your brand is taken over by another company, will they economise on the number of units available for sales and service?
- Is the model the best performer for your climate?
- Does it operate on the least greenhouse gas polluting fuel?
- Is it the most energy efficient model on the market?
- Is it made locally using Australian components?
- Will it add to investment of your property?
- Are you buying it because of a trend or image?

After due consideration of the above issues, one should then compare with the assistance of a technical practitioner, the pros and cons of installing a 'Solar Air Heating and Cooling' system.

7.3 The opportunities

7.3.1 For the builder

It is the builder that this report is primarily written for because it is the builder who has the potential to gain the most from both promoting and incorporating 'Solar Air Heating and Cooling 'systems into their client's homes. The builder is in the best position to influence people because it is from the builder who the majority of the public get their advice from during the process of: looking at new homes, inquiring on alterations / extensions, costing and having repair work carried out on their home.

It has been said that only a small percentage of builders market their business successfully, with some smaller operators and sole traders purely relying on past client recommendations, repeat services and word of mouth. A pretty fair statement that may hold true for many builders most of the time but as all builders know, when times gets tough they need a competitive edge. A specific practice or way of conducting their business that embraces the goals, direction and principals of their business plan that wins them contracts over their rivals.

There are many practices in which builders can specialise to gain this competitive edge, 'Solar Air Heating and Cooling' systems is one such practice. And as this report presents, it is a relative new concept with limited detailed information available at the moment, which makes this report along with the associated training program essential to decide if they wish to up-skill into this specialised practice.

Once acquired then coupled with their existing construction knowledge and extensive understanding of the building regulations, the builder (with limited design guidance) can deliver an superior new home project (or addition) enhanced with an integrated solar air system.

Given the exposure the builder has with the public, if these newly acquired skills are actively discussed in the initial builder / client consultation process 'Solar Air Heating and Cooling' systems will certainly become a more common practice in the near future.

7.3.2 For the designer

Much of the above is also applicable to the design profession however their exposure to the public is much less than that of the builder. In residential construction the designers also don't control the cost of the construction, they should err on the side of caution because it can be irresponsible if by nature of their design, with desired inclusions, the client's budget is grossly exceeded. Therefore before they start actively promoting 'Solar Air Heating and Cooling' systems they would need to be abreast of the builder's construction costs.

This would not be that difficult if they plan to be a specialist in this practice, it is certainly an opportunity considering our changing environmental values they should seriously take up this challenge.

7.3.3 For the owner

As for the owners they have the opportunity to put a real environmental investment into their property, one that will certainly add value to their home, reduce their energy bills and give them a comfortable home to live in, with only a moderate increase in the cost of their home.

7.3.4 For the Government

Apart from a reduced level of greenhouse gas emissions from each house equipped with a 'Solar Air Heating and Cooling' system it supports the Government's environmental policy. If they actively provided support by way of funding/incentives they would be seen as taking Ecological Sustainable Development (ESD) in the housing industry seriously.

8 Appendices

8.1 Glossary of Terms

As referenced earlier, one of the objectives of this report was produce a document with limited technical jargon that the general public would easily understand. However in order to convey to the reader specific issues in context the following terms were unavoidably included:

Adaptability

Is the ability for the design and/or the construction of the house to be easily modified at a very low cost to suit the changing needs of the occupants. The term is generally associated with modifications for the disabled i.e. a wall removal adjacent to a toilet pan so that a wheelchair user can do a side transfer. But in its broader context as in Solar Air Heating and Cooling it means the allowance for or constructed with the ability to complete the installation at a later date. Also referred to as 'Universal'.

Convection

Is the transfer of heat from one part of a fluid (air) to another by the natural unassisted flow (rising heat) in the fluid (air) displacing the cooler fluid (air).

Conductance

Is the measure of heat flow through a material of given size under steady conditions. Generally referred to as Thermal Conductance and is measured in $W/m^2.degC$

Emitted

Associated with the measure of heat radiated from a material. *Emissivity* is the capacity of a material to emit radiant heat. The term Low E (as in glazing) refers to low emissivity, that is low levels of heat are emitted from that surface.

Long wave radiation

Is a form of heat that is emitted from materials that have, in our context, been warmed by the energy of the sun.

Phase Change Materials (PCM)

Are materials that have the ability to change between solid and liquid state forms at temperatures close to human comfort levels i.e. 20^0 - 30^0C. They act as storage banks that release their stored energy to assist in heating and cooling of buildings.

Radiation

Is the direct passage of solar energy to earth by means of electromagnetic waves.

Thermal mass

Is the term applied to heavy building materials that have the capacity to store high amounts of energy. Also referred to as Volumetric Heat Capacity or more commonly Specific Heat and is measured in J/m^3.degC

Thermodynamics

Is the study of the flow of heat.

Thermosiphon

Is a process in a system whereby the circulation of a liquid (air) is activated by the differences in the density within the fluid (air) i.e. as the fluid (air) heats up it become lighter and displaces the cooler denser fluid (air).

8.2 Bibliography

1 S. Robert Hastings & Ove Mørck (2000) *Solar Air Systems*, A Design Handbook, Solar Heating & Cooling Executive Committee of the International Energy Agency (IEA), James & James.

2 S. Robert Hastings (1999) *Built Examples*, Solar Heating & Cooling Executive Committee of the International Energy Agency (IEA), James & James.

3 S. Robert Hastings & H Røstvik (1998) *Solar Air Systems - Product Catalogue,* Solar Heating & Cooling Executive Committee of the International Energy Agency (IEA), James & James.

4 V Papanek (1995) The Green Imperative, Thames & Hudson.

5 S Kornher & A Zaugg (1984) *The Complete Handbook of Solar Air Heating Systems,* Rodale Press

6 N. K. Bansal (1994) *Passive Building Design - A Handbook of Natural Climatic Control,* Elsevier Science,

7 D Rennie & F Parand (1998) *Environmental Design Guide - for naturally ventilated and daylight offices,* Building Research Establishment (BRE)