International Specialised Skills Institute Inc



# AIRTIGHT AND SUPER INSULATED CONSTRUCTION TECHNIQUES



### **Professor Shane West**

International ISS Institute/DEEWR Trades Fellowship

Fellowship supported by the Department of Education, Employment and Workplace Relations, Australian Government

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## **Executive Summary**

Many of the significant advances in building science driven by the research and development work of organisations such as the Experimental Building Station (EBS) and the 'Notes on the Science of Building' series developed by the former Department of Housing and Construction are more than 40 years old. Techniques and products have advanced considerably since then. Global businesses now play a major role in the development of modern building materials. Companies such as BASF, Dow Building Solutions, SIGA and DuPont have a significant market share in plastics, foams, membranes, tapes, adhesives and patented insulation products now associated with airtight, super insulated construction.

Australian research and development efforts that meet our particular climatic and building specifications are essential if we are to keep a strong local construction industry. Australian construction businesses require secure supplies of quality materials. The synergistic systems approach to building is gaining ground as an advanced lean construction concept. Such systems require fast building techniques, high quality finishes and energy saving materials.

The Fellow travelled to Japan, Germany and the United Kingdom to evaluate airtight and super insulation construction techniques of the type developed by the Passivhaus Institut (PHI). PHI projects have been tried and proven in European climatic conditions. In particular the evaluation focused on whether PHI insulation materials and techniques are as effective in Australian climatic conditions as the techniques that are currently common in Australia.

The adoption of some PHI designs and construction techniques—such as advanced glazing—would bring benefits. Double glazed vacuum windows initially developed by Dr Mills of Sydney University some 18 years ago are now a commercial reality in Germany. Construction techniques that deliver airtight, super insulated interiors have the potential to be a contributor to improvements in energy efficiency.

The adoption of PHI-style construction designs into the Australian building and construction industry would require new and improved skills in vapour transfer: the capacity to handle condensation issues associated with creating airtight internal spaces and mechanical ventilation that use Heat Recovery Ventilation systems to maximise energy savings.

Existing Vocational Education and Training (VET) packages cover installation, thermal and acoustic environmental protection systems and the construction of thermally efficient sustainable structures. Existing education and training packages in Technical and Further Education institutions (TAFEs), Registered Training Organisations (RTOs), the Construction Property Services and Skills Council (CPSISC) and the Master Builders Association (MBA) can be upgraded if, and when, the Australian building and construction industry begin to embrace super insulation techniques such as vapour membrane installations.

Skill and knowledge deficiencies in super insulation and airtight construction techniques should also be addressed at the higher education level. Current and aspiring construction managers, architects and engineers undertaking degree and higher qualifications will need to be proficient in the many design and application techniques specific to this building methodology.

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## Abbreviations and Acronyms

ACH	Air changes per hour
AIA	Australian Institute of Architects
AIB	Australian Institute of Building
AIG	Australian Industry Group
AIRAH	Australian Institute of Refrigeration, Air Conditioning and Heating
API	Australian Property Institute
ASBEC	Australian Sustainable Built Environment Council
BRI	Building Research Institute (Japan)
CAD	Computer Aided Design
CEnvP	Certified Environmental Practitioner
CEPHEUS	Cost Efficient Passive Houses as European Standards
CIB	International Council for Building Research Studies and Documentation
CoP	Coefficient of Performance
CNC	Computer Numerical Controlled
CPSISC	Construction Property Services and Skills Council
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DIN	Deutsches Institut für Normung e.V. (German Institute for Standardisation)
EBS	Experimental Building Station
EIANZ	The Environment Institute of Australia and New Zealand
EN	European norm
ERV	Energy Recovery Ventilation
EU	European Union
FM	Facilities management
GBCA	Green Building Council Australia
H-1	The unit used to refer to air change rate and can be infiltration or escape and measured to a constant 1 at 50 Pa
HIA	Housing Industry Association

## Abbreviations and Acronyms

HRV	Heat Recovery Ventilation
IBP	Institute for Building Physics
IEQ	Indoor Environmental Quality
JIT	Just in time
kWh	Kilowatts per hour
MBA	Master Builders Association
MJ	Megajoule
Pa	Pascal: unit used to measure pressure
PHI	Passivhaus Institut (Passive House Institute)
PHPP	Passivhaus Planning Package (Passive House Training Package)
PPM	Parts per million
RACCA	Refrigeration and Air Conditioning Contractors Association of Australia Inc
RICS	Royal Institution of Chartered Surveyors
RTO	Registered Training Organisation
TAFE	Technical and Further Education
UC	University of Canberra
UV	Ultra Violet
VET	Vocational Education and Training
VIP	Vacuum Insulation Panel
WUFI	Franhofer-Institut for Building Physics (IBP) developed heat and moisture transfer software

## Definitions

#### **Buoyancy/Stack effect**

Buoyancy of air varies with temperature and pressure differentials. The varying density of air, coupled with the height of buildings, and differences of pressure and temperature between the inside and outside of structures, gives rise to the phenomenon referred to as the stack effect. The stack effect is usually associated with hot, less dense air rising and cooler, denser air sinking. Solar chimneys utilise the stack effect by exhausting warm air at the top of the chimney, which is replaced by cooler, denser air at the bottom of the chimney.

#### Design

Design is problem setting and problem solving.

Design is a fundamental economic and business tool. It is embedded in every aspect of commerce and industry and adds high value to any service or product—in business, government, education and training, and the community in general.

Reference: 'Sustainable Policies for a Dynamic Future', Carolynne Bourne AM, ISS Institute 2007.

#### EcoCute

A Japanese developed heat pump that utilises carbon dioxide as a refrigerant in the heating and cooling cycle. The EcoCute system is an effective means of using heat from the air to heat water for domestic hot water systems.

#### **Embodied energy**

Embodied energy refers to the total lifecycle energy associated with a material, product or system. The lifecycle is classified as being 'cradle to cradle', which includes the energy used in raw material extraction or growth and development, processing, manufacture, transportation, installation, deconstruction and or decomposition of the material, product or system.

#### **Energy Recovery Ventilation (ERV)**

ERV is a system that recovers (heating and cooling) energy in the air circulating through a buildings ventilation system by an exchange process of mixing intake air streams with air that is being mechanically exhausted out of the building to either transfer useful heating or cooling of the air stream as desired for the most comfortable indoor climate setting

#### Heat pumps

Heat pumps usually refer to devices such as a refrigerator or air conditioning units. These heat pumps draw heat from the air and via a vapour compression cycle produce either desired heating or cooling. Some systems may exchange heat from the surrounding air or from soil at varying depths or water. The process, by switching a valve and changing the compression cycle from condensing to evaporating, allows cooling and heating to take place as desired.

#### Heat Recovery Ventilation (HRV)

HRV is a system that recovers heat energy in the air circulating through a building's ventilation system by an exchange process of mixing intake air streams with air that is being mechanically exhausted out of the building to transfer useful heat to cooler intake air.

#### Passivhaus

Passivhaus designs are based on the Darmstadt Institutes set of design criteria published in the Passivhaus Planning Package (PHPP). The Passivhaus reference is used to signify a quite distinct set of design criteria and is applied to reference the Darmstadt-based Institutes designs over the traditional Anglicised Passive House design definitions of the past.

Passivhaus designs are characterised by super insulation, and airtight construction that has mechanical ventilation optimised through a HRV system, which maintains a 15 kWh/m²/pa maximum energy usage.

#### Photogrammetry

Photogrammetry is the art, science and technology of taking measurements off photographs.

#### **R-value**

R-value is the measure of thermal resistance in the building and construction industry. It is the heat resisting units of any section of building assembly described. A material's R-value is the measure of its resistance to heat flow: the higher the R-value the higher the resistance to heat flow. R-value is the reciprocal of U-value.

#### Sarking

Sarking is a flexible membrane material normally used for waterproofing, vapour proofing or thermal reflectance.

#### Skill deficiency

A skill deficiency is where a demand for labour has not been recognised and training is unavailable in Australian education institutions. This arises where skills are acquired on-thejob, gleaned from published material or from working and/or studying overseas.

Reference: 'Directory of Opportunities. Specialised Courses with Italy. Part 1: Veneto Region', ISS Institute, 1991.

There may be individuals or individual firms that have these capabilities. However, individuals in the main do not share their capabilities, but rather keep the intellectual property to themselves. Over time these individuals retire and pass away. Firms likewise come and go.

#### Supatherm

Supatherm is a wall panel system that was designed to provide extra external insulation to a timber frame, brick veneer construction. It provides this extra insulation by utilising the improved thermal benefits of a reflective foil air gap and rigid, closed cell, polystyrene foam backing to Hebel power panels. The system creates an R5 wall that can be used in place of the 150 mm brick cavity used in traditional brickwork and in brick veneer construction. The system offers far greater insulation, less weight and superior 'buildability'.

### Definitions

#### Sustainability

The ISS Institute follows the United Nations for Non-Governmental Organisations' definition on sustainability: *"Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"*. Reference: http://www.unngosustainability.org/CSD\_Definitions%20SD.htm

#### **Thermal bridge**

A Thermal bridge occurs when materials that are either good conductors or poor insulators come in contact. This is usually associated with heat flow-through from a warmer area to a cooler area.

#### **U-value**

A measure of the flow of heat through an insulating or building material: the lower the U-value, the better the insulating ability. U-value refers to the co-efficient of thermal transmittance, which is the measure of heat transferred through complete building components, such as a wall. The U-value is the reciprocal of R-value.

#### Vapour barrier

A vapour barrier is a material or system that adequately impedes the transmission of water vapour. These are usually installed to specific requirements.

#### WUFI

Software developed by the Fraunhofer-Institut for Building Physics (IBP) to calculate the coupled heat and moisture transfer in building components.

Shane West would like to thank the following individuals and organisations who gave generously of their time and their expertise to assist, advise and guide him throughout the Fellowship programme.

## Awarding Body – International Specialised Skills Institute (ISS Institute)

The International Specialised Skills Institute Inc is an independent, national organisation that for over two decades has worked with Australian governments, industry and education institutions to enable individuals to gain enhanced skills and experience in traditional trades, professions and leading-edge technologies.

At the heart of the Institute are our Fellows. Under the **Overseas Applied Research Fellowship Programme** the Fellows travel overseas. Upon their return, they pass on what they have learnt by:

- 1. Preparing detailed reports to government departments, industry and education institutions.
- 2. Recommending improvements to accredited educational courses.
- 3. Offering training activities including workshops, conferences and forums.

Over 180 Australians have received Fellowships, across many industry sectors.

Recognised experts from overseas also conduct training activities and events. To date, 22 leaders in their field have shared their expertise in Australia.

According to Skills Australia's 'Australian Workforce Futures: A National Workforce Development Strategy 2010':

Australia requires a highly skilled population to maintain and improve our economic position in the face of increasing global competition, and to have the skills to adapt to the introduction of new technology and rapid change.

International and Australian research indicates we need a deeper level of skills than currently exists in the Australian labour market to lift productivity. We need a workforce in which more people have skills, but also multiple and higher level skills and qualifications. Deepening skills across all occupations is crucial to achieving long-term productivity growth. It also reflects the recent trend for jobs to become more complex and the consequent increased demand for higher level skills. This trend is projected to continue regardless of whether we experience strong or weak economic growth in the future. Future environmental challenges will also create demand for more sustainability related skills across a range of industries and occupations.<sup>1</sup>

In this context, the Institute works with Fellows, industry and government to identify specific skills in Australia that require enhancing, where accredited courses are not available through Australian higher education institutions or other Registered Training Organisations. The Fellows' overseas experience sees them broadening and deepening their own professional practice, which they then share with their peers, industry and government upon their return. This is the focus of the Institute's work.

For further information on our Fellows and our work see www.issinstitute.org.au.

Patron in Chief	Board Members	Mr John Iacovangelo		
Lady Primrose Potter AC	Mr Mark Bennetts	Mr David Wittner		
Board Chairman	Mr Franco Fiorentini	Chief Executive Officer		
Ms Noel Waite AO	Sir James Gobbo AC, CVO	Mr Jeremy Irvine		

<sup>1</sup> Skills Australia's 'Australian Workforce Futures: A National Workforce Development Strategy 2010', pp. 1-2 http://www.skillsaustralia.gov.au/PDFs\_RTFs/WWF\_strategy.pdf

#### **Fellowship Supporter**

This Fellowship has been supported by the Department of Education, Employment and Workplace Relations (DEEWR).

DEEWR provides national leadership and works in collaboration with the States and Territories, industry, other agencies and the community in support of the Government's objectives. DEEWR aims to touch the lives of all Australians in a positive way, working towards a vision of creating a productive and inclusive Australia. Shane West would like to thank them for providing funding support for this Fellowship.

#### Supporters

- ACT Government, The Hon Andrew Barr, Minister for Education
- Australian Institute of Building (AIB), Troy Williams, formerly Chief Executive Officer
- Construction Property Services and Skills Council (CPSISC), Alan Ross, Chief Executive Officer
- Department of Education Employment and Workplace Relations, Ray Dingli, Assistant Director, Workforce Development Branch, Tertiary Skills and Productivity Group
- Master Builders Association ACT (MBA), Jerry Howard, Deputy Executive Director
- University of Canberra, Australia (UC), Professor Atique Islam, Dean of Faculty Business
   and Government

#### Individuals Involved in the Development of the Overseas Programme

- Dr Abbas Elmualim, University of Reading, United Kingdom
- The Hon Andrew Barr, Minister for Education, ACT Government, Canberra
- Andy Russell, Proctor Group Australia
- Helmut Meyer, CEO, Transsolar Energietechnik GmbH, Stuttgart, Germany
- Professor Hideki Shibaike, Kyoto Institute of Technology
- Professor Noriyoshi Yokoo, Utsunomiya University, Utsunomiya, Japan
- Professor Stefan Winter, Munich, University of Technology, Munich, Germany
- Professor Wolfgang Feist Passivhaus Institut, Darmstadt, Germany

#### Individuals and Organisations Impacted by the Fellowship

#### **Government and Government Agencies**

- Australian Building Codes Board (ACCB)
- CSIRO Industrial Research Services
- Department of the Environment, Heritage and the Arts
- Department of Climate Change
- Department of Innovation, Industry, Science and Research
- State Education Departments (and, through these departments, TAFEs)
- State and Territory Planning Departments
- State and Territory Building Commissions
- State and Territory Environment and Sustainability Departments

### Acknowledgements

#### **Industry and Professional Associations**

- Australian Constructors Association (ACA)
- Association of Consulting Architects
- Australian Industry Group (AIG)
- Australian Institute of Architects (AIA)
- Australian Institute of Building (AIB)
- Australian Institute of Building Designers
- Australian Institute of Refrigeration, Air Conditioning and Heating
- Australian Property Institute (API)
- Australian Sustainable Built Environment Council (ASBEC)
- Association of Wall and Ceiling Industries
- Construction Property Services and Skills Council (CPSISC)
- Engineers Australia
- Good Environment Choice Australia
- Green Building Council Australia (GBCA)
- Housing Industry Association (HIA)
- Master Builders Association of Australia (MBA)
- Master Plumbers and Mechanical Services Association of Australia
- Refrigeration and Air Conditioning Contractors Association of Australia Inc. (RACCA)

#### Home Building and Construction Companies

- Alcock Brown-Neaves Group
- BGC (Australia) Pty Ltd
- Burbank Homes
- Clarendon Residential Group
- Coral Homes
- Dennis Family Homes
- Devine Group
- GJ Gardner Homes
- Henley Properties
- Hickory Developments Pty Ltd
- Hickinbotham Group of Companies
- Hotondo Homes
- JG King
- JWH Group
- Meriton Apartments
- Metricon Homes
- Mirvac Group
- Multiplex Limited
- Porter Davis Homes
- Simonds Group

## About the Fellow

Name: Professor Shane West

#### Employment

• Professor, Chair and Head of Building and Construction, University of Canberra

#### Qualifications

- Bachelor of Building, University of New South Wales, 1982
- Accredited ACT Class A (Commercial) licensed builder and consultant
- Graduate Diploma in Adult Education, Sydney College of Advanced Education, 1988
- Masters in Environmental Studies, University of New South Wales, 1992
- PhD University of Technology, Sydney, 2008

#### Memberships

- Chartered Environmental Practitioner (EIANZ) CEnvP
- Committee member of the International Council for Building Research Studies and Documentation (CIB)<sup>2</sup>
- Fellow of the Australian Institute of Building (AIB)
- Former Director of Addison Road Community Centre, Marrickville
- Former Vice President (NSW) Environment Institute of Australia &New Zealand.
- Member of the Royal Institution of Chartered Surveyors (RICS)
- Member of Standards Australia Committee for AS/NZ 47402000 Natural ventilatorsclassification and performance completing the mathematical analysis for wind driven ventilators

Shane West has been involved with the Building Industry for 30 years. He is currently the ACT Government Chair of Building and Construction Management and the Head of the Building and Construction Management course at the University of Canberra. Prior to his current position, the Fellow was Head of School at the Applied Technology Institute, Unitec, New Zealand, where he managed a staff of 130 and a \$NZ22 million budget. He also served as Associate Head of School (Research and External) at the University of Technology, Sydney, Faculty of Design, Architecture and Building where he was Head of the Construction Program.

Since 1989, the Fellow has been a Director of Environmental Sciences Australia Pty Ltd. He is also a founding member of Insite Industries. He was a Board member of the Addison Rd Centre, Marrickville, for six years, during which time he designed and project managed five community building projects for the centre.

As well as having a business and university consulting background, the Fellow has research interests in sustainable building technologies and methodologies for improving the built environment. He has been responsible for several patents and innovative product developments in sustainable building technologies, the most recent being the Wind Directional Skylight Vent. West is a member of a number of national and international design advisory groups.

<sup>&</sup>lt;sup>2</sup> CIB is part of the International Scientific Committee of CIB Task Group W116-Environmental Assessment of Buildings-SASBE.

## **Aims of the Fellowship Programme**

The purpose of the Fellowship was to undertake a study programme to better understand the skills required for new advanced airtight insulated construction applicable to new lightweight envelopment technologies.

Specific Fellowship objectives are to:

- Examine and assess the use of airtight construction techniques and lightweight walling materials that could be utilised in Australia as hybrid (medium density) designs.
- Compare lightweight exterior envelope building techniques and conduct a detailed analysis of buildability, health and safety.
- Determine the skills required and how these skills can be translated into the Australian Building and Construction Industry.
- Evaluate international mechanical and natural ventilation rates, as well as new technologies utilising heat recovery ventilation, coupled with efficient heating and cooling systems.
- Obtain up-to-date information on new wall envelopment methods and associated technologies using a systems approach.
- Learn the latest techniques employed in constructing houses, incorporating airtight and super insulation construction methods, such as those designed by the Passivhaus Institut in Germany.
- Make recommendations for up-skilling in the relevant Australian educational packages for Vocational Education and Training (VET) and higher education courses.

## **The Australian Context**

Through the introduction of new technologies and methodologies that deliver improved energy efficiencies, the Australian Building and Construction Industry can make a significant contribution to meeting national greenhouse gas reduction targets.

The Centre for International Economics estimates that buildings are responsible for approximately 23 per cent of Australia's greenhouse gas emissions.<sup>3</sup> When demolition, renovation and refrigeration activities are added, the contribution to greenhouse emissions by the Australian construction and facilities service sectors may well be in the order of 25 per cent.

Often neglected in studies of sustainable building materials and energy efficient designs are economic viability, buildability and safety requirements. Products need to be built quickly and be mainstream, as well as be safe and cost efficient.

Energy leakage due to inadequate insulation and poor building design is a significant issue for the Australian building and contruction industry. While moving to more airtight construction methods will overcome energy leakages, new challenges subsequently arise in ensuring proper airflow and air quality.

Achieving and maintaining indoor air quality that meets Occupational Health and Safety requirements is of particular importance. Reports show that even in air conditioned buildings, poor filtration systems can result in a fresh air intake of less than 15 per cent leading to internal air spaces remaining contaminated.<sup>4</sup>

While Australian homes and commercial buildings do not have to contend with months of freezing conditions, the heating and cooling of our buildings require heavy domestic energy consumption that is reliant on cheap (mainly coal fired) energy. In order to help meet government mandated greenhouse gas emission targets, new technologies will need to be embraced to reduce the inefficient heating and cooling of our current poorly insulated housing stock. Substantial energy savings can be made by building more energy efficient houses and commercial buildings. The issue is how best to achive greater energy efficiency.

Determining the merits of adopting airtight super insulation construction techniques across the Australian building and construction sector requires a detailed cost/benefit analysis. Improvements in energy efficiency are already being achieved. In some instances achieving airtight buildings that need to be supplemented with mechanical ventilation to reduce subsequent  $CO_2$  build ups may increase energy use. Schools that are naturally ventilated also reduce peak load energy demand and these points need to be contextualised. Australian office buildings are meeting existing standards, which are lower, at 10.3 Kilo watts per hour (kWh)/m<sup>2</sup>, than Passivhaus Institut's (PHI's) prescribed limits for heating, but the vexed question of cooling loads also needs to be considered in the Australian context.

The Passivhaus Institut's designs are based on the Darmstadt Institute's design criteria published in the Passivhaus Planning Package (PHPP).

In the Australian context, low load heating options that are now being developed such as solar thermal water slab heating should be assessed and compared as an option to the PHPP approach. Australia's potential to utilise solar renewable energy resources reduces the need for the high levels of insulation mandated in European PHI accredited buildings and again an Australian contextualised model needs to be evaluated.

<sup>&</sup>lt;sup>3</sup> The Centre for International Economics (2007)

<sup>&</sup>lt;sup>4</sup> Australian Standard 1668 Pt 2 1991 recommends offices to have a ventilation rate of 10 litres per second per person

Conversely, Europe does not have to contend with Australia's higher cooling requirements. Further research is needed to determine the suitability of PHI designs for high cooling environments.

Also, the PHPP focuses on HRV applications, while Energy Recovery Ventilation (ERV) systems<sup>5</sup>, capable of utilising cooling loads while simultaneously enabling a house to operate in hybrid natural ventilation mode, would be more appropriate for Australian-style living and climatic conditions.

#### SWOT Analysis

A SWOT analysis provides a useful avenue for exploring airtight construction applications applied to new lightweight envelopment technologies. Exploring strengths, weaknesses, opportunities and threats provides an effective means of 'mapping' the current situation and identifying opportunities for future developments.

#### Strengths

- Increased energy efficiency
- Reduction in greenhouse gas emissions
- Faster building times and better buildability of structures
- Lighter weight materials may offer safety advantages in construction
- Potential cost savings
- Improved health and wellbeing

#### Weaknesses

- Possible cost
- Material availability
- The set views of trades

#### **Opportunities**

- Implementation of new techniques and synergistic systems
- Opportunity to adopt a more professional approach to managing construction sequences (instead of haphazard methods)
- Opportunities to implement leading-edge technologies and to reduce substantial greenhouse emissions

#### Threats

- Not mainstream building materials
- Resistance to change
- Not mainstream techniques
- Distribution and supply

<sup>&</sup>lt;sup>5</sup> An ERV works on similar principles to a HRV. Fresh air is continuously brought into the home replacing the indoor stale air. Before the stale air is exhausted, its heat or cooling energy is transferred to incoming air via plastic pathways.

## **Identifying the Skills Deficiencies**

Australian domestic construction has had a different pedigree to Europe's and North America's due largely to Australia being generally a milder, more temperate climate. The need to build buildings that are airtight and well insulated is now seen as being of benefit even in the Australian context, with rising carbon footprints and the need to reduce energy demand. In Australia there has been confusion between the terms 'thermal mass' and 'insulation'. Low embodied energy materials/high thermal mass materials such as in situ concrete (based on a MJ/kg metric), are often thought of as being good insulators. In reality concrete, because of its density, exhibits high thermal conductance, ie it is a poor insulator. High thermal mass is often rated as a means of providing sustainable qualities, and high mass structures also contain large amounts of material resulting in heavy lifting and added transport costs.

It is now timely to consider lightweight foam, timber and other airtight building techniques utilised in Europe and North America. Highly insulated envelopes containing thermal mass interior inertia and natural ventilation and daylighting are building techniques and designs that should be promoted in Australia. Because the construction skills and techniques associated with these new designs are yet to be employed widely in Australia, there are knowledge and skill deficiencies that need to be addressed.

The Fellow identified the following skill deficiencies:

- 1. Knowledge and application of appropriate insulation integrity and ability to analyse and reduce thermal breaks.
- 2. Identifying and understanding the newer materials and qualities associated with sealants and weatherproof foams and other lightweight and airtight construction materials.
- Understanding the sequential processes involved with joining and fixing materials that are currently not utilised to the same degree in the Australian building industry, ie foams and other lightweight and airtight construction materials.
- 4. The application and science of vapour breathing sarkings and appropriate material application of membrane skin technologies.
- 5. Knowledge of appropriate ventilation rates and Heat Recovery Ventilation (HRV) units, and the application and ability to calibrate and design natural ventilation rates also need to be evaluated in concert with the envelopment systems employed.
- 6. An ability to adopt a synergistic systems approach to combining appropriate technologies, such as sealed building envelopes that rely on mechanical ventilation. The required knowledge and skill base to correctly select and operate associated technologies, such as appropriately sizing and employing heat exchangers utilised in new HRV technology.

#### Nationally Accredited Courses

Nationally accredited courses need to design curriculum to include student learning outcomes enabling students to be able to adequately assess new technologies and have the organisational and management ability to be able to apply the technologies as synergistic systems. This will enable total systems operations that will maximise energy efficiencies. Sustainable systems, building technology and management including construction quality training components need to be incorporated into multi-level educational training packages and, in particular, university delivered building and construction degrees.

The relevant training packages and university units, courses and subjects impacted by this Fellowship are the Construction and Property Services Industry Skills Council (CPSISC) training packages and the Building and Construction tertiary level University degree courses. The latter are affiliated with the Australian Institute of Building, the Australian Institute of Quantity Surveying and the Australian Institute of Building Surveyor's accreditation.

The relevant CPSISC training packages are:

- CPC08 Construction, Plumbing and Services Integrated Framework Training Package
- CP07 Property Services Training Package
- PRM04 Asset Maintenance Training Package
- CPCCPB3014A Install Batt Insulation Products
- CPCCPB3015A Install Acoustic and Thermal Environmental Protection Systems
- CPCCBC4020A Build Thermally Efficient and Sustainable Structures

The relevant University tertiary degrees are those accredited by the Australian Institute of Building, the Australian Institute of Quantity Surveyors and the Australian Institute of Building Surveyors.

The Fellow travelled to Japan, Germany and the United Kingdom.

#### Japan

#### Passive House Centre, Tokyo

**Contacts:** Masazumi Horiuchi, CEO, El Ltd; Nobukazu Iwase, Partner, ECO Transfer Japan; and Norbert A Baumann, Representative, ECO Transfer Japan and Professor Hideki Shibaike, Kyoto Institute of Technology

The Fellow was briefed on the initial stages and design rationale of Japan's first passive house, to be built at Saitama on the outskirts of Tokyo. The project is headed by Professor Hideki Shibaike of Kyoto University of Technology and partnered with ECO Transfer Japan. ECO Transfer Japan supplied the vapour barrier technology and is consulting on the project. ECO Transfer's supplied membrane material is from German producer pro clima MOLL GmbH of Schwetzingen, Germany. Pro clima MOLL GmbH of Schwetzingen, Germany, was visited by the Fellow and is elaborated on further in the report.

The membranes to be utilised in the project include internal membranes, marketed under the name of Intello, manufactured by pro clima. The external sarking is called Solitex UD and is also manufactured by pro clima. The hydrothermal envelope simulation was performed using WUFI vapour/condensation software developed by Franhofer Institute of Building Physics (IBP).

The difference in climate and vapour flow rate between European climates with hot interiors and cool exteriors is quite a different application when compared to Tokyo's humid marine summers with warm moist exterior air that flows through to cooler air-conditioned internal environments. As condensation occurs when hot moist air comes into contact with colder surfaces: a hot, humid, external airflow through to a cooler environment inside a building, as in a Tokyo summer, is the opposite of the traditional European condensation scenario. Reverse condensation control may be experienced in Tokyo's buildings and having the vapour barrier on the inside of the building envelope, as in the European context, may not be appropriate.

Having one membrane that operates in dual directions for vapour flow is being considered by the Saitama group and may be the preferred option for Tokyo housing, albeit likely at a higher production cost. Given Tokyo's latitude, higher cooling loads are also required compared to measured data for the European Passivhaus designs. The Tokyo Passive House design holds a lot of interest because of similarities with Australian climatic zones.

#### Saitama Passive House, Saitama-City, Saitama

**Contacts:** Kazuhiro Haishima, CEO Haishima Corporation; Professor Hideki Shibaike, Kyoto Institute of Technology; Kouketsu, Haishima Corporation; Sugimoto, Maruden Corporation and Hayama, Maruden Corporation; T-Itoh, Maruden Corporation

The Fellow visited the Saitama Passive House to see the systems employed. At the time of visiting the house was only completed to the hold down plates for the timber framing.

The project is a small 86-square-metre development, designed for occupancy by an aged couple. The building is designed to include, south facing shading devices, insulated slab, vapour barriers and insulated walls.



Saitama Passive House. Note: insulation to concrete basement

The structural frame includes unique Japanese nail-less notched framing.

The envelope of the building incorporates an insulated, airtight and weatherproof wrap utilising German pro clima technology.

An external polypropylene rain screen membrane excludes water vapour from the outside. The internal breathable skin is placed before the internal air gap. The project is also utilising BASF SmartBoard with a 27 degree Celsius phase change material resin and Proctor Aerogel where there is a load bearing thermal bridge.<sup>6</sup>

The windows are locally made, triple glazed, vinyl framed and achieve a rating of 1.23 watts per square metre.

The project is supported by the External Insulation Council of Japan and features a polystyrene external of 50 mm, 250 mm of blown fibreglass insulation and a 30 mm air gap. The structure uses Japanese sourced timber that is CNC (Computer Numerical Controlled) machined and delivered without any nail fixing.

The skill sets required for such a building are substantially different to Australian construction methods.

<sup>&</sup>lt;sup>6</sup> Aerogel is a low density solid derived from a gel in which the liquid component has been replaced by gas in a process known as supercritical drying. This gives a material with remarkable insulation properties.



Notched structural timber frame awaiting on-site assembly



Section of the wall envelope





Insulation and vapour barriers on the interior and exterior of the envelope

Swedish Heat Exchanger REC Heat Recovery Ventilation unit as employed in the Saitama project

The project uses a Swedish Heat Exchanger, REC Indovent, which claims an 80 per cent heat recovery capability.

The Saitama Passive House is fitted with thermo couples to measure the energy performance of the thermal envelope.

Additional meetings were subsequently held with the Haishima Corporation where the relative merits of the Maruden Corporation's Panasonic EcoCute carbon dioxide refrigerant systems/heat pump systems were considered.

#### Misawa Homes Institute of Research and Development Co Ltd, Tokyo

**Contacts:** Professor Nori Yooko, Design & Engineering, Utsunomiya University; Dr Kurihara, Technical Manager, Missawa Homes and Dr Junichi Kurihara, Director, Misawa Homes

Misawa Homes is a pioneer in prefabricated housing systems and has more than a decade of experience in the construction of zero-energy homes. Misawa Homes Institute of Research and Development is the R&D arm of Misawa Homes.

Although the Misawa product has many excellent features, it does not utilise airtight construction. Misawa Homes use  $4 \times 2$  (stick) timber frame, ventilated skins and eaves similar to contemporary Australian construction materials.

#### The Building Research Institute of Japan (BRI), Tokyo

**Contacts:** Dr Takao Sawachi, Director, Department of Environmental Engineering, BRI and Professor Nori Yooko, Design & Engineering, Utsunomiya University

The visit to the Building Research Institute of Japan (BRI) better informed the Fellow of the skill sets required to determine ventilation rates. New insights were gained into the calibration and design of natural ventilation systems in envelopment building construction.

The BRI assesses new technologies continually to determine their capabilities in delivering maximum energy efficiencies throughout the building construction sequence.

The facilities at the BRI are world class. Their extensive on-site research capabilities include the capacity to construct full-scale model ventilation systems in actual building layouts.



BRI full-scale ventilation modelling

The BRI automated bath system

The BRI even boasts a vacant three-storey apartment building that has been constructed solely for product and design testing. The building is fully automated to replicate everyday living functions, such as opening doors and windows. It even replicates bath times and other moisture producing functions. Effective moisture control is considered a significant indoor environment quality issue that delivers a healthy indoor living environment with a positive contribution to preventative health outcomes.

Future points of interest and potential research alliance with the BRI would be beneficial especially with the BRI's research interest in hybrid natural ventilation/air conditioned spaces. This research is also very applied and with similar climatic extremes to Australia results would be directly transferable to Australian scenarios.

Tests and applicability to Australian conditions also provide similar benefits economically with payback analysis. Access to training guides developed and results from Dr Sawachi's heat pump performance—coefficient of performance (CoP) to room size research are also valuable potential data for Australian applications.

#### Daikin, Osaka

Contacts: Professor Hideki Shibake and Dr Takanori Yamamoto

The visit to Daikin Headquarters in Osaka enabled the Fellow to compare the heat pump CoP of the EcoCute hot water system against the Quantum heat pump system. The EcoCute is patented in Japan and considered a potential replacement for refrigerant heat pump hot water systems commonly used in Australia.

Quantum-style air-to-water heat pumps extract heat from the air and use a refrigeration cycle to compress this heat into the water which, in turn, delivers domestic hot water. The use of hot water is one of the biggest contributors to energy use in the domestic house.

In contrast, the EcoCute system uses carbon dioxide as its refrigerant and offers a means of carbon capture and greater energy efficiency. Further cost benefit analysis is required to assess the relative merits of the Quantum/EcoCute comparison. The EcoCute system's use of carbon dioxide as a refrigerant does provide a significant use for CO<sub>2</sub>, and the system has a higher CoP than a Quantum system and deserves the attention of Australian business.

#### Sumitomo Forestry Co Ltd, Home Show, Setagaya, Tokyo

Contact: Takashi Shibayama, Manager, Overseas Business Division

Sumitomo is an established quality timber and building company committed to building green, energy efficient housing. Sumitomo builds approximately 10,000 houses a year in Japan. At the time of the Fellow's visit, Sumitomo Forestry announced it had taken up a 50 per cent stake in Henley Properties Pty Ltd Australia. Henley builds over 1700 homes a year and is Australia's sixth largest homebuilder.<sup>7</sup> Sumitomo sees Australia as a growing market. Conversely, Japan is a declining market due to an ageing demographic and negative population growth.

Sumitomo are vertically integrating their company. It has interests in forest timber through to construction. It is particularly interested in adopting an Australian-style home energy rating scheme. No such scheme currently operates in Japan. The Fellow undertook to seek approval from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) for Sumitomo to test run CSIRO's Accurate House Energy Rating Programme in a selection of their project homes. Sumitomo's concerns about certain Australian building methodologies relate to issues such as Australian builders' lack of attention to detail and poor finishing practices including sarking and vapour barriers.

<sup>&</sup>lt;sup>7</sup> Housing Industry Association (HIA), Top 20 Builders by Volume 2009, <economics.hia.com.au/publications/ housing\_100.aspx - top 20 builders by volume 2009>

Noise insulation to second floor joists in Australian housing construction was also identified as an issue of concern.

Sumitomo champions natural ventilation in its homes. It incorporates vented cavity construction and vented roof ridge vents with unique above-doorway breezeway panels to provide cross flow and stack flow ventilation.



Sumitomo green display home, Setagaya, and a Sumitomo natural design with an adjustable breezeway panel

#### Germany

#### Passivhaus Institut (PHI), Darmstadt

Contacts: Soren Peper, Senior Scientist and Jurgen Schnieders, Senior Scientist

Peper and Schnieders outlined the principles for using the Passivhaus Planning Package (PHPP). The PHPP is the guiding methodology used to design and measure the performance, operationally, of a building and to see if it complies and meets the Passivhaus Institut PHI standards.

The Fellow inspected super insulation material used in PHI-certified buildings. This is a new polystyrene mixture with infrared reflecting beads that deliver superior performance over normal blown polystyrene. Super insulation significantly reduces heat transfer through walls, roofing and floors. Australia brick veneer construction has, at best, R-value of R2.5 insulation wall values. In contrast, a European Passivhaus' construction may have wall values in excess of R9.

The minimum PHPP requirement for the elimination of thermal bridges is R6.6. Super insulation helps trap low base heat sources, such as internal lighting and household equipment, to provide sufficient internal heat loads without the need for supplementary heating.



External insulation used in PHI-certified buildings

External insulation ready for fixing in PHI certified buildings

Airtight construction around doors and windows is an important requirement. An efficient Heat Recovery Ventilation (HRV) unit is crucial to the integrity of the PHPP system. A HRV unit strips heat from stale air as it is being exhausted and being exchanged for incoming air. The relatively low rate of Air changes per hour (ACH) at 0.5–0.6 and the low rate of fresh air exchange, saves on heat loss.

The potential downside of a system such as a HRV unit is mechanical failure. The alternative, natural ventilation, is not included in PHI designs.

Following his meeting with PHI scientists, the Fellow visited building sites employing PHI insulation principles. The volume of internal and external foam used for PHI-certified buildings was quite surprising.

Installing the insulation is straightforward. Plastic nails and adhesives are used for some sections to minimise thermal bridging and achieve sufficient bond strength. Taping skills and attention to detail are learnt on site under experienced supervisors. The correct use of adhesives, taping and accuracy were seen as the main considerations and would be easily taught and incorporated into TAFE, CPSISC training packages in Australia.

The properties of foam such as the low water absorption varieties used below ground with high compressive strength ability, UV resistance capacity and compatibility are set out in product technical and installation manuals. Tradespeople working with this material would be capable of developing the necessary skill sets in a short time. Construction managers, quantity surveyors, architects, structural and civil engineers would also need to be fully conversant with manufacturers' specifications and proven application techniques.

The Passivhaus Institut has set new international standards in energy efficiency benchmarking for buildings. The European Union for example has commissioned a project called Cost Efficient Passive Houses as European Standards (CEPHEUS) to identify and assess energy efficient techniques for incorporation into European buildings.

The requirements for a quality approved passive house are set out in the Passivhaus Planning Package (PHPP). The energy efficiency standards established by the Passivhaus Institut are as follows:

- The entire specific primary energy demand (including domestic electricity) must not exceed 120 kWh/m<sup>2</sup> per year.
- The exterior building elements must have a U-value below 0.15 W/(m<sup>2</sup> K) or exceed an R-value of R6.6.
- The building's demand for space heating does not exceed 15 kWh/m<sup>2</sup> per year. This
  includes cooling as well, which is sometimes overlooked when discussions focus on
  Central Europe (which has a heating demand greater than cooling).
- The total final energy demand for space heating, domestic hot water and household appliances is below 42 kWh/m<sup>2</sup> per year.
- The air tightness of the building envelope should be verified by means of an air leakage test complying with Deutsches Institut f
  ür Normung e.V./the German Institute for Standardisation (DIN) EN 13829 standard. The measured air leakage must not exceed 0.6H-<sup>1</sup> at a pressure differential of 50 Pa for both over and under pressurisation.
- An ACH of 0.3 times an hour minimum.
- All glazing must have U-values under 0.8 W/(m<sup>2</sup>K), R1.25 according to European Norm EN 673, and a high total solar transmittance (g) of at least 50 per cent according to EN 410 to achieve net heat gains in winter.
- The ventilation system must be designed with the highest energy recovery efficiency of greater than 75 per cent complying with PHI certification for results and minimal electricity consumption less than 0.45 Wh/m3 supply air volume.
- Domestic hot water generation and distribution systems with minimal heat losses must be used.
- Highly efficient use of household electricity is essential.

PHPP certification for a building requires that demand for heating and cooling does not exceed 15 kWh/m<sup>2</sup> per year; the building passes a pressurisation test to verify that it is airtight; and primary energy demand—including domestic electricity—does not exceed 120 kWh/m<sup>2</sup> per year.

Implementing the PHPP in Australia would require vapour membranes and air tightness to be assessed and tested under Australian climatic conditions. Airtight buildings in a temperate climate such as Australia may not be a significant contributor to improved energy efficiency.

Studies such as (Begert, 2009) have shown that  $CO_2$  levels increase dramatically above 1200 parts per million (ppm) in schools due to airtight sealing of light fittings, resulting in unacceptable levels of  $CO_2$  which, in turn, requires higher mechanical ventilation rates over the original natural ventilation operation.<sup>8</sup> A cost/benefit analysis of operational energy savings needs to be balanced against the cost of increasing insulation and design requirements to meet the PHPP standards.

#### Pro clima MOLL GmbH, Schwetzingen

**Contacts:** Lothar Moll, Managing Director and CEO; Jens Lüder Herms, Project Manager; and Norbert Baumann, Sales Manager

Pro clima MOLL GmbH manufactures and supplies many of the PHI building products including: breathing and non-permeable vapour membranes, high speed adhesive tapes, universal adhesive tapes, elastic and double-sided adhesive tapes, connection tapes for component units, airtight sealing glues for connections to component units and waterproof glue for outdoor application. The company also consults on appropriate installation applications and techniques.

The company is involved with the Saitama Passive House project in Japan. It also has a presence in New Zealand and is keen to market its expertise and product range in Australia.

The Fellow's discussions with pro clima MOLL GmbH focussed on suitable Australian solutions for vapour transfer and condensation reduction. A wall panel system developed by the Fellow, Supatherm, was modelled and evaluated by pro clima MOLL GmbH using the WUFI advanced software program. Using weather data supplied from Canberra, Melbourne, Sydney and Brisbane, the evaluation found Supatherm to have acceptable moisture transfer for Australian climatic conditions.



Pro clima MOLL GmbH CEO, Lothar Moll, evaluating the Supatherm wall panel

<sup>&</sup>lt;sup>8</sup> C Begert, Four seasons in one Day Passive Houses in Volatile Climates, 2009, 13th International Passive House Conference, Frankfurt Main, Germany, 2009.

The pro clima MOLL GmbH insulation material used for airtight buildings in Europe is covered on both sides with an exterior-facing protective rain screen layer and an interior-facing airtight vapour active membrane.



Pro clima airtight insulation. Image courtesy of pro clima MOLL GmbH.

In the pro clima MOLL GmbH teaching facility, student's layup vapour membranes and tape joints. A small vacuum is then applied to the structure to test for air tightness. A vacuum fan can also be used to test for leakages in applied membranes installed off site. Photographs of pro clima MOLL GmbH can be seen Attachment 3.

These training facilities would be relatively easy to replicate in our TAFE and Registered Training Organisation (RTO) operations in Australia.

#### Transsolar Energietechnik GmbH, Stuttgart

Contacts: Helmut Mayer, Managing Director and Matthias Rudolph, Engineer



Transsolar-Energietechnik GmbH natural ventilation stack – Stuttgart Community Performing Arts Centre

Transsolar Energietechnik GmbH handles larger commercial projects than PHI. While the PHI approach to achieving and maintaining energy efficiency is based on HRV units and insulated boxes.

Transsolar Energietechnik GmbH have a more expansive view of hybrid ventilation systems. Transsolar Energietechnik GmbH designs utilise natural ventilation pressure and temperature differentials (buoyancy/stack effect) to supply fresh air and exhaust stale air in extreme climatic locations.

A number of buildings in Stuttgart utilise Transsolar Energietechnik GmbH natural ventilation systems.

#### Munich University of Technology, Munich

**Contacts:** Michael Merk, Department of Building; Norman Werther, Department of Building; Annette Hafner, Department of Architecture and Klaudius Henke, Department of Architecture

The Munich University of Technology is home to one of the leading German research teams specialising in timber structures. The team is lead by Professor Stephan Winter. At the time of the Fellow's visit, Professor Winter was in Finland running the Finnish Government's building upgrade program. The Fellow's visit coincided with research work on retro fitting with a particular focus on Vacuum Insulation Panels (VIPs).

A VIP has high performance potential. However, it can be damaged easily, cannot be sawn, cut or drilled and, if left unprotected, is vulnerable to high temperatures and humidity.

A particularly interesting aspect of the insulation retrofit programme observed by the Fellow was the use of photogrammetry to measure the outside area of a building being retro fitted with foam insulation. Measurements were fed to a Computer Assisted Design (CAD) program and sent to a computer CNC machine for cutting off site allowing for direct onsite installation.



Experimental Vacuum Insulation Panels



Multiple view photogrammetry for measuring an exterior surface. Image courtesy of Klaudius Henke.



A VIP layout. Image courtesy of Klaudius Henke.



Finished VIP panels in place. Image courtesy of Klaudius Henke.

#### Holzbau Vorholz Hawran GmbH, Stuttgart

Contact: Tilmann Vorholz, Managing Director



In Stuttgart the Fellow made a site visit to Holzbau Vorholz Hawran. The company manufactures prefabricated PHPP buildings.

Holzbau Vorholz Hawran is noted for its precision manufacturing, attention to detail and the exceptional quality of its input materials. The Managing Director, Tilmann Vorholz, is also the chief architect. Holzbau Vorholz Hawran also builds the Nil (Zero) Energy House.

Holzbau Vorholz Hawran Nil (Zero) Energy House

#### **United Kingdom**

#### Department of Sustainable Design, Construction and Facilities Management (FM), University of Reading, Reading

**Contacts:** Professor Emeritus Derek Clements-Croome, Professor of Construction Engineering; Dr Abbas Elmualim, Lecturer and Coordinator, Sustainable Design, Facilities Management and Informatics; Ian Biggin, Head of New Technologies, CIBA-BASF, University of Reading contact and collaborator; and Mike Mapston, CEO, One42morrow

Meetings at the University of Reading dealt principally with ventilation issues and the application of airtight membranes. The rise in internal  $CO_2$  levels (especially in school buildings) due to increasingly airtight construction techniques being applied has brought about a need to supplement fresh air supply via mechanical ventilation. Buildings were previously fairly drafty due to the fact that they were not airtight and provided natural ventilation exchange.

Due to the new dryer building methods employed with sealed and mechanically ventilated buildings, drying out has caused movement in some older buildings in the United Kingdom. Incorrect placement of vapour membranes has also exacerbated condensation.

An important outcome from the Fellow's visit was mutual recognition that great potential exists for cooperative research involving the University of Canberra and the University of Reading. One specific research area discussed was natural ventilation options versus HRV systems of the type mandated by Passivhaus.

The evaluation of airtight and super-insulation construction techniques developed by Passivhaus Institut (PHI) require further appraisal as to whether they are the best methodologies to be adopted for the Australian climate. Further lifecycle and cost benefit evaluation will be conducted by the Fellow to assess the potential for the adoption of PHI techniques into the Australian construction industry.

The evaluation process will require a different set of variables to those evaluated under different climatic parameters (cooling) to verify superior sustainability credentials over the more mainstream techniques that are currently common practice in Australia.

Firstly a broader scale evaluation needs to take place to determine the relative merits of adopting in whole super-insulation and airtight construction techniques. Reducing energy consumption can be achieved in several ways. Schools cooled by natural ventilation have reduced energy consumption. Some office buildings already meet Passivhaus Institut's criteria.

While Australia does not have to contend with months of freezing conditions, it does have to deal with heavy domestic energy consumption and has relied on cheap (mainly coal fired) energy to provide a simple means of heating and cooling buildings. New insulation technologies that reduce the inefficient heating and cooling of our poorly insulated housing stock is an urgent priority. Substantial savings in energy can be made by building more energy efficient housing.

The PHI has set new energy benchmarking standards. The Japanese are currently evaluating the Passivhaus Japan option. The many similarities and benefits of sharing a 35 degree latitude climate between Tokyo and Sydney has much merit and synergies for research outputs. Close Australian and Japanese knowledge sharing in this field would be of significant benefit in accelerating knowledge sharing and reducing energy consumption for both countries.

The Japanese EcoCute carbon dioxide refrigerant system is one example of technology that Australia can benefit from when assessing best methods to reduce greenhouse gas emissions.

The European Union has commissioned a Cost Efficient Passive Houses as European Standards (CEPHEUS) project study group. Outcomes from CEPHEUS will form the next stage in the development of energy efficient techniques that have been inspired by the Passivhaus Institut.

The Passivhaus Institut criteria have been evaluated and accredited by the Darmstadt Institute. The PHI certifies that a building is meeting certain base requirements. The basic requirements for a quality approved passive house are available in the Passive House Planning Package (PHPP) 2007. While they state that the referenced values are set for a central European climate, they also state that the principles are valid in other climates. PHI basic requirements are:

- Entire specific primary energy demand must not exceed 120 kWh/m<sup>2</sup> per annum including domestic electricity.
- The exterior building elements must have a U Value below 0.15 W/(m $^2$  K) or exceed an R-value of above R6.6

- The building's annual demand for space heating does not exceed 15 kWh/(m<sup>2</sup> per annum). This includes cooling as well, which is sometimes overlooked when discussions focus on Central Europe (which has a heating demand greater than cooling.
- The total final energy demand for space heating, domestic hot water and household appliances is below 42 kWh/(m<sup>2</sup>per annum).
- The air tightness of the building envelope should be verified by means of an air leakage test complying with DIN EN 13829 standard. The measured air leakage must not exceed 0.6H-<sup>1</sup> at a pressure differential of 50 Pa (for both over and under pressurisation).
- ACH of 0.3 times an hour minimum.
- All glazing must have U-values under 0.8 W/(m<sup>2</sup>K), R1.25 according to European Norm EN 673 and a high total solar transmittance (g) of at least 50 per cent according to EN 410 to achieve net heat gains in winter.
- The ventilation system must be designed with the highest energy recovery efficiency (of greater than 75 per cent) complying with PHI certification for results and minimal electricity consumption of less than 0.45 Wh/m3 supply air volume.
- Domestic hot water generation and distribution systems with minimal heat losses must be used.
- Highly efficient use of household electricity is essential.

The evaluation criteria for PHPP certification includes the net living area being evaluated and the following validated:

- 1. Specific space heating and or cooling demand must not exceed 15 kWh/(m<sup>2</sup> per annum).
- 2. Pass the pressurisation test (airtight).
- 3. Entire specific primary energy demand must not exceed 120 kWh/m<sup>2</sup> per annum including domestic electricity.

Other calculations and certificates are required such as shading factor and summer overheating calculations.

To implement the PHPP in Australia the evaluation of vapour membranes and air tightness needs to be assessed and tested to Australian climatic conditions. Is air tightness such a requirement for energy savings in a temperate Australian climate? Studies (Begert, 2009) have shown that  $CO_2$  levels increased dramatically above 1200 ppm in schools due to airtight sealing of light fittings, resulting in unacceptable levels of  $CO_2$  which in turn required higher mechanical ventilation rates over the original natural ventilation operation.<sup>9</sup> Operational energy needs to be balanced with insulation thickness, cost to relative savings and initial capital cost outlays.

The application of the law of diminishing returns for insulation was considered in the evaluation by West (2005) and supported by McChesney (2008)<sup>10</sup>; where the heat flowing through an uninsulated wall was compared with successively adding increments of insulation with an effective R-value of 1.0 m<sup>2</sup> °C/W.

<sup>&</sup>lt;sup>9</sup> C Begert, Four seasons in one Day Passive Houses in Volatile Climates, 2009, 13th International Passive House Conference, Frankfurt Main, Germany, 2009.

<sup>&</sup>lt;sup>10</sup> I McChesney, I Cox-Smith and L Amitrano, *Thermal Insulation in New Zealand homes: A status report*, Beacon Pathway Limited, 2008.

The uninsulated wall is assumed to have an R-value of 0.4 m<sup>2</sup> °C/W, while the particular conditions chosen assume a heat flow through the uninsulated wall of 1000 Watts. Adding the first increment of insulation with R1.0 reduces the heat flow by approximately 710W (71 per cent); adding a further increment reduces heat flow by only about another 120W (12 per cent). When the insulation is increased from R3.0 to R4.0 the heat flow is reduced by only about 30W (3 per cent). Therefore, determining 'optimum' levels of insulation involves assessing the marginal cost effectiveness of each increment of insulation, for each element of the building.

While the R5 value falls just short of the PHI R 6.6 minimum, on diminishing returns for energy saved in a temperate climate the R5 limit seems justifiable. R5 insulation was considered as being sufficient for Australian applications and a further study was presented on information modelled by Exergy and West and presented at Delft University of Technology – Synergistic Systems (West 2009).<sup>11</sup>

The synergistic systems approach of good passive design incorporating the R5 Supatherm panel with new renewable slab tank heating technology was assessed as being comparable for Canberra's climatic conditions to that of the Passivhaus designs achieving 36.7 kW/m<sup>2</sup>. This system was designed for a larger residence with good shading and average double glazing. It had reduced insulation compared to the PHPP requirements but was coupled with renewable energy sources, with solar hot water providing balanced heating.

Vapour retardants need to be tested under Australian climatic conditions before European systems are adopted for use. Australia does not contend with issues associated with leaky house syndrome prevelent in New Zealand. The New Zealand experience was exacerbated by poor building practices.

The drained cavity system has served Australia well in this regard, but lack of insulation and inappropriate placement of vapour barriers without adequate knowledge of condensation etc requires that these issues be improved.

The European climate requires an interior vapour retarder. Cooling-dominated climates require an exterior vapour retarder. Using German WUFI software the Fellow evaluated Canberra's climate and assessed an R5 building envelope, which was good to -4 degrees centigrade. If condensation did occur it would be safely drained using vapour-permeable reflective foil. This system was deemed satisfactory under WUFI and was also evaluated by Proctor Group Australia see Attachment 2. Details of the assessment undertaken by the Fellow of the Supatherm system can be found in Attachment 1.

This system also offers a very important retro fitting function that can be supplied and utilised in existing stock of poorly insulated standard brick veneer houses. The thermal performance of the R5 drained cavity option is twice that of most Australian building systems, but is built with ease and is a mainstream technique requiring little additional skilling to current Australian building techniques. PHPP software does not factor incremental cost/ benefit analysis. Further evaluation is required to determine if super-insulation and airtight construction is commercially feasible.

<sup>&</sup>lt;sup>11</sup> S.T.K West, Adopting Systems Methodologies to Acieve Synergistic Results for Sustainable Buildings, CIB Smart and Sustainable Built Environments conference, June Delft, The Netherlands, 2009.

A further recommendation is that several natural, versus airtight, designs be adopted and testing be conducted to determine the efficiency outcomes of utilising hybrid construction. Synergistic systems should be evaluated and compared to the PHPP systems utilising low load or zero load heating options.

Because Australia has high sunlight hours, solar renewable energy resources should be considered as a passive/active system that may reduce the need for such high levels of insulation compared to European PHI accredited buildings.

Conversely, Europe does not have to contend with the higher cooling requirements of Australia and this situation calls for different design solutions suitable for various regional microclimates. The suitability of PHI designs for high cooling environments is still to be properly evaluated. There is no doubt that the concept achieves excellent results in Central Europe.

The PHPP also focuses on HRV applications. More appropriate for Australian climatic conditions may be an Energy Recovery Ventilation (ERV) system that can be coupled for cooling loads, enabling a house to operate in hybrid natural ventilation mode for nine months of the year in most regions of Australia. ERV works on similar principles to a HRV. Fresh air is continuously brought into the home and stale indoor air is exhausted, exchanged via plastic pathways.

The Fellow has facilitated knowledge transfer of PHI information into the University of Canberra's, Sustainable Buildings and Technologies unit in the Bachelor of Building and Construction Management degree.

Skill set requirements for onsite applications will be largely determined by the material supplier's approved application techniques. These techniques may include issues such as tight tolerances and sealing of joints, use of plastic plugs and nails to eliminate thermal bridges, and acceptable application of new foams and adhesives.

The evaluation of technologies and methodologies applicable for Australia can be readily taught in Australian Institutions if required.

Based on assessment and as discussed in this report, very few of the current skill deficiencies will present a problem if these systems are adopted in Australia.

Many of the existing training facilities can be adapted as well as our teaching and learning strategies to deliver these skills.

## Recommendations

#### Government

Recommendations:

- 1. That locally sourced advanced glazing (vacuum double glazing) be mandated as part of the Federal, State and Local Government sustainable procurement policies for new buildings and refurbishments.
- 2. That the Australian Government support the uptake of carbon dioxide refrigerants to help accelerate Australia's uptake of more energy efficient technologies.

#### Industry

Recommendations:

- 3. That industry and its associated professional bodies pursue joint research opportunities with European Union (EU), Japanese and US institutions and professional bodies currently conducting research in these fields.
- 4. That Australian building and construction companies increase their research and development efforts into green and clean-building technologies.

#### **Professional Associations**

Recommendation:

5. That the AIB, MBA, RTOs and other accredited training courses give priority to curricula updates in new and commercially available building technologies that deliver improved energy efficiency outcomes.

#### **Education and Training**

**Recommendations:** 

- 6. That current carpentry and building course curricula be upgraded to require knowledge of the basic science involved with climate design, and to ensure practical applications of taping airtight membranes and joining foams are part of the training courses. These syllabus changes could be done through TAFE and approved RTO centres throughout the country.
- That the CPC32008 Certificate III in Carpentry and Joinery as well as the CPCCA3064A unit curricula include knowledge of materials and techniques used to improve air tightness of building frames and envelopes. PHI-style materials and techniques should be incorporated into updated curricula for these certificates.
- 8. That CPC50108, CPC50208, CPC50308, CPC50408 diplomas and CPC60208 Advanced Diploma of Building and Construction Management Degree curricula incorporate material as per the certificate courses.
- That architecture and engineering degree courses be cognisant with material specification and performance, and design of new lightweight insulating products, such as high compressive strength foam foundations.
- 10. That the University of Canberra establish research programmes associated with natural ventilation and Indoor Environmental Quality (IEQ) objectives with the University of Reading and evaluate the Saitama project in Tokyo through research partnering with Kyoto Institute of Technology.

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#### Attachment 1: Modelled Supatherm Wall Panel System

Supatherm R5 wall panel

The application of the law of diminishing return for insulation was considered in the evaluation by West (2005) and supported by McChesney (2008), where the heat flow through an uninsulated wall was compared with successively adding increments of insulation with an effective R-value of 1.0 m<sup>2</sup> °C/W. The uninsulated wall is assumed to have an R-value of 0.4 m<sup>2</sup> °C/W, while the particular conditions chosen assume a heat flow through the uninsulated wall of 1000 Watts.

Adding the first increment of insulation with R1.0 reduces the heat flow by approximately 710W (71 per cent); adding a further increment reduces heat flow by only about another 120W (12 per cent). When the insulation is increased from R3.0 to R4.0 the heat flow is reduced by only about 30W (3 per cent). Therefore, determining 'optimum' levels of insulation involves assessing the marginal cost effectiveness of each increment of insulation, for each element of the building.

While the R5 value falls just short of the PHI R6.6 minimum, on diminishing returns for energy saved in a temperate climate the R5 limit seems justifiable. R5 insulation was considered as being sufficient for Australian applications and a further study was presented on information modelled by Exergy and West and presented at Delft University of Technology – Synergistic Systems (West 2009).

The synergistic systems approach of good passive design incorporating the R5 Supatherm panel with new, renewable slab tank heating technology was assessed as being comparable for Canberra's climatic conditions to that of the Passivhaus designs achieving 36.7 kW/m<sup>2</sup>. This system was soundly designed for a larger residence with good shading and average double glazing as per freely available in Australia. It had reduced insulation compared to the PHPP requirements but was coupled with renewable energy sources, with a solar hot heater providing balanced heating.

Also, further consideration is needed regarding vapour retardants. These need to be tested under Australian climatic conditions before European systems are adopted for use in Australian conditions. Australia does not appear to suffer from the issues encountered with the leaky house syndrome in New Zealand—possibly the New Zealand experience was exacerbated by poor building practices (drained cavities were not utilised) and a more aggressive building climate.

The drained cavity system has served Australia well in this regard, but lack of insulation and inappropriate placement of vapour barriers without adequate knowledge of condensation etc requires that these issues be improved.

Heating-dominated climates such as Europe require an interior vapour retarder. Coolingdominated climates require an exterior vapour retarder, especially if air conditioning is used, as warm moist air from the outside can condense on the inside. In mixed climates (a large part of Australia) this option requires careful consideration. Using German WUFI software the author evaluated Canberra's climate and assessed an R5 building envelope. This envelope was good to –4 degrees Celsius and utilised a drained cavity system so that if condensation did occur it would be safely drained using appropriate vapour permeable reflective foil. This system was deemed satisfactory under WUFI and was also evaluated by the Proctor Group Australia see Attachment 2.

This system offers also a very important retro fitting function that could be utilised on the large pool of existing Australian building stock, these being mainly of a poorly insulated standard brick veneer construction. Removal of the brick skin or removal of weatherboards allows external access to the timber frame and retro fitting is then able to be completed without disturbing the internals of the building. A new vapour barrier and external insulation (where it best serves the building) is easily retro fitted using the Supatherm concept.

The R5 Supatherm drained cavity option has twice the thermal performance of most Australian building systems but is built with ease and is a mainstream technique, requiring very little additional skills to traditional Australian building techniques. PHPP software does not factor in incremental cost/benefit analysis and this requires some further evaluation to determine if superinsulation and airtight construction is economically feasible and justifiable to introduce these new techniques and skills as mainstream construction methodology for builders in Australia.



Reflective foils sarking to frame with vapour drainage to outside, 25 mm air gap, furring channel, then interlocking tongue and grove Styrofoam sheets, covered by a protective layer of aerated concrete.



The Supatherm system applied to a timber structural frame to be insulated.

The modelling and appropriateness of the Supatherm envelope system for Australian Climatic conditions has been analysed and shown to be operationally sound as shown in Attachment 2.

### **Attachment 2: Proctor Report on Supatherm**

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Reference	20 Jap 10					Tel: 02 andy	2-8788-955 /.russell@p	5 Fax: 02 roctorgrou	-9604-74 up.com.a
Client	Shane West	Project	ClimateData	Canberra Airpor	t				
Internal surfa	ce emissivity	: High	External	surface emissivit	ty ∶Hig	n			
Internal surfa Building use Constructio	nce emissivity	: High : BS5250	External dry/moist occu	surface emissivit pancy	ty : Hig Thickness	Thermal	Thermal	Vapour	Vapour
Internal surfa Building use Constructio	ace emissivity	: High : BS5250	External dry/moist occu	surface emissivil pancy	ty : Hig Thickness (mm)	n Thermal Conductivity (W/mK)	Thermal Resistance (m²K/W)	Vapour Resistivity (MNs/gm)	Vapour Resistanc (MNs/g)
Internal surfa Building use Constructio	ace emissivity an ace resistance	: High : BS5250	External dry/moist occu	surface emissivit pancy	ty : Hig Thickness (mm) -	n Thermal Conductivity (W/mK)	Thermal Resistance (m²K/W) 0.040	Vapour Resistivity (MNs/gm)	Vapour Resistanc (MNs/g)
Internal surfa Building use Constructio Outside surfa Hebel	ace emissivity an ace resistance	: High : BS5250	External dry/moist occu	surface emissivit pancy	ty : Hig Thickness (mm) - 75.0	n Thermal Conductivity (W/mK) - 0.150	Thermal Resistance (m²K/W) 0.040 0.500	Vapour Resistivity (MNs/gm) - 40.00	Vapour Resistanc (MNs/g) - 3.00
Internal surfa Building use Constructio Outside surfa Hebel Dow Styrofo	nce emissivity n ace resistance am	: High : BS5250	External dry/moist occu	surface emissivit pancy	ty : Hig Thickness (mm) - 75.0 50.0	n Thermal Conductivity (W/mK) - 0.150 0.028	Thermal Resistance (m <sup>2</sup> K/W) 0.040 0.500 1.786	Vapour Resistivity (MNs/gm) - 40.00 800.00	Vapour Resistanc (MNs/g) - 3.00 40.00
Internal surfa Building use Constructio Outside surfa Hebel Dow Styrofo Reflectashiel	nce emissivity n ace resistance am Id Cavity	: High : BS5250	External dry/moist occu	surface emissivit pancy	ty : Hig Thickness (mm) - 75.0 50.0 25.0	n Conductivity (W/mK) - 0.150 0.028	Thermal Resistance (m²K/W) 0.040 0.500 1.786 0.469	Vapour Resistivity (MNs/gm) - 40.00 800.00	Vapour Resistanc (MNs/g) - 3.00 40.00 0.00
Internal surfa Building use Constructio Outside surfa Hebel Dow Styrofo Reflectashiel Tyvel Encore	nce emissivity n ace resistance am Id Cavity	: High : BS5250	External dry/moist occu	surface emissivit pancy	ty : Hig Thickness (mm) - 75.0 50.0 25.0 0.4	n Conductivity (W/mK) - 0.150 0.028 - 0.000	Thermal Resistance (m <sup>2</sup> K/W) 0.040 0.500 1.786 0.469 0.000	Vapour Resistivity (MNs/gm) - 40.00 800.00 - 1497.50	Vapour Resistanc (MNs/g) - 3.00 40.00 0.00 0.60
Internal surfa Building use Construction Outside surfa Hebel Dow Styrofo Reflectashiel Tyvel Encore Glass fibre	ace emissivity n ace resistance am Id Cavity e	: High : BS5250	External dry/moist occu	surface emissivit pancy	ty : Hig Thickness (mm) - 75.0 50.0 25.0 0.4 90.0	n Conductivity (W/mK) - 0.150 0.028 - 0.000 0.040	Thermal Resistance (m <sup>2</sup> K/W) 0.500 1.786 0.469 0.000 2.250	Vapour Resistivity (MNs/gm) - 40.00 800.00 - 1497.50 10.00	Vapour Resistanc (MNs/g) - 3.00 40.00 0.00 0.00 0.00
Internal surfa Building use Construction Outside surfa Hebel Dow Styrofo Reflectashiel Tyvel Encore Glass fibre Plasterboard	ace emissivity n ace resistance am Id Cavity a	: High : BS5250	External dry/moist occu	surface emissivit pancy	ty : Hig Thickness (mm) - 75.0 50.0 25.0 0.4 90.0 12.5	n Conductivity (W/mK) - 0.150 0.028 - 0.000 0.040 0.167	Thermal Resistance (m <sup>2</sup> K/W) 0.040 0.500 1.786 0.469 0.000 2.250 0.075	Vapour Resistivity (MNs/gm) - 40.00 800.00 - 1497.50 10.00 45.00	Vapour Resistanc (MNs/g) - 3.00 40.00 0.00 0.60 0.90 0.56

U-value, CombinedMethod : 0.19 W/m²K (lower limit5.250 m²K/W, upper limit5.250 m²K/W, dUf 0.000, dUg 0.000) (Correction for mechanical fasteners, Delta Uf = 0.000W/m²K) (Correction for air gaps, Delta Ug = 0.000W/m²K)

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Proctor Group Australia Pty. Ltd. are not chartered mechanical engineers. These calculations are based on details supplied by the client and have been prepared to assist in the design of the building system. Please seek the advice of your mechanical engineer.



### **Attachment 3: Photographs of the Fellowship Visits**

Saitama Passive House Project, Japan





Working with foam installation and fixing methods applicable to material make up

#### Passivhaus Institut Projects, Darmstadt



Specialist adhesive requirements for insulation fixing as per manufacturer's instructions



Complete facade envelopment in foam insulation techniques and product knowledge



Internal insulation to floors and compressive strength qualities



Using WUFI software to determine satisfactory vapour/condensation operation of building envelopes



Layup and pressurisation testing for leaks and air tightness of taped joints



Students taped membrane under pressure to test for leakage and adequate fixing of joints



Methods for fixing airtight membranes and film around wall, roof and ceiling penetrations.





Prefabricated Passive House factory



Thick insulated walls with taped joints and vapour membrane



Canaflex 140 mm hemp (renewable resource) insulation



Layup showing renewable timber insulated structure, with renewable hemp insulation infill