International Specialised Skills Institute

Improving Energy Efficient, Sustainable Building Design and Construction in Australia – Learning from Europe

Susan Morris

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i. Executive Summary

Throughout Europe during April 2012, the Fellow visited experts in the field of sustainable building design and engineering, academics (researchers and educators) and a number of sustainable buildings including Net Zero Energy Buildings. To gain an holistic view of the European situation regarding educational methodologies for 'greenskills' students and progress towards nearly Zero-Energy Buildings, skills deficiencies were addressed by investigating these topics:

- Regulatory frameworks for energy efficient buildings
- The development of Net or Nearly Zero-Energy Building (NZEB) definitions and the implication for regulatory reform
- EU rating processes
- Affordable solutions in sustainability for new and renovated building developments including innovative materials and methods to improve sustainability
- Skills to implement successful collaborative and multidisciplinary learning environments for building design, engineering, building and construction trade students.

The Multidisciplinary learning environments

By visiting universities in Denmark and Germany the Fellow was able to evaluate multidisciplinary projects for greenskills students and discuss multi-disciplinary problem based learning methodologies.

Erasmus Project – VIA University College, Horsens, Denmark (Refer to 6.4)

The Erasmus Project brought together 60 international students in the fields of constructing architects, architects, civil (structural) engineering, environmental engineering and construction management from Bachelor degree to PhD level. The input of 21 teachers with different expertise and student groups from different disciplines created a much greater understanding and appreciation of the role of each of the participants in the design phase of construction projects. Inclusion of cost estimating and cost optimisation as an integral part of the project work had benefits for the students and hopefully will generate long term benefits as these future professionals inform and educate their clients on the economic viability of highly sustainable development. The Erasmus project allowed students to experience a working environment where collaboration was the key to success. The experience was extremely valuable in preparing students for industry.

Problem-based learning (PBL), Aalborg University, Aalborg, Denmark (Refer to 6.6.2)

Aalborg University has been implementing PBL for many years and have tremendous experience in this model of learning. Associate Professor Henrik Brohus explained that project-organised education is multidisciplinary by nature and can be divided into two main groups: design-oriented education and problem-oriented education.

Problem-oriented project-organised education deals with the solution of theoretical problems through the use of any relevant knowledge, whatever discipline. The knowledge gained goes beyond 'knowing how' to 'knowing why'.

Visit to Digital Days at University College Nordjylland, Aalborg, Denmark (Refer to 6.6.4)

Digital days was a three day intensive multi-disciplinary Building Informatics Project. Students participated from eleven different Danish colleges and a diverse range of disciplines. The students used software relevant to their discipline to analyse and create digital models for a proposed four storey oncology building project. Trades students also participated through building prototype building elements.

i. Executive Summary

The students were very actively engaged in the Digital Days Project. Communication between the disciplines was the key to success and this could be seen visually by looking across the room as participants wearing different colour t-shirts conferred.

Madrid Solar Decathlon 2010 Team Wuppertal- University of Wuppertal, Germany (Refer to 6.8.3)

Every few years university teams from across the world compete in the Solar Decathlon. The teams design and build solar houses to suit the climatic conditions of the city where the competition is held. The houses are then made open to the public and judged in ten categories. Primarily the buildings are required to demonstrate their self-sufficiency and energy efficiency.

About 40 students from different departments in the University of Wuppertal worked together to plan, design and build their Decathlon house for the Madrid Solar Decathlon. One of the successes of the project derived from multidisciplinary input. The intent was to develop a building that suited any location in Europe.

The creation of this building enabled an amazing multidisciplinary learning experience for all the students and lecturers involved. Additionally, 190,000 visitors had the opportunity to visit and learn from the many buildings displayed at the Decathlon competition in Madrid. The building, now located in Wuppertal, continues to be an educational resource to students and visitors.

The Case Studies

Solar XXI, Lisbon, Portugal (Refer to 6.1)

Solar XXI is a prototype Net Zero Energy Building (nZEB). Importantly, this building was constructed at no additional cost to a typical office building.

Boutiquehotel Stadhalle, Vienna, Austria (Refer to 6.2)

Boutiquehotel Stadhalle was the first hotel to achieve a zero energy balance.[1]

Crowne Plaza, Copenhagen Towers, Ørestad, Denmark (Refer to 6.3)

Crowne Plaza is described as the first CO_2-neutral hotel building in Denmark and has the largest Building Integrated Photovoltaic system (BIPV) in northern Europe and Denmark's first groundwater-based cooling and heating system.

Green Lighthouse, Copenhagen, Denmark (Refer to 6.5.1)

The Green Lighthouse was built as a prototype nZEB building for the Climate Summit in 2009. It demonstrates impressive sustainability and was the first public CO_2-neutral building in Denmark.

Østerbro Community Housing Sustainability Project, Copenhagen, Denmark (Refer to 6.5.2)

The existing 1960s Community Housing buildings accommodate low income residents. The process of retrofitting these buildings for social, environmental and economic sustainability is one that involves empowering and involving the residents.

Neue Burse Student Residence Hall, Wuppertal, Germany (Refer to 6.8.1)

Two near identical student residence buildings originally constructed in 1977 have been extensively upgraded for improved functionality and thermal performance; one to Low Energy building standard and the other to Passivhaus standard. Information regarding energy monitoring, occupant behaviour and education, commissioning and defects rectification is included in addition to the sustainability measures undertaken to achieve sustainable retrofit buildings.

Waste Disposal Building, Remscheid, Germany (Refer to 6.8.2)

The office building of the Waste Disposal Unit was constructed in 1968 and completely renovated in 2004. The energy concept and the architectural quality were recognised by the State with the 'State Prize for Architecture, Residential Building and Urban Planning'. Wuppertal University nZEB experts have been monitoring and evaluating the building operation for energy efficiency and thermal comfort.

Decathlon Building, Wuppertal, Germany (Refer to 6.8.3)

The creation of this highly energy efficient building as an entrant in the Madrid Solar Decathlon in 2010 enabled an amazing multidisciplinary learning experience for all involved.

IWB Energy Customer Centre, Basel, Switzerland (Refer to 6.10.2)

Although this seven-storey building is located in a crowded city location with poor solar access it was still possible for it to achieve a Minergie-P® energy standard.

Gundeldinger Feld, Basel, Switzerland (Refer 6.10.4)

An engineering works industrial site has been transformed into a community business, activity and leisure centre with a public character. Sustainability measures include renovation rather than demolition, water-saving devices, sensor-controlled energy saving lighting, recycled and green building materials, ecological paint, roof gardens and a 370 m^2 photovoltaic solar installation.

Regulatory frameworks for energy efficient buildings

The three main EU policies that are driving change for energy efficient buildings are:

- 20-20-20 (refer 6.7.4)
- EPBD Recast to be implemented by July 2012 (refer to 6.7.4)
- Energy Efficiency Directive (EED) June 2011 (refer to 6.9.2).

The Energy Performance of Buildings Directive dictates that the implementation of nearly Zero-Energy Buildings will take place from 2020 onwards (2018 respectively for public buildings).

The European Union is setting stringent targets for energy efficient buildings with very specific carbon emission reduction targets to be achieved by 2050. There is an acknowledgement that buildings have a long lifespan (and long intervals between significant refurbishments) and therefore significant change needs to be implemented in the very near future to achieve long term goals.

In this regard the Europeans have a sense of urgency and commitment to tackling this task. The implementation of nZEB as a mandatory requirement in the future has been calculated to create about 345,000 additional jobs assuming an extra investment of EUR 39 billion per year and an average turnover in the EU construction industry of EUR 113,000 (in 2008) per person and year.[2] Although Europe has been severely affected by the global financial crisis their obligations under the Energy Performance of Buildings Directive are going ahead.

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Indoor Environmental Quality (IEQ) testing of buildings will be introduced across the EU as part of the EPBD directive in 2018-2020. Thermal comfort, lighting comfort, noise comfort and indoor air quality will all be monitored and tested to ensure mandatory standards are met for new and retrofit buildings. We can learn from the early adopter, Portugal.

The development of nearly Zero Energy Building definitions and the implication for regulatory reform

The European Member States will be drawing up national plans for increasing the number of nearly Zero-Energy Buildings and these will need to include:

- A definition of nearly Zero-Energy Buildings, reflecting national, regional or local conditions including a numerical indicator of primary energy use, expressed in kWh/m^2 per year
- Intermediate targets for improving the energy performance of new buildings by 2015.[3]

There are many challenges ahead for Europe in defining nearly Zero-Energy Buildings (refer to Section 7.5). This report includes a summary of the challenges and variables currently being discussed and does not attempt to deliver a recommendation.

EU rating processes

Throughout Europe there are a variety of concepts and voluntary standards for highly energy efficient buildings. These include Passivhaus, Zero-energy, 3-litre, Plus energy, Minergie®. and Effinergie. This report includes a description and comparison of two concepts: Passivhaus and Minergie®.

Both Passivhaus and Minergie® rating methods and tools are effective in achieving energy efficient and thermally comfortable buildings. The methodologies have been used to build many buildings. Extensive monitoring and research has been undertaken proving the effectiveness of both.

Built for cold climates Minergie-P® and Minergie-A® buildings, like Passivhaus, require highly efficient heat recovery systems.

Building envelope leakage has a large impact on the energy use of a building. To achieve accreditation Passivhaus and Minergie-P® and Minergie-A® must have a high level of air-tightness (< 0.6 ach at 50 Pa). Buildings undergo an air-tightness test (also known as a blower door pressure test) at an appropriate time to ensure quality requirements are met. Air leaks in the building envelope can be found using thermal imaging.

Thermal-bridge free construction is also essential with thermal imaging being used to locate weaknesses in older building stock. New buildings are designed and constructed with zero thermal bridges.

The reasons for adopting Passivhaus as the preferred alternative for Australian practitioners to try, develop and monitor in Australia are discussed.

Affordable solutions in sustainability for new and renovated building developments including innovative materials and methods to improve sustainability

New innovative building materials for improved thermal efficiency, energy efficient service equipment and on-site energy generation products are all being developed and trialled in Europe. These are not necessarily affordable at this time but if proven to be effective will become mass-produced thereby reducing costs and increasing their uptake. Materials and products discussed in the report include:

- Nanocoatings and Nanomaterials
- Aerogel products
- Vacuum insulated panels
- Eco-cellulose
- Phase Change Materials
- GlassX
- BIPV and
- Nano solar technology.

The emphasis on life-cycle costing, pay back calculations and cost-optimisation in greenskills education is of particular interest. In Europe cost estimating is not a stand-alone profession but an essential educational element for every construction design professional.

One of the major barriers to sustainable building development in Australia is the perception that it will be too expensive. There can be a lack of informed documentation to enable clients to evaluate the payback time on their initial financial investment or to compare alternative options on the basis of future cost-savings. This barrier will be removed in time where cost optimisation goes hand-in-hand with the design of thermally efficient and sustainable buildings.

In the recast Energy Performance of Buildings Directive (EPBD) adopted in May 2010 by all EU Members, a benchmarking mechanism for national energy performance requirements was introduced. The purpose of this is to determine cost-optimal levels to be used by Member States for comparing and setting these requirements.[4]

Cost estimating and cost-optimisation skills gaps for Australian students undertaking building design studies and similar professions should be addressed. The information gained from multi-disciplinary learning environments and case study buildings regarding cost-optimality can be found throughout this report.

Skills to implement successful collaborative and multidisciplinary learning environments for building design, engineering, building and construction trade students

Evaluations of multidisciplinary projects for greenskills students and discussions regarding multi-disciplinary problem based learning methodologies reveals success for greenskills students in preparing them for collaborative workplace environments.

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ii. Abbreviations/Acronyms

ASBEC	Australian Sustainable Built Environment Council
AIBS	Australian Institute of Building Surveyors
BCA	Building Code of Australia (also referred to as the NCC)
BEI	Building Energy Index
BIM	Building Information Modelling
CDD	Cooling Degree Days
CSH	Code for Sustainable Homes (UK)
CO_2	Carbon Dioxide
ECEEE	European Council for an Energy Efficient Economy
EED	Energy Efficiency Directive
EEP	Energy Efficiency Plan
EPBD	Energy Performance of Buildings Directive
ERV	Energy Recovery Ventilation
EU	European Union
DHW	Domestic hot water
GSHP	Ground-source heat pump also known as geothermal heat pump
GWP	Global Warming Potential
HDD	Heating Degree Days
HVAC	Heating Ventilation and Air-conditioning
IAQ	Indoor Air Quality
ICT	Information and communications technology
IEQ	Indoor Environmental Quality
IR	Infrared
LED	Light-emitting diode
MS	Member States (of the European Union)
PCM	Phase Change Materials
MVHR	Mechanical Ventilation with Heat Recovery
NCC	National Construction Code (also referred to as the BCA)
nZEB	Nearly Zero Energy Building
nZEB	Net Zero Energy Building
ODP	Ozone Depletion Potential
UK	United Kingdom

ii. Abbreviations/Acronyms

VABSN	Victorian Advanced Building Studies Network
ZCB	Zero Carbon Building
ZEB	Zero Emissions Building
ZLEG	Zero or low emission energy generation

iii. Definitions

Cooling Degree Days (CDD)

Cooling degree days (CDD) are calculated using daily temperature data. It is an index to estimate the amount of energy required for cooling during the summer or warm season. Base temperatures of 18°C or 24°C represent the threshold temperature for cooling with CDD18 or CDD24 being the abbreviations used to define the base temperature.

Ground-source heat pump also known as geothermal heat pump (GSHP)

GSHPs move heat into or out of a building. They work like a refrigerator, which uses a circulating refrigerant and a compressor to move heat from inside the fridge out into the room, lowering the temperature inside the fridge. GSHPs consist of a loop field usually in the ground as the name implies and another part of the system is a loop within the occupied space. A compressor is used and refrigerant circulated through the loop. This system then connects to a heating, cooling and/or hot water system of choice.[5]

Energy Recovery Ventilators (ERVs)

are a type of air-to-air heat exchanger that transfers sensible heat and also latent heat. Both temperature and moisture is transferred. During the cooling season, ERVs cool and dehumidify the incoming, outside air. In the heating seasons, the system works in reverse.

Heating Degree Days (HDD)

Heating degree days are calculated using daily temperature data. It is an index to estimate the amount of energy required for heating during the winter or cool season. 18°C represents a threshold temperature for residential heating and this is a fairly common industry standard internationally.

Indoor Air Quality (IAQ)

The chemical, physical and biological characteristics of indoor air which may affect the comfort or health of the occupant (refer to Section 6.4.6).

Indoor Environmental Quality (IEQ)

refers to all environmental factors that affect the health and wellbeing of building occupants. IEQ includes such factors as indoor air quality (IAQ), thermal comfort (TC), acoustics comfort and visual comfort (refer to Section 6.4.6).

Insolation

is a measure of solar radiation energy received on a given surface area and recorded during a given time.

Mechanical Ventilation with Heat Recovery (MVHR)

(refer to Section 6.4.5).

iii. Definitions

Nearly Zero Energy Building (nZEB)
(refer to Section 6.7).

Zero Emissions Building (ZEB)
(refer to Section 6.7).

Zero Carbon building (ZCB)
(refer to Section 6.7).

1. Acknowledgements

Susan Morris would like to thank the following individuals and organisations who gave generously of their time and their expertise to assist, advise and guide her throughout the Fellowship program.

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 ISS Institute are our Fellows. Under the **Overseas Applied Research Fellowship Program** the Fellows travel overseas. Upon their return, they are required to pass on what they have learnt by:

1. Preparing a detailed report for distribution to government departments, industry and educational institutions.
2. Recommending improvements to accredited educational courses.
3. Delivering training activities including workshops, conferences and forums.

Over 200 Australians have received Fellowships, across many industry sectors. In addition, recognised experts from overseas 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.[AK]

In this context, the ISS 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 ISS Institute's work.

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

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1. Acknowledgements

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Supporters

Australian Supporters

- Roy Hodgson, Director & Building Designer, Past President & Fellow of the Building Designers Association of Victoria (BDAV)
- Jeff Norton, Director, Strategic Projects, Building Commission of Victoria
- Abdul Rauf, Teacher, Box Hill Institute, Australia
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- David Waldren, National Executive Design Manager, Grocon Group, Australia
- Joan Whelan, Project Manager, Construction and Property Services Industry Skills Council (CPSISC)
- Anthony Wright, Project Manager, Buildings, Sustainability Victoria

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- Daniel Aelenei, Assistant Professor, Faculty of Science and Technology, Universidade Nova de Lisboa, Portugal
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Organisations Impacted by the Fellowship

Government

- The Building Commission – Victoria
- Sustainability Victoria
- Department of Climate Change and Energy Efficiency – Department of Foreign Affairs and Trade

Industry

- Building Designers
- Architects
- Builders and Developers
- Building Certifiers
- Engineers
- Quantity Surveyors
- Construction Trades

Professional Associations

- Building Designers Association of Victoria (BDAV)
- Australian Institute of Architects
- Australian Sustainable Built Environment Council (ASBEC)
- Australian Institute of Building Surveyors (AIBS)
- Green Building Council, Australia (GBCA)
- Master Builders Association of Victoria (MBAV)

1. Acknowledgements

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- Box Hill Institute of TAFE (BHI)
- Victorian Advanced Building Studies Network (VABSN)
- Construction and Property Services Industry Skills Council (CPSISC)

2. About the Fellow

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- Building Thermal Performance Assessment (FirstRate5) – Holmesglen Institute, 2011
- Diploma in VET Practice – Box Hill Institute, 2010
- Cert IV in Training and Assessment – Box Hill Institute, 2008
- Introduction to Online Facilitation (Teaching & Communicating Online) –GippsTAFE 2008
- Grad. Dip Arts (Australian Tourism) – NCAS, Monash University,1994
- AACA examination in Architectural practice – Registered Architect,1990
- Bachelor of Architecture (Hons) – University of Melbourne, 1987

Membership

Accredited Member of the Association of Consultants in Access Australia (ACAA)

Victorian Advanced Building Studies Network Group

Short Biography

Susan Morris gained her Bachelor of Architecture degree with honours from the University of Melbourne in 1987. Since graduation, her experience has included 11 years as both a Project Architect and consultant with KLCK architects – now Woodhead International. The Fellow's work involved all aspects of feasibility studies, project briefing, design, contract documentation and contract administration of aged care residential facilities. The Fellow also worked at Deakin University as an architect and access consultant. The Fellow's responsibilities included strategic planning and management of upgrade works to Deakin University campuses to improve access for people with disabilities. The Fellow was also responsible for reviewing new building and refurbishment projects and for designing and documenting built environments to provide safe, dignified and equitable access for people with disabilities – the implementation of Universal Design.

In 2008, the Fellow was appointed in the role of teacher at Box Hill Institute. She began educating students in the Diploma of Building Design and Technology, which in 2009 was superseded by the Advanced Diploma of Building Design (Architectural). The course has a strong focus on the design of sustainable buildings. As a teacher of Design and Sustainability units, the Fellow developed training assessment strategies and created extensive on-line resources that are used in a blended learning environment. A passion for increased knowledge to educate students regarding social, environmental and economic sustainability has motivated the Fellow to pursue continuing education including FirstRate5 Training, seminars, extensive reading of relevant publications and now a study trip to Europe supported by the ISS Institute.

In 2011 the Fellow was finalist for three Box Hill Institute awards: Teaching Sustainability Award, Innovation Award and Employee of the Year Award.

3. Aims of the Fellowship Program

The aim of the Fellowship program is to increase knowledge of sustainability issues and regulatory change relating to the building industry through participation in a multidisciplinary intensive program in Denmark. The program will focus on energy and sustainability laws, regulations, demands and guidelines in the European Union (EU). Attending the two-week Erasmus Intensive Program, meeting experts in sustainable building design and regulatory systems and visiting some of Europe's most advanced sustainable buildings will provide the Fellow with a deeper knowledge of sustainability issues and regulatory frameworks.

Participating in the intensive program environment is relevant to the Fellow's role as a teacher in educating students in sustainability and in implementing a new collaborative and multidisciplinary learning environment at Box Hill Institute.

3.1 Sustainability

Gain a detailed understanding of European sustainability regulations to inform future developments in Australian sustainability and thermal performance regulatory reform:

- Learn about the regulatory system and reform process in the EU
- Compare regulatory frameworks (EU to Australia)
- Learn of innovative materials and methods to improve sustainability
- Investigate EU rating processes
- Explore methods to reduce energy consumption and CO_2 emissions
- Learn solutions in sustainability for new and renovated building developments.

3.2 Education

Skills to implement a successful collaborative and multidisciplinary learning environment for building design, engineering, building and construction trade students:

- Participate in a multidisciplinary project that brings together international groups of architecture, construction, engineering and construction management students
- Collaborate with lecturers from six participating countries in the Erasmus Intensive Program
- Learn effective methods to encourage participation and engagement
- Identify possible problems that may be encountered whilst introducing a new type of multidisciplinary learning environment
- Build international networks with lecturers highly educated in sustainability and the thermal performance of buildings.

4. The Australian Context

The Australian context is explained regarding:

- Sustainability in relation to the built environment
- Education - existing and proposed 'greenskills' teaching methodologies for the diverse range of students involved in the construction industry.

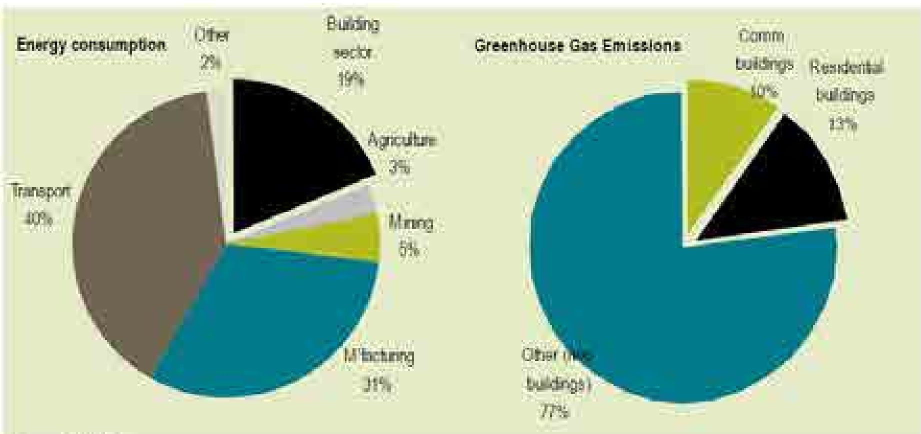
4.1 Sustainability

Sustainable buildings are designed, constructed and operated to minimise the total environmental impacts. They are therefore energy efficient, utilise renewable materials and energies, contribute minimally to greenhouse gas emissions (or are carbon neutral), offer thermal comfort and health to occupants and are designed to consider their environmental impact throughout their entire life cycle from construction to refurbishment or demolition.

Fossil fuels produce large amounts of CO_2 emissions. In Australia, coal is currently used to generate around three quarters of Australia's electricity and in 2007–08 accounted for 40 per cent of total primary energy consumption.[6]

"Australia's per capita greenhouse gas emissions are the highest of any OECD country and are among the highest in the world. In 2006 our per capita emissions (including emissions from land use, land-use change and forestry) were 28.1 tonnes carbon dioxide equivalent (CO_2-e) per person (DCC 2008d). Only five countries in the world rank higher—Bahrain, Bolivia, Brunei, Kuwait and Qatar. Australia's per capita emissions are nearly twice the OECD average and more than four times the world average." Garnaut Climate Change Review.[7]

According to a report by UNEP, buildings are responsible for 30-40 per cent of global energy use (DOE, 2007; UNEP, 2007).[8]



Source: CIE (2007).
Based on energy consumption data from ABARE (2006) and Australia's National Greenhouse Accounts: National Inventory Economic Sector (2005). AGO (2007).

Source: ASBEC, The Second Plank – Building a Low Carbon Economy with Energy Efficiency Buildings 9

Figure 1: Energy consumption and greenhouse gas emissions

The energy used by Australian buildings accounts for approximately 19 per cent of Australia's greenhouse gas emissions. Residential buildings contribute 13 per cent and commercial buildings 10 per cent to this percentage.[10] Improving the thermal performance and energy efficiency of new and refurbished buildings is an important component in the Australian Government's strategies to address climate change, mitigate greenhouse gas emissions and reduce energy use. Using renewable energy sources such as solar and wind to replace coal fired power generation will also significantly contribute to a reduction in greenhouse gas emissions.

ASBEC's document, The Second Plank- building a low carbon economy with energy efficient buildings cite McKinsey and Company's view that "energy efficiency in the building sector could reduce emissions by around 60 Mt per annum by 2030. They report that energy efficiency in the building sector presents the lowest cost abatement technology available in the economy".[11]

The Building Code of Australia (BCA) dictates the minimum standard for the thermal performance of buildings. For residential buildings in Victoria the minimum requirement is six stars on a scale of zero to 10. When compared to many international thermal performance requirements, Australia sets a low benchmark.

"Australia's building energy standards are still low: most developed nations push beyond the equivalent of eight stars (the Building Code of Australia (BCA) aims for six stars). Many countries are moving to net zero energy or net zero carbon. Building codes across Europe, the UK, US, and Asia are being modified to approach a net zero carbon standard as early as 2016-2020." Stephen Barry, Getting practical with push for zero carbon homes.[12]

European countries including Denmark, Germany, Austria and Switzerland are significantly more advanced than Australia in their standards for thermally efficient buildings, the upgrading of existing building stock, development of highly efficient prototype buildings, lower dependence on fossil fuels and progress towards carbon emission abatement. Regulatory reform plays a large part in driving change and, therefore, a great deal can be learnt from exploring the successes and hurdles faced in these countries. The following table shows the targets set for low energy buildings in countries (with heating dominated climates) that are leading the way in addressing energy efficiency and greenhouse gas abatement.

Country	Low-energy target
Austria	Planned: social housing subsidies only for passive buildings as of 2015
Denmark	By 2020 all new buildings use 75% less energy than currently enshrined in code for new buildings. Interim steps: 50% less by 2015 , 25% less by 2010 (base year=2006)
Finland	30–40% better than standard buildings by 2010; passive house standards by 2015
France	By 2012 all new buildings are low-energy buildings; by 2020 new buildings to be energy positive
Germany	By 2020 buildings should be operating without fossil fuel
Hungary	New buildings to be zero-emissions buildings by 2020, and for large investments by 2012
Ireland	60% less energy than current standards by 2010, net zero energy buildings by 2013
Netherlands	25% less energy than current standards by 2010, 50% less energy than current standards by 2015, energy neutral by 2020
United Kingdom (England and Wales)	New homes to be 44% lower carbon than current standards by 2013 and zero carbon as of 2016. New non-domestic buildings to be zero carbon from 2019.

Source: Report of the Prime Minister's task group on Energy Efficiency 13

Figure 2: Selected national targets for low-energy buildings

4.2 Education

One of the keys to significant improvement in sustainable design and energy performance of buildings is education. Thermal performance assessors, building designers, engineers, builders, developers, building product manufacturers, construction tradespeople, building regulators and building certifiers are all stakeholders in creating and improving highly energy efficient building infrastructure. Currently students training for these careers are taught in stand-alone programs. Not until they enter the workforce do they meet to work together towards constructing buildings. Establishing excellent communication and collaboration between all stakeholders is required for the seamless development of buildings from briefing, design development, construction and building management through the entire life cycle of the building.

The Master Builders Association made a submission to the Prime Minister's Task Group on Energy Efficiency stating "Construction of new, more energy efficient buildings and the retrofitting of existing buildings will require a more skilled workforce. Government assistance is needed to overcome structural skills shortages in the building industry and to train workers in the new green building techniques that will be required".[14]

To pave the way for a collaborative greenskills workforce the adoption of multidisciplinary learning environments is planned. The aim is to facilitate collaboration between students seeking to enter the construction workforce. To this end, Box Hill Institute is creating a new facility, the Integrated Technology Hub, to be completed in 2013. The design for the facility by Spowers architects is targeting 5 Star Green Star accreditation under GBCA's Education Rating Tool V.2 (Design). It is to be a model for sustainability where students of the Building Diploma, Advanced Diploma of Building Design (Architectural), building trades and degree students in the Bachelor of Sustainable Environments are encouraged through projects to work collaboratively. Students will have access to view the building's services and building management system (BMS) to further facilitate their understanding of designing, constructing and monitoring highly efficient buildings.

Source: Spowers- Box Hill Institute of TAFE, Integrated Technology Hub 15

Figure 3: Box Hill Institute – Integrated Technology Hub to be completed in 2013

In summary, there is a great deal to be learnt regarding sustainable buildings from world leading countries within Europe. As we work towards improving the education of the greenskills workforce, a significant step will be developing learning environments that facilitate communication and collaboration between all construction professions and trades.

SWOT Analysis

4.3 Strengths – the Australian context

National and state governments are increasingly recognising the built environment's role and the need to respond by encouraging and regulating for improved building energy efficiency and performance. Organisations like as the GBCA have been strong advocates driving change for more sustainable building development. Through all levels of government, policy is now being implemented and improved towards more sustainable outcomes:

- Australia's regulatory system is well established with the Building Code of Australia (BCA) dictating nationwide mandatory minimum building energy performance standards
- The Nationwide House Energy Rating Scheme (NatHERS) provides a reliable way to estimate and rank the potential thermal performance of residential buildings in Australia
- The comprehensive voluntary Green star rating tools evaluate a range of building types including offices, multi-residential, retail, industrial, educational and healthcare buildings
- A significant number of architects, building designers, builders, developers, researchers, educational centres and not-for profit organisations (including GBCA) are actively encouraging, driving and implementing green building practices
- Exemplar buildings such as Council House 2 and Pixel (both in Melbourne, Australia) have been built to demonstrate leadership in sustainable design
- Australia has a well-established education and training system.

4.4 Weaknesses – the Australian context

There are identified obstacles including skills gaps that prevent Australia from rapidly improving its building stock towards highly efficient, sustainable buildings. The Prime Minister's Task Group on Energy Efficiency has identified barriers that may prevent the take-up of energy efficiency in Australian buildings. These include:

- Lack of accurate pricing — for example, poor reflection of savings from a delayed network infrastructure investment
- Split incentives — where the developer, building owner, building manager, financier, and occupier bear different costs or have different interests, separating the incentives for energy efficiency investments
- Lack of market understanding and recognition of the benefits of advanced buildings (including broader benefits such as health benefits, increased market value and higher tenancy rates)
- Lack of information, knowledge and broad experience about what can be achieved and how
- Skills gaps — which inhibit promotion, take-up, and the quality of the end product (particularly in emerging technologies and systems)
- Planning, transaction costs and energy market barriers that inhibit distributed generation and the innovative partnerships which support them
- Materiality issues — where energy costs often make up only a relatively small portion of total expenditure
- Uncertainty — including about future increases in minimum energy efficiency performance standards or long-term goals
- Capital constraints for smaller businesses and households.[16]

4.5 Opportunities

- Ability to align Australia's building energy performance standards with other developed countries. This will result in the construction of more energy efficient building stock and increase the progress in carbon abatement.
- Possibility to implement a successful collaborative and multidisciplinary learning environment for building design, engineering, building and construction trade students in Australia.

4.6 Threats

- The application of regulatory reform in Europe may prove less relevant for Australian reform than anticipated.
- Setting minimum energy performance standards will slow innovation because there is no incentive to go beyond the minimum.
- Differences between the building energy assessment software performance rating determined at design/building approval stage to the actual rating achieved after building completion. This undermines confidence in the system as does lack of consistency in rating results derived by application of different approved building energy assessment software tools.
- Ongoing uncertainty regarding the timing and stringency of future increases in the minimum energy efficiency performance standard and undefined national targets for low energy buildings.
- Ongoing industry skills deficiencies about what can be achieved and how.
- Applying multidisciplinary learning environments may go unsupported regarding funding or be impeded by organisational constraints, creating problems with applying new teaching methodologies.

5. Identifying the Skills Deficiencies

Specific skill deficiencies addressed through the Fellowship were as follows:

5.1 Compare regulatory frameworks for energy efficient buildings

The Institute for Building Efficiency (IBE) has conducted extensive research[17] into policy options that enable transformation in building efficiency and these include:

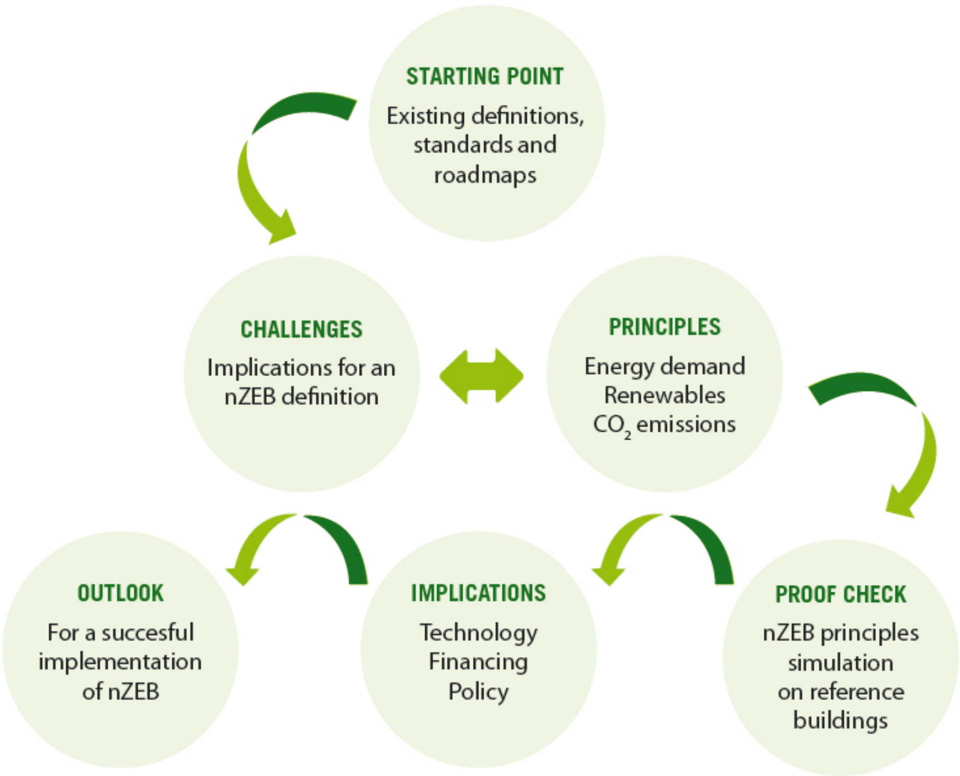
- Building efficiency codes and standards
- Energy efficiency improvement targets
- Policies and actions that increase awareness
- Financial incentives
- Utility programs
- Human and technical capacity building.

Using the model developed by the IBE to analyse Australia's regulatory system creates a framework to compare the regulatory systems with those of more advanced European countries.

Action: *By analysing and comparing these systems, it is anticipated that the Fellow will be able to identify areas for discussion regarding Australian regulatory reform and potentially advise on areas where European policies have been very effective and where they have failed to generate the gains anticipated.*

5.2 Investigate the development of Net or Nearly Zero-Energy Building definitions and the implication for regulatory reform

A key theme for discussion and research in regulatory systems is the lack of an agreed definition for Net or Nearly Zero-Energy Buildings (nZEBs). These buildings are currently models for best practice and often use innovative technologies to achieve very high levels of energy performance. However in the EU from 2019 onwards nZEB buildings will be the requirement for all public buildings and from 2021 onwards for all new buildings. nZEB definitions vary and can be complicated. The starting point for unified and successful policy is in understanding the implications of the range of definitions and working towards principles that can be consistently applied to build nZEB buildings in a range of climate zones. Recently the Australian Sustainable Built Environment Council (ASBEC) released the document Defining Zero Energy Emissions, whilst Engelund Thomsen, Jørgen Rose, Soren O. Aggerholm of the Danish Building Research Institute (SBi) Denmark have written the report Principles For nearly Zero-energy Buildings - Paving the way for effective implementation of policy. By meeting with Kirsten Engelund Thomsen and Jørgen Rose, in Denmark the Fellow will be able to discuss the variances in Australian to European nZEB definitions and possible policy and implementation implications.



Source: Principles for nearly Zero-Energy Buildings - Paving the way for effective implementation of policy 18

Figure 4: Structure of the Study Principles for nearly Zero-Energy Buildings

Action: *Understanding the range of definitions and the way in which European national codes will be gradually strengthened towards the more stringent requirements of these nZEB definitions is an area of interest to Australian regulatory bodies and ultimately the Australian construction industry.*

5.3 Investigate EU rating processes

Throughout Europe there are a variety of concepts and voluntary standards for highly energy efficient buildings. These include Passivhaus, Zero-energy, 3-litre, Plus energy, Minergie® and Effinergie. Whilst in Europe the Fellow will research Passivhaus in Horsens, Denmark with the Erasmus Project and discuss Minergie® with Professor Armin Binz, Head of Institute and technical office of Minergie® in Basel, Switzerland.

Action: *Comment and compare the two rating processes: Passivhaus and Minergie®.*

5.4 Affordable solutions in sustainability for new and renovated building developments including innovative materials and methods to improve sustainability

The opportunity for the Fellow to identify affordable solutions, new innovative materials and sustainable building methods is made possible by participating in the multidisciplinary project at VIA Horsens in Denmark, visiting nZEB buildings throughout Europe and meeting with experts in sustainable building design.

Action: *Disseminating information on these findings will be an important part of the research findings.*

5.5 Skills to implement a successful collaborative and multidisciplinary learning environment for building design, engineering, building and construction trade students.

- Participate in a multidisciplinary sustainability project that brings together international groups of architecture, construction, engineering and construction management students.
- Collaborate with lecturers from six participating countries in the Erasmus Intensive Program at VIA Horsens, Denmark.
- Participate at Aalborg University, Denmark, in a multidisciplinary workshop focusing on the use of digital tools in the design process with participation of several teaching institutions in the building sector.
- Learn effective methods to encourage participation and engagement.
- Identify possible problems that may be encountered whilst introducing a new type of multidisciplinary learning environment.
- Build international networks with lecturers highly educated in sustainability and the thermal performance of buildings.

Actions:

- Disseminate learnings to teachers regarding multidisciplinary projects
- Implement multidisciplinary learning strategies in the new Integrated Technology Hub.

6. The International Experience

6.1 Lisbon, Portugal – 2nd and 3rd April 2012

Meetings were held with Helder Gonçalves and Laura Aelenei of the LNEG Laboratório Nacional de Energia e Geologia in Lisbon including a site visit to the nZEB office and research building Solar XXI.

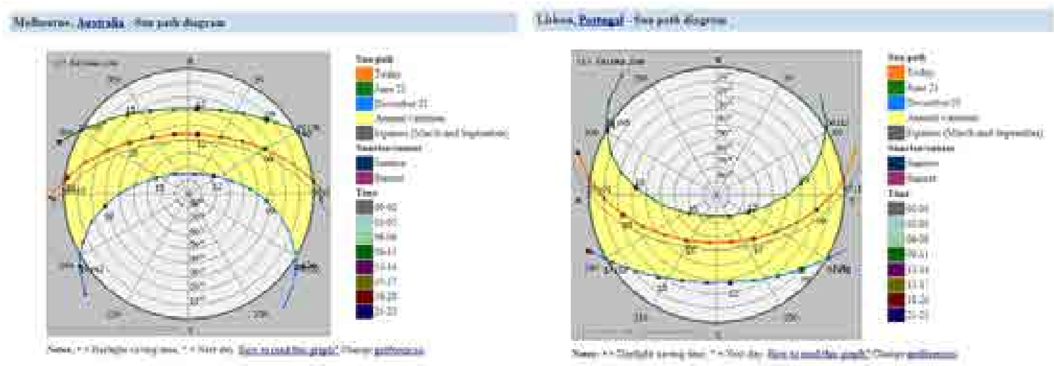
The climatic conditions of Lisbon, Portugal are similar to that of Melbourne, Australia. Whilst the cities are in different hemispheres their latitudes are similar and both have mid-latitude, maritime temperate climates.[19]

Melbourne, Australia - Basic information	Lisbon, Portugal - Basic information
Latitude: -37.81 (37°48'36"S)	Latitude: +38.72 (38°43'12"N)

Source: GAISMA 20

Figure 5: Climate data; Melbourne and Lisbon

The sun path diagrams for both cities are similar, noting that northern and southern hemisphere locations have sun paths that dictate the optimum building facade to benefit from passive solar design and solar access. In the northern hemisphere the focus is on building orientation to benefit from southern sunlight and southern hemisphere buildings benefit from northern access to sun.



Source: GAISMA 21

Figure 6: Sun Path diagrams for Melbourne and Lisbon

Melbourne, Australia - Solar energy and surface meteorology

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, kWh/m²/day	6.15	5.65	4.34	3.07	2.12	1.66	1.81	2.52	3.40	4.60	5.63	6.07
Clearness, 0 - 1	0.52	0.53	0.50	0.47	0.44	0.42	0.42	0.45	0.45	0.47	0.49	0.50
Temperature, °C	20.12	20.59	18.12	14.53	11.51	8.98	7.91	8.65	10.75	13.43	16.20	18.54
Wind speed, m/s	4.42	4.36	4.17	4.33	4.17	4.50	4.65	5.08	4.69	4.71	4.36	4.38
Precipitation, mm	51	45	44	54	64	40	48	56	54	62	55	56
Wet days, d	9.8	8.8	9.5	8.6	10.1	10.2	10.3	10.2	10.2	12.0	10.2	8.8

These data were obtained from the NASA Langley Research Center Atmospheric Science Data Center; New et al. 2002
Notes: Help. Change preferences.

Lisbon, Portugal - Solar energy and surface meteorology

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, kWh/m²/day	1.91	2.74	4.05	5.09	5.82	6.58	6.59	6.02	4.65	3.14	2.06	1.62
Clearness, 0 - 1	0.44	0.48	0.52	0.53	0.53	0.57	0.59	0.59	0.55	0.49	0.43	0.41
Temperature, °C	9.30	10.29	13.07	14.43	17.65	22.12	24.50	23.82	21.55	17.42	13.28	10.91
Wind speed, m/s	5.73	6.11	5.99	5.85	5.48	5.17	5.28	5.21	4.82	5.00	5.52	6.01
Precipitation, mm	109	110	68	64	39	21	4	5	26	80	111	106
Wet days, d	14.3	14.0	12.8	11.5	8.3	4.9	1.8	1.8	5.8	10.4	13.0	13.8

These data were obtained from the NASA Langley Research Center Atmospheric Science Data Center; New et al. 2002
Notes: Help. Change preferences.

Source: GAISMA 22

Figure 7: Solar energy and surface meteorology of Melbourne and Lisbon

Temperatures, insolations and windspeeds are similar and follow similar seasonal changes. Note that rainfall and number of wet days per month do not follow similar patterns, but these are not factors in terms of designing for optimal thermal building performance.

Solar XXI

Address: *INETI –Instituto Nacional de Engenharia, Tecnologia e Inovação, Portugal*

Building Description:

Solar XXI is a prototype building with renewable technology concepts employed to achieve high levels of energy efficiency whilst achieving thermal comfort for the building occupants. The building was opened in 2006 and has been carefully monitored each year for energy generation and consumption and for thermal performance and comfort. This building is a particularly relevant example applicable to this study as it incorporates passive cooling technologies in conjunction with the full complement of Passivhaus design principles. Passivhaus design achieves high energy efficiency for buildings in Northern European climates where efficient heating is the main concern and cooling is not required.

Designers: Project coordinator – Helder Gonçalves

Architects - Pedro Cabrito and Isabel Diniz

Sustainability:

With Solar XXI many design factors work together to create efficiency and thermal comfort:

- Well insulated and sealed building envelope
- Building orientation and shape
- Adjustable external shading devices (venetian blinds) to the south facing windows
- Building Integrated Photovoltaic wall
- Heating strategies including passive heating and heat recovery by natural convection in the space behind the photovoltaic facade
- Passive cooling using buried pipes
- Natural ventilation and natural lighting
- Functional planning with the most frequently occupied rooms having better solar access
- Manually operated systems to each space to achieve optimal thermal comfort for each occupant or group of occupants
- Photovoltaic systems and solar hot water with gas boiler.

Source: Helder Gonçalves Solar Building XXI Presentation National Energy Laboratory 23

Figure 8: Solar XXI Building

Building Envelope

The external wall of the building is a single skin of 220 mm thick brickwork with 60 mm of expanded polystyrene to the exterior. The external application of the insulation corrects any thermal bridges thereby improving the thermal performance of the walls. The concrete roof slab is massive and has 100 mm of insulation (50 mm expanded polystyrene and 50 mm extruded polystyrene). The section of floor in contact with the earth is isolated with 100 mm thick expanded polystyrene.

By placing all the insulation to the exterior of the building, winter efficiency is increased as the inertial mass retains summer heat. The thermal mass also creates a first barrier to summer heat.

Windows are double glazed with aluminium frames. External adjustable blinds create sun shading when required in summer to reduce the solar heat gain coefficient.

Figure 9: Solar XXI –South facade with double glazed windows, adjustable external shading and BIPV panels with heat recovery system

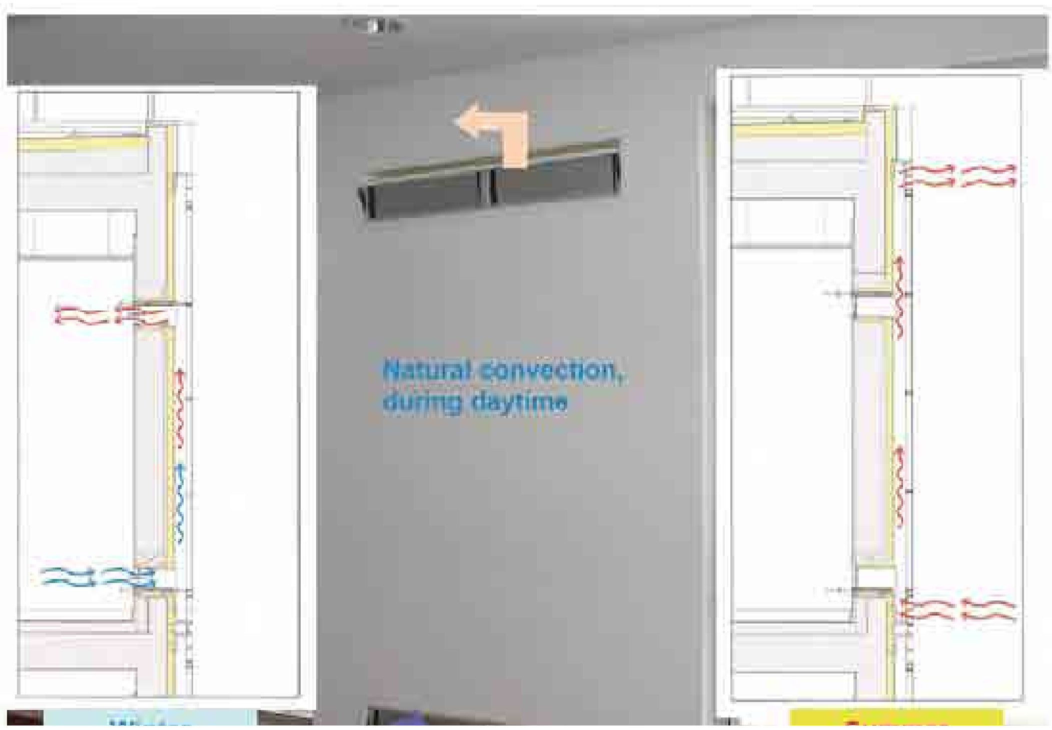
Building orientation and shape

The facade is orientated directly to the south to optimise passive solar access. The longest facade has 45 per cent of its area as south facing windows. The most frequently occupied rooms are situated to benefit from solar heat gain in the cooler months. Other facades have a much lower ratio of glazing to wall.

Building Integrated Photovoltaic wall

Approximately 45 per cent of the south facing wall comprises photovoltaic panels mounted on the wall to generate electricity and create a heat recovery system for heating the building. Photovoltaic modules generate a substantial quantity of heat which warms air in the cavity between the panels and insulated external wall.

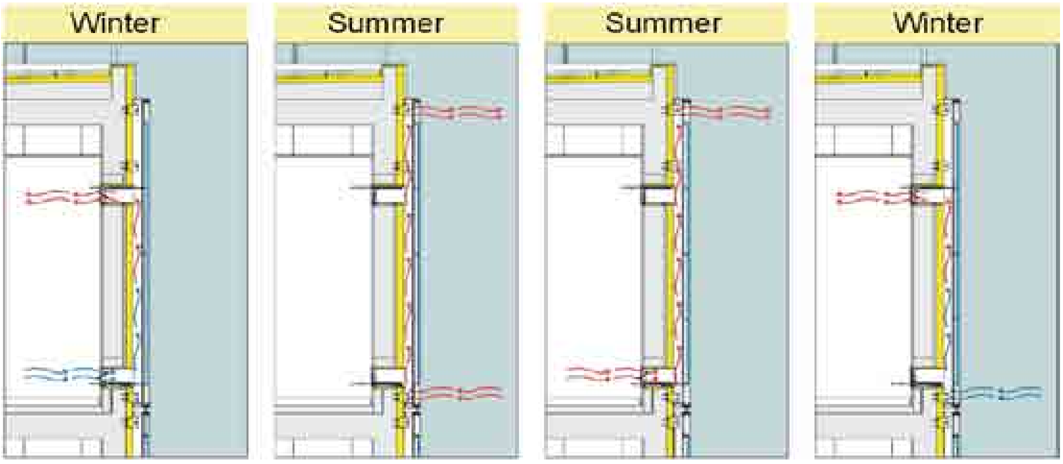
The heat rises through natural convection and can be vented inside the building during winter or released outside during summer.



Source: Solar Building XXI Presentation National Energy Laboratory 24

Figure 10: Solar XXI Winter and summer thermal strategy

Manually adjusted vent operation also allows for several mid-season options including pre-heated fresh air intake or purging of warm room air.

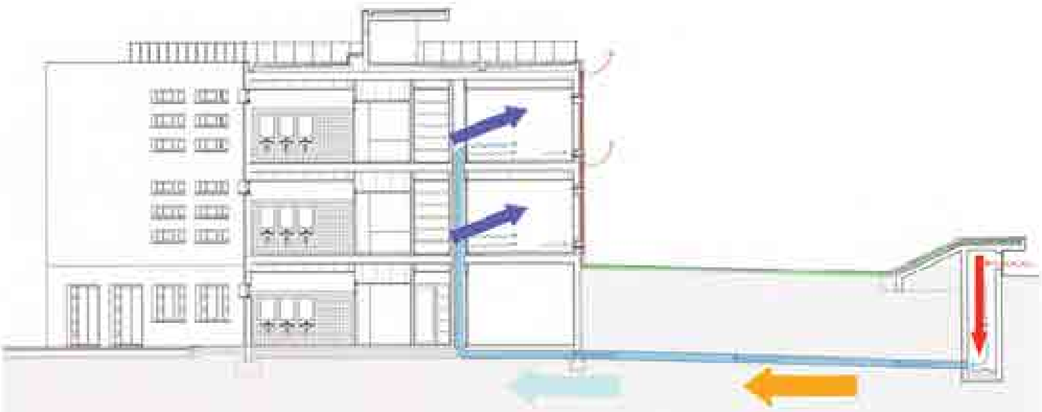


Source: Case Study No 4 Edifício Solar XXI Lisbon, Portugal 25

Figure 11: Solar XXI Modes of operation of the photovoltaic panels to supplement ventilation

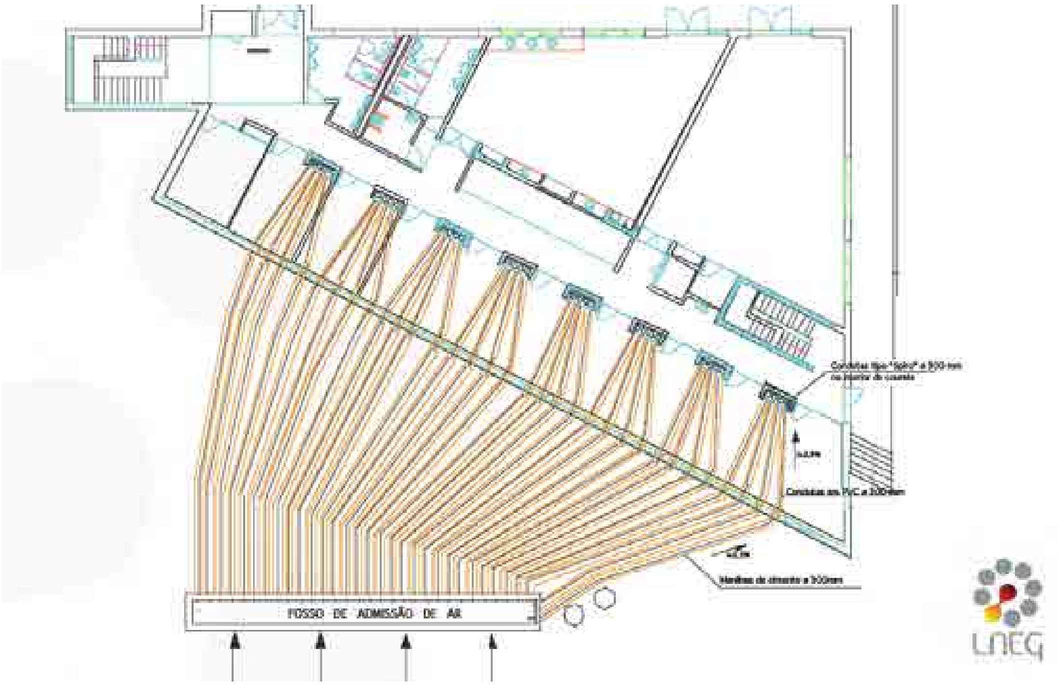
Passive cooling using buried pipes

The ground temperature at a depth of 4.6 metres is between 13ºC and 19ºC. In summer, air enters the building via thirty two 300 mm diameter buried concrete pipes. The air temperature within the pipes drops significantly over 15 metres due to thermal exchange with the cooler earth and lowers the room temperatures by 2-3ºC.



Source: Solar Building XXI Presentation National Energy Laboratory 26

Figure 12: Solar XXI Passive cooling system using buried pipes- section



Source: Case Study No 4 Edifício Solar XXI Lisbon, Portugal 27

Figure 13: Solar XXI Passive cooling system using buried pipes- plan

The air travels by natural convection from the external air intakes via the buried pipes to vents in each room. Small fans can be used to increase the rate of air flow when required. There are two vents in each office with occupant operated sliding panel doors to block or allow passive cooling.

Figure 14: Solar XXI Passive cooling system - vents and fans in offices

Helder Gonçalves stated that while the system was very effective at passively cooling the building, the quality of air at the beginning of summer was an issue with several staff reporting an earthy smell due to initial dampness in the pipes. Gonçalves explained that some ground cooling systems have a loop and exchanger which would eliminate this problem. However, those systems require more electricity to operate.

Natural ventilation and natural lighting

Part of the passive cooling strategy for Solar XXI is natural cross ventilation assisted by adjustable vents over room doors to the central corridor and light well. A chimney or stack effect is achieved with motorised roof top vents allowing rooms at all levels to purge warm air at night.

Figure 15: Solar XXI Laura Aelenei demonstrating natural ventilation strategies

All rooms have windows to provide natural lighting. A central light well with south facing windows above the main roof level ensures that internal parts of the building are naturally lit but are not subject to excessive solar heat gain. Northern rooms borrow light from the central space via translucent windows. The north-eastern rooms also have an external blind wall built as a reflector to increase natural light levels within the rooms.

Manually operated systems

The occupants of the building have the opportunity to manually adjust the vents, fans and window shading devices to achieve their desired thermal comfort. There is no automated building management system (BMS), although ongoing monitoring is undertaken for research. Interestingly, as buildings become very thermally efficient the amount of power used to automatically operate shading devices, vents and other environmental features can become a significant load. Eike Musall (refer to Section 6.8.3) when explaining the Solar Decathlon Project undertaken by Wuppertal University, stated that when the BMS was turned off the building was more energy efficient.

Source: Solar Building XXI Presentation National Energy Laboratory Portugal 28

Figure 16: Solar XXI Natural ventilation and lighting

Photovoltaic systems and solar hot water

In addition to polycrystalline photovoltaic panels (12 kWp) on the south facade, large car shading structures are also covered with amorphous silicon photovoltaic modules (6 kWp) at an angle of 15^{o} creating a PV power station. In 2009 the PV generated a daily average of 54 kWh whilst building consumption was 78 kWh.[29] An additional PV car shading structure was installed in 2011 effectively doubling the size of the carport PV module area and achieving a closer balance between the building's energy generation and consumption.

The vertical panels on the facade are less efficient for energy collection in summer than the PV panels tilted at 15° but in winter they are a very effective source of heating through the passive heat recovery process.

Note - whilst the Fellow was researching ideal PV tilt angles for Lisbon and Melbourne, the American National Renewable Energy Laboratory website was found to be useful.[30] It is an online calculator that uses hourly typical meteorological year weather data and a PV performance model to estimate annual energy production. The calculator allows different tilt angles and orientations to be tested to calculate the most effective positioning for PV panels based on the site location.

Figure 17: Solar XXI Photovoltaic array in carpark

Solar hot water panels supplemented with a gas boiler provide hot water to the building.

Source: Solar Building XXI Presentation National Energy Laboratory Portugal 31

Figure 18: Solar XXI Photovoltaic systems and solar hot water with gas boiler

Concluding Remarks

Helder Gonçalves, Laura Aelenei and the team at the Laboratório Nacional de Energia e Geologia (LNEG) are continuously monitoring and researching sustainable building design and performance from within their laboratories and offices in the prototype building Solar XXI. The building demonstrates low energy consumption, integrated renewable technologies and passive systems for heating and cooling.

A survey of occupants showed that 77 per cent of users were very satisfied with the conditions in summer and winter. The highest percentage of users were satisfied with the conditions of lighting and acoustics. Slightly lower percentages of acceptance were observed for thermal comfort. This was influenced by occupants in the northern rooms as these spaces do not benefit from solar gains in winter in the same way south facing rooms do. In response to this, these rooms are now heated and cooled using a solar system.[32]

Solar XXI, like other highly energy efficient buildings visited by the Fellow has required ongoing monitoring and adjustments to bridge the gap between modelled and actual performance. In this case, performance of thermal comfort required additional attention to ensure both occupant comfort and energy efficiency.

Built in 2005/06 the Solar XXI building cost EUR 800 per metre square. The building did not cost more than a typical building of the same size and type. Gonçalves explained that costs were kept in check by having very detailed and clear documentation and specifications prior to construction thereby minimising contract variations. Cost saving were also achieved as the passive heating and cooling systems are operated manually rather through a building management system.

Outcomes

This is a useful building for greenskills students to study due to the location's climatic similarities with Melbourne. Passive cooling and heating strategies have been successfully implemented to achieve energy efficiency and thermal comfort.

The perception that thermally high performing buildings are always expensive and come at a significant cost premium is one of the barriers that limit Australia's progress in building new highly efficient, sustainable buildings.

This and other prototype projects that have been built without significant extra costs to typical buildings are more likely to accelerate change.

Lack of accurate pricing is an identified barrier that may prevent the take-up of energy efficiency in Australian buildings. Therefore communicating information about projects such as this will influence students, builders, engineers, designers and the public. An increased focus for greenskills students on cost optimisation for thermal efficiency will also address this issue.

6.2 Vienna, Austria – 5th and 6th April 2012

The Fellow stayed at the Boutiquehotel Stadhalle which is the first hotel ever to achieve a zero energy balance.[33] Christiane Burklein's article on Monday, 9th January 2012 in Sustainable Architecture states that the hotel is "the world's first city centre hotel with a zero energy balance certified by the European environmental quality mark". The Fellow met with the building owner and Director of the hotel, Michaela Reitterer on 6th April for a guided tour.

Boutiquehotel Stadhalle

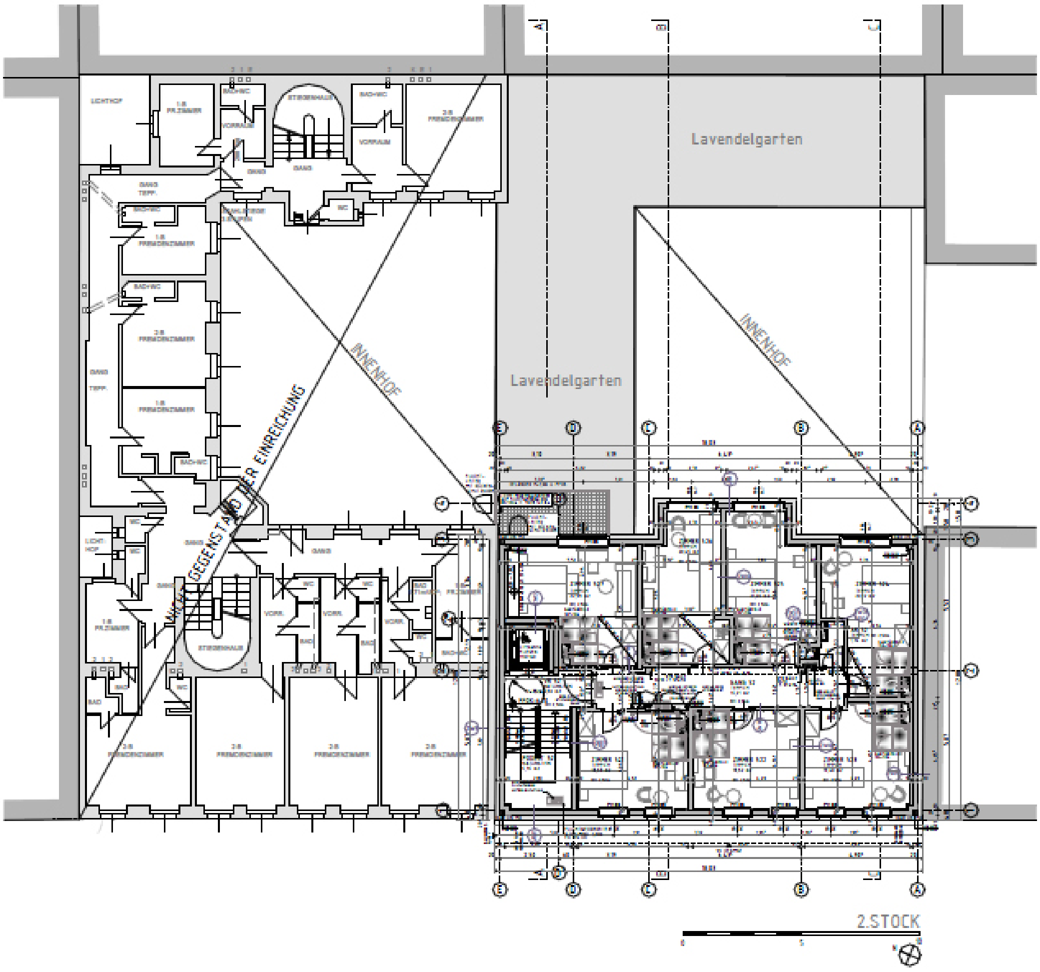
Address: Boutiquehotel Stadthalle, Hackengasse, Vienna, Austria

Building Description:

The hotel provides three star accommodation with 80 guest rooms arranged around a central courtyard. Parts of the building are two storeys whilst other parts are taller at six storeys. The building is comprised of three joined sections:

- A renovated 120 year old Viennese apartment building. This part has been converted into 35 hotel rooms and upgraded with improved insulation and a range of sustainability features
- Seven hotel rooms added ten years ago with consideration for thermal performance and sustainability. This area is two storeys and called the 'Garden Rooms' as there is lavender planted on the roof
- 38 new hotel rooms completed in 2009 built to Passivhaus standard.

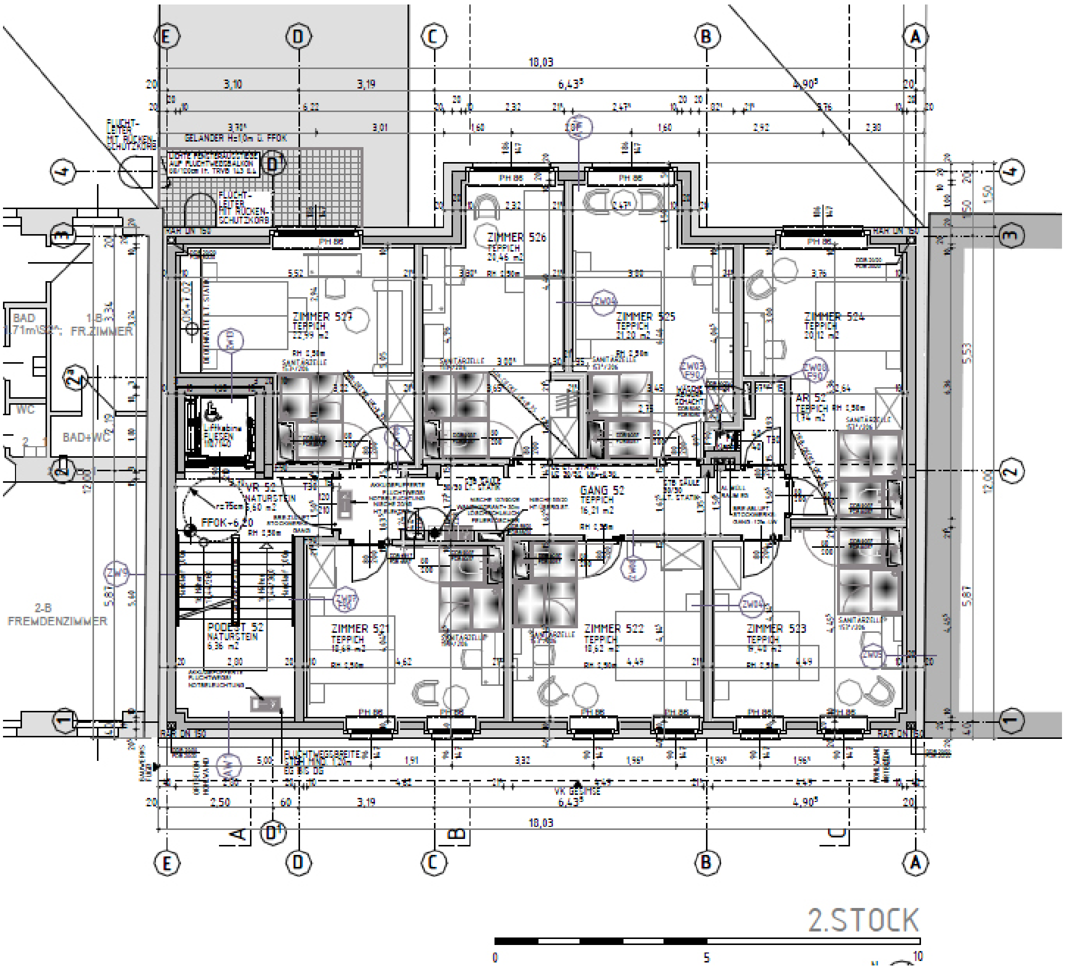
Figure 19: Boutiquehotel Stadhalle- Front facade with 120 year old Viennese wing on the left and new Passivhaus wing to the right



Source: Floor Plans courtesy of Michaela Reitterer 34

Figure 20: Boutiquehotel Stadhalle– Floor Plan with 120 year old Viennese wing on the left, Garden Rooms Wing top right and new Passivhaus wing to the bottom right

Information in this report relates essentially to the new Passivhaus section of the hotel although some comparisons on energy usage are made between the areas.



Source: Floor Plans courtesy of Michaela Reitterer 35

Figure 21: Boutiquehotel Stadhalle– Floor Plan - Passivhaus wing

The hotel has an impressive 83 per cent occupancy rate.[36] It has won numerous awards not only for sustainability but also for quality. The hotel is rated in the top 99 in the world and within the top nine city hotels worldwide.

Design: Architekt DI Heinrich Trimmel

Sustainability:

- 130 m^2 solar panels for hot water
- 95 m^2 photovoltaic panels to generate electricity
- Hydronic system for heating and cooling the concrete floors/ ceiling in conjunction with ground water heat pumps and solar energy
- Ground water heat pumps: an in-house well supplies cooling energy and provides the heat pump system with groundwater. A single 14 metre deep bore pumps 14°C groundwater into holding cisterns. 7000 litres/hr of well-water is required for energy extraction. In the process the water temperature drops to 6°C and is then stored for toilet flushing in separate cisterns. This is a special

case as typically the well-water should be returned: 60 per cent at the lower temperature is permitted and the remainder at 14°C. The use of well-water for energy extraction is allowed on a first come first served basis and therefore the hotel reserves the right to the ground water for a distance beyond its boundaries

- Heat recovery system (pre-heating fresh air through a ventilation system which achieves over 90 per cent heat recovery)
- A DESIGO™ building automation system from Siemens integrates all the system components and processes. The BMS monitors and controls thermal comfort whilst achieving very efficient energy usage. It features programmable automation controllers as well as flexible key performance indicators related to measurement and control technology that enable the monitoring and regulation of heating and ventilation based on actual demand or pre-defined schedules. The system also controls and monitors the concrete core activation, water heating, the solar panel system, buffer management and the groundwater heat pump. The system's web-based operation enables energy data and reports to be accessed at all times, increasing energy monitoring capability, consumption transparency and usage efficiency[37]
- Double glazed windows
- Windows that open to allow natural ventilation (although a notice indicates to guests that windows should be kept closed to assist the heat recovery system)
- Highly insulated walls: concrete with 200mm polystyrene insulation
- Improved air quality from the green roof of the Garden Rooms, adjacent garden courtyard and green walls of the 120 year old section
- Rainwater for garden watering
- Well-water for toilet flushing and garden watering
- Energy efficient LED lighting
- Water efficient bathroom fittings and low-flow toilets
- Automatic room temperature controls based on occupancy
- Lighting turns of automatically as guests leave rooms
- Corridor lighting is motion activated
- Refrigerators are not provided in the hotel rooms. Drinks are available at the front desk
- Rooms have a television and phone but do not have electric kettles, clocks or other electrical appliances that contribute to energy usage
- Close to a main train station
- Bicycle garage
- Recycled decorations and furnishings
- Solid timber cabinetry
- Discount for guests arriving by public transport or bicycle
- Information for guests to assist in energy efficiency and CO_2 emission reduction. CO_2 emissions for each guest can be checked at the hotel lobby
- Wind turbines and on-street charging stations for electric cars are proposed for the future. However, planning permission is proving problematic.

Source: Boutiquehotel Stadhalle Corporate Social Responsibility Report 2011 38

Figure 23: Boutiquehotel Stadhalle - Bedroom

Figure 24: Boutiquehotel Stadhalle- View of rooftop lavender garden and green walls

Figure 22: Boutiquehotel Stadhalle - View from Passivhaus wing to PV panels and rooftop Lavender garden over the Garden Wing

Figure 25: Boutiquehotel Stadhalle – View of Passivhaus Wing from central courtyard

Figure 26: Boutiquehotel Stadhalle – View of PV from central courtyard

EnergyPass, energy usage records for mandatory disclosure are required for selling property in Vienna. The following figures were quoted by Michaela Rettierer:

	Rooms	Energy use
Renovated 120 year old wing	35	100,000 kWhr
Passivhaus and Garden Wing	45	60,000 kWhr

	Energy use/m^2
Passivhaus (ground floor and basement where old and new parts of the building join)	11.73 kWhr/m^2
Passivhaus (from the first floor up)	9.00 kWhr/m^2

Concluding Remarks

Michaela Reitterer has met with planning approval obstructions in her requests to install wind turbines and electric car recharge stations.

In regards to the wind turbine one neighbour has placed objections based on medical reports indicating his epilepsy may be affected by viewing the wind turbines. This is an interesting variation on neighbours' objections which would more typically be related to noise from wind turbines or streetscape/ neighbourhood character issues.

The electric car recharge stations are proposed to be located on the public footpath as the hotel itself has no off-street car parking. At present there are no street electric car recharge stations in Vienna and the city council is not yet ready to implement, monitor and regulate the installation and planning permissions. Consequently the planning permission request is still in progress.

Figure 27: Electric car recharge station in Brussels Belgium

The photo above was taken in Belgium, Brussels where on-street electric vehicle recharge stations are installed. May 2012 saw Melbourne's first electric vehicle charging station installed in Port Melbourne as a shared project by Holden and ChargePoint.[39] As electric vehicles become more affordable, the availability of locations and means to power them away from home will be a factor in their success. The relationship between environmentally friendly transport and buildings is an increasingly important issue for building designers, owners, planners and councils to consider.

Outcome

The Boutiquehotel Stadhalle hotel has won numerous awards for its green credentials but is not certified under LEED or other green building certification schemes. The hotel was awarded the EU-Ecolabel for tourism businesses for its sustainable building design and ongoing commitment to sustainable practices.

Ground water heat pumps and more than 200m^2 of solar and photovoltaic panels provide self-sustained energy to the whole hotel and in combination with energy saving measures and excellent thermal performance, the building achieves a net zero energy balance.[40]

Investing in sustainable building design and energy efficient renovations appears to have been emotionally rewarding and economically successful for Michaela Reitterer. The hotel has attracted positive media attention as well as awards relating to its green credentials. Marketing the green credentials of the hotel may have contributed to the high occupancy rate (83 per cent) in conjunction with its convenient location, reasonable price and quality of amenity.

6.3 Copenhagen – 7th and 8th April 2012

The Fellow visited the Crowne Plaza, Copenhagen Towers, Ørestad. The hotel is built in accordance with the Danish Low Energy Class 2 standard, which means that the energy consumption must not exceed 42.6 kWh per m^2 per year.[41] However, the current data on the hotel's website indicated that the hotel is using 190 kWh per m^2. It is the first CO_2-neutral hotel building in Denmark and has the largest Building Integrated Photovoltaic system (BIPV) in northern Europe. The hotel has Denmark's first groundwater-based cooling and heating system.

Address: Ørestads Boulevard, Copenhagen, Denmark

Building Description:

The hotel provides four star accommodation with 365 guest rooms, a seven storey conference centre, gym, restaurant, bar, a ball room with capacity for 800 people and 400 car parking spaces. It was opened on 16th November 2009.

Design: Architects: Dissing + Weitling Architektfirma A/S

85 m high

Hotel and conference centre 72,500 m^2

25 floors with 365 hotel rooms

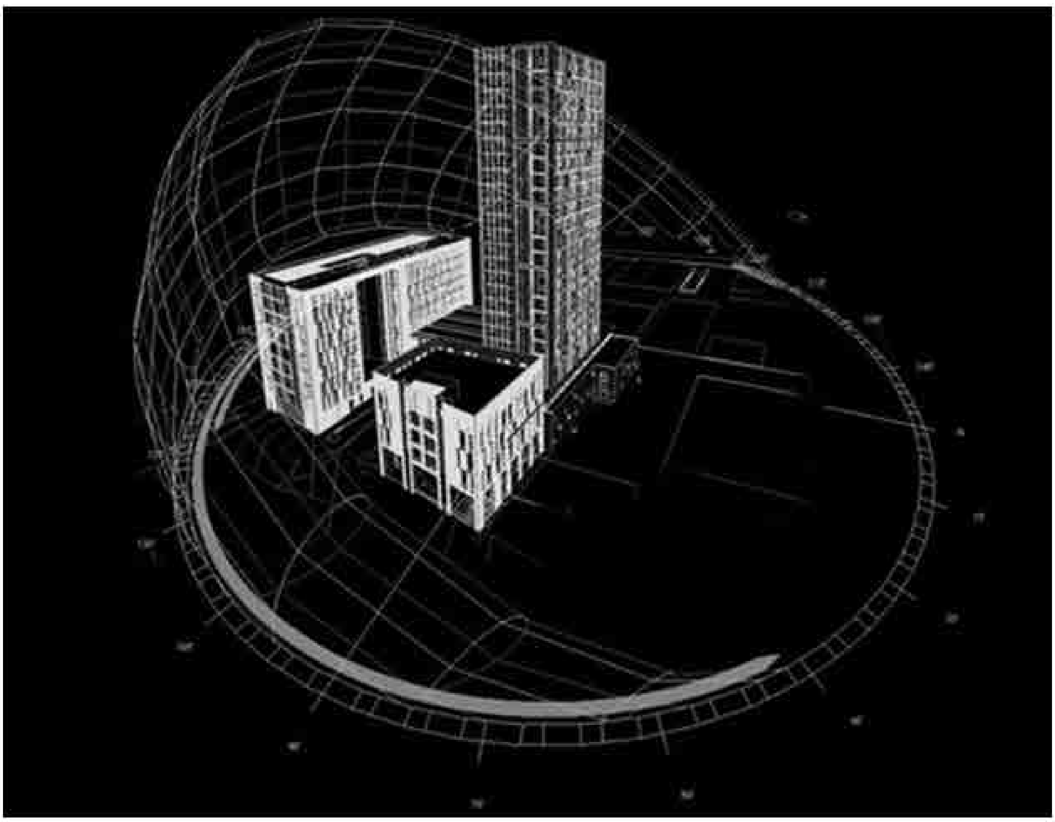
Sustainability:

- BIPV located on the facade of the building generating 10 per cent of the buildings electrical demand
- Groundwater-based cooling and heating system reducing the energy required for heating by almost 60 per cent and for cooling by almost 90 per cent
- Building orientation for optimum daylight
- BMS regulates variable air volume values by electronically regulating the amount of air in each room
- Low energy LED lighting
- Hotel corridor lighting reacts to sound and movement, switching off when not required
- Commitment to Corporate Social Responsibility (CSR)[42]
- Guest rooms have LED television screens, refrigerators and kettles
- All hotel information is electronically provided to reduce paper from hotel rooms.

The video at http://energy.grundfos.com/en/broadcast-center/sustainability/crowne-plaza-%E2%80%93-the-world%E2%80%99s-greenest-hotel [43] explains the sustainable design and groundwater-based cooling and heating system of the Crowne Plaza Hotel.

Source: Dissing + Weitling architecture, Projects Copenhagen Towers 44

Figure 28: Crowne Plaza, Copenhagen Floor Plan



Source: Dissing + Weitling architecture, Projects Copenhagen Towers 45

Figure 29: Crowne Plaza Solar modelling diagram

Concluding Remarks

The lower four storeys of south facing BIPV are in shade due to the tower located directly to the south of the main hotel building. This photo was taken at 11:00am, 8th April. For a large proportion of the year (from autumn equinox through winter to spring equinox) these panels would not receive much direct sunlight and it is interesting to consider whether these BIPV panels at this lower level are correctly placed for energy generation. The Fellow speculates that their location at these lower levels is to provide a homogenous facade for aesthetic reasons.

Figure 30: Crowne Plaza Photo indicating shading of lower BIPV panels

Outcome

Due to timing the visit over Easter the Fellow was unable to coordinate a meeting with the Facility Manager to further investigate the environmentally sustainable features and energy efficiency of the hotel.

The Fellow is unclear as to how Crowne Plaza Hotel achieves its CO_2-neutrality. However, the hotel markets its green credentials and has utilised impressive sustainability measures.

It is possible (but not confirmed) that there is an issue of actual performance not matching modelled performance.

There is a skills gap in Europe in managing and maintaining systems to perform as they are designed. This issue was reiterated in several meetings by lecturers and nZEB experts met throughout the study tour.

6.4 Erasmus Sustainability Workshop, VIA, Horsens – 9th-13th and 16th-22nd April 2012

60 students and 21 lecturers from six participating countries were involved in the Erasmus Intensive Program which involved lectures, workshops, site visits, final presentations and evaluations over a two week period. The students and lecturers were from Danish, Lithuanian, Hungarian, Portuguese, British and Austrian colleges and universities. It should be noted that the Danish college VIA attracts students internationally and so the Danish participants actually originated from many other countries with only one Danish student being involved. Typically about 10-15 lecturers were present at any one time, as not all stayed for the entire 13 day project. All activities were conducted in English. The workshop aims were:

- Integration of architectural design and construction into a multi-disciplinary project
- Understanding of the working process in the early stages of the architects and engineers design and building management phase
- Implementation of multi-national passive housing conception in the redevelopment and renovation of multi-storey residential buildings from the1970s
- Promotion of cultural understanding within the European Union.
- Understanding of the diverse construction and building traditions with in Europe.[46]

6.4.1 Erasmus project concept and activities

The Erasmus Project brought together international students in the field of constructing architects, architects, civil (structural) engineering, environmental engineering and construction management. The terminology of the qualifications and fields of expertise vary from those familiar to Australians. Constructing architects are similar to architectural draftspeople but with more knowledge in cost estimating and engineering. The concept however was to bring together many construction industry design disciplines with a diverse range of expertise.

The students were formed into 12 groups with five students in each group having a mix of nationalities and different disciplines. Then two Community Housing projects were introduced. The existing buildings require extensive refurbishment to improve liveability and thermal performance. Each group needed to decide amongst themselves which of the two projects they wished to work on for the two week program:

- A five storey residential building erected in 1968 in prefabricated concrete elements, containing 30 apartments, situated in Vilnius, Lithuania
- A three storey residential building erected in 1973-74 containing 290 apartments situated in Horsens, Denmark.

The groups' first tasks were to decide on their group name and their preferred project. They were given about 20 minutes to make these decisions.

The information below sets out the brief for both projects including client demands, project tasks, presentation requirements and evaluation method.

The client's demands

The client's demand of the renovation of the apartment block is to prepare proposals for:

- Reduction of energy consumption in order to approach to Passivhaus standards regarding energy consumption, building envelope air-tightness and the use of renewal energy sources
- Sustainable energy production
- Energy reduction calculation
- Modernisation of each apartment including kitchens and bathrooms
- Installation of an elevator (where applicable)
- Modernisation building services, mechanical ventilation in all wet rooms and kitchens
- Facade, gable and roof insulation
- Green roof and the addition of an extra roof storey (where applicable)
- Sustainable building materials and construction (where applicable)
- Water recycling and collection system
- Balcony renovation.

The Projects tasks

There were ten main tasks to be completed in the project:

1. Energy efficiency
2. Sustainable design and construction
3. Ground source heating
4. Heat pumps
5. Solar heating
6. Building services
7. Green roofs
8. Wind turbines
9. Penthouse/community house design and construction
10. Landscaping.

In order to find the best solution for the implementation of the existing buildings, it was each group's assignment to research and analyse each of the ten tasks outlined above. The client's demands had to be applied.

The possible solutions in the renovation project needed to fulfil the frames of the Passivhaus concept. The Energy consumption and CO_2 emissions had to be reduced to the maximum level for a Passivhaus according to the calculation tool BYG-SOL. At the evaluation all research and decisions were presented orally.

Workshops solutions and presentation

In order to present the solutions achieved in the Renovations Projects, an oral presentation and 'posters' were to be done. It was each group's responsibility to document their work regarding task research and client's demands solutions.

The posters contained:

- Workshop planning
- Task research information
- Sketch proposal, scale drawings, calculations, modelling
- Client's proposal.

Workshop evaluation

Each group presented their work for a maximum of 30 minutes with all group members taking part equally.[47]

Figure 31: The lecture theatre

Figure 32: The lecture theatre

Figure 33: Groups forming

Figure 34: Lectures by Ernst Heiduk

Figure 35: Lectures by Ernst Heiduk

Figure 36: Group preparing to present

6. The International Experience

Figure 37: Students Presenting

Figure 38: Students Presenting

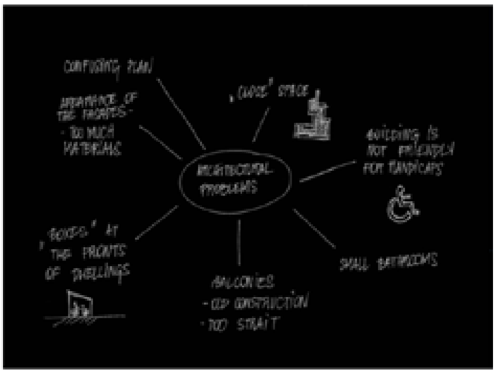


Figure 39: PowerPoint imges from student presentations

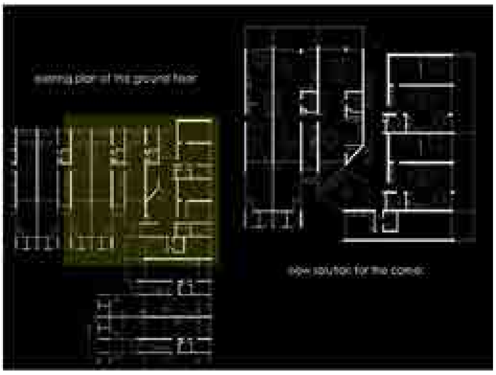


Figure 40: PowerPoint imges from student presentations

Figure 41: Students recieving certificates

Figure 42: Students recieving certificates

Figure 43: Erasmus Project group photo

Program of activities

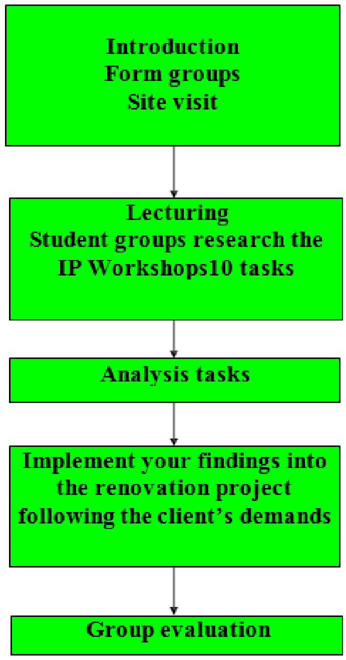
Typically lectures were conducted each morning and the afternoon was dedicated to group work. Occasionally guest speakers gave evening lectures. A site visit to the Danish project site and a construction site were also coordinated. The first weekend involved an excursion and overnight stay in Copenhagen to visit architectural projects. The second weekend was dedicated to group presentations, assessment, certificate ceremony and celebrations of the project's completion.

Concluding Remarks

6.4.1.1 Effective methods that encouraged participation and engagement

The effective methods included:

- The forming of groups made up of specialist students in a range of architectural, engineering and construction related professions allowed opportunity for collaboration and peer learning
- An intensive focus on the project. Every day was relevant to the project. There were no rest days over thirteen days
- Shared goals with clearly defined objectives enabled the groups to work together to achieve design solutions, analysis documentation and presentations
- A balance of activities including relevant formal lectures with enough time provided for group work
- The input of knowledge from structural and services engineers, architectural technologists, architects and project managers contributed to more informed design solutions
- Of particular interest was the emphasis on cost estimating which in Europe is not a stand-alone profession but an essential educational element for every construction design professional. Cost optimality principles were demonstrated in the students' project work. A Danish tool, BYG-SOL software was used to enable indicative costing of refurbishments work and cost-optimisation. While other students used costing tools that they were familiar with from their own countries. Cost estimating is a skills gap for many Australian students in the construction industry. One reason it is not included as units within Australian curriculums such as the Advanced Diploma of Building Design (Architectural) could be the perception that it is a separate profession - the quantity surveyor's role. However, from the Erasmus Project experience it would appear that if all the participants in a project are grounded in cost-estimating then more cost effective solutions are likely to emerge. One of the major barriers to sustainable building development is the perception that it will be too expensive. A lack of informed documentation to enable clients to evaluate the payback time on their initial financial investment or to compare alternative options on the basis of future cost-savings. This barrier will be removed in time where cost optimisation goes hand-in-hand with the design of thermally efficient and sustainable buildings. In the recast Energy Performance of Buildings Directive (EPBD) adopted in May 2010 by all EU Members, a benchmarking mechanism for national energy performance requirements was introduced. The purpose of this is to determine cost-optimal levels to be used by Member States for comparing and setting these requirements.[49] The report, Cost optimal building performance requirements - Calculation methodology for reporting on national energy performance requirements on the basis of cost optimality within the framework of the EPBD, outlines a possible methodology for calculating and comparing the cost of different packages of energy-related measures when applied to new or existing buildings or building elements.[50] Cost estimating and cost-optimisation skills gaps for students undertaking building design studies and similar professions is an area of interest for further investigation



Source: Erasmus Sustainability Workshop, The Assignment Book 48

Figure 44: Schematic time span diagram for the IP project

- Educational activities beyond the walls of the college including a construction site visit to a social housing project and a weekend trip to Copenhagen to visit an older Community Residential Development undergoing sustainability upgrades and new architectural projects
- Mentoring of students in their group work by specialist lecturers. Students could consult the relevant expert at any stage in their project
- Social activities beyond the walls of the college including sightseeing in Copenhagen, barbecues and a sailing excursion on Horsens Fjord
- The students from countries other than Denmark all shared cabin accommodation in a campground and were able to socialise or study together after school hours.

6.4.1.2 Identified problems encountered whilst introducing a new type of multidisciplinary learning environment

The following problems were encountered:

- Some groups worked better together than others and all followed to various degrees Bruce Tuckman's stages of group development: forming, storming, norming and performing. Given the short time framework for a complex project, the groups that came to early decisions without procrastination and prolonged debate achieved better results. This is a valuable lesson for all involved that collaborative project work requires skills in communication and cooperation. Personalities that are combative, lazy, procrastinating or unwilling to bend obstructed the progress of the group. Learning to work in groups can be frustrating and it only through experiences like this that students learn to manage group dynamics, adjust their own behaviours and learn skills to improve the outcomes of group work
- Interesting debate occurred between lecturers of all countries regarding the assessment of the student groups. In Denmark, typically student feedback is given verbally without anything written besides a grade score. My reaction was similar to others who found grading students difficult without an assessment sheet. Some teachers worked to create the assessment sheets on the day of the assessment so that written comments could be provided to students. 'Should any students fail?' was another debate. Not all groups met all the client demands or delivered on the ten required tasks. It was agreed by teachers that as all students had worked in collaborative groups and presented their projects that this represented success (and a pass)
- Logistical problems were encountered including underestimating the time involved in moving people on buses, allocating students into cabins for accommodation and regrouping for lectures and meals. This was a learning experience for all the project coordinators who as lecturers in construction industry disciplines were not also travel, accommodation and tourism planners. All the lecturers involved worked tirelessly (almost to the point of exhaustion) and did a great job. In hindsight, the involvement of a conference and travel planning consultant (perhaps also a lecturer from the college) would have had more experience in managing the logistics of accommodating and transporting 75 international lecturers and students. Removing this task from the organising lecturers would free them up to focus on mentoring the students and educational aspects of the project
- Interestingly, Gunnar Eriksen the Director of the Construction Department at VIA Horsens in his closing address to the project participants remarked that, "It was harder to get multi-disciplinary learning happening in a single institute than bringing together international students for a project". Considering that participants had flown or bussed in from the UK and many parts of Europe this is quite an extraordinary idea. My thoughts are that the internal processes, curriculum and assessment requirements, funding structures and perhaps personalities within colleges create obstacles impeding the implementation of multi-disciplinary learning within a single institute. Perhaps when collaborating with other colleges; managers and teachers can operate with different rules, more flexibility and mindset that it can and will happen.

6.4.1.3 Build international networks with lecturers highly educated in sustainability and the thermal performance of buildings

Contacts

The following lecturers participated in the project:

- Henrik Blyt, Head of Sustainability Department, Center for Applied Research and Development - Energy and Constructions, Horsens, VIA University College, Horsens, Denmark
- Michael Christiansen, Lecturer, Programme Coordinator in the Center with specific focus on Integrated Energy, Constructing Architect Program, VIA University College, Horsens, Denmark - Architect
- Torben Lundberg, Lecturer, Project Manager in the Center with specific focus on Integrated Energy Constructing Architect Program, VIA University College, Horsens, Denmark - Architect
- Arnaldo Landivar, Lecturer, Constructing Architect Program, VIA University College, Horsens, Denmark
- Ernst Heiduk, Civil Engineering & Architecture, FH Kärnten -Carinthia University of Applied Sciences, Klagenfurt, Austria – Architect
- Peter Nigst, Civil Engineering & Architecture, FH Kärnten -Carinthia University of Applied Sciences, Klagenfurt, Austria - Architect
- Andràs Pandula, Assistant Professor, Department of Built Environment, St. István University, YBL Miklós Faculty of Architecture and Civil Engineering, Budapest, Hungary
- Gergely Vizi, Department of Building Construction, St. István University, YBL Miklós Faculty of Architecture and Civil Engineering YBL Miklós Faculty of Architecture and Civil Engineering, Budapest, Hungary
- Luis Prola, Department Coordinator, Civil Engineering, Polytechnic Institute of Leiria, Leiria, Portugal
- Cristin Caracaleanu, Professor, Polytechnic Institute of Leiria, Leiria, Portugal – Energy Engineer
- Maria João Dias, Lecturer, Institute for Systems Engineering and Computers at Coimbra, Polytechnic Institute of Leiria, Leiria, Portugal -PhD- Indoor Air Quality
- David Beaney, Senior Lecturer and Construction Group Programmes Leader, Department of Architecture, Engineering and Construction, Northumbria University, Newcastle upon Tyne, UK - Chartered Quantity Surveyor and Economist
- Paula Bleanch, Senior lecturer, Department of Architecture, Engineering and Construction, Northumbria University, Newcastle upon Tyne, UK - Building Design Management
- Mark Siddall, Senior lecturer, Department of Architecture, Engineering and Construction, Northumbria University, Newcastle upon Tyne, UK – Architect and Certified Passivhaus designer
- Paul Staiss, Senior lecturer, Department of Architecture, Engineering and Construction, Northumbria University, Newcastle upon Tyne, UK - Engineer
- Vijoleta Sulciene, Director, Study and Consulting Center, Perkunkiemio, Vilnius, Lithuania
- Mindaugas Krutinis, Associate Professor, Vilnius Gediminas Technical University, Lithuania
- Nerija Banaitiene, Lecturer, Faculty of Civil Engineering, Economics and Property Management, Vilnius Gediminas Technical University, Lithuania
- Leena Paap, Lecturer, Tallinna Tehnikakõrgkool - TTK University of Applied Sciences, Estonia
- Anti Hamburg, Lecturer, Engineering, Tallinna Tehnikakõrgkool - TTK University of Applied Sciences, Estonia.

Figure 45: Teachers collaborating

Meeting and learning from all these lecturers was exciting and rewarding. It is not possible within this report to summarise the information from all lectures and discussions. The following report contains summaries of information gained from Torben Lundberg, Paula Bleanch, Arnaldo Landivar, Paul Staiss, Maria João Dias and Ernst Heiduk.

Outcomes

It may be easier to implement multi-disciplinary projects across a number of institutes and universities rather than within a single institute. The planning and logistics of bringing together many students and teachers would be assisted with the help of specialist event coordinators/ or project manager freeing up teaching staff for educational activities. The input of a range of teachers with different expertise and student groups from different disciplines created a much greater understanding and appreciation of the role of each of the participants in the design phase of construction projects. Inclusion of cost estimating and cost optimisation as an integral part of the project work had benefits for the students and hopefully will generate long term benefits as these future professionals inform and educate their clients on the economic viability of highly sustainable development. The Erasmus project allowed students to experience a working environment where collaboration was the key to success. The experience was extremely valuable in preparing students for industry.

6.4.2 Introductory lecture – Torben Lundburg

Interestingly, Australia shares similar barriers in progress towards sustainable building development as Europe. Torben Lundberg, architect and lecturer at VIA Horsens identified these as the barriers.

Untrendy: Low energy options can't compete with new kitchens and bathrooms.

Aversion: Rules for social housing makes it difficult to focus on low energy.

Disinclination: It's a hassle - energy savings must wait until we get more time.

Disengagement in economics: The savings are too small to drive engagement.

Insecurity: Do energy efficient buildings work? Can designers and contractors in general do it properly? And can we count on the tradespeople?

Invisibility: We do not know our energy consumption. 'Products' are not on the shelf and savings may not be visible to others. Benefits and future cost savings are intangible.

Ignorance by user: There are many other 'unknown' factors of energy optimisation - indoor climate, comfort, maintenance - no fresh air in an airtight box, noisy, air quality.

Ignorance by guides: Knowledge of energy efficient and cost-effective construction and renovation methods is lacking in building operators.

"Very few buildings are built or renovated in a sustainable manner, although there are proven techniques. The biggest obstacle is lack of interest from builders and buyers who erroneously believe that sustainable construction is expensive... "

Remember that an energy efficient building offers good indoor climate, good health, high learning capacity and high productivity. [51]

Making significant advances in sustainable design and energy efficiency is determined to a large degree by improving awareness and education to all involved in buildings; not only clients, designers, engineers, building contractors, facility managers but at all stages and levels including tradespeople and the people that live and work within the buildings.

6.4.3 The Passive House – Passivhaus Concept

The Passive House Standard (translated from German 'Passivhaus') is not a regulation but a methodology and certification system for creating very thermally efficient buildings. Passivhaus design principles can be applied not only to the residential sector but also to commercial, industrial and public buildings.

Passivhaus originated in Germany in 1991 and is used across Europe where there are now more than 20,000 examples. Examples can also be found in the United Kingdom, North and South America, Africa and Asia. Heating and cooling consumption has been tested in Passivhaus buildings and has been verified to be over 80 per cent lower than conventional buildings.[52]

The concept is appropriate for all climates. Passivhaus buildings individual characteristics are optimised for local climatic conditions. In hotter climates more emphasis is placed on passive shading of windows and window ventilation to enable comfort in summer.

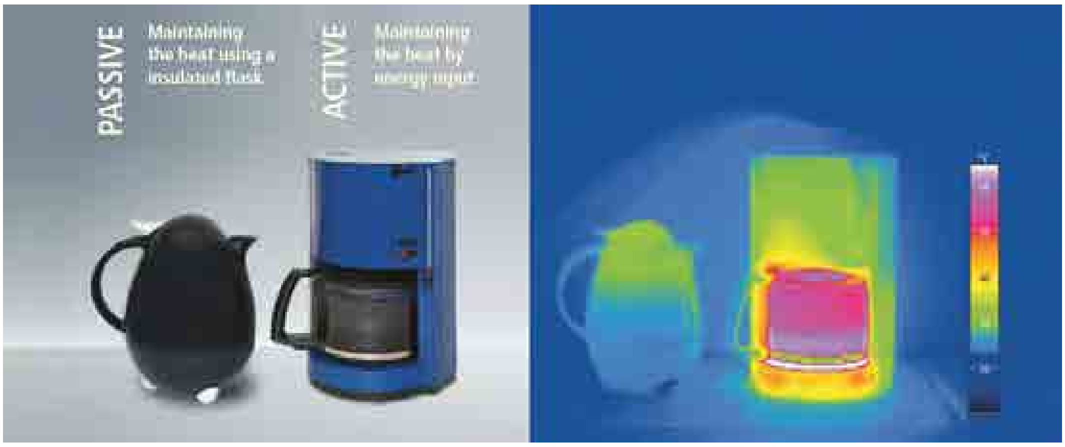
To achieve the certification requirements for Passivhaus the space heating demand must not be more than 15 kWh per square metre of living space per year or alternatively the heating load must not exceed 10 W/m^2. In situations (warmer climates) when active cooling is required to ensure comfort in summer, the energy demand is also limited to 15 kWh/(m^{2}a). The building must be tested with an independently administered pressure test (blower door test) to confirm the building has an air-tightness n50 value of less than 0.6 air changes per hour (ACH). The primary energy requirement for the total amount of domestic hot water, heating, cooling, auxiliary and household electricity must not exceed 120 kWh/(m^{2}a). Energy efficient equipment and appliances must be selected to achieve this target.

Passivhaus Planning Package (PHPP) is an Excel based software tool used for all the calculations.

These five details enable buildings to achieve Passivhaus standard:

1. Exceptionally high levels of thermal insulation
2. Well-insulated window frames with triple low-e glazing
3. Thermal-bridge free construction (refer to Section 6.4.4)
4. Air-tight building envelope (refer to Section 6.4.4)
5. Comfort mechanical ventilation with highly efficient heat recovery [53] (refer to Section 6.4.5).

These principles, together with good orientation, window and shading design comprise a building that is very thermally efficient. The Passivhaus standard does not only apply to the cooler European climates. It also works for warmer countries including Spain and Portugal, parts of which have similar climates to Melbourne. The Passive-On project is a completed research and dissemination project which worked to promote Passivhaus and the Passivhaus Standard in warm climates. [54]



Source: International Passive House Association, Passive House Brochure 55

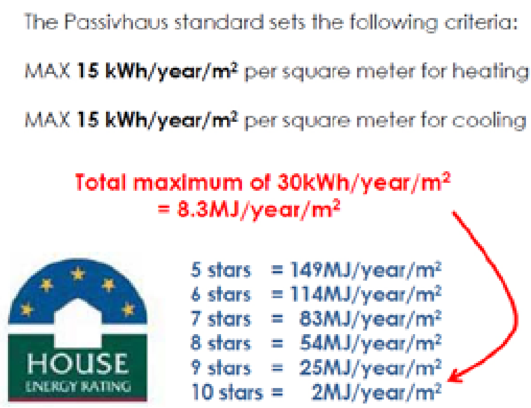
Figure 46: Passive heating (insulating) rather than active heating

To achieve accreditation Passivhaus buildings undergo an air-tightness test (also known as a blower door pressure test) at an appropriate time to ensure quality requirements are met. A positive pressure is created, followed by negative pressure and total air leakage is measured. Detected air leaks are then sealed.

In low air permeability houses, controlled ventilation is essential. Mechanical ventilation with heat recovery (MVHR) allows the recovery of heat from the stale, used air, transferring it to the incoming air leading to reduced energy consumption and CO_2 emission reduction. MVHR Heat Systems have strict compliance requirements to meet Passivhaus standards. The system runs 24 hours a day to ensure fresh air is delivered into the airtight building. The systems are therefore required to be very energy efficient. Opening windows while the system is operating will greatly decrease energy efficiency.

However, depending on the design of the building and the MVHR system it is possible to turn off the system and open windows for natural ventilation when outdoor temperatures are moderate. In a building that doesn't breathe, moisture can develop causing mould and other issues. Passivhaus buildings include a vapour barrier into the structure, which protects the interior spaces from moisture.

When comparing Passivhaus standard to the Australian House Energy Rating Star rating system it can be seen that the thermal performance is equivalent to a nine-plus star house.



Source: Sustainable Built Environments, Passivhaus Seminar Presentation 56

Figure 47: Comparison - Passivhaus standard to the Australian House Energy Rating Star rating system

Concluding remarks

Passivhaus is not a new concept. There are more than 20,000 built examples in Central Europe as well as Passivhaus buildings in North and South America, Asia and Africa.[57] A great deal of research has been conducted to verify that Passive House buildings can be built to suit a wide range of climates, offer impressive energy savings and a high level of thermal comfort.

To date Australia has been slow to adopt Passive House principles. New Zealand has been quicker with eight designers certified by Europe's Passivhaus Institute and EcoBuild Developments Inc. constructing a Passivhaus display home with an air-tightness of 0.62 air changes per hour.[58]

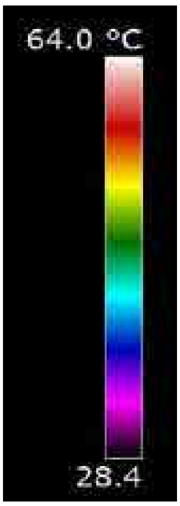
Melbourne appears to be the Australian city with the most interest in trialling Passivhaus principles with Grocon, Studio 505, Sustainable Built Environments and Passive House Pty Ltd (Peter Steudle and James Anderson) all active in this area.

Passivhaus design principles can be applied to high temperature and high humidity locations. However, they may need to be modified and adjusted to suit the Australian climate. The Passive-On research undertaken by the warmer European countries will be a useful resource.

Outcome

Greenskills students will benefit from information disseminated by architects, builders and engineers involved in the design, construction, monitoring and building management of the first Passivhaus building constructed in Australia.

Tours of Passivhaus buildings will also be useful for students and practitioners to see the buildings in action and experience the level of thermal comfort and indoor air quality that can be achieved. Any preconceived ideas about poor indoor environmental quality in airtight buildings can then be reconsidered.



Source: Building Renewal Thermography + THERM Software IP Erasmus-Reno Pass code 2012 59

Figure 48: Infrared colour temperature diagram

6.4.4 Thermal imaging, thermal bridge free construction and airtight building envelope – Arnaldo Landivar

Thermography has many applications in many fields including, medicine, fire-fighting, printing and surveillance. The areas of interest to the construction industry are the application to achieve high thermal performance in buildings and to identify faults without destructive testing. It is useful in the refurbishment of existing buildings and for quality control of new buildings. Infrared (IR) inspection using an IR camera is a non-invasive method of monitoring and diagnosing the condition of buildings. Without direct contact an IR camera can create brightly coloured images of buildings and building elements identifying warmer areas as red, colder areas as blue or purple and temperatures in between as orange, yellow and green. It is not like x-ray which can see behind the surfaces. IR cameras measure IR radiation from surfaces only.

Thermographic imaging using an IR camera can:

- Visualise and detect energy losses
- Detect missing or defective insulation
- Source air leaks
- Find moisture in the insulation, in roof and walls, both internal and outside
- Detect mould

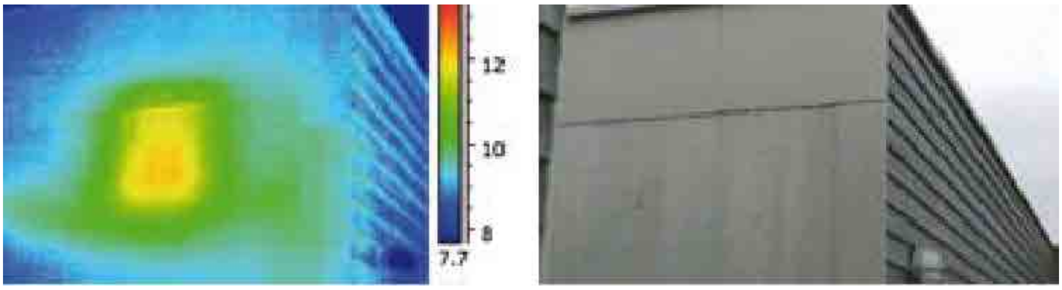
- Locate thermal bridges
- Locate leaks in flat roofs
- Detect humidity and pipe leaks
- Detect construction failures
- Locate hydronic floor heating faults
- Monitor the drying of buildings
- Detect electrical faults.

Energy losses from a building can be identified effectively using an IR camera as demonstrated with the images below.

Source: Building Renewal Thermography + THERM Software IP Erasmus-Reno Pass code 2012 60

Figure 49: Identifying energy losses using thermography

Thermography allows the identification of missing or defective insulation. The image below shows a missing section of insulation which is not possible to see using the human eye from the inside or the outside.

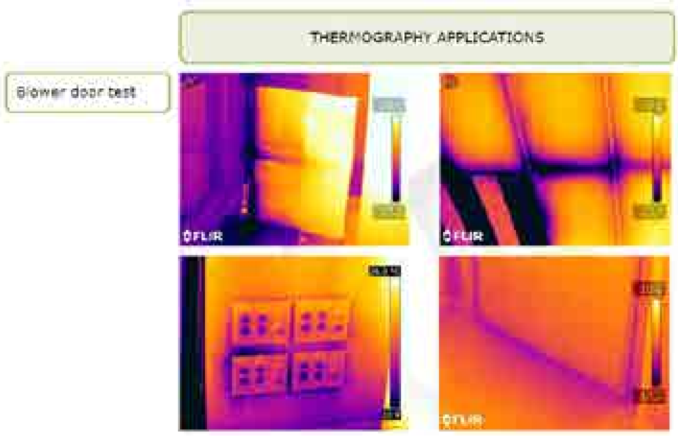


Source: FLIR, Infrared Guidebook for Building Applications 61

Figure 50: Thermography identifying a panel of missing insulation in a sandwich construction concrete wall

Source: FLIR, Infrared Guidebook for Building Applications 62

Figure 51: Blower door testing equipment



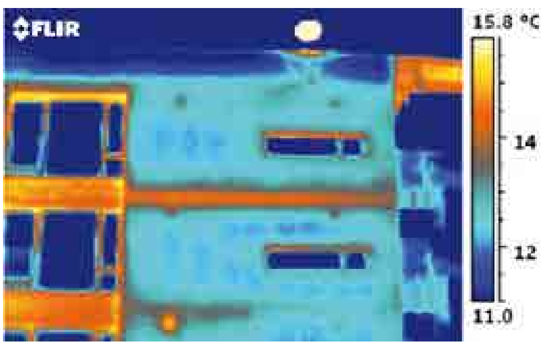
Source: Building Renewal Thermography + THERM Software IP Erasmus-Reno Pass code 2012 63

Figure 52: Thermography in combination with blower door testing to identify air leaks

During a blower door test an external door is removed from the building and temporarily replaced by a door with a calibrated fan. A blower door system is used to blow air into or out of the building, which creates a small pressure difference between inside and outside. This pressure difference forces air through all holes and penetrations in the building envelope. The greater the air-tightness of the building the less air is needed from the blower door fan to create a change in building pressure. A device measures fan flow and building pressure to determine the level of air-tightness.

During the pressure testing process thermography can be used effectively to identify the location of air leaks. The purple areas in the images below show the location of air leaks.

A thermal bridge is an area with less insulation due to the construction materials such as a metal window frame (without thermal breaks), a metal fastener, concrete beam, slab or column. Heat will take the path with least resistance and flow the easiest path from the heated internal space to the outside or from the warmer outside environment to the cooler space indoors. Very often heat will race quickly through an element which has a much higher conductivity than surrounding material. This is described as a thermal bridge.



Source: FLIR, Infrared Guidebook for Building Applications 64

Figure 53: Image of thermogaphic image identifying thermal bridges

Thermography helps to identify thermal bridges in existing buildings so that rectification works for improved thermal performance can be undertaken. The image below shows a thermal bridge at one of the floors.

THERM software allows heat transfer to be identified in the design stage by engineers and is a useful tool to improve thermal performance in new buildings by eliminating construction details with thermal bridges.

Eliminating thermal breaks is important not only to improve thermal performance but also to reduce the possibility of condensation within buildings.

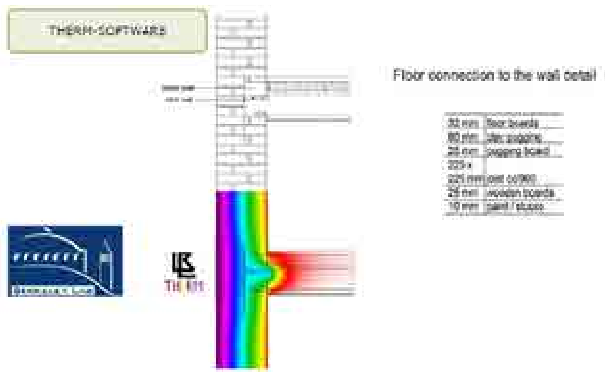
Outcomes

Thermographic imaging is an extremely useful tool but has some limitations. It does not work well with bodies of low emissivity, reflective surfaces, materials opaque to IR (e.g. water) and in some weather conditions. Arnaldo Landivar lists the advantages of using thermography as follows:

- Non-destructive method
- Provides hidden information
- Provides a visualisation of the overall thermal performance
- IR cameras are becoming more affordable
- Feasible and reliable for quality control
- Easy to use.

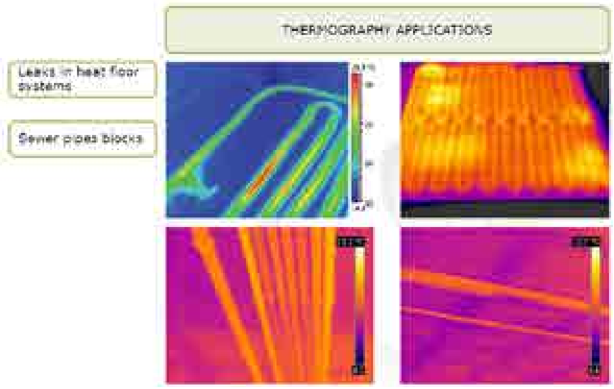
The disadvantages are:

- The data obtained is qualitative rather than quantitative
- Trained personnel are required to interpret the images
- Climatic conditions affect the data (IR does not perform well on rainy days)
- Additional costs are involved.



Source: Building Renewal Thermography + THERM Software IP Erasmus-Reno Pass code 2012 65

Figure 54: THERM software identifies and calculates thermal bridges



Source: Building Renewal Thermography + THERM Software IP Erasmus-Reno Pass code 2012 66

Figure 55: Thermographic images are also useful for identifying leaks and blocked pipes

Concluding Remarks

Whilst thermal imaging is now being used by building inspectors and thermal performance assessors in Australia, its use is primarily to identify defects rather than for quality control on new projects. From an educational perspective the Fellow believes thermography has many potential benefits and to the best of her knowledge is not used extensively in building design courses or in trade apprenticeship courses in Australia. Now that thermographic equipment is becoming affordable it would be useful for a range of students:

- Building design, building and engineering students could conduct building inspections using thermography to help them learn from the mistakes of others
- These students would also learn from site testing involving blower door tests in conjunction with thermal imaging to identify air leaks in the building envelope
- For trades apprentices testing their construction work for thermal breaks would help them identify this fault and recognise construction design errors before they start building
- For plumbing apprentices the viewing of hidden plumbing leaks would be a valuable learning aid

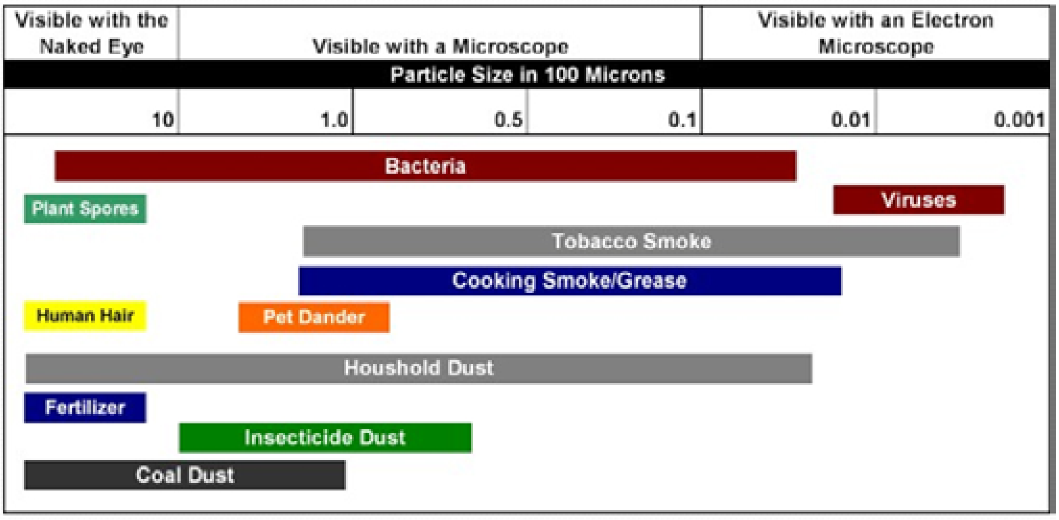
- The importance of installing insulation without gaps is important for carpentry apprentices. Once all linings and claddings are in place there is a possible belief that 'no-one will know'. By using thermal imaging students can be made aware that faulty workmanship can be identified after the completion of a project. The images also visually reinforce the significant effect poor insulation installation has on the thermal performance of the building.

One of the lecturers participating at the project mentioned that the use of an IR camera at open days was exciting to prospective students. Students were interested in technology, enjoyed using the IR camera and viewing IR images. They were swayed in their decision to study at an institute by this interactive tool.

All education with thermography would need to be coordinated by trained professional who can explain to the students the use of the equipment and the interpretation of the images. It should not be used as a toy but as an aid for a wide range of construction students to improve design, technical knowledge and construction for thermal performance.

6.4.5 Mechanical Ventilation with Heat Recovery (MVHR) – Paul Staiss

Buildings that have a high level of air-tightness require mechanical ventilation. Draughts are eliminated through tight construction and when windows are closed the exchange of indoor and outdoor is inadequate to provide a healthy indoor air quality. An unventilated, occupied building will have increased carbon dioxide levels as a consequence of people breathing. Other pollutants such as bacteria, plant spores, tobacco smoke, cooking odours, pet dander, dust, VOC off-gassing from furniture and so on would accumulate to unhealthy levels without the exchange of fresh air from outside.



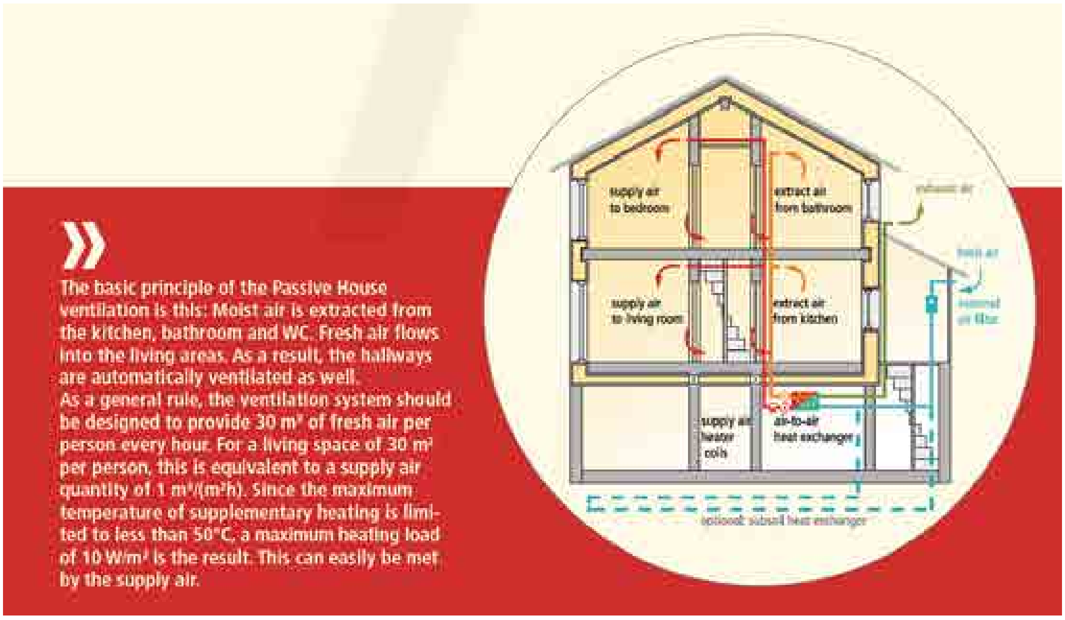
Source: Mechanical Ventilation with Heat Recovery Part 1- Background 67

Figure 56: Indoor Air Quality Pollutants

Conventional HVAC systems take in a percentage of fresh air which then needs to be heated or cooled to a comfortable temperature. Mechanical ventilation with heat recovery systems allows the outgoing air to warm or cool the incoming air without any cross-contamination. Depending on the efficiency of the heat exchanger over 90 per cent of the heat from the exhaust air can be transferred to the intake air bringing the incoming air almost up to room temperature.

Source: Mechanical Ventilation with Heat Recovery Part 1- Background 68

Figure 57: MVHR heat exchange unit

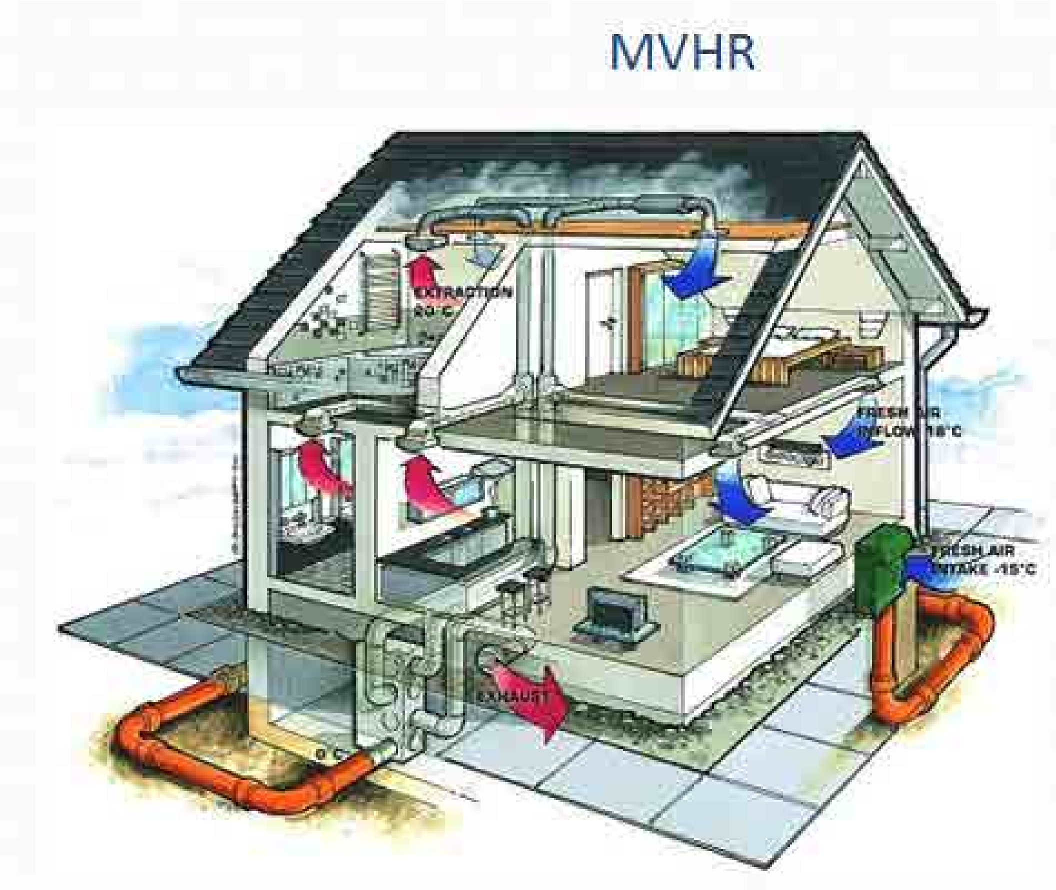


Source: International Passive House Association, Passive House Brochure 69

Figure 58: Passivhaus ventilation diagram

Air is exhausted from the kitchen, toilets and bathrooms and fresh air is supplied to living and bedrooms. Closed doors do not obstruct the air flow because acoustically optimised vents are installed above each door frame. The maximum sound level is 25 dB(A) and to comply with this limit the supply and exhaust air ducts are fitted with silencers that prevent sound transmission between rooms.

Optional subsoil heat exchanges take the incoming air through a pipe in the soil beneath the building allowing the stable earth temperature to pre-heat (winter) or pre-cool (summer) the incoming air.



Source: Mechanical Ventilation with Heat Recovery Part 1- Background 70

Figure 59: MVHR system

There are a few ventilation modes in a Passivhaus MVHR system:

- In winter, the MVHR uses the heat in the exhausted air to warm the incoming fresh air
- In summer, a bypass in the unit can be set so that the incoming fresh air is not heated
- Alternatively in summer natural cross ventilation may be used and the MVHR system can be switched off. This depends on the design and layout of the Passivhaus as sometimes it is necessary to let the fans run in order to avoid overheating in summer. [71]

Maintaining good indoor air quality is essential so the MVHR systems are fitted with high quality filters in the fresh air intake and course filters in the exhaust air valve. The filters should be replaced regularly between one and four times a year.

Most MVHR systems are based on set occupancy levels so many have different settings for different circumstances allowing occupancy levels to be adjusted. MVHRs use surprisingly little energy given the essential role that they have in the Passivhaus. The maximum for a Passivhaus is 0.4Wh of electricity consumption for every m^3 of flow rate.

6.4.6 Indoor Air Quality Measurement Methods (mandatory regulations in Portugal) – Maria João Dias

Portugal was the first country to implement mandatory Indoor Air Quality (IAQ) standards. The testing and certification requirements for IAQ were introduced in 2006 for government buildings and in 2009 for all new buildings with a floor area greater than 1000m^2 or a HVAC system larger than 25kW. All buildings including residential buildings to be sold or rented after January 2009 require an Energy Efficiency Certificate, which states the efficiency level of the building.[72] All other European countries will be required to adopt mandatory IAQ regulations in 2018 for government buildings and 2020 for all buildings larger than 500m^2 as part of the Energy Performance of Buildings Directive (EPBD). Denmark and the Netherlands may adopt the regulations earlier.

Indoor air quality has a direct impact on the health and productivity of the occupants of buildings. On average people in developed countries spend 90 per cent of their time indoors.[73] The factors that affect the air quality in closed environments are inappropriate ventilation, atmospheric pollution, indoor air pollution and biological contamination due to due to materials used in construction. Factors affecting indoor air quality are outlined below.

Building Services:

- Type of heating ventilation and air conditioning systems (HVAC)
- Quantity of fresh air intake via HVAC systems
- The ongoing maintenance and cleaning of HVAC filters and ducts
- Building services with water present at temperatures between 35-37ºC can potentially develop the bacteria Legionella, a toxic contaminant capable of causing illness and death.

External conditions:

- Quality of the outdoor air including presence of allergens, infiltration of petrol fumes, sewerage odours, fertilisers, insecticides, including dioxins and radon
- Presence of contaminants and microorganisms that enter from the external environment.

Building construction including furniture and furnishings:

- Off-gassing of synthetic products and materials i.e. formaldehyde and volatile organic compounds (VOCs)
- Types of adhesives, paints and polyurethane finishes
- The tightness of the building, i.e. the level to which the building can be sealed to limit indoor/outdoor ventilation. To achieve thermal performance goals and energy efficiency new buildings are increasing better sealed
- Furniture selection (formaldehyde and isocyanides).

Human activity:

- Combustion of fuels
- Chemical cleaning products and disinfectants
- Pesticide use
- Contaminants from printers, computers and copiers
- Gas (i.e. kitchens, laboratories)
- Smoking

Type of Agent	Contaminant
Physical	Particles
	Noise
	Vibrations
	Thermal Conditions
	Radiations
Chemical	Carbon Dioxide (CO_2)
	Carbon Monoxide (CO)
	Ozone (O_3)
	Formaldehyde (HCHO)
	Total Volatile Organic Compounds (VOCs)
Biological	Bacteria
	Fungi
	Mite
	Pollen

Source: M. João Dias, Indoor Environment and Energy Efficiency in Higher Schools [74]

Figure 60: Air quality contaminants

- Occupants of the building are also a possible source of contamination.

The measurement of CO_2 is a good parameter for measuring air quality. When the fresh air intake is inadequate, a concentration of CO_2 greater than 1000 ppm can indicate malfunctioning of the ventilation system. In Portugal the measurement of IAQ requires numerous tests involving an extensive array of equipment (refer to the following photo and tables provided by Maria João Dias). The direct measurements of the indoor air quality (IAQ) include the following parameters:

- Temperature
- Relative humidity
- Particulate matter
- Carbondioxide
- Carbonmonoxide
- Ozone
- Formaldehyde
- Volatile organic compounds
- Microbiologic analysis (fungi and bacteria).

Source: Photo courtesy of Maria João Dias [75]

Figure 61: Portable IAQ equipment

The tests must be completed in many parts of the completed building by trained professionals qualified in the use of the equipment. Fungi samples are incubated for three days and bacteria samples for two days before they are examined. Therefore the testing process is time consuming and very expensive due to both labour costs and the provision of specialised equipment. Private companies are agents for IAQ certification and to date auditing to verify the quality and reliability of certification reports has not been undertaken. Maria João Dias stated that the process has been ‘a machine to make money’ with an indication that the figures within the reports do not represent the reality. Certifiers advise building owners to open the windows, remove rugs and plants and steam clean carpets (without chemical cleaning products) for one week prior to testing to obtain the best possible results. Even with these activities undertaken there is some evidence that certifiers are fabricating results to speed up the process and increase their profits.

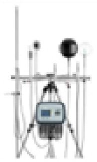
Figure 62: Diagram showing the factors influencing Indoor Environmental Quality

Maria João Dias is optimistic that the implementation across all Europe of IAQ regulations embedded within the new Energy Performance of Buildings Directive will drive improvements within the Portuguese system. Government auditing of IAQ certifiers for quality control and inspection of the qualified experts work should result in improvements in the quality and accuracy of reporting.

IAQ testing of buildings will be introduced across the EU as part of EPBD directive in 2018-2020. However, it will expand to encompass more aspects of Indoor Environmental Quality (IEQ). These will include thermal comfort, lighting comfort, noise comfort and indoor air quality.

Concluding Remark

Indoor Air Quality regulations including IAQ testing of buildings will be introduced across the EU. We can learn from Portugal (the early adopter) that the testing process is expensive and time-consuming. The introduction of this system requires a robust auditing process by qualified IAQ professionals to ensure accurate and reliable certification reporting. The health, well-being and productivity of people are an essential aspect of providing sustainable buildings. Improvements in sealing the building envelope, increased use of computers and printers, synthetic building materials and ongoing maintenance requirements for HVAC systems are all factors that could adversely affect the quality of indoor air. In improving energy efficiency and thermal performance we may unwittingly decrease IAQ. As we move towards more intensive testing for thermal performance including blower door testing and thermography it seems appropriate to complete the testing regime to ensure thermal comfort, health and energy efficiency are all achieved.

Equipment	Brand	Model	Measurement	Sensitivity/Error	Analytic Method	Equipment
Analyser for Thermal Comfort	Delta OHM	HD 32.1 Thermal Microclimate	Long Term	Temperature ± 0,01 °C Black Globe - Class 1/3 DIN Air speed ± 0,02 m/s Temperature and bulb humidity - Class A Relative Humidity ± 0,1 %	PT100 temperature sensors Unidirectional hot wire probes Capacitive RH Sensors	
Temperature and HR Analyser	LogTag	HAXO-8	Long Term	± 0,1 %	Temperature - Thermocouple sensor type Relative Humidity - capacitive type sensor	
Analyser multifunction	Testo	Testo 435-4	Sampling Point and Long Term	± 1 %	Carbon Monoxide - electrochemical sensor Carbon dioxide sensor - NDIR (non dispersive infrared)	
Analyser multifunction	Fluke	975	Sampling Point and Long Term	± 1 %	Temperature - sensor thermistor type Relative Humidity - capacitive type sensor Carbon Monoxide - electrochemical sensor Carbon dioxide sensor - NDIR (non dispersive infrared)	
Analyser multifunction	SENSOTRON	PS32	Long Term	± 3 %	Carbon dioxide sensor - NDIR (non dispersive infrared)	

Source: Indoor Environment and Energy Efficiency in Higher Schools 76

Figure 63: IAQ monitoring equipment

Equipment	Brand	Model	Measurement	Sensitivity/Error	Analytic Method	Equipment
Ozone Analyser	aeroQUAL	Series 500	Sampling Point	± 10 %	Technology GSS (Gas Sensitive Semiconductor) - High correlation with the reference method UV Photometry	
PM_{10} Analyser	DUSTTRAKII Aerosol Monitor	8530	Sampling Point	± 0,1 %	Metering real time laser / NIOSH 0600	
Formaldehyde Analyser	htV-m	Formaldemeter htv-m	Sampling Point	± 2 %	Electrochemical cell in real time	
VOCs level detector	Photovac	202ppbPRO	Sampling Point	± 1 %	PID Detector (standard 10.6 eV lamp UV) Photo-ionizing detector	
Diffuser flow rate measure	TSI	AccuBalance 8375	Sampling Point	± 3 %	Barometric Sensor / Air Flow Methodology	
Microbiologic Analyser	SAS QAI	SUPER 90593	Sampling Point	---	Method of impact on Agar	

Source: Indoor Environment and Energy Efficiency in Higher Schools 76

Figure 64: IAQ monitoring equipment

Equipment	Brand	Model	Measurement	Sensitivity/Error	Analytic Method	Equipment
Ozone Analyser	aeroQUAL	Series 500	Sampling Point	± 10 %	Technology GSS (Gas Sensitive Semiconductor) - High correlation with the reference method UV Photometry	
PM_{10} Analyser	DUSTTRAKII Aerosol Monitor	8530	Sampling Point	± 0,1 %	Metering real time laser / NIOSH 0600	
Formaldehyde Analyser	htV-m	Formaldemeter htv-m	Sampling Point	± 2 %	Electrochemical cell in real time	
VOCs level detector	Photovac	202ppbPRO	Sampling Point	± 1 %	PID Detector (standard 10.6 eV lamp UV) Photo-ionizing detector	
Diffuser flow rate measure	TSI	AccuBalance 8375	Sampling Point	± 3 %	Barometric Sensor / Air Flow Methodology	
Microbiologic Analyser	SAS QAI	SUPER 90593	Sampling Point	---	Method of impact on Agar	

Source: Indoor Environment and Energy Efficiency in Higher Schools 76

Figure 65: IAQ monitoring equipment

Equipment	Brand	Model	Measurement	Sensitivity/Error	Analytic Method	Equipment
Analyser of luminance	**KOBAN**	**KL 1330**	**Sampling Point**	**± 2 %**	**Silicon photodiode with filter**	
Sound Level Meter	**Brüel & Kjaer**	**2260 Investigator**	**Sampling Point and Long Term**	**± 0,5 %**	**Equipment for measurement of spectral analysis for the frequency range of 1/3 of the eighth Pre-polarized Free-field ½" Microphone**	
Sound Level Meter	**RION**	**NL-31**	**Sampling Point and Long Term**	**± 0,1 %**	**Equipment for measurement of instantaneous sound pressure level (Lp, Leq, LE, Lmax, Lmin and 5 values of Ln) UC-53A Pre-polarized microphone with ½" capacitor**	
Measuring the Length of Reverberation	**Bertram Schapal**	**Dodecahedral Loudspeaker DO 12**	**Sampling Point**	**± 1 %**	**Equipment used for obtain the reverberation time (*RT*)**	
DesignBuilder Software	***DesignBuilder* is a user-friendly modelling environment. It provides a range of environmental performance data such as: energy consumption, carbon emissions, comfort conditions, maximum summertime temperatures and HVAC component sizes.**			—	**Physical mathematical dynamic models**	DesignBuilder SOFTWARE

Source: Indoor Environment and Energy Efficiency in Higher Schools 76

Figure 66: IAQ monitoring equipment

6.4.7 Innovative materials and products - Ernst Heiduk and other lecturers

Innovative materials and products mentioned during presentations included the following 14 products:

6.4.7.1 Nanocoatings and nanomaterials

These materials are structured at the molecular level to trap air between particles. They are much more efficient (two to four times more) than traditional insulators like mineral wool, fibreglass and polystyrene which work at the macro level. Because nanomaterials trap air at the molecular level, an insulating nanocoating even less than a millimetre thick can have a dramatic effect. These products do not have the hazardous off-gassing of many other coatings.

Source: High performance thermal insulation materials RenoPassCoDe 2012 – Horsens 77

Figure 67: Aerogel

"Nano has the potential to greatly reduce emissions from buildings, reduce construction waste, while providing cleaner air and water inside buildings.

In the first wave, nanotech is making its way into insulation, coatings and solar PV. The next wave, currently in the development stage, will bring advances in lighting technology, air and water purification. In about seven years we will begin to see changes in structural components like concrete and steel, adhesives, and batteries." [78]

6.4.7.2 Aerogel insulation - blankets

Aerogels are nanomaterials. They are extremely light solid materials composed of up to around 95-98 per cent air by volume. Aerogel has a very high R-value and can be used in insulation for walls, roofs and floors. Due to the high thermal performance of Aerogel the thickness of the insulation can be much thinner than that of other insulative materials. Aerogel is available as an insulative blanket in 5 mm and 10 mm thicknesses.

Source: High performance thermal insulation materials RenoPassCoDe 2012 – Horsens 79

Figure 68: Aerogel blanket

6.4.7.3 Aerogel insulation plaster

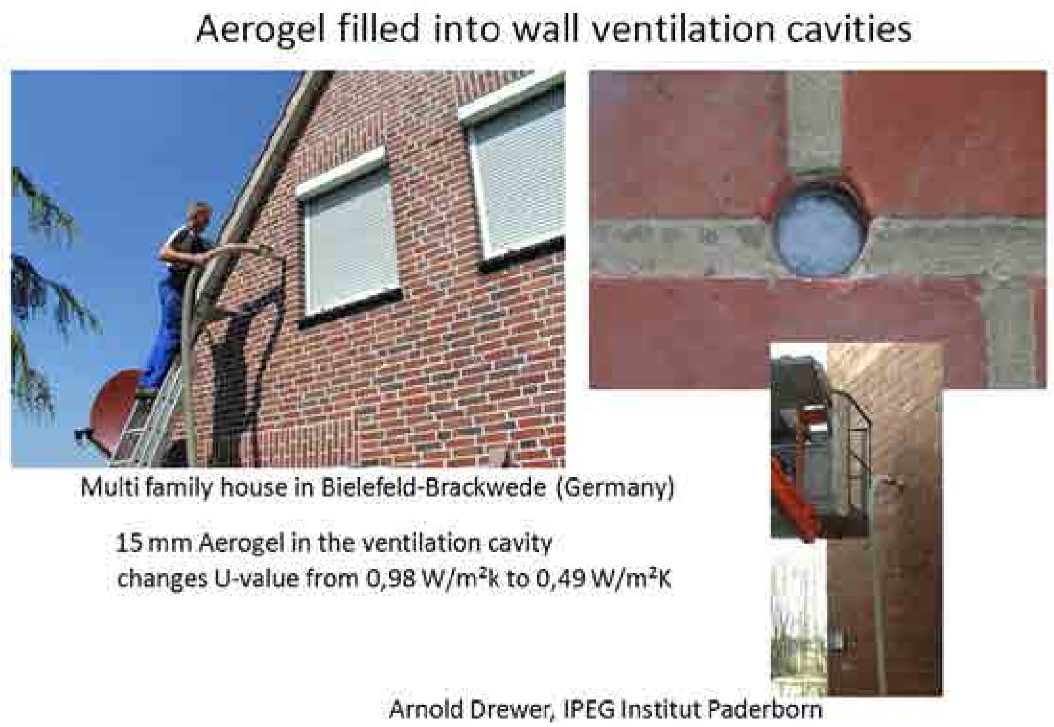
The thermal conductivity of the new insulating plaster is less than 0.03 W/(mK); two to three times lower than that of conventional plaster. It has the ability to act as a permeable water vapour barrier and is water repellent. This product (under development and soon to be tested) could be useful in historic renovations to improve thermal performance of existing walls.

Source: High performance thermal insulation materials RenoPassCoDe 2012 – Horsens 80

Figure 69: Aerogel plaster

6.4.7.4 Aerogel insulative application to fill wall cavities

Another application for Aerogel is in existing buildings. Filling the ventilation cavity with the product greatly increases the thermal performance of the wall.



Source: High performance thermal insulation materials RenoPassCoDe 2012 – Horsens 81

Figure 70: Aerogel application to fill wall cavities

6.4.7.5 Aerogel insulative application for glazing

Aerogel trapped between glazing creates a translucent highly insulated panel that can be used as a curtain wall or window elements. A facade made of this material admits natural light into the interior, thereby reducing artificial lighting costs. The Yale University Sculpture Building uses a triple-glazed curtain wall of insulated glass and super insulated R-20 Aerogel insulated translucent panels. The warm air trapped in the curtain wall cavity is retained by the Aerogel insulation and is either used internally in the winter months or vented to the exterior during the warm months resulting in significant reductions in both heat gain and loss year round.

6.4.7.6 Vacuum Insulated Panels

Vacuum insulated panels (VIPs) have thermal conductivity three to seven times lower than conventional insulating materials. They can be used in applications where it is important to reduce the insulation thickness to a minimum value without losing thermal performance. Extremely good gas barrier envelopes have to be used to limit air and moisture penetration in the panel due to gas diffusion from the ambient air. A gas absorbent is usually necessary in most panel designs to remove gases and keep stable pressure.

Source: Architectural Daylighting Solutions: Yale University 82

Figure 71: Yale University Sculpture Building with Aerogel insulated translucent panels

The downside of VIPs is the risk of damage. Their use in walls is risky as any penetrations from the inside for picture hanging hooks, additional electrical power points and so on will ruin the effectiveness of the entire panel by destroying the vacuum. Likewise penetrations from the outside to fix downpipes or other fixtures are also likely to destroy the effectiveness of the panels. Being completely hidden within the wall means that over time, various occupant and maintenance activities are likely to occur that will cause penetrations in the walls thereby ruining the thermal performance.

Source: High performance thermal insulation materials RenoPassCoDe 2012 – Horsens 83

Figure 72: Vacuum insulated panels

6.4.7.7 Eco-cellulose

Blow in eco-cellulose insulation is not a new product as it has been used since the 1970s. However, it is attracting renewed interest because of its green credentials. Eco-cellulose is manufactured from 100 per cent recycled paper using a low energy production process. Many other insulation products are manufactured using raw materials with high embodied energy and have very high energy manufacturing processes.

Eco-cellulose is shredded and ground up recycled paper which has been coated with chemicals to make it fire retardant. These chemicals are safe for humans but do not repel rodents, insects and mould.

Cellulose fibres have a higher density and R-value than many other insulation types and can be blown in without leaving any empty space. This creates a layer with no heat bridges and a more efficient insulation capacity than other blow-in insulation types. Extremely small spaces can be filled up with cellulose insulation resulting in a heat bridge free insulation layer. The cellulose has a high volume density and due to its way of felting it keeps its form without shrinking.

An additional benefit of using eco-cellulose is its excellent acoustic properties.

6.4.7.8 Phase change materials

Storing heat and evening out the diurnal or daily temperature swings in buildings can be achieved in two ways. One is with massive materials like stone, brick or concrete and the other is with phase change materials. Phase change materials (PCMs) store heat by melting, and then radiate heat back into the space at night, as the material cools and re-solidifies. More information can be found about the application for phase change materials in buildings in the research paper Phase Change Materials in Architecture by Alice Harland, Christina Mackay and Brenda Vale. [84]

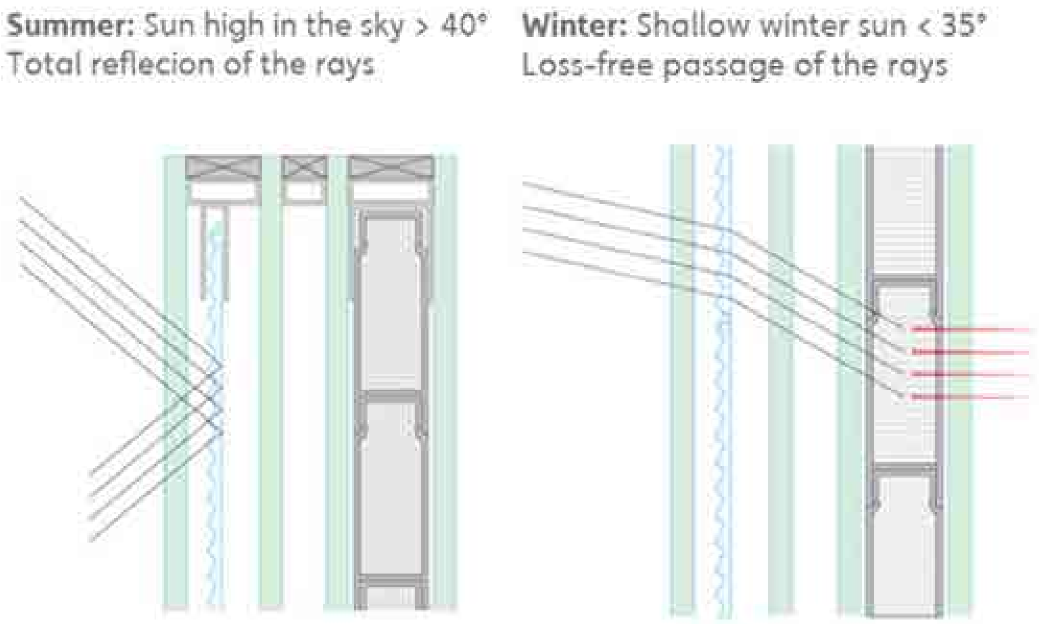
6.4.7.9 GlassX (phase change windows)

Swiss window technology, GlassX windows, are super high-efficiency windows that use thermodynamic glazing. Phase-change material is sandwiched between two of panes of glass. Polycarbonate spacers are used between the panes to separate the PCM and give the windows a venetian blind appearance.

GlassX windows also have a prismatic plane that deflects high-angle sunlight in the summertime, rather than transmitting it, to keep the building cool. Lower-angle winter light is transmitted through this layer.

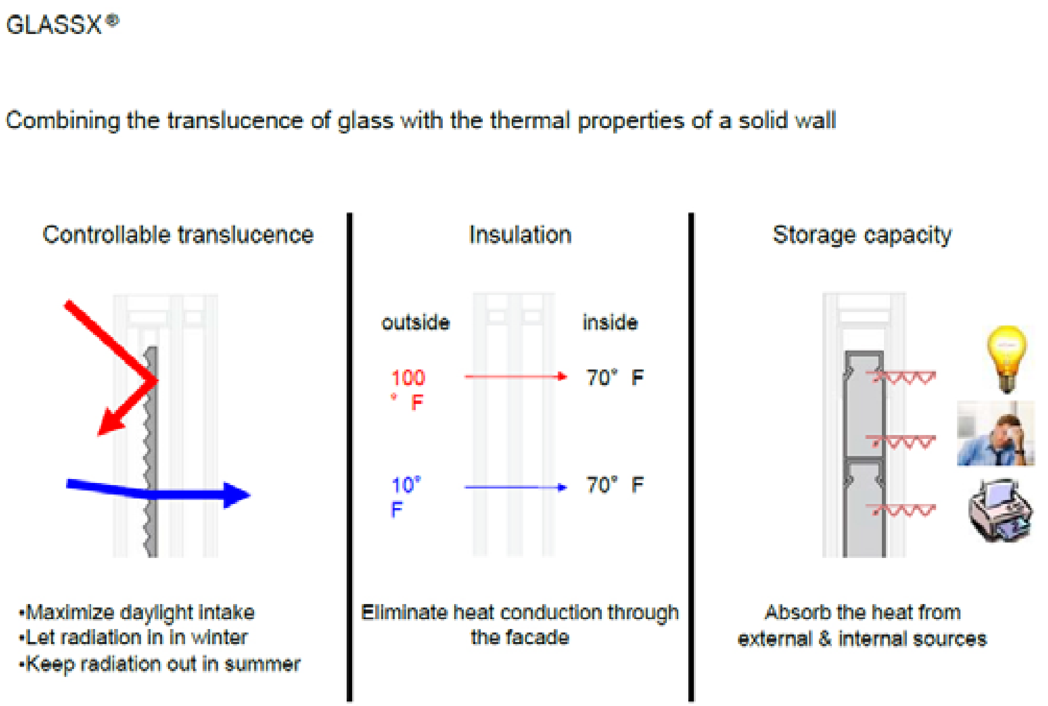
Source: Energy Efficiency 85

Figure 73: GlassX facade



Source: GlassX North America, How GlassX works 86

Figure 74: GlassX technology

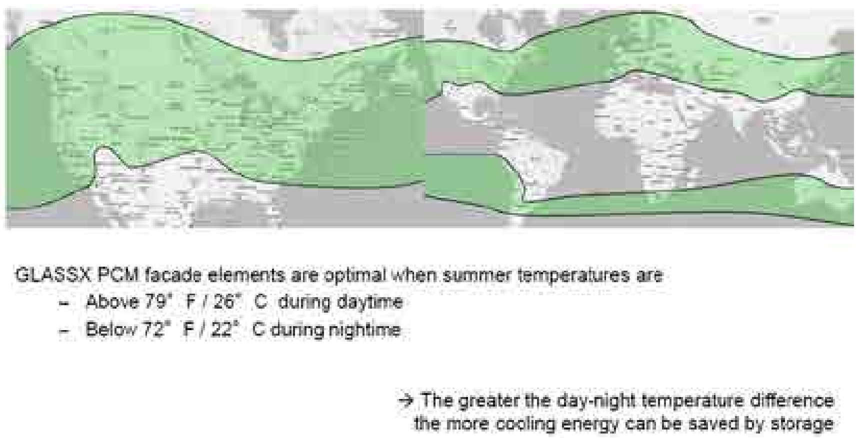


Source: High performance thermal insulation materials RenoPassCoDe 2012 – Horsens [87]

Figure 75: GlassX technology

The phase change material stores heat by melting, and then radiates it back into the space at night, as the material cools and re-solidifies. At room temperature 16mm of this material can absorb as much heat as a 250mm thick concrete wall.[88] When solid the PCM still transmits about 25 per cent of the visible light, and when liquid transmits more than 40 per cent.

GlassX is a passive energy system with no electronic or mechanical parts. The PCM core is guaranteed for 100 years and the windows require no maintenance. However, GlassX windows are very expensive.



Source: GLASSX® – the translucent solid wall [89]

Figure 76: GlassX suitable climatic locations for use

6.4.7.10 Phase change plasterboard

An example of phase change building product is Smartboard which has been developed by BASF as a replacement for gypsum plasterboard. It is a dry-line gypsum based board impregnated with BASF's Micronal® PCM. These are microscopically small polymer spheres containing a wax storage medium in their cores which, melt and solidify and regulate environmental temperatures.[90] The spheres begin to store latent heat when interior temperatures begin to become too warm. The wax has a melting point of 26°C and it begins to absorb heat from the ambient air at this temperature, preventing the interior from heating up any further. The product allows temperature buffering so that peak loads that usually occur during the day are reduced. The stored energy is released when the temperatures drop at night. This time delay effect works only for climates where there are higher daytime temperatures and lower night time ones. Energy efficiency and thermal comfort is achieved as part of a passive cooling concept.

Source: Phase Change Materials – latent heat storage for interior climate control [91]

Figure 77: Smartboard by BASF fact sheet

6.4.7.11 Phase change material trowel-on plaster

Clima 26 by Maxit is a trowel on internal plaster finish with phase change material in a gypsum base. It has the same temperature regulating effect as phase change plasterboard but is applied onto the wall surface with the required thickness for thermal performance.

6.4.7.12 Phase change concrete

H+H Celcon manufactures aircrete products and has a product called CelBlocPlus which incorporates microencapsulated phase change materials into the aerated cement block. This substantially increases the heat storage capacity of walls created with the blocks and allows increased peak load shifting (thermal inertia).

Use of Microencapsulated Phase Change Materials in Building Applications is an interesting research paper with case studies for phase change concrete structures. [92]

6.4.7.13 Building Integrated Photovoltaic modules (BIPV)

Building-integrated photovoltaics are photovoltaic materials that are used to replace conventional building materials in parts of the building envelope. Mike Tomassi, International Business Development Director of System Photonics believes that to be considered a BIPV module it should meet the standards for and serve the function of the part of the building that they are meant to replace. For example if a module is designed to be a roof tile then when it is removed, the roof should leak when it rains. It should also meet all the other requirements that roof tiles are ordinarily subject to such as durability and wind resistance. A BIPV roof tile should also to be capable of being stepped on without damage so that roof maintenance can be undertaken. [93]

BIPV generates electricity using solar energy and can replace many building materials such as glass facades, windows, walls and roofs. Ongoing costs of a building are reduced via operational cost savings and reduced embodied energy.

Source: BIPV: Building-integrated Photovoltaics, the future of PV 94

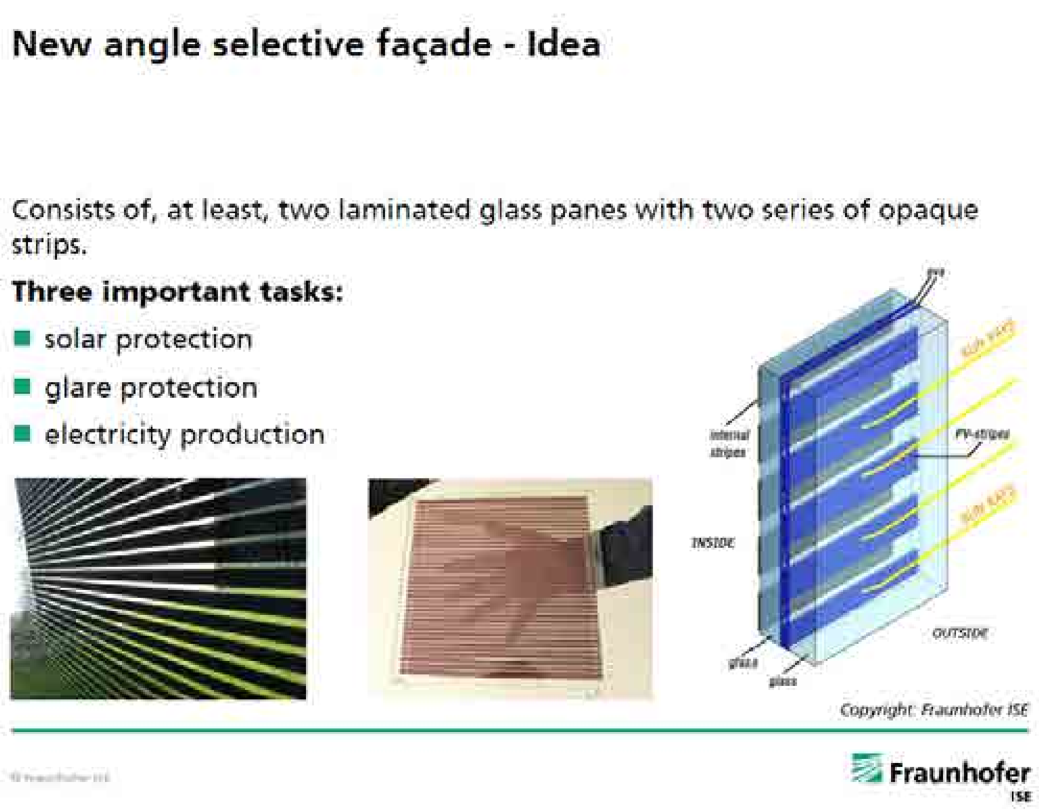
Figure 78: BIPV Roof slates

Source: BIPV: Building-integrated Photovoltaics, the future of PV 95

Figure 79: BIPV Roof shingles

Source: BIPV: Building-integrated Photovoltaics, the future of PV 96

Figure 80: BIPV Sun shading devices



Source: A new angle-selective, see-through BIPV facade for Solar Control Eurosun 97

Figure 81: Angle-selective, see-through BIPV facade

Photovoltaic transparent glass can be used to illuminate a building with sunlight and generate electricity. The transparent BIPV glass allows sunlight to pass through, views out and screening out of ultra-violet and infra-red radiation. There are options for 10 per cent, 20 per cent or 30 per cent semi-transparency depending on the level of lighting required. Double and triple glazed units are available. [98]

Source: Building Integrated Photovoltaics - BIPV Glass Facades 99

Figure 82: BIPV transparent glass

Ventilated and unventilated facade systems are available. Facade systems are not recommended in Australia as the energy output is lower than roof systems due to vertical elevation and generally high sun angles.[100] However the Solar XXI building in Lisbon, Portugal (with similar solar irradiation levels to Melbourne) has a BIPV facade system. This building has proven highly efficient thermal performance without substantial building expense.

Source: Building Integrated Photovoltaics - BIPV Module Facades 101

Figure 83: BIPV ventilated facade

Some BIPV technologies are still under development. The products that are available are very expensive and until standards and expertise is developed in Australia they are likely to be only used in prototype projects.

6.4.7.14 Nano solar technology

The company Nanotech Solar is developing a 'roll to roll' process, where thin film, nanotech solar cells are printed onto plastic or metal. It makes integrating solar into a building similar to printing a newspaper. According to Cathryn Bang and Partners these solar sheets can be made for less than a tenth of what current panels cost and can be manufactured extremely quickly (several hundred feet per minute). Cathryn Bang and Partners also believe that nano solar technology could replace silicon photovoltaic technology in three to seven years.[102] Spire Corp and Innovalight are other developers of nano solar technology.

In Australia, the Victoria-Suntech Advanced Solar Facility is developing the integration of nanomaterials into thin film solar cells with a product called NanoPlas. This technology can be directly integrated into building glass similar to a tint layer and thereby converting normal windows into solar cells. Professor Min Gu at Swinburne University of Technology states that the current efficiency of the NanoPlas technology allows one m^2 of solar cell to produce 90 W of electricity and this technology can potentially be used to power skyscrapers with sunlight.[104]

Source: Integration of Nanotechnology Materials for Green Building (I) Impacting Design and Construction 103

Figure 84: Nano solar technology

Concluding remarks

The Fellow was hoping to learn about affordable solutions in sustainability for new and renovated building developments including innovative materials and methods to improve sustainability. The new innovative materials and products discussed at the Erasmus project were all expensive and some are still under development.

Increasing energy costs and more stringent building regulations will with time drive increased demand for higher performance sustainable buildings and the products that can achieve this. Costs will diminish as products are produced in larger quantities to meet demand. Only a decade ago double glazing and solar panels were considered overly expensive in Australia. They are now significantly less expensive and are viable options for new and renovation projects in the residential and commercial sector.

Outcome

The use of innovative materials and products should be used and tested in new thermally efficient prototype buildings in Victoria to assess their suitability and effectiveness under our environmental conditions.

Prototype refurbishment projects are also required so that thermal comfort and performance data can be collected and interpreted. Analysis is required to determine the most effective materials in terms of thermal performance, practicality, ease of installation and cost. This research is necessary to enable building owners to make cost optimal decisions when upgrading existing building stock to achieve improved thermal performance.

Increased affordability (as products become mass-produced) will then enable their use if there are demonstrated and quantifiable benefits for new and retrofit projects under local climatic conditions.

6.5 Sustainability Study Tour to Copenhagen – 14th-15th April 2012

6.5.1 Green Lighthouse

The Green Lighthouse was opened on 20th October 2009 for the Climate Summit. Built as a prototype nZEB building it demonstrates impressive sustainability. It was the first public CO_2-neutral building in Denmark. A guided tour was provided to the Erasmus Project Group on 14th April.

Address: Faculty of Science, North Campus, University of Copenhagen, Copenhagen Denmark

Building Description:

The Green Lighthouse houses the Student Service Centre of the Faculty of Natural Sciences at University of Copenhagen. The project partners were the Ministry of Science, Technology and Innovation, Copenhagen University, the City of Copenhagen, the VELUX Group and VELFAC.

The architectural design was inspired by the sundial and the movement of the sun around the building. The architects state that "the sun is an important topic in science and one of the most significant energy sources in Green Lighthouse".[105] Just beneath the ceiling hangs a sculpture with a myriad of mirrors. These have been carefully aligned to create circular patterns of light on the floor of the building.

Figure 85: Green Lighthouse – view of entrance

Figure 86: Green Lighthouse - roof windows and sundial sculpture

Figure 87: Green Lighthouse -sundial sculpture patterns of light on the floor

Floor area:	950 m^2
Construction:	2008-2009
Project cost:	37,000,000 DKK (approx $6,300,000 AUD)
Designers:	Architect - Christensen & Co.
	Engineer - COWI.

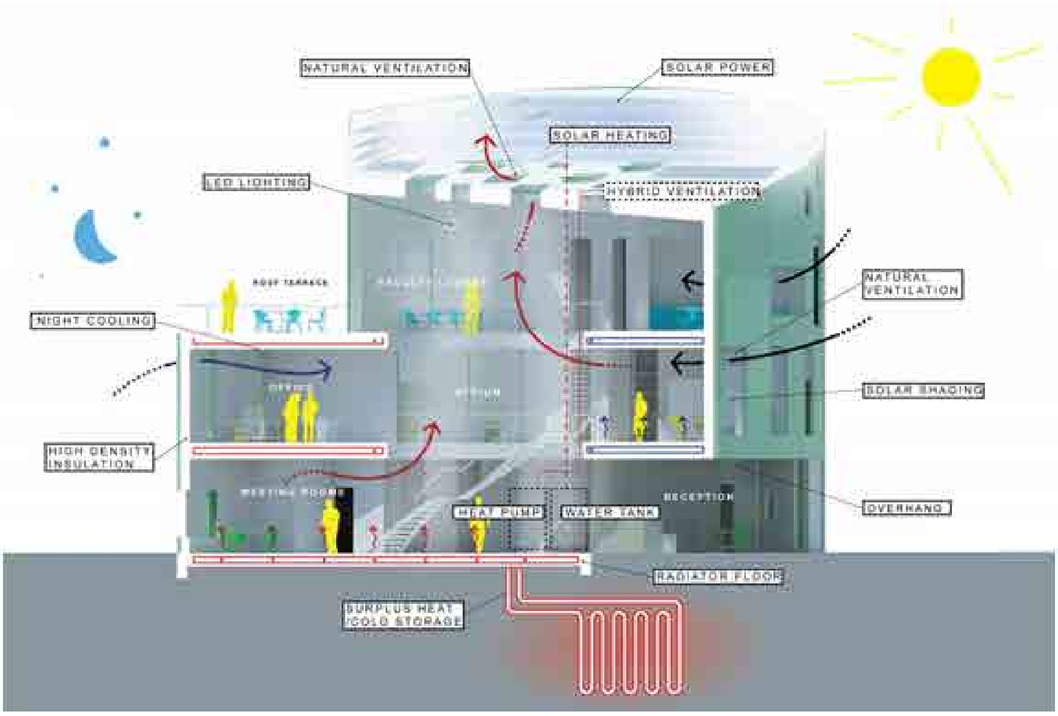
Sustainability:

- 76 m^2 solar cells on the roof provide electricity for lighting, ventilation and pumps.
- The operable roof windows create natural ventilation and the natural stack effect.
- Automated external shading devices control solar heat gain through windows.
- Light sensors and dimmer controls are used to minimise electricity usage. Typically the building is flooded with natural light through the roof windows. However, artificial light is activated when required and only to the degree necessary. The result is an efficient balance between available daylight and artificial light.
- Efficient LED lighting.
- Building management system and monitoring equipment.
- The external cladding is made from Swissfiber, a 30 per cent glass, 70 per cent polymer composite material that is extremely light and strong. The entire façade weighs only six tonnes.
- Geothermal heat pump.
- Solar heat energy is generated by directing solar heat through south facing windows. It is used for floor heating or when not required is stored in the ground. A heat pump circulates solar heat, geothermal heat and cooling in the building. This ensures optimal utilisation of district heating, as it will only be used if solar heat is out of stock. District heating is used to power a heat pump. By using district heating instead of electricity less CO_2 is produced.

Figure 88: Green Lighthouse – view of solar cells on roof

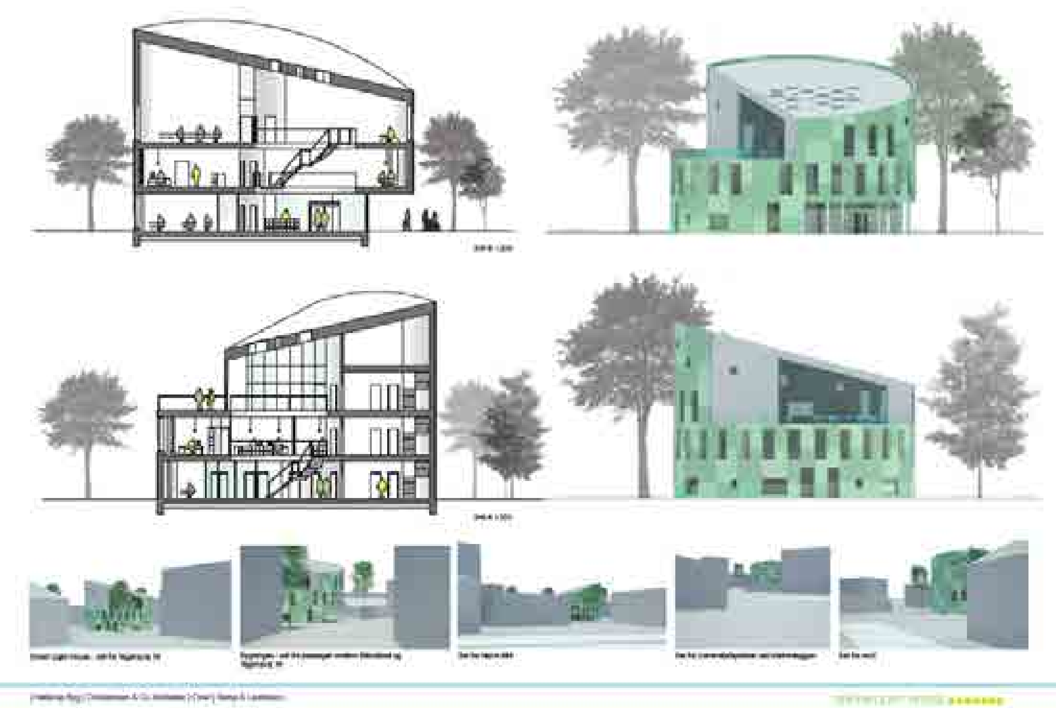
Figure 89: Green Lighthouse – view of automated external shading devices

Figure 90: Green Lighthouse - LED lighting



Source: Erasmus Project - Study tour to Copenhagen notes 106

Figure 91: Green Lighthouse, Copenhagen – Energy concept



Source: Velux, Sustainable Living, Architectural Concept 107

Figure 92: Green Lighthouse, Copenhagen – Architects drawings

However, monitoring since the building opened is yet to show a net zero energy performance. Some of the reasons why this is the case could include:

- The revolving door was initially inoperative, so that the adjacent conventional swing door was used. This increased the rate of external air infiltration to the building.
- Staff manually over-rode automated controls for individual comfort. Users opted for a higher temperature than the 20°C determined by BE06.[108]
- Running in and optimisation of hybrid ventilation.
- Missing ventilation baffle.
- Some windows were left open due to a malfunction.
- Many visitors have visited the building increasing the air change due to door opening. Visitors have also been encouraged to manipulate controls for window shading and lighting disrupting energy efficiency.
- Six more staff members occupy the building than initially planned so different loads apply.
- Non-typical weather with two very cold winters and cool summers.

The following extract from a press release in 30th May 2011 explains some of the problems encountered in achieving the projected energy efficiencies.

"During the running-in phase, the agreed monitoring procedures detected that the solar cell arrays were not connected properly and that a main baffle in the ventilation system was missing; it was installed only four months ago. Finally, it has taken longer than expected to learn to control the building – factors such as arriving at the optimum level of regulation of heating in all rooms. This has given the partners particular experience in handing over new sustainable buildings to the user. Initial constructional and control teething problems, and the building's enormous popularity, have resulted in higher energy consumption than calculated. In the first year, energy consumption for heating and ventilation was more than twice that predicted in the original calculations." [109]

Figure 93: Green Lighthouse, Copenhagen – Main entrance

Figure 94: Green Lighthouse, Copenhagen –Erasmus Project study group

Concluding remarks

Disseminating information regarding both the success and problems encountered with this project enables others to learn. The difficulties in achieving an nZEB building are numerous with many factors influencing the outcomes. The Green Lighthouse web-based materials and building tours give greenskills students and practitioners great insight into the hurdles encountered after construction is complete. Defects rectification, system balancing, facility management and user education are all essential to continue to improve this buildings performance until such time as it can achieve a net zero energy balance. All of this cannot be achieved without ongoing monitoring and resources for research.

Figure 95: Green Lighthouse, Copenhagen – View of west facade

Outcomes

Visiting prototype buildings like the Green Lighthouse shares knowledge regarding innovative solutions for sustainable buildings and also the ongoing requirement for attention to detail at handover, defects rectification and building facility maintenance. Ensuring greenskills students are aware of the ongoing project involvement after design and construction is an important learning.

An online video about the Green Lighthouse is available.[110]

It should be noted that some buildings in Melbourne also have impressive educational resources for greenskills students. For example Council House 2 has excellent web-based resources and the architect's online video provides a virtual tour. [111]

Site visits are excellent learning tools and if these are not possible then virtual tours in conjunction with on-line resources are essential.

Allocating funding to create educational resources for exemplar prototype buildings is essential for communicating both the successes and problems encountered.

6.5.2 Østerbro Community Housing Sustainability Project 2100.nu

A group tour to Østerbro Community Housing was coordinated for student and lecturer participants of the Erasmus Project.

Jesper Minor of the Minor Change Group explained the innovation project '2100.nu' which focuses on reducing overall CO_2 emissions of the urban area of Østerbro. 1400 housing associations with 60,000 residents are involved. The residents are searching for solutions to reduce the CO_2 emissions of the urban Østerbro area; initially 10 per cent in the first year and more in the longer term with the ultimate goal for all of Copenhagen to be CO_2 neutral by 2025. Copenhagen aims to be the first major city in the world to achieve this objective.

Minor explained the process of starting a 'movement' involving a loan nut and first follower. The video http://www.youtube.com/watch?v=fW8amMCVAJQ was a tool he used to help explain the concept. Both a top down and bottom up approach is required to achieve these ambitious goals for CO_2 emission reduction. "The Østerbro project will bring residents, knowledge centres, grass-roots, educational establishments and companies together in completely new ways." http://www.2100.nu

Address: Øbrohus/Tåsingegade Community Housing, Østerbro, Denmark

Building Description:

The existing buildings were built in the 1960s and accommodate low income residents.

Figure 96: Øbrohus/Tåsingegade Community Housing

Flemming Olsen gave a tour of non-profit Øbrohus/Tåsingegade community housing in Østerbro and explained the democratic process by which lower income residents (tenants not owners) influence the type and extent of upgrades to their 1960s buildings by becoming actively involved in initiating ideas and attending group meetings. Once proposals have been agreed by tenants, additional funding can be accessed via the Cooperative Housing Trust. A roof garden has recently been created for all the residents to share and enjoy. Increased pride in the building being an important step in empowering people to be involved in the process and community activities.

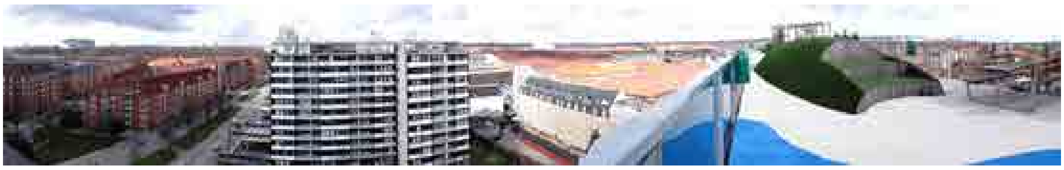


Figure 97: Øbrohus/Tåsingegade Community Housing – New roof top garden and amazing view

Figure 98: Øbrohus/Tåsingegade Community Housing – View from rooftop

Figure 99: Øbrohus/Tåsingegade Community Housing – New rooftop garden

Figure 100: Øbrohus/Tåsingegade Community Housing – New rooftop garden

Sustainability:

Already the old boiler has been replaced with an efficient one and the next projects are ambitious sustainability ones. Plans have been developed regarding:

- Extensive PV panel installation on roofs and walls to provide energy for common areas
- Increased insulation of the building envelope
- Green roofs.

Plans are currently being developed to deal with storm water catchment to create a creek and for garden watering in the shared area between apartments. This will reduce the anticipated costs and taxes for stormwater disposal.

The decision has been made to install individual meters to each apartment to enable accurate charging for utilities including heating, electricity and water use to encourage residents to be responsible utility users. At present all utilities are divided equally amongst residents giving no incentive for people to minimise their energy or water usage.

Concluding remarks

Sustainability is successful when the social, environmental and economic aspects are all carefully considered. The upgrading of existing social housing stock is essential across Europe where so much of the existing infrastructure from the 1960s and 1970s offers:

- Very poor thermal performance in summer and winter
- No independent control for heating
- Very low efficiency district heating systems
- Many barriers to access for people with disabilities
- Small overcrowded rooms that are not adaptable to occupant requirements
- Lack of storage space
- Poor acoustic performance with impact, airborne and external sounds all being problematic.

Austrian lecturer, Ernst Heiduk believes that the biggest European construction duty is to retrofit East-European prefabricated panel residential buildings of which there are hundreds of thousands comprising an estimated 34 million apartments.

Heiduk states adamantly that, "Half-hearted and poor quality activities are worse than no activities. They will absorb not only valuable investment money now and allow no opportunity in the future for improvements. This eliminates the benefits of better long-term solutions".[113]

Basically, it is not easy to get funding and each retrofit project is likely to get only one chance at major refurbishment. Future proof solutions require life-cycle costings to ensure that the right decisions are made and implemented. Decisions should not be based on short and long term economics alone but also require a holistic view of all aspects including:

- Social
- Cultural
- Economical
- Ecological
- Technical
- Legal.

The number of East-European "Panel Buildings

Country	Apartments	m² in 1,000.000
Bulgaria	780.000	40
former DDR	2,200.000	154
Estonia	110.000	7
Croatia	175.000*	12
Latvia	190.000*	13
Lithuania	286.000	20
Moldawia	470.000*	30
Poland	2,500.000	175
Russia	17,500.000*	975
Slovakia	630.000*	44
Slovenia	100.000*	7
Serbia	330.000*	23
Czechia	1,200.000	70
Ukraine	5,700.000	400
Hungarian	750.000*	50
Belarus	1,050.000*	60
Summe	**33,971.000**	**2.080,000.000 m²**

Source: The Reconstruction of 'East' – European Prefabricated Panel Buildings 112

Figure 101: Statistics East-European prefabricated panel buildings

Therefore, it was very encouraging to meet Minor and Olsen as they are both highly motivated and passionate about encouraging change. Whilst committed to CO_2 emission reduction, the focus on the Øbrohus/Tåsingegade community housing project was holistic. By empowering and involving the residents, Minor and Olsen are creating a cooperative environment. They are facilitating upgrades to improve thermal comfort, energy efficiency, liveability, community pride, efficient water use and accessibility.

Outcomes

Retrofitting existing buildings for social, environmental and economic sustainability is essential. Melbourne also boasts interesting retrofit projects some of which offer educational tours and all of which have on-line educational resources. These include:

- 500 Collins St, Melbourne [114]
- The Szencorp Building, 40 Albert Road, South Melbourne [115]
- Building Commission's Good Shed North, 733 Bourke Street, Docklands [116]
- Green Building Council Australia case studies. [117]

Projects like Sydney's new 'Smart Green Apartments' program are designed to help building owners improve the energy efficiency and environmental performance of their buildings. Robin Mellon, the GBCA's Executive Director of Advocacy and Business Services says, "Boosting the sustainability of our existing building stock remains a huge challenge and we are pleased to see the City of Sydney taking a leadership position on this issue". [118]

Expanding the range of educational resources regarding these retrofit projects is essential for greenskills students and lifelong learning for building practitioners. Future learning will be facilitated by communicating and sharing documentation on retrofit projects regarding:

- The decision making process for social, environmental and economic sustainability
- Life-cycle costing /pay back calculations
- Cost-optimisation methodologies
- Project successes and problems/ failures
- Handover, defects rectification and building facility maintenance.

This extra level of information is then available as learning tools for all greenskills students including designers, builders, planners, cost estimators project managers and engineers.

In conjunction with multi-disciplinary learning, educational tools that facilitate broader knowledge beyond a single discipline's area of expertise will lead to improved collaboration and project outcomes. For example life-cycle costing, pay back calculations and cost-optimisation methodologies should be introduced, studied and understood by all greenskills participants, not just the cost estimators.

6.6 Aalborg University and collaborative multi-disciplinary workshop at University College Nordjylland, Denmark – 19th April 2012

6.6.1 Introduction to Architectural Engineering Division and the M.Sc. Education in Indoor Environmental and Energy Engineering by Per Heiselberg, Professor

Professor Per Heiselberg is Head of the Division of Architectural Engineering at Aalborg University. He explained Architectural Engineering as a multi-disciplined engineering approach involving an integrated field of study, in contrast to other more specific engineering disciplines. Architectural engineering requires training in appreciation of architecture, the integration of building systems within overall building design concepts and the design of building systems including heating, ventilation and air conditioning (HVAC), plumbing, fire protection, lighting, transportation and structural systems.

Demand for this type of architectural engineering graduate is strong across Europe. This was confirmed by Adam McCarthy of Johnson Controls in Belgium (refer to Section 6.9) who explained that the undersupply required his company to sponsor other types of engineering graduates to further their education in 'green building' engineering.

The Division's main research areas are:

Building Informatics

Design, integration and structuring of ICT tools and product and process models across the entire building process. Focus is on model collaboration and knowledge transfer between participants in design, construction, operation, maintenance and use of buildings.

Indoor Environmental Fluid Dynamics

Ventilation and air flow processes in buildings and building services and their impact on energy and mass flow in buildings, thermal comfort, indoor air quality and health.

Energy-Efficient Building Design

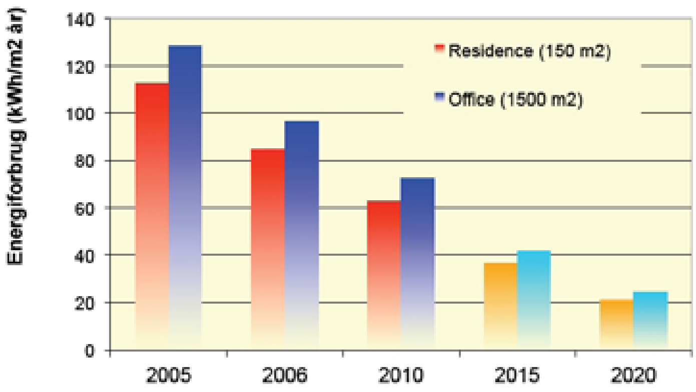
Energy efficient building design, interaction of passive energy technologies and building design and optimisation of interaction between building services and passive systems. [119]

Europe is working towards challenging targets for improving the energy performance of new buildings as all European Member States are required to meet the requirements of the Recast of Directive on Energy Performance of Buildings 2010.

Summary of the requirements of the Recast of Directive on Energy Performance of Buildings 2010

Members States shall ensure that:

- By 31st December 2020, all new buildings are nearly zero-energy buildings
- After 31st December 2018, new buildings occupied and owned by public authorities are nearly zero energy buildings
- Intermediate targets for improving the energy performance of new buildings are in place by 2015. [120]



Source: Per Heiselberg AE March 2012 Presentation Aalborg University Strategic Research Centre for Zero Energy Buildings 121

Figure 102: Graph showing existing and proposed energy use in new Danish buildings

Researching relevant aspects of energy-efficient design and training architectural engineers to meet these targets and challenges is the focus of education at the Division of Architectural Engineering at Aalborg University. The educational methodology is Problem Based Learning (refer 6.6.2) with a focus on multi-disciplinary learning. Collaboration and knowledge transfer between all participants is essential. This century has seen increasing use of Building Information Modelling (BIM) and design and calculation software in the fields of architecture, engineering, cost estimating and project management leading to a demand for a new area of learning in Building Informatics (refer to Section 6.6.3).

6.6.2 Introduction to Engineering School and PBL at AAU by Henrik Brohus Associate Professor

What is Problem-Based Learning (PBL)?

"A learning method, based on the principle of using problems as a starting point for the acquisition and integration of new knowledge" H.S. Barrows, 1982

Problem-based learning (PBL) is not a new concept. However, Aalborg University has been implementing PBL for many years and have tremendous experience in this model of learning. The document Principles of Problem and Project Based Learning - The Aalborg PBL Model written by Scott Barge, Harvard University is an invaluable resource used to introduce new students, new members of staff and external parties in understanding the way in which the University implements PBL throughout all its courses. [122]

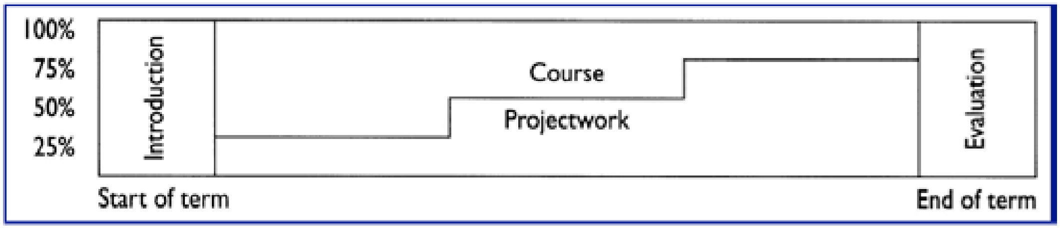
Associate Professor Henrik Brohus explained that project-organised education is multidisciplinary by nature and can be divided into two main groups: design-oriented education and problem-oriented education.

"Design-oriented project-organised education deals with practical problems in constructing and designing on the basis of a synthesis of knowledge from many disciplines, i.e. KNOW HOW. Whilst problem-oriented project-organised education deals with the solution of theoretical problems through the use of any relevant knowledge, whatever discipline the knowledge derives from, i.e. KNOW WHY." [123]

The benefits of project work are explained by Brohus as follows:

- Working processes are similar to working in modern organisations
- Develops analytical, methodical and transferable skills
- Develops learning motivation
- Student oriented
- Decreases drop-out rates
- Meets the new qualification requirements
    - » Collaboration
    - » Communication
    - » Problem solving.

Brohus explained the structure of learning at Aalborg University. As seen in figure 103, after an introduction students participate in course work (lectures or seminars) in the initial stages of the term. Throughout the term, project work increases as course work requirements decline resulting in the students having increased time and workload for group projects towards term completion and evaluation.



Source: The Aalborg PBL model, Henrik Brohus Aalborg University 124

Figure 103: Diagram- Structure of learning at Aalborg University

In summary students are assessed on the following basis:

50 per cent courses (lectures or seminars)

- 25 per cent project courses (assessed by project-examination)
- 25 per cent study courses and lectures (assessed by individual examination)

50 per cent project work (student groups working on problem-based projects).

6.6.3 Introduction to Building Informatics and the M.Sc. education - Kjeld Svidt, Associate Professor

Building Informatics is the study of design, integration and structuring of information and communications technology (ICT) tools, and product and process models in the entire building process. Focus is on model collaboration and knowledge transfer between participants in design, construction, operation, maintenance and use of buildings. The Digital Days project is an opportunity for Building Informatics students to demonstrate their skills in managing the data from many disciplines and ensure that communication flows are seamless to build a unified consistent model without clashes and inconsistencies. Skills are developed both in building the digital model and extracting the relevant data from the model for use in other software programs.

Associate Professor Kjeld Svidt explained that the communication challenge is to create consistent information flow through the entire process. Digital building models are created from the early design phases and used and modified through construction to operation, maintenance and the use of the building (facility management). There is now an increased focus on integration with analysis tools, i.e. thermal performance modelling, assessment of thermal bridges, cost estimating, project programming, indoor daylight assessment etc. This makes models much more than geometry alone.

Svidt states that, “changes start with the new generation of engineers” and the multidisciplinary workshops are the method by which the participating Danish universities and colleges are ensuring from the outset that each of the disciplines are communicating with each other to collect and disseminate relevant inputs and outputs in a professional and time effective way.

Ensuring information transfer during the construction process is an issue faced on all building sites. Svidt’s researchers have been working on effective methods for relevant information for tradespeople to be extracted from the digital model in easy-to-use formats. One researcher, Haraldur Arnorsson, has built a prototype for optimising the information flow on construction sites enabling workers to print the most up-to-date drawings relevant to their activity at the time they are about to undertake a particular task. A significant problem on-site is tradespeople working from superseded drawings. The mobile unit is robust, portable and enables printing to allow tradespeople to work from the most recently amended drawings (paper being less fragile and easier to work from than iPad screens, or other electronic devices that can be difficult to view due to glare and screen size). Svidt emphasised that digital models give new possibilities with interactive display systems. However, he states, "Paper is still good for presentations!" and paper also has an important to role to play on construction sites.

Figure 104: Haraldur Arnorsson with his prototype for a portable computer and printer for use on construction sites

6.6.4 Visit to Digital Days (De Digitale Dage) at University College Nordjylland hosted by Maria Thygesen and Michelle Østergaard

The Fellow visited on the second day of a three day workshop, students working on a multi-disciplinary Building Informatics Project. There were two large groups; one working in Danish and the other in English. The students were using software relevant to their discipline to analyse and create digital models for a proposed four storey oncology building project. Preliminary design concepts were provided by local architects. Students were participating from eleven different colleges and a diverse range of disciplines (each identified with a different colour T-shirt):

- Bachelor of Architecture
- Constructing architects
- Civil (structural) engineers
- Architectural engineers
- Environmental engineers (HVAC)
- Electrical/ Electronics Engineers
- Masters in Building Informatics (BIM specialists)
- Information Technology
- Project Construction Management
- Plumbers
- Bricklayers
- Carpenters.

The participation of the trades involved actual construction of building elements.

All data was centrally stored via Webmaster [126] for full access to all users and to allow checking and version control. IFC format allows data to be transferred between different programs. Exchanging data using USBs was not permitted. The Digital Days projects simulates industry best practice where data is transferred and monitored to ensure superseded copies are methodically stored and all current digital data from all agents is consistent. As an extensive range of programs were being used, data transfer and version control were essential for success. This was the management role undertaken by the Building Informatics students. The range of software in use was extensive:

Source: Digital Construction development and implementation in the Danish education and industry 125

Figure 105: Digital Days trades students making full scale parts

- REVIT- Architectural (Autodesk 3-D modelling and BIM)
- REVIT- Structural (Autodesk 3-D modelling and BIM)
- Ecotect - Sustainable Building Design Software (Autodesk) [127]
- Project Vasari (Autodesk design tool design tool for creating building concepts with analysis for energy and carbon) [128]
- SIGMA (cost estimating)
- BE10 (Danish thermal performance tool with indicative cost estimates)
- Bsim (Danish Building Simulation tool for analysing buildings and installations. Simulates and calculates thermal indoor climate, energy consumption, daylight conditions, synchronous simulation of moisture and energy transport in constructions and spaces, natural ventilation and electrical yield from building integrated photovoltaic systems)
- VICO Office – (Integrated 3-D modelling with cost estimating)
- DIAL-Europe (a tool for evaluating the use of daylight in buildings. It calculates Daylight Factor values on the work plane. (CIE overcast sky). Estimates the Annual Daylight Sufficiency (time during which no artificial lighting is required) using climatic data from 160 European cities. Predicts the number of Overheating Days. Estimates the illuminance due to artificial lighting. Optimises the performance of the room (Diagnosis function based on the use of fuzzy logic rules). Compares proposed rooms with similar case studies stored in a database) [129]
- Comsol (dynamic assessments of thermal bridges) [130]
- Therm (static assessments of thermal bridges) [131]
- RIUSKA is a thermal comfort and energy simulation application. It uses a building's information model (BIM) to calculate the thermal conditions of a building and its spaces in different loading and weather conditions. It was developed in Finland. [132]
- VIP-Energy (Swedish tool) [133]
- Winbeam (structural beam analysis program for shear, moment rotation and deflection)
- MSProject.

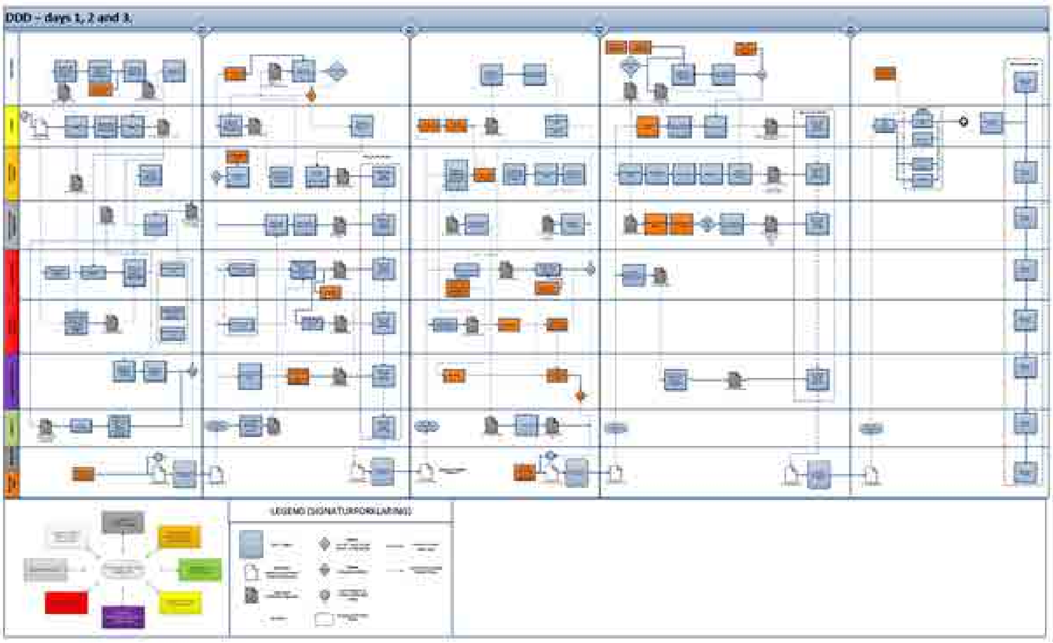
Source: Digital Construction development and implementation in the Danish education and industry 134

Figure 106: Students making digital models and collaborating through discussions while projecting their work on screens

Source: Digital Construction development and implementation in the Danish education and industry 135

Figure 107: Students collaborating through discussions

Joakim Lockert, Building Informatics student and his team prepared a process diagram prior to the workshop, showing the expected flow of activities and information that would occur over the three days. The flow that actually occurred was not completely as anticipated. Therefore the process diagram has been revised (see below) and orange activity-boxes are shown where activities have been moved or revised.



Source: Process diagram designed and updated by Joakim Lockert 136

Figure 108: Revised Process Diagram

Figure 109: Legend for T-shirt identification of students

Concluding remarks

The students were very actively engaged in the Digital Days Project. Communication between the disciplines was the key to success and this could be seen visually by looking across the room as participants wearing different colour t-shirts were conferring. At the end of each day presentation were given by each group to inform all of the progress being made.

Source: Digital Construction development and implementation in the Danish education and industry 137

Figure 110: Digital Days Students at work

Outcomes

Regarding the 3-Day multidisciplinary workshop

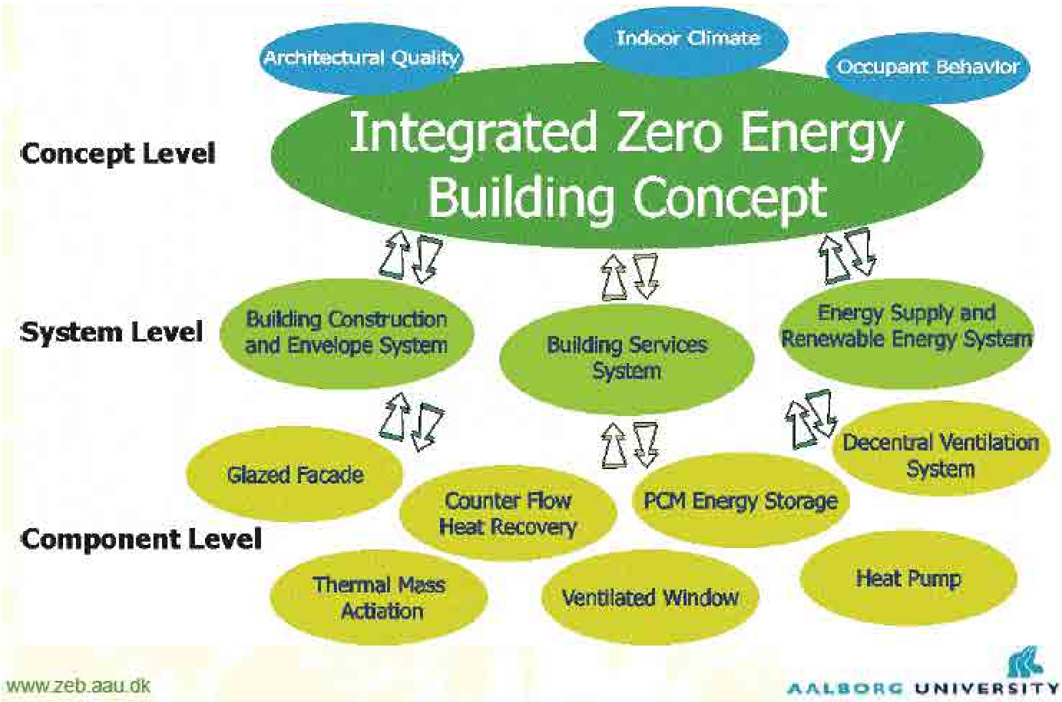
- The focus of the event was communication between all disciplines and this was essential to achieve the outcomes.
- A high level of student engagement was evident.
- The students, while explaining their work, showed expertise and satisfaction with their progress and participation.
- A very high level of IT support was available to ensure computers and software issues could be quickly resolved.
- A very high level of pre-planning and coordination of activities was evident to ensure that the three day program was a success.

Regarding the Aalborg University Architectural Engineering Division model for research and education

Multi-disciplinary problem-based learning is possible as demonstrated within Aalborg University and across the Danish institutes that participated in the Digital Days Project.

The Division of Architectural Engineering at Aalborg University has identified three essential areas for research and education; Building Informatics, Indoor Environmental Fluid Dynamics and Energy-Efficient Building Design.

- Building Informatics enables multi-disciplinary collaboration, project management and mastery of digital data for building projects.
- Indoor Environmental Fluid Dynamics involves the ventilation and air flow processes in buildings and building services and their impact on energy and mass flow in buildings, thermal comfort, indoor air quality and health. Thermally efficient buildings are becoming increasingly airtight to improve thermal performance and therefore require non-traditional methods to achieve high quality indoor air. Natural ventilation can be achieved by opening windows or vents but doing this drastically reduces thermal efficiency. In Europe, Passivhaus, Minergie® buildings and Net (or nearly) Zero energy buildings are all dependent on mechanical ventilation and the controlled intake of fresh outdoor air to achieve good indoor air quality. This area of research and study is therefore essential.
- An integrated approach to Energy-Efficient Building Design is one that works on a concept, system and component level as demonstrated in the diagram below.



Source: Architectural Engineering Per Heiselberg 138

Figure 111: Aalborg University – Integrated Zero Energy Concept

The Division of Architectural Engineering at Aalborg University has developed a strategic research centre in cooperation with industry for the development of zero emission buildings. The Fellow considers that the areas of research they have chosen to focus on are those most relevant to achieving long-term sustainable development in the building sector.

The teaching methodologies developed over many years by educators at Aalborg University have achieved very successful outcomes for their learners. The document Principles of Problem and Project Based Learning - The Aalborg PBL Model is an invaluable resource for all educators interested in learning more. [139]

Per Heiselberg's recommendation for implementing PBL multidisciplinary learning is that it takes time. Change will not happen overnight.

6.7 Visit to SBI Aalborg University, Denmark – Kirsten Engelund Thomsen, Jørgen Rose, Nils Lykke Sørensen and Gabriel Teodoriu – 20th April 2012

Address: Danish Building Research Institute, Hørsholm, Denmark

6.7.1 Introduction of discussion participants

Kirsten Engelund Thomsen and Jørgen Rose are Senior Researchers at the Danish Building Research Institute, SBI Aalborg University. Thomsen and Rose have written and contributed to many resources on nearly zero-energy buildings including, Principles for nearly zero-energy buildings - Paving the way for effective implementation of policy requirements [140] and Implementing the Energy Performance of Building Directive (EPBD) Featuring Country Reports 2010. [141]

They were joined by their colleagues Nils Lykke Sørensen (whose expertise is in data organisation in construction – building informatics) and Gabriel Teodoriu, Engineer and PhD Student.

Although not present at the meeting Mark Siddall, Senior Lecturer, Department of Architecture, Engineering and Construction, Northumbria University, Newcastle upon Tyne, UK has contributed his expertise regarding nZEBs to this section of the report. Siddall is an architect and Certified Passivhaus designer. He was able to give views regarding the UK experience where the focus for nZEB metrics is carbon emissions.

The Fellow has also referenced a range of sources in the writing of this section including documents by Nick Grant (Technical Director Passivhaus Trust UK) and from the Australian Sustainable Built Environment Council and Department of Climate Change and Energy Efficiency.

6.7.2 Aim

The purpose of the Fellow's visit was to study the development of nearly Zero Energy Building definitions and investigate the implication for regulatory reform.

6.7.3 Definitions

There are so many variants on definitions for highly energy efficient buildings. Terms used to define these buildings include climate neutral, carbon neutral, zero energy, zero carbon, Living Buildings, near zero-energy, net zero energy and energy positive buildings. nZEB is the acronym for both 'net' and 'nearly' Zero-Energy Buildings. The Fellow in trying to clarify these definitions has come to the following conclusions.

Subject to the definition of nZEB, the concept is for such a building to produce as much as or more energy than it uses annually* and export excess renewable energy generation to the utility (electricity grid, district hot water system or other central energy distribution system) to offset the energy used. The time period for assessment is usually considered to be annual, however some believe a shorter period say monthly would be better. Some researchers have argued that for an nZEB, the period of consideration should be the life cycle of the building.[142] Also, buildings that produce more energy than they consume are sometimes referred as energy-plus buildings.[143]

Four commonly used definitions described by Shanti Pless and Paul Torcellini in Net-Zero Energy Buildings: A Classification System Based on Renewable Energy Supply Options are as follows: [144]

Zero Site Energy - A site ZEB produces as much renewable energy as it uses in a year, when accounted for at the site

Zero Source Energy - A source ZEB produces (or purchases) as much renewable energy as it uses in a year, when accounted for at the source. Source energy refers to the primary energy used to extract, process, generate, and deliver the energy to the site. To calculate a building's total source energy, imported and exported energy is multiplied by the appropriate site-to-source conversion multipliers based on the utility's source energy type

Zero Energy Costs - In a cost nZEB, the amount of money the utility pays the building owner for the renewable energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year

Zero Energy Emissions - A net-zero emissions building produces (or purchases) enough emissions-free renewable energy to offset emissions from all energy used in the building. Carbon, nitrogen oxides, and sulphur oxides are common emissions that nZEBs offset. To calculate a building's total emissions, imported and exported energy is multiplied by the appropriate emission multipliers based on the utility's emissions and on-site generation emissions (if there are any).

The EPBD defines a nearly Zero-Energy Building as a, "building that has a very high energy performance as determined in accordance with Annex I. The nearly zero or very low amount of energy required should to a very significant extent be covered by energy from renewable sources, including renewable energy produced on-site or nearby".

Nearly all definitions (including nearly Zero-Energy Buildings) fail to consider the significant amount of energy used by the building occupants' electrical appliances (plug and miscellaneous loads). However, as buildings become more energy efficient regarding thermal performance and lighting, the plug and miscellaneous loads form a greater proportion of the total energy use. Identifying opportunities to address plug loads further improves energy efficiency, although at this time reducing plug load energy usage has no relationship to meeting a building's nZEB status.

6.7.4 Background regarding nearly Zero-Energy Building targets in the European Union

The Energy Performance of Buildings Directive (EPBD) dictates to all European Member States climate targets. All member states are now working towards achieving the 20-20-20 target. That is:

- To reduce emissions of greenhouse gases by 20 per cent by 2020
- To increase energy efficiency to save 20 per cent of EU energy consumption by 2020
- To reach 20 per cent of renewable energy in the total energy consumption in the EU by 2020.

	Energy efficiency	Emissions	RE share
2020 (cross sectoral targets)	Saving 20% of the EU's energy consumption compared to projections for 2020[15] (non-binding target)	At least a 20% reduction of greenhouse gas emissions by 2020 compared to 1990[16] -30% under specific circumstances[17] (binding target)	20% share of renewable energies in overall EU energy consumption by 2020[18] (binding target)
2030 (non-binding aim for the building sector; residential and non-residential)	N.a.	Min. -37 to -53% compared to 1990 level[19]	N.a.
2030 (non-binding aim for the power sector)	N.a.	Min. -54 to -68% compared to 1990 level[20]	N.a.
2050 (non-binding aim for the building sector)	N.a.	Min. -88 to -91% compared to 1990 level[21]	N.a.
2050 (non-binding aim for the power sector)	N.a.	Min. -93 to -99% compared to 1990 level[22]	N.a.

[15] Commission Green Paper on Energy Efficiency [Presidency conclusions 8/9 March 2007]
[16] Presidency conclusions 8/9 March 2007 and COM(2010) 639
[17] Presidency conclusions 29/30 October 2009
[18] Presidency conclusions 8/9 March 2007
[19-22] A roadmap for moving to a low carbon economy in 2050, European Commission 2011

Source: Principles for nearly Zero-Energy Buildings 145

Figure 112: Climate targets at EU level

Each Member State creates its own system for achieving these targets and therefore a myriad of regulatory requirements and definitions for low energy buildings such as Passivhaus (refer to Section 6.4.3), Zero-Energy, Zero-Carbon, 3-litre, PlusEnergy, Minergie® (refer to Section 6.10.1) and Effinergie have been developed.

By 31 December 2020, all new buildings should be nearly Zero-Energy Buildings.

After 2020 the situation changes and more stringent targets apply.

The Energy Performance of Buildings Directive dictates that the implementation of nearly Zero-Energy Buildings will take place as from 2021 onwards (2019 respectively for public buildings).

"The European Union has ambitious targets for 2050 and the question is what ambition level needs to be decided upon for nearly Zero-Energy Buildings so that new buildings (but also in renovation) can achieve them? When projecting CO_2 emissions towards 2050, three crucial activities have to be taken into account: new building activities, refurbishment and demolition of buildings."

Extract from Principles for nearly Zero-Energy Buildings [146]

The European Member States will be drawing up national plans for increasing the number of nearly Zero-Energy Buildings and these will need to include:

- A definition of nearly Zero-Energy Buildings, reflecting national, regional or local conditions including a numerical indicator of primary energy use, expressed in kWh/m² per year
- Intermediate targets for improving the energy performance of new buildings by 2015.[147]

"Acknowledging the variety in building culture and climate throughout the EU, the EPBD does not prescribe a uniform approach for implementing nearly Zero-Energy Buildings and neither does it describe a calculation methodology for the energy balance. To add flexibility, it requires Member States to draw up specifically designed national plans for increasing the number of nearly Zero-Energy Buildings reflecting national, regional or local conditions. The national plans will have to translate the concept of nearly Zero-Energy Buildings into practical and applicable measures and definitions to steadily increase the number of nearly Zero-Energy Buildings."

Extract from Principles for nearly Zero-Energy Buildings [148]

As a consequence of this flexibility in the definition for nZEBs, questions have emerged concerning the practicalities of the definition:

- How close should 'nearly zero' be to 'zero'? (zero was considered too ambitious)
- How to keep the nZEB definition sufficiently flexible so as to build upon existing low-energy standards and enable energy-positive buildings?
- How to establish the boundary conditions for determining the definition of nZEB? Are on-site or off-site renewable energy sources permitted?
- What are the system boundaries for estimation of consumed energy? Is energy required for maintenance and replacement of materials included? Is initial embodied energy included? Are plug loads (energy used by the building occupant's electrical appliances) included?
- Should the renewable energy actually be included in the definition of nZEB?
- How to properly define and set the share of renewable energy?
- How to determine the optimal balance between energy efficiency and renewable energy?
- How to forge the nZEB definition as a 'silver bullet' for reaching the same levels of energy and Greenhouse emissions reduction?
- How to link the nZEB definition to cost-optimality principles in order to have convergence and continuity?

There are a variety of approaches and calculation methodologies different countries have adopted towards low energy (or low carbon) buildings.

Austria, Czech Republic, Denmark, the UK, Finland, France, Germany and Belgium have established governmental low energy building definitions. Luxemburg, Romania, Slovakia and Sweden are working towards introducing low energy building definitions. Germany, the Netherlands, Poland, Austria, Denmark and Sweden all have non-governmental Passivhaus definitions based on the German definition.[149] European countries use numerical indicators of primary energy use, expressed in kWh/m² per year for achieving nZEBs by 2020, whilst the UK focuses on carbon emissions using the Code for Sustainable Homes to achieve zero carbon new housing by 2016.

6.7.5 Challenges

Thomsen and Rose have identified ten challenges for stakeholders and experts to consider as there is an urgent need to establish common principles and methods across Europe.

Challenge no. 1: How do current targets of the EU (CO_2 emissions, energy efficiency, renewable energy etc.) affect the nZEB definition?

Implication for the nZEB definition

- 2050 aims for a 93 per cent to 99 per cent CO_2 reduction from 1990 levels therefore nZEBs need to be nearly zero CO_2 (3 kg CO2/m^{2}yr). Otherwise, there is an unrealistic ambition level for renovation of the pre-2010 building stock (>90 per cent savings)

Challenge no. 2: How different are the solutions for nearly zero CO_2 and nZEB (primary energy)?

Implication for the nZEB definition

- Primary energy is sufficiently proportional to CO_2 (except in the case of nuclear electricity). Conversion factors (weighting factors) are used for different types of energy such as electricity, gas, oil or district heating. These factors can help obtain a more accurate measure of the total energy use from an environmental or economic perspective. They vary from country to country across Europe with electricity having a higher factor at 2.5-3.0 and wood fuel being as low as 0.2.
- The greatest issue here is scalability of available resources. Biomass heating will generate a low figure for primary energy and carbon emissions allowing a building with poor fabric performance to achieve a Zero Carbon building or Zero Energy building status. However, there are not enough plantation (or native) forests to allow every building to be heated using biomass.
- Biomass is considered a zero carbon fuel because the carbon emitted when plants are burnt is equal to that absorbed during growing. Aside from the environmental impact of pollution resulting from burning biomass, indoor air quality issues, sustainable sourcing of timber, soil carbon balance and the transport impact of delivery of biomass to the site, Nick Grant and Alan Clarke believe that by incorrectly defining biomass as a low carbon fuel we are actually increasing global carbon emissions.[150] Grant and Clark explain three concepts:
    - » The reasons why burning biomass produces more carbon emissions than most fossil fuels
    - » How if biomass is grown and not burnt, and an equivalent amount of gas burnt instead, then lower carbon emissions result
    - » Defining biomass as low-carbon, and then setting carbon-based energy standards leads to relaxation of building energy efficiency, and ultimately, higher carbon emissions. [151]

Conversion factors from final to primary energy must be based on reality and should be adapted continuously to the real situation of the energy system. The challenge here is to ensure that these figures are correct (whether for primary energy or carbon emission multipliers). Otherwise inefficient buildings using unsustainable energy sources will meet all the required calculations created by various countries to achieve nZEBs or ZCBs, but not facilitate an overall global reduction in carbon emissions.

Challenge no. 3: How to deal with temporal disparities (e.g. daily vs. annual balance) and local disparities (e.g. on-site vs. off-site production) between produced and consumed energy?

Implication for the nZEB definition

- For the time being it seems sufficient to use an annual balance, but moving towards monthly (weekly or daily) energy balances in the future. The dilemma with annual balances is that in the future when enough buildings are producing on-site electricity (via solar or wind) there will be surplus of power that cannot be utilised. At other times the buildings will have increased power demand when little or no on-site renewable energy production occurs.

- The advantage of calculation methods based only on on-site energy production is that it ensures that renewable energy taken into account in the design and initial calculation is related directly to that building. Off-site renewable energy sources via grid connections are susceptible to change and any changes would influence CO_2 emissions for the building, completely altering the energy balance and nZEB status of the building.
- Allowing only on-site and nearby renewable energy production could be a considerable barrier in implementing nZEB. For example, a house and neighbourhood that has poor solar access and is without reliable wind for energy generation has extremely limited options for generating on-site or nearby energy.
- Thomsen and Rose propose that off-site energy should be allowed. This creates more opportunities for the development of 'green' energy production. However, the off-site renewable energy has to be properly controlled and certified for avoiding fraud and double counting.

Challenge no. 4: How to ensure that an nZEB definition does not lock-in effects and allows the concept to be expanded later towards energy positive buildings?

Implication for the nZEB definition

Nearly Zero-Energy Buildings should not be regarded as an endpoint but only as an interim step towards even better buildings such as 'plus energy' or 'energy positive' buildings. The three variables; time, space (boundaries) and quality (energy) will enable future improvement towards plus energy buildings.

- Energy performance based on an annual balance but moving towards monthly balance in the future.
- The system boundaries should allow renewable energy sources from grid.
- The energy balance must take into account the quality of the energy.

Challenge no. 5: How to ensure that an nZEB definition is transferable to different climates, building types, building traditions etc.?

Implication for the nZEB definition

- Climate: There are two options under consideration

1. Calculate the energy requirement for an average European building located in an average European climate on the basis of the EU's 2050 climate target. This average energy requirement can then be corrected and adapted at national or regional level by a factor derived from combining cooling degree days (CDD) plus heating degree days (HDD).
2. Calculate and dictate a fixed value of zero or very close to zero for each Member State. This option is easier to communicate but might be perceived as unfair. However, it would be chosen should the first option become too complicated or if an absolute zero-energy balance for all new European buildings is required to achieve the European climate targets.

- Geometry: The preference is to define a fixed threshold for maximum allowed energy demand or consumption (e.g. in kWh/m²a) independent from the building's geometry and size.
- Usage: Residential buildings and buildings with a similar usage pattern should have same

requirements. Non-residential buildings should be categorised and have individual performance requirements.

Challenge no. 6: Should an nZEB definition include household electricity and (if so) in which way could this be done?

Implication for the nZEB definition

- It is not recommended to include household electricity (the energy consumed by plug-in appliances) in the initial nZEB definition. The energy consumed by space heating and cooling, hot water systems, BMS and HVAC equipment are all considered in the definition whilst the EPBD includes lighting for non-residential buildings but not for residential buildings. Lifts and fire protection systems are not within the scope of the nZEB definition and this is an omission that requires reconsideration.
- However, in future nZEB redefinitions, all energy uses should be included to avoid sub-optimisation.
- A feasible interim solution for avoiding sub-optimisation might be to systemise all energy uses and clearly show the subset of uses currently included in the EPBD.

Challenge no. 7: Should an nZEB definition include production and disposal stage of building elements, components and systems?

Implication for the nZEB definition

- Life Cycle Analysis for nZEB is far beyond the current intention of EPBD, however it may very well be relevant to include in future.
- A practical solution for the near future would be to require an informative mention of this value in addition to the indicator reflecting the energy performance of the building.

Challenge no. 8: Should it be possible within the nZEB definition to look at groups of buildings rather than at a single building?

Implication for the nZEB definition

There are no apparent arguments why a certain required threshold should not be reached on an individual building level. The benefits from synergies relating to pooling buildings (energy related or financially) and are not obvious. Even if an individual building has specific disadvantages such as a landscape that limit solar gains, allowing off-site renewable energy offsets this disadvantage.

Challenge no. 9: What guidance can/needs to be given regarding the balance of energy efficiency and renewable energy within the nZEB definition?

Implication for the nZEB definition

- It is necessary to have a separate threshold for the energy demand and a requirement on minimum percentage of renewable energy sources.

A set of principles for achieving nZEB buildings will be necessary to achieve a balance. For example:

1. A fixed maximum value for energy demand [kWh/m²a] (depending on climate/use of buildings) for the sum of the following demands: space heating /cooling, domestic hot water (dhw), auxiliary energy, lighting, appliances (optional). e.g. 30-40 kWh/m²a (for heating, cooling, dhw).

2. Have a fixed percentage of the remaining energy demand to be covered by renewable energy (annual balance). This could be 50-90 per cent. At least a minimum share of renewable energy might be generated and used onsite/ nearby to stabilise grids and reduce dependencies.
3. Fixed overarching value for primary energy consumption [kWhfossile/m²a] and CO^2-emissions (optional) depending on climate and use of a building.

There is debate as to whether renewable energy should actually be included in the definition of nZEB. Siddall believes there is a very strong and pragmatic case for the two to be separate to avoid a confusion of two system boundaries; demand side management and supply side management. Is it an efficient use of resources for every building to generate renewable energy or more effective for energy providers to provide renewable energy? According to Siddall separate polices for decarbonisation of the national grid would be advantageous. He proposes two options:

1. All new electrical supply should be zero carbon
2. A requirement that energy companies should on an annual basis match the arising energy demand from new buildings with renewable energy (which may include decommissioning old power stations if required).

In the Australian report, Inclusion of Energy Generation in Building Energy Efficiency Standards prepared by Energetics for the Department of Climate Change and Energy Efficiency the following recommendations are made.

“Zero or low emission energy generation (ZLEG) should not be used in preference to improvements in the energy efficiency of the building shell and fixed appliances, unless it can be shown that it offers clear financial benefits.

A study into the optimum balance between further improvements in the energy performance of the building and take-up of ZLEG be undertaken. This is especially relevant to residential buildings.”

Energetics recommends that, “any scheme that encourages the ZLEG must clearly separate the thermal performance/energy efficiency of the building from the application of ZLEG to supply the remaining energy requirements of the building.” [152]

Challenge no. 10: Is there a necessary or optional link between the principle of cost optimality and the concept of nearly zero-energy buildings within the EPBD recast?

“The cost optimality methodology requires Member States to:

- Define reference buildings that are representative in terms of functionality and climate conditions. The reference buildings need to cover residential and non-residential buildings (e.g. offices), both for new and existing
- Define energy efficiency measures to be assessed for the reference buildings. These can be measures for buildings as a whole, for building elements, or for a combination of building elements
- Assess the final and primary energy needs of these reference buildings. The calculations must be done in accordance with relevant European standards
- Calculate the costs of the energy efficiency measures during the expected economic lifecycle of the reference buildings. Investment costs, maintenance and operating costs, earnings from energy produced and disposal costs (if applicable) need to be taken into consideration.” [153]

Implication for the nZEB definition

Probably by 2020 there will still be a gap between cost optimal levels and nZEB levels. However, it is most likely that a convergence between cost-optimal and nZEB levels will occur (due to estimated increase of the energy prices and expected decrease of the technology costs). [154]

A recently released report by Pitt and Sherry, Pathway to 2020 for Increased Stringency in New Building Energy Efficiency Standards: Benefit Cost Analysis prepared for the Department of Climate Change and Energy Efficiency, analysed the range of cost-effective savings in the energy consumption of new buildings that could be achieved in Australia by 2015 and 2020, relative to buildings compliant with the 2010 version of the Building Code of Australia (BCA2010). The analysis was based on three scenarios; new buildings designed to use 40 per cent, 70 per cent and 100 per cent less energy than those compliant with BCA2010.

It was found that, "there are very significant cost effective opportunities for energy savings in new commercial buildings in 2015 and 2020, relative to BCA2010".

Regarding residential buildings, the study showed, "that energy efficiency improvements with photovoltaics (PV) in the mix, zero net energy becomes cost effective in all climate zones by 2020, and even by 2015 in most climate zones". However, it was noted that in some locations within some climate zones it would not be possible to attain zero net energy, given limitations on roof area and solar access to install the amount of PV required. [155]

The issue of split incentives was not discussed in the report. In the scenarios analysed the base building gets more expensive for the benefit of the occupant who reaps the reward of ongoing cost savings due to energy efficiency. This is the situation except in cases where the building owner is also the building occupant. To overcome the problem of split incentives, mandatory disclosure of building energy efficiency at the time of sale or lease would assist the buyer or tenant to make informed financial decisions. Ongoing public education regarding the cost benefits of sustainable building design in conjunction with accurate building sustainability statements (mandatory disclosure) is recommended to address the split incentive barrier.

The result of Pitt and Sherry's benefit cost analysis are encouraging and identify the potential for Australian building design and construction to move cost-effectively towards achieving nZEB status.

6.7.6 Additional considerations

In addition to the challenges of defining and implementing regulations to achieve nearly Zero-Energy Buildings, Thomsen believes the areas that will require the most effort to enable successful implementation across Europe are:

1. Educating the occupants

Building occupants need to learn new behaviours to operate MHRV systems, heat pumps and other new technologies. Lack of awareness may lead to inefficiency as faulty equipment is not recognised as such. Ensuring that occupants allow the systems to introduce fresh air rather than opening windows also involves behavioural change.

It is the responsibility of the contractors to provide manuals for the operation of the building. A range of methods were discussed for ensuring occupants have access to the information and these included written manuals and video instruction on DVD. When buildings are sold or leased this documentation should also form part of the contract of sale or lease to ensure future occupants understand how to operate the building.

2. Post-construction commissioning

Fine tuning the systems to ensure optimum efficiencies have been achieved and rectifying defects is essential. Ongoing monitoring of buildings is not cost effective for typical home building owners. However, more technical systems require ongoing maintenance including regular filter changes to ensure they are delivering optimum thermal comfort, indoor air quality and energy efficiency. As systems become more complex, ongoing commissioning and maintenance must not be overlooked or neglected.

Siddall also believes that the importance of post-construction commissioning cannot be underestimated. There are major issues in the UK and the Netherlands with mainstream practices falling far below the regulatory requirements. Siddall states, "It seems that no one knows how to check the 'independent' data".

6.7.7 The Australian context

ASBEC has published Defining zero emission buildings - Review and recommendations: Final Report discussing the range of alternative definitions for defining Australia's zero emission buildings. The authors are Reidy, Lederwasch and Ison.

It is this fourth definition 'Zero Energy Emissions' (described in Section 6.7.3) that is most similar to the definition that ASBEC recommends as their preferred option for Australia.

Reidy, Lederwasch and Ison recommend the following standard definition for zero carbon buildings:

A zero carbon building is one that has no net annual Scope 1 (emissions resulting from direct fuel combustion such as burning natural gas in the home) and Scope 2 (emissions resulting electricity use) emissions from operation of building-incorporated services.

- Building-incorporated services include all energy demands or sources that are part of the building fabric at the time of delivery, such as the thermal envelope (and associated heating and cooling demand), water heater, built-in cooking appliances, fixed lighting, shared infrastructure and installed renewable energy generation.
- Zero carbon buildings must meet specified standards for energy efficiency and on-site generation.
- Compliance is based on modelling or monitoring of greenhouse gas emissions in kg CO_2-e/m^2/yr. [156]

Terminology for variations on Zero Carbon Buildings is clarified in the table and diagram below.

Variation	Terminology
Standard definition	Zero carbon building
Include occupant emissions	Zero carbon occupied building
Include embodied emissions	Zero carbon embodied building
Include all emission sources in the building life cycle	Zero carbon life-cycle building
No grid connection	Autonomous zero carbon building
Achieves less than zero emissions	Carbon positive building (or carbon positive occupied building etc.)

Source: ASBEC, Defining zero emission buildings- Review and recommendations: Final Report 157

Figure 113: Variants on Zero Carbon Building Definitions

According to the authors of Zero Energy Building – A review of definitions and calculation methodologies, “The first and probably by far the most important point on the ZEB agenda is the metric for the balance”. [158]

One of the main differences in the European nZEB definition and the proposed Australian ZCB is the metric for calculations.

nZEB	Nearly Zero-Energy Buildings (Europe)	kWh/m² / year.
ZCB	Zero Carbon Buildings (Australia) – recommendation	kg CO_2-e/m²/yr
ZCB	Zero Carbon Buildings (UK)	kg CO_2-e/m²/yr

The AECB Energy Standards (a voluntary set of energy standards developed in the UK) for clarity uses three energy standards: useful space heating energy, primary energy consumption and CO_2 emissions. [159]

Standard	Useful space heating energy	Primary energy consumption	CO_2 emissions
Silver	40 kWh/m²/yr	120 kWh/m²/yr	22 kg/m²/yr
Passivhaus Passivhaus in a UK context	15 kWh/m²/yr 15 kWh/m²/yr	120 kWh/m²/yr 78 kWh/m²/yr	No explicit limit 15 kg/m²/yr
Gold	15 kWh/m²/yr	58 kWh/m²/yr	4 kg/m²/yr

Source: AECB CarbonLite Programme 160

Figure 114: The three energy standards as applied to a typical dwelling

Evaluating the advantages and disadvantages of the alternatives for nZEB/ ZCB metrics (primary energy demand/ CO_2 emissions) is beyond the scope of this report.

6.7.8 Conclusions

- Energy efficient building design and construction is a higher priority than renewable energy options as it is ‘almost always easier to save energy than to produce energy’. [161]
- Calculations are not simple and require professional ‘greenskills’ expertise.
- Certificates clarifying calculated building performance are many and varied. Each European Member State has their own type, dependent on the certifier and/ or the software tool being used. It is important that they clearly assign an energy performance label and define critical information such as primary energy demand and the CO_2 emissions.
- Primary energy weighting factors and/or carbon emission multipliers must accurately reflect reality and should be adapted continuously to the real situation of the energy system.
- Smart metering is necessary to accurately measure energy usage and renewable energy generation fed back into the grid. Without these measurements, identifying a difference between design intent and actual performance is not possible.
- Bridging the gap between the design intention and the actual performance of the constructed building requires extensive post-occupancy commissioning and expertise. According to Siddall, actual building performance, rather than regulated (desired) performance has not been sufficiently addressed. Research in the UK suggests that this may be a major obstacle to delivering actual nZEB type buildings as the building industry needs to be re-skilled.

Skills deficiencies that require further education to enable the successful implementation of nZEB buildings are:

- Training in energy efficient building design for designers, engineers and architects
- Trade skills for construction of nZEBs, including all building trades
- Training of 'greenskills' professionals in calculation methodologies and ongoing building monitoring to enable the difference between calculated and actual building performance to be identified and addressed
- Training in post-occupancy commissioning and maintenance.

6.7.9 Recommendations and Outcomes

The European Union is setting stringent targets for energy efficient buildings with very specific carbon emission reduction targets to be achieved by 2050. There is an acknowledgement that buildings have a long lifespan (and long intervals between significant refurbishments) and therefore significant change needs to be implemented in the very near future to achieve long term goals.

In this regard the Europeans have a sense of urgency and commitment to tackling this task. The implementation of nZEB as a mandatory requirement in the future has been calculated to create about 345,000 additional jobs assuming an extra investment of EUR 39 billion per year and an average turnover in the EU construction industry of EUR 113,000 (in 2008) per person and year. [162] Although Europe has been severely affected by the global financial crisis, their obligations under the Energy Performance of Buildings Directive are going ahead.

Similar to the European Union the UK Government announced a rapid transition to 'zero carbon' new building in December 2006 as a key step forward in reducing the Greenhouse Gas (GHG) emissions from the domestic and non-domestic sectors. [163]

In contrast Australian policy appears to have no timeline and lacks urgency in increasing minimum energy efficiency and thermal performance requirements for buildings. Whilst the Fellow was in Europe (April 2012), the Victorian government was considering scrapping 6 Star energy ratings in lieu of 5 Star indicating this as a useful method of cutting government red tape. [164] This blip on progress towards more sustainable built environments indicates a lack of awareness and consideration for the long term consequences of stalling improvements in thermal performance and energy efficiency. Consequences not only relate to carbon emission mitigation but also to affordability of utility bills for building occupants and long-term financial benefits for householders. [165]

A great deal of excellent work towards sustainable building design and construction is being undertaken by Department for Climate Change and Energy Efficiency, Green Building Council Australia (GBCA), Australian Sustainable Built Environment Council (ASBEC), Building Designers Association of Victoria (BDAV), Australian Institute of Architects, building designers, architects, builders, engineers, building surveyors, educators, researchers and many others.

Generating the political will to adopt more stringent mandatory requirements more quickly is the key to accelerating environmental benefits, carbon mitigation, energy affordability, thermal comfort and long-term financial benefits for Australians.

The European Union and UK have the political will to make this happen quickly even in the midst of economic crisis. They realise the consequences of inaction or slow action would have serious environmental and economic ramifications for 2050 and beyond.

6.8 Visit to Wuppertal, Germany - Eike Musall - 23rd April 2012

Eike Musall from the Architecture, Civil Engineering, Mechanical Engineering, Safety Department at the University of Wuppertal (Bergische Universität) provided a tour to three exemplar buildings. Musall explained the theory behind their design and construction and the outcomes from monitoring for energy efficiency.

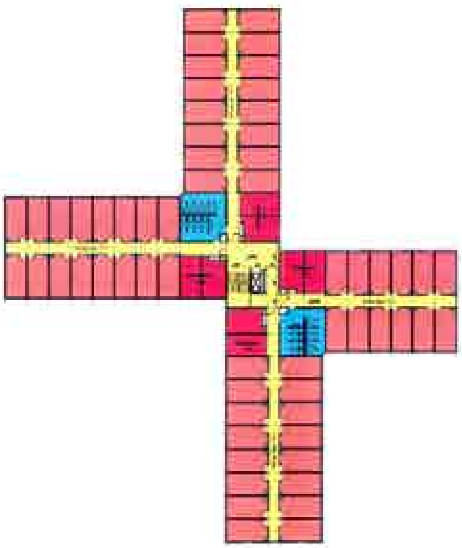
6.8.1 Neue Burse student residence hall, Wuppertal

Address: Wuppertal, Nordrhein-Westfalen

Building description:

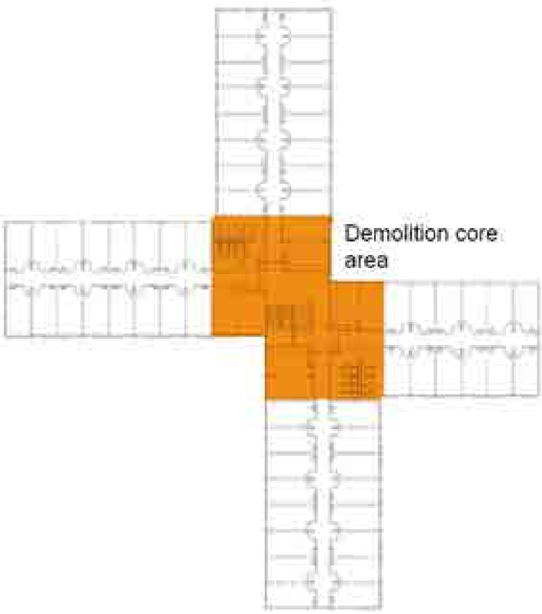
Before refurbishment Neue Burse student residence hall comprised of two cross shaped buildings accommodating 600 students. The buildings were originally constructed in 1977 and required upgrades for improved functionality and thermal performance. There were significant problems in construction and building physics including: outdated building equipment, poor insulation and leaky facades allowing moisture penetration and inadequate solar access due to the small windows.

Functional problems included one shared kitchen for groups of 16 people, sharing of toilet and shower facilities for up to 32 people and a lack of modern infrastructure. This created a high vacancy rate and social problems.



Source: Retrofit to Low Energy and Passivhouse, Student Residence Neue Burse, Wuppertal 166

Figure 115: Neue Burse student residence hall - Original floor plan

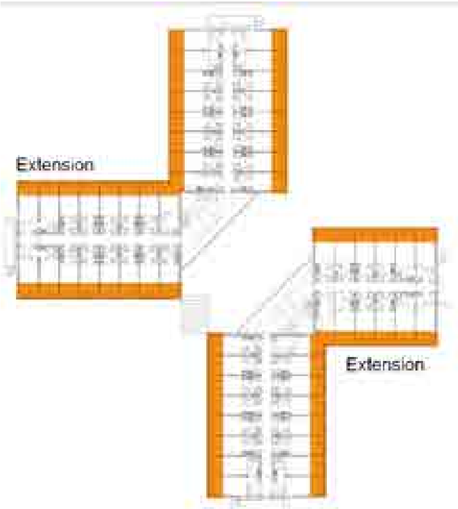


Source: Retrofit to Low Energy and Passivhouse, Student Residence Neue Burse, Wuppertal 167

Figure 116: Neue Burse student residence hall – Floor plan showing core to be demolished

New works included removal of the old staircase and central core area, removal of the old facade and infrastructure and a two metre wide extension to the building wings. The extensions resulted in a 40 per cent increase in floor area and allowed space for every student room to have a private kitchen and bathroom.

A different performance standard was chosen for each building; the first was built to Low Energy house standard and the second to Passivhaus standard.



Source: Retrofit to Low Energy and Passivhouse, Student Residence Neue Burse, Wuppertal 168

Figure 117: Neue Burse student residence hall – new floor plan

Figures 118, 119 and 120: Neue Burse student residence hall

Sustainability:

1st Building (Low Energy building standard) completed in 2001:

- Improved thermal insulation
- Window ventilation (dependant on residents to adjust ventilation)
- Space heating - 65 kWh/m² approx.

2nd Building (Passivhaus Building standard) completed in 2003:

- Optimised thermal insulation (e.g. triple glazed windows)
- Ventilation system with heat recovery
- Space heating - < 30 kWh/m²a (for economic and building specific reasons a simpler ventilation and heating system was chosen resulting in good values for a refurbished building but not the requirement of 15 kWh/m² a max required for a Passivhaus building).

After the completion of construction, a three year scientific examination of the services equipment and energy consumption was undertaken.

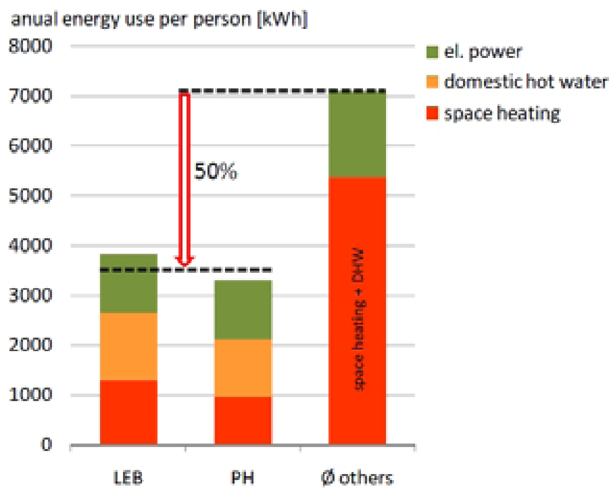
Lessons learned related to:

- Ventilation and indoor air quality
- Commissioning and defects rectification
- Occupant behaviour and education.

Ventilation and indoor air quality

The first building had indoor air quality problems due to the high occupation density, airtight construction and dependence on residents to perform window ventilation. Random measurement checks with closed windows and one person present gave an indication the CO_2 concentration was above 1000 ppm. The energy consumption saving were at times related to poor indoor air quality. [169]

The second building built to Passivhaus standard had a heat recovery ventilation system installed to reduce heat losses and to ensure good indoor air quality.



Source: Retrofit to Low Energy and Passivhouse, Student Residence Neue Burse, Wuppertal [170]

Figure 121: Energy consumption shown for Low Energy Building (LEB), Passivhaus Building (PH) and typical student residences

Annual energy use per person can be seen in the diagram above. Compared to average energy consumption of other dormitories in Wuppertal, the Low Energy building and Passivhaus building had an approximate reduction of 50 per cent of total site energy consumption. The thermally efficient buildings showed the greatest proportion of energy use was for domestic hot water, exceeding the energy requirement for heating. A recommendation was made that installing water reducing taps would make a big impact.

Commissioning and defects rectification

Energy monitoring in the first years of operation was important to identify errors in technical equipment and to compare the actual operation with data from the planning process. Several problems were identified including faulty attachments of mixing valves and circulation losses in supply pipes. Heating provided by warming the supply air occurred via one heat exchanger per wing creating inefficiencies as the same output was delivered for north and south facing rooms. In 2005, the ventilation system was converted to exhaust air-dependant temperature control to improve efficiency.

Occupant behaviour and education

Behaviour had a major impact on actual versus expected energy consumption in the buildings. [171] Opening windows depends on individual habits and is strongly related to outdoor temperature. The students living at Neue Burse student residence hall are all provided written instructions on how to maintain energy efficiency and also warnings regarding placing bright or reflective surfaces with 200 mm of the triple glazed windows. The special glass used in Passivhaus design is susceptible to overheating. Reflective surfaces could lead to localised heating and broken glass.

Outcome

Construction costs for the refurbishment project were 25 per cent lower than constructing new buildings. [172]

The refurbishment project is considered a success because both buildings have drastically reduced energy costs and full occupancy with long waiting lists for accommodation.

6.8.2 Waste Disposal Building, Remscheid

Address: Remscheid, Nordrhein-Westfalen

Contact: Frank Ackermann (Client project coordinator, building facility manager and public relations manager for Remscheider Entsorgungsbetriebe)

Building description:

The office building of the Remscheider Entsorgungsbetriebe REB (Waste Disposal Unit in Remscheid) was constructed in 1968. A feasibility study demonstrated that the demolition and construction of a new building of the same standard would have cost around 40 per cent more than refurbishment.

Consequently, the existing building was completely renovated in 2004 with an additional floor added. The energy concept and the architectural quality were recognised by the State with the ‘State Prize for Architecture, Residential Building and Urban Planning’. The Bergische Universität in Wuppertal (Karsten Voss, Eike Musall and team) are responsible for monitoring and evaluation of the building operation within a project funded by the German Federal Ministry for Economics BMWi in the EnSan section of the Energy-Optimised Building EnOB Programme [EnOB]. [173]

Source: Experimental Results and Experience from the Retrofit of an Office Building with Passive Cooling – REB Remscheid 174

Figures 122 and 123: Waste Disposal Unit Office Building in Remscheid- before and after refurbishment

Sustainability:

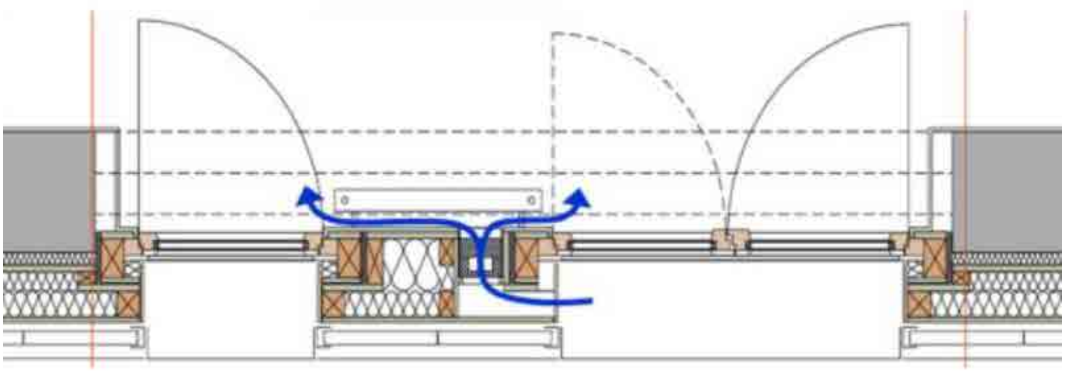
- A new prefabricated facade with a translucent external skin made from multi-layers of polycarbonate was installed supported by a lightweight timber structure and insulated with 160mm - 240mm thermal insulation. However, the innovative polycarbonate skin is not proving to be robust regarding moisture penetration and physical damage.

Source: Eike Musall 175

Figure 124: Night view showing translucent polycarbonate facade

Figure 125: Damage to polycarbonate skin

- Double-glazed insulated glass and solar protection glass with thermally insulated spacers and timber frames. U-values for the glazing: 1.1 W/m²K. U-value for the windows: 1.4 W/m²K.
- Thermal bridges have been eliminated in the design and detailing of the new construction.
- Passive cooling using night ventilation is implemented by reducing thermal load as much as possible in summer. Adjustable external shading devices to windows and sun protection glazing reduce solar heat gain. The thermal mass of the solid building structure allows a delay in heating loads enabling night ventilation to purge the warmer air from the building. The uppermost level is an addition. Due to structural limitations this level was required to be lightweight. Therefore, Phase Change Materials (refer Section 6.4.7.8 and Section 6.4.7.10) in the wall and ceiling plaster have been used to increase the effective thermal capacity. Micronal (BASF) has been used with a phase change at 24°C.
- Automated vent opening to achieve night ventilation is sufficient to maintain comfortable daytime temperatures during warm weather. The system depends upon adequate negative pressure in the office rooms and fresh air is drawn only through acoustically dampened outdoor air inlets adjacent the windows in each office.



Source: Experimental Results and Experience from the Retrofit of an Office Building with Passive Cooling – REB Remscheid 176

Figure 126: Horizontal cross-section through the façade showing adjustable vents for fresh air intake

- Airtight construction was designed and intended to enable passive cooling and thermal efficiency. There are no fans provided and therefore differential air pressures are necessary to facilitate the flow of air. Air-tightness has been hard to achieve due to leakage between zones which should be cooled by night ventilation (the offices) and zones without planned night ventilation such as stairwells and service rooms. This has resulted in the passive cooling system being less effective than intended.
- A central gas condensing boiler is used to provide heating through hydronic panels. The location of the panels allows preheating of fresh air via the automated air intake vents adjacent the windows. Dependent on the season and mode of operation the air inlets can be fully open (night during summer), half-open (inside working hours) or completely closed (outside working hours in winter to prevent heat loss). Air renewal is automatically reduced when there are very low outdoor temperatures.

Figures 127 and 128: Air intake vents and hydronic heating panels

- Before exhaust air leaves the insulated envelope it passes via heat exchangers to pre-heat supply air for the ground floor offices and the washroom and hall areas. Vehicle garages are kept frost-free by blowing in exhaust air from the office area into the garages as required.

- A significant proportion of the domestic water heating is achieved using a 30 m² flat-plate collector system. Waste collection employees use the shower area and require around 1000 litres of hot water each day. A gas condensing boiler supplements the domestic water heating. Frank Ackermann explained that there had been problems achieving solar heated water in the quantities that the system was specified to deliver.
- All building services are automated and networked using a central building control technology system.
- External contoured Venetian blinds by Retrolux allow optimum natural light while reducing solar heat gain. The shape of the blind blades redirects sunlight to increase the amount of natural light reaching inside the building. The tilt angle of the slats also changes in accordance with the viewing angle. Ongoing maintenance is an essential aspect to ensure this system remains effective because build-up of dirt significantly reduces the reflectivity of the blades.
- A daylight-dependent artificial lighting control system with presence detection also reduces the energy usage for artificial lighting.
- The offices on the upper floor previously had a depth of eight metres. The depth of the rooms was reduced during the refurbishment to allow increased day light penetration and reduced requirement for artificial lighting. Central areas of photocopiers, kitchenettes were created in the middle. The uppermost level has a central light shaft which increases natural light to circulation areas.

Figure 129: External contoured venetian blinds

Figures 130 and 131: Increased natural light to uppermost level

Outcome

Energy data comparing usage before and after refurbishment shows the building to now be significantly more efficient.

Energy indices according to German regulation EnEV (in kWh/m^{2}a)	before refurbishment	after refurbishment
Heating energy demand	343.00	46.00
Overall primary energy requirement according to DIN 18599, Data after refurbishment exclusive of vehicle garage	440.00	108.00

Source: Waste disposal given a new facelift 177

Figure 132: Key energy data

Ongoing monitoring of the building revealed that the systems required modifications to achieve optimum performance. For example planned air changes in offices were initially too high. The shower and drying areas only required high ventilation rates whilst in use and so the rates and timings were altered.

Although it proved difficult to achieve the necessary airtight construction in the building envelope and interior, a comfortable indoor climate in summer was achieved without the installation of active cooling. This was verified with evaluation of the measurement data and occupant surveys.

6.8.3 Decathlon Building

Madrid Solar Decathlon 2010 Team Wuppertal

Building description: Every two years university teams from across the world compete in the Solar Decathlon. The teams design and build solar houses to suit the climatic conditions of the city where the competition is held. In 2010 Team Wuppertal and 16 other teams competed in Madrid. Ten days only were allowed for the teams to erect their buildings on the site. The houses were made open to the public and competed in ten categories. Primarily the buildings are required to demonstrate their self-sufficiency and energy efficiency.

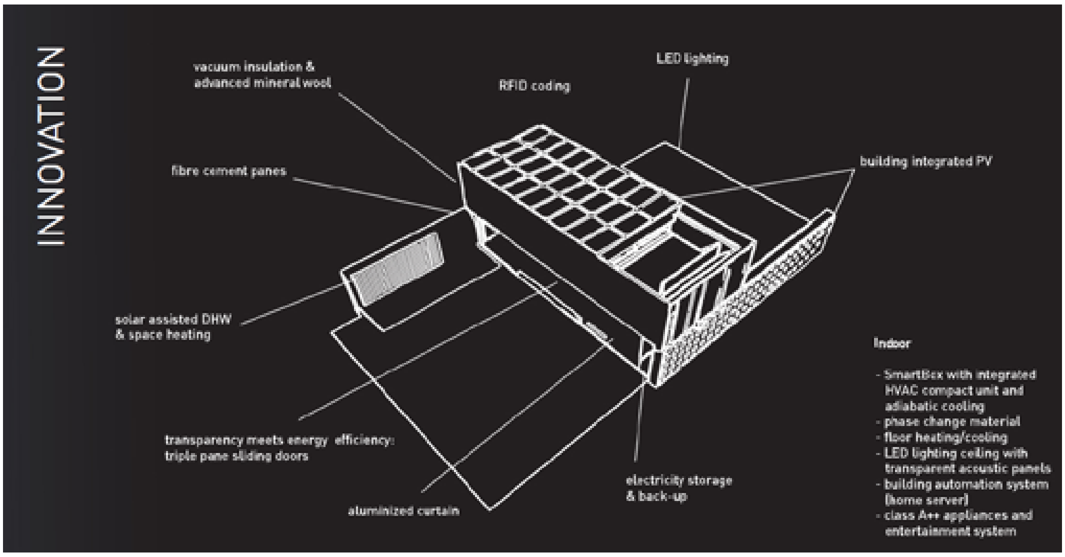
After the competition was finished the Team Wuppertal building was dismantled and reconstructed in Wuppertal, Germany where it is occupied and monitored for energy efficiency. The Fellow visited the building with Eike Musall on 23rd April 2012 and learned about the process of its creation and its sustainable design.

About 40 students from different departments in the University of Wuppertal worked together to plan, design and build their Decathlon house. One of the successes of the project derived from multidisciplinary input. The intent was to develop a building that suited any location in Europe. The team aimed at creating a holiday park unit prototype where holiday makers could experience living in an energy-plus house.

The team logo is made up of the team members and contributors to the project including sponsors of materials and equipment.


Figures 133 and 134: Team logo on the north facade of the house

Sustainability:



Source: Solar Decathlon Europe Team Wuppertal 2010, brochure 178

Figure 135: Team Wuppertal Decathlon House - Energy Concept diagram

- Small building size and optimum orientation contributes to thermal efficiency
- High level of air-tightness
- Triple glazing
- Solar assisted air-to-air heat pump
- Integrated heat exchanger that allows more than 80 per cent of the ventilation heat to be recovered in winter
- Effective cooling of supply air by evaporation of water in the exhaust air in summer
- Vacuum Insulated Panel insulation (refer to Section 6.4.7.6)
- Thermal mass using phase change materials (refer to Section 6.4.7.8)
- Solar hot water

- Photovoltaic south facade combining mono and polycrystalline solar cells
- Building integrated photovoltaic roof
- Appliances with the lowest possible energy demand
- Building management system (controlling HVAC and automated curtains for control of heat gain and loss)
- LED lighting with integrated motion sensors to track occupants and provide lighting only where needed
- Life cycle analysis demonstrated that the building will offset all its embodied energy and the associated carbon emissions after 13 years of grid connected operation. [179 180]

Figure 136: West facade with mechanically adjustable external curtains

Figure 137: Exterior view showing south facing solar hot water collectors and photovoltaic wall panels

Figure 138: View of interior, deck and south facing solar hot water collectors

Figure 139: Interior view of kitchen with south facing clerestory windows.

Outcome

The Wuppertal Decathlon House was awarded second place in the categories 'Architecture' and 'Lighting', third place in 'Household appliances and functionality' and sixth place in the overall assessment at the Madrid Decathlon in 2010.

The creation of this building enabled an amazing multidisciplinary learning experience for all the students and lecturers involved. Additionally, 190,000 visitors had the opportunity to visit and learn from the many buildings displayed at the Decathlon competition in Madrid. The building now located in Wuppertal continues to be an educational resource to students and visitors.

A team of students from the University of Wollongong and Illawarra TAFE has won a place to enter the Solar Decathlon to be held in China in August 2013. The building will be built in Wollongong and then shipped to Datong, about 300 kilometres from Beijing.[181 182]

Solar Decathlons are tremendous learning opportunities for the decathletes who participate and also for homeowners, building professionals, teachers and greenskills students who can visit and compare an impressive range of extremely efficient buildings.

6.8.4 Geothermal heat pumps in Germany

Karsten Voss is professor of building physics and building technical services at the School of Architecture at the University Wuppertal, Germany. Voss and Musall are co-authors of the book Net Zero Energy Buildings – International projects of carbon neutrality in buildings.

Voss explained that geothermal heat pumps were now very common in Germany. A typical new house would have one or two closed loops to a depth just under 100 metres.

The combination of airtight, well insulated buildings, triple glazing, photovoltaic modules, heat recovery ventilation and geothermal heat pumps creates efficient buildings and utilises renewable energy sources.

Outcome

The Fellow recommends that Australia has a great deal to learn about geothermal systems and their application to heating and cooling buildings. Europe would be an excellent place for future ISS Fellows to gain information.

6.8.5 Split Incentives

Voss also discussed a major barrier to building thermally efficient buildings. He gave the example of a proposed University building under consideration at present. One government department is responsible for the construction of the building and another for paying the utilities. This creates a split incentive as the building department is focused on minimising upfront construction costs. The department has no motivation to build in such a way as to reduce ongoing utility, maintenance or equipment replacement costs.

Outcome

Australia is not alone in facing the barriers of split incentives.

6.9 Visit to Brussels, Belgium-Adam McCarthy, Johnson Controls– 25th April 2012

Adam McCarthy is the Director, Government & Trade Relations Europe, Building Efficiency of Johnson Controls International.

Johnson Controls are a leading provider of equipment, controls and services for heating, ventilating, air-conditioning, refrigeration and security systems. They are an international company with 500 branch offices in more than 150 countries. Johnson Controls have been involved in more than 500 renewable energy projects including solar, wind and geothermal technologies. [183]

6.9.1 Learning from Europe and the UK

The Fellow asked McCarthy where to look for expertise.

McCarthy sees Germany as the poster child for energy efficiency with the UK having impressive and ambitious targets. France comes in third in his opinion with the Grenelle Environmental Laws.

The Grenelle Environmental Project was launched in 2007 with a conference which brought together government, local authorities, trade unions, business and voluntary sectors to draw up a plan of action of measures to tackle the environmental issues and sustainable development. Bills and laws have followed including the following relating to buildings;

"The Grenelle 2 law sets a target of reducing the average energy consumption of buildings nearly 40 per cent by 2020, and puts a focus on advanced energy performance for both old and new buildings. New buildings built after 2012 are to consume less than 50 kilowatts per square meter, and those built after 2020 must be 'energy positive', producing more energy than they consume. As of 2013, old buildings must be renovated at a rate of 400,000 buildings per year, with the renovation of public buildings starting before the end of 2012. Through this means, the government aims to reduce the energy consumption of public buildings by at least 40 per cent and to cut their greenhouse gas emissions 50 per cent by 2020.

Additionally, as of 2012, renters of real estate must be informed about the energy performance of their buildings so that they can make energy costs part of their decision to rent a place or not." [184]

6.9.2 EU Policies

McCarthy explained the three main EU policies that are driving change:

- 20/20/20 (refer to Section 6.7.4)
- EPBD Recast to be implemented by July 2012 (refer to Section 6.7.4)
- Energy Efficiency Directive (EED) June 2011.

The main purpose of the Energy Efficiency Directive (EED) is to make a significant contribution to meeting the EU's 2020 energy efficiency target. The Directive does not propose to introduce binding national energy efficiency targets, but proposes, what the Commission calls 'binding measures'. The Commission will review progress in 2013/14 and propose binding targets for all Member States if it appears the 20 per cent target will not be achieved. [185]

The main elements of the Energy Efficiency Directive

- *Each Member State will establish an energy efficiency obligation scheme. There will be a legal obligation to establish energy saving schemes in all MS. Energy companies will be obliged to save* *every year 1.5 % of their energy sales, by volume, through the implementation of energy efficiency measures such as improving the efficiency of the heating system, installing double glazed windows or insulating roofs, among final energy customers. However, Member States are given the option to introduce alternative measures than an efficiency obligation scheme to achieve savings among final customers. The savings must be equivalent to the target as set out in the obligation scheme.*

- *Public sector will be required to renovate 3% of their building stock by floor area annually to cost optimal levels. Buildings need to have a useful area larger than 250 sq. m. in order to be covered by this requirement.*
- *Billing of energy consumption should be based on the actual consumption reflecting data from the metering. There should be easy and free-of-charge real-time and historical consumption based on smart metering.*
- *There should be incentives for SMEs (small and medium sized enterprises) to undergo energy audits and disseminate best practices. Large companies will be required to make an audit of their energy consumption in order to identify the potential for reduced energy consumption.*
- *The directive calls for improving the efficiency in energy generation. This includes monitoring of efficiency levels of new energy generation capacities, establishment of national heat and cooling plans as a basis for a sound planning of efficient heating and cooling infrastructures, including recovery of waste heat.*

Extract from The proposed EU Energy Efficiency Directive [186]

McCarthy believes that renewable energy is an easier concept for politicians to invest in. Energy efficiency is more complex. The Fellow, having gleaned information from many sources whilst in Europe regarding EU policy for energy efficient buildings, is inclined to agree.

6.9.3 Demand for Greenskills Engineers

McCarthy explained the difficulty faced in recruiting energy engineers. Demand for this type of graduate is strong across Europe. This undersupply requires Johnson Controls to sponsor other types of engineering graduates to further their education in 'green building' engineering.

The Energy Efficiency Plan March 2011 which preceded the EED in June 2011 supports improving training for architects, engineers, auditors and others because energy efficient building solutions are often technically demanding. [187]

Training

Energy efficient building solutions are often technically demanding. There is a lack of appropriate training for architects, engineers, auditors, craftsmen, technicians and installers, notably for those involved in refurbishment. Today, about 1.1 million qualified workers are available, while it is estimated that 2.5 million will be needed by 2015 . The Commission is therefore launching the 'BUILD UP Skills: Sustainable Building Workforce Initiative' to support Member States in assessing training needs for the construction sector, developing strategies to meet them, and fostering effective training schemes. This may lead to recommendations for the certification, qualification or training of craftsmen. The Commission will also work with the Member States to adapt their professional and university training curricula to reflect the new qualification needs (in line with the European Qualification Framework). The Commission's Flagship Initiative "An Agenda for New Skills and Jobs" calls for skills supply to be matched with labour market needs. Transition to energy-efficient technologies requires new skills, environment-conscious vocational education and training in construction and in many other sectors.

Extract on 'Training' from Energy Efficiency Plan March 2011 [188]

6.9.4 Collaboration

There is industry identified need for different disciplines to communicate and collaborate effectively. McCarthy of Johnson Controls says, “Engineers are terrible at talking to architects. They speak different languages and this creates conflict”.

McCarthy is not talking about different European languages but the conflicts that result when participants in a building project are on different wavelengths with different priorities. An example of a project where poor communication created problems was given. However, McCarthy requested that no details regarding specific clients or projects be given. Time together collaborating and understanding is the key to successful implementation of projects and McCarthy supports the concept of multidisciplinary learning for greenskills students.

6.9.5 Refrigerants dilemma

Johnson Controls provide HVAC systems and therefore face a dilemma regarding types of refrigerants used. Continued use of hydrofluorocarbons (HFCs) and chlorofluorocarbons (CFC) refrigerants (which are highly efficient) have a global warming potential (GWP) when released to atmosphere. Changing to alternatives such as ammonia (NH_3), CO_2 and hydrofluoro-olefin (HFO) refrigerants are less harmful to the environment. HFO’s are categorised to have zero ODP (Ozone Depletion Potential) and lower Global Warming Potential than HFCs.[189] NH_3, CO_2 and HFO offer a more environmentally friendly alternative than CFCs, HCFCs and HFCs. However, these alternatives are less energy efficient and have flammability and toxicity risks. The tightness of the system to contain the refrigerant in all situations is imperative.

6.9.6 Building Management Systems (BMS) Systems

McCarthy commented regarding Building Management Systems that, “the old view was the more buttons is better”. Now there is evidence that the energy cost of running automated BMS is considerable and needs careful design and consideration.

There are also issues for data security and privacy in collecting energy performance data. Energy usage data is commercially sensitive and this can create a problem for clients agreeing to install monitoring systems for energy performance.

Concluding Remarks

By studying European policies the Fellow had anticipated identifying areas where policies have been very effective and where they have failed to generate the gains anticipated in order to inform Australian regulatory reform. The complexity of this topic is vast and well beyond the scope of this report. EU is in the process of significant change. There are key milestones in 2013/14 and 2020 where progress will be assessed by the EU to determine if energy efficiency targets are being met. The Fellow recommends that this be the subject of further research activities when this information becomes available.

Outcomes

The implementation of ambitious energy efficiency initiatives has created a skills shortage in Europe. It is estimated that 2.5 million workers will be needed by 2015 up from 1.1 million in 2011.[190] There is a lack of appropriate training for greenskills workers including professionals, technicians and tradespeople with the area of refurbishment being particularly identified.

In addtion to applying stringent energy efficiency and nZEB principles to buildings the EU are focussing on vocational education and training in the areas of energy-efficient technologies and construction. Educational methodologies such as multidisciplinary learning which promote collaboration and understanding between all participants in the design and construction of buildings will facilitate better outcomes.

6.10 Visit to Muttenz and Basel, Switzerland – Armin Binz – 27th April 2012

Professor Armin Binz is the Head of the Institute of Energy in Building, FHNW School of Architecture, Civil Engineering and Geomatics at the University of Applied Sciences and Arts, Northwestern Switzerland. Binz is also the Head of Minergie® Building Agency.

6.10.1 Minergie®

Minergie® is the Swiss energy label launched in 1998. It is a private organisation owned by the non-profit Minergie® Association and sets benchmarks and tools to combine energy efficiency in building with improved comfort. Minergie® is a registered trademark and a labelling system. It is not just about accrediting energy efficient buildings. Also involved are groups and individuals who can be accredited organisations or professional partners, accredited building products and the methodologies to achieve a quality label for new and refurbished buildings. There are also planning tools, seminars, conferences and training courses. The information is available in German and French.

Minergie® Members

There are approximately 370 Cantons, Federations, Associations, firms, Universities and people who are Minergie® members.

Minergie® Fachpartners

Fachpartners are professional partners and specialised firms for the planning and implementation of Minergie®. There are currently about 1700.

Minergie® Modul

The 'moduls' are accredited building products and equipment which are certified as having exceptionally high energy efficiency. Minergie® Moduls currently include 160 wall/roof products, 70 window types, 21 door types and 200 lamps.

Minergie® Buildings (25,000)

Buildings of this standard require general energy consumption not higher than 75 per cent of that of average buildings and their fossil-fuel consumption must not be higher than 50 per cent of the consumption of average buildings.

For accredited Minergie® Buildings there are limiting values for energy consumption and these can be found on the Minergie® website [191] or in English on the Information for Architects brochure. [192]

For a building to be accredited there is a requirement for detailed qualitative proof of energy performance (for heating, hot water, ventilation and air conditioning).

There are standardised solutions for Residential Minergie® Buildings for the building itself and the equipment. A set of U-values for the building envelope must not be exceeded; 0.15 W/m^{2}K for walls, roof and floor, 1.0 W/m^{2}K for windows and 1.2W/m^2 for doors. Fan assisted balanced ventilation systems with a heat recovery unit (with 80 per cent minimum efficiency) need to be installed and must be driven by an AC or DC motor.

There are then five possible standard solutions from which to choose:

1. Ground-source heat pump (geothermal heat pumps) for heating and hot water (all year)
2. Wood-fired systems for heating and hot water in winter, thermal collectors for hot water in summer
3. Automatic wood-fired systems for heating and hot water (all year), e.g. pellet-furnace
4. Use of waste heat (industry, waste incineration and sewage treatment plants) for heating and hot water (all year as single source)
5. Air-to-water heat pump (outside air) for heating and hot water (all year). [193]

As an alternative to the standard solutions, Minergie® certification is also possible by adopting custom-designed solutions.

The combination of a high quality building envelope and good indoor air quality from the heat recovery ventilation system creates thermal and environmental comfort for building occupants.

Importantly, to meet the Minergie® Standard, costs cannot exceed 10 per cent of total building costs. The intention is to ensure feasibility and increased uptake of the standard. This is a voluntary standard and there are now 25,000 Minergie® Buildings across Switzerland (population less than eight million).

Minergie-P® Buildings (1500)

This standard defines buildings with very low energy consumption and it is especially demanding in regard to heating energy demand. Minergie-P® buildings have a similar performance standard to Passivhaus buildings.

Minergie-ECO® Buildings (200)

There are about 200 Minergie-ECO® Buildings. This standard adds ecological requirements such as embodied energy, recyclability, indoor air quality and noise protection to the regular Minergie® Buildings requirements. The embodied energy requirement was added to this classification since March 2011.

Minergie-P-ECO® Buildings (280)

This standard adds ecological requirements such as embodied energy, recyclability, indoor air quality and noise protection to the regular Minergie-P® Buildings requirements.

Minergie A® Buildings (30 built and 130 current applications)

Minergie-A® is a label for new and refurbished low-energy-consumption buildings that seek ‘nearly Zero-Energy Buildings’ according to the EU guidelines 2010/31.[194]

These buildings demonstrate reasonable and feasible ways of reaching Nearly Zero-Energy Buildings and foster and promote new technologies, materials and solutions for energy efficient buildings. For these reasons they are not to be perceived as Minergie-P® Buildings with lots of photovoltaic according to the authors of From MINERGIE- P to MINERGIE-A (Nearly Zero Energy Buildings). [195]

Minergie-A® buildings take into account the energy balance unlike Minergie® and Minergie-P® standards.

The following requirements must be met:

- Heat demand 90 per cent or less of the limit of the standard SIA 380/1 (like Minergie®)
- At least half of the heat demand must be met using solar panels
- Weighted Energy Index < 0 kWh/m^2 (15 kWh/m2 BEI using a biomass plant)
- Energy-efficient household appliances
- Gray Energy Index < 50 kWh/m^2 (Gray energy is that which is produced from fossil fuels)
- The energy balance of zero in the operation is mandatory.

The Minergie-ECO® Standard can be combined with the Minergie-A® leading to the Minergie-A-ECO® Standard. [196]

Like Passivhaus, Minergie-P® and Minergie-A® buildings require highly efficient heat recovery systems. Binz explained that all Swiss houses, even those with heat recovery ventilation have openable windows. Therefore if the weather is pleasant or the house becomes smelly or smoky, windows can be opened. The heat recovery systems have three settings: one, two and Fondue. Fondue is the setting used when maximum mechanical ventilation is required.

6.10.2 IWB Energy Customer Centre

Address: IWB Customer Centre, Basel, Switzerland

Building Description:

Binz explained that although this seven-storey building is located in a crowded city location with poor solar access, it was still possible for it to achieve a Minergie-P® energy standard. IWB is the city of Basel's energy provider. The building was completed in 2008 and consumes only a tenth of the energy used by similar business premises. [197]

Sustainability:

- Quadruple-glazed windows to the back and triple-glazed windows to the front.
- External adjustable louvres control solar heat gain. The shape of the louvres allows increased sunlight penetration reducing demand for artificial lighting.
- Airtight building shell with no electrical sockets or unsealed windows to allow draughts of air. The electrical cables were all laid in floor ducts.
- For reasons of sustainability the primary and secondary structures were built separately (no pipes set in concrete etc.).
- The sun's radiation through the windows and waste heat from appliances, lighting and people are almost sufficient to heat the seven-storey building.
- The small amount of remaining energy required is provided by a gas-fired heat pump.
- Heat recovery ventilation system provides fresh air intake and exhaust without wasting energy.
- The environmental impact of demolition and construction activities was considered
- Low embodied energy of new building materials.
- Design optimised for future maintenance so that for example no walls need to be opened up to replace the ventilation system.

- Sliding doors were put through a blower door test. A hydraulic pump in the cellar blows up the rubber tubes in the glass sliding doors until they are airtight. [198]

Source: IWB Customer Center Fact Sheet 199

Figures 140 and 141: IWB Customer Centre- night and day views

6.10.3 2000-Watt Society

"The concept of the 2000 Watt society is grasped by many people not just the professionals," say Binz. Currently USA uses 10,000 watts per person and Europe 6,000. It is a top down approach that started around ten to 12 years ago and is integrated into the policies of many countries including Switzerland. It aims at sustainability and fair distribution of global resources. The concept covers all aspects including housing, commercial buildings, construction, mobility and recreation.

One of the main objectives in Switzerland of the 2000 Watt-Society is a reduction in primary energy consumption by a factor of three from the current 6,000 watts per person to 2000 watts. Within the 2000 watts only 500 watts should come from fossil fuel energy sources with the rest coming from renewable energy. These levels of consumption would meet the needs of a sustainable society and the target is to be achieved by 2050.

Basel, Switzerland is the home of 2000-Watt Society pilot projects including:

- A practice laboratory for Sustainable Urban Growth
- Gundeldinger Feld
- 100 environmentally friendly taxis
- Street cleaning vehicle powered by hydrogen fuel cell
- New and retrofit pilot building projects to Minergie-P® standard [200]

6.10.4 Gundeldinger Feld

A visit to the Gundeldinger Feld project (one of the 2000-Watt Society pilot projects) was conducted by Binz where the Fellow met the architect, Barbara Buser. The project concept was explained by Binz and Buser.

Address: Gundeldinger Feld, Basel, Switzerland

Description:

An engineering works industrial site (12,000m^2) has been transformed into a community business, activity and leisure centre with a public character. The local area previously had very little green or open space and when the opportunity for development was muted, the greatest need was not for more housing, but for a socially and culturally diversified mix of activities in the heart of a very densely populated district.

Now there are sixty-five organisations leasing tenancies within the former factory site. These are non-profit organisations, small workshops, craft studios, consulting companies, lawyers, libraries, playgrounds, children's circus, climbing hall, a brewery and several restaurants. One of the restaurants is operated by blind people who serve their customers in complete darkness. The tenants are required by their tenancy agreements to use energy sparingly. Each tenant has been carefully selected to create as varied and complementary mix as possible. The area is very popular and used by more than 1000 people daily.

Designer: Barbara Buser - Architect

Sustainability:

Sustainability measures include renovation rather than demolition, water-saving devices, sensor-controlled energy saving lighting, recycled and green building materials, ecological paint, roof gardens and a 370m^2 photovoltaic solar installation. Gundeldinger Feld is essentially a car-free zone with only two accessible car parking spaces available.

Figure 142: Gundeldinger Feld- Tenancy board and solar energy generation display

Figure 143: Gundeldinger Feld – Inside one of the renovated factory buildings

6.10.5 Multidisciplinary learning

Source: Cultural oasis in the middle of the town, Gundeldinger Feld, Basel 201

Figure 144: Gundeldinger Feld – View of green roof and outdoor community space

Binz discussed multidisciplinary learning that is undertaken in the University of Applied Sciences and Arts. The most difficult aspect of multidisciplinary projects shared by architectural and engineering students is coordinating the timing so that all students are busy and not waiting on others so that they can progress.

Concluding Remarks

The success of Minergie® can be attributed to several factors;

Great communication – The Minergie® website has a database with details of all the Minergie® buildings so that future building project clients can investigate local examples and view project data. The website has a database of energy professionals and one for all the accredited building products and equipment options including heat recovery ventilation.

Resources, tools and training – Available on-line are a comprehensive range of publications and tools to assist the public and professionals to understand and use the accreditation system. Unfortunately this information is in German and French only.

Cost optimisation – Ensuring that costs to meet the Minergie® Standard do not exceed 10 per cent of total building costs sends out a positive message that high performance buildings are affordable. Since compared to a conventional building, a Minergie® certified building can cut energy costs by up to 60 per cent, the long term economic benefits are also recognised by the public. [202]

Unlike some other parts of Europe, a substantial amount of construction is being undertaken in Switzerland, with a strong uptake of Minergie® accredited buildings. Binz and Buser commented that the employment prospects for architectural and greenskills graduates were good in Basel.

Outcomes

Due to the Swiss energy label, Minergie®, Switzerland is in a strong position to be able to achieve the nearly Zero-Energy Buildings requirements by 2020 according to the EU guidelines. Both Minergie® and Passivhaus have years of research and development, numerous examples and tested methodologies for students and practitioners to learn from.

7. Knowledge Transfer: Applying the Outcomes

7.1 Dissemination Sessions

Box Hill Institute of TAFE (BHI)

Event: Teaching and Learning Symposium

Date: Thursday, 13th September 2012, 10.45am – 11.45 am

Location: Nelson Campus, Box Hill, Victoria

Audience: All interested teachers across all disciplines at BHI

Workshop session

Collaborative and multidisciplinary learning environments – Problem Based Learning.

Victorian Advanced Building Studies Network (VABSN)

Event: VABSN meeting

Date: (tbc)

Location: RMIT (tbc)

Audience: Teachers and managers responsible for delivering the Advanced Diploma of Building Design (Architectural) and Diploma of Building and Construction (Building) including, Box Hill Institute, RMIT University, Northern Melbourne Institute of TAFE, Chisholm Institute, Holmesglen Institute, Swinburne University of Technology, Wodonga Institute, University of Ballarat, Bendigo Regional Institute of TAFE, Gordon Institute and Victoria University.

Briefing Report

Collaborative and multidisciplinary learning environments for building design, engineering, building and construction trade students; and European case studies for thermally efficient, sustainable building design and construction.

Australian Institute of Building Surveyors (AIBS)

Event: Australian Institute of Building Surveyors International Conference

Date: Monday 22rd October 2012, 1.30 – 2.00pm

Location: The Promenade Room P1/2/3, Crown Promenade Hotel

8 Whiteman Street, Southbank Melbourne

Audience: Building surveyors

Session

Net or Nearly Zero Energy Building Definitions and the Implications for Regulatory Reform.

7.2 Outcomes

7.2.1 Compare regulatory frameworks for energy efficient buildings

Action:

By analysing and comparing European regulatory systems, it was anticipated that the Fellow would be able to identify areas for discussion regarding Australian regulatory reform and potentially advise on areas where European policies have been very effective and where they have failed to generate the gains anticipated.

Outcomes and recommendations:

The three main EU policies that are driving change for energy efficient buildings are:

- 20-20-20 (refer to Section 6.7.4)
- EPBD Recast to be implemented by July 2012 (refer to Section 6.7.4)
- Energy Efficiency Directive (EED) June 2011 (refer to Section 6.9.2).

The Energy Performance of Buildings Directive dictates that the implementation of nearly Zero-Energy Buildings will take place as from 2021 onwards (2019 respectively for public buildings).

The EPBD defines a nearly Zero-Energy Building as a “building that has a very high energy performance as determined in accordance with Annex I. The nearly zero or very low amount of energy required should to a very significant extent be covered by energy from renewable sources, including renewable energy produced on-site or nearby”.

The EPBD does not prescribe a uniform approach for implementing nearly Zero-Energy Buildings and neither does it describe a calculation methodology for the energy balance. To add flexibility, it requires Member States to draw up specifically designed national plans for increasing the number of nearly Zero-Energy Buildings reflecting national, regional or local conditions. The national plans will have to translate the concept of nearly Zero- Energy Buildings into practical and applicable measures and definitions to steadily increase the number of nearly Zero-Energy Buildings. [203]

Many EU member states have already created their own methodologies for achieving these targets and therefore a myriad of tools, labelling systems and definitions are already established for low energy buildings such as Passivhaus (Refer Section 6.4.3), Zero-energy, Zero-Carbon, 3-litre, Plus energy, Minergie® (refer to Section 6.10.1) and Effinergie.

Indoor Air Quality (IAQ) testing of buildings will be introduced across the EU as part of EPBD directive in 2018-2020. However, it will expand to encompass more aspects of Indoor Environmental Quality (IEQ). These will include thermal comfort, lighting comfort, noise comfort and indoor air quality.

We can learn from Portugal (the early adopter) that the testing process can be expensive and time-consuming. The introduction of this system requires a robust auditing process by qualified IAQ professionals to ensure accurate and reliable certification reporting. The health, well-being and productivity of people are essential aspects of providing sustainable buildings. Improvements in sealing the building envelope, increased use of computers and printers, synthetic building materials and ongoing maintenance requirements for HVAC systems are all factors that could adversely affect the quality of indoor air. In improving energy efficiency and thermal performance we may unwittingly decrease IAQ. As Australia moves towards more intensive testing for thermal performance including blower door testing and thermography, it seems appropriate to complete the testing regime to ensure thermal comfort, health and energy efficiency are all achieved.

The European Union is setting stringent targets for energy efficient buildings with very specific carbon emission reduction targets to be achieved by 2050. There is an acknowledgement that buildings have a long lifespan (and long intervals between significant refurbishments) and therefore significant change needs to be implemented in the very near future to achieve long term goals.

In this regard the Europeans have a sense of urgency and commitment to tackling this task. The implementation of nZEB as a mandatory requirement in the future has been calculated to create about 345,000 additional jobs assuming an extra investment of EUR 39 billion per year and an average turnover in the EU construction industry of EUR 113,000 (in 2008) per person and year.[204] Although Europe has been severely affected by the global financial crisis, their obligations under the Energy Performance of Buildings Directive are going ahead.

Similar to the European Union, the UK Government announced a rapid transition to 'zero carbon' new building in December 2006 as a key step forward in reducing the Green House Gas (GHG) emissions from the domestic and non-domestic sectors.[205]

In contrast Australian policy appears to have no timeline and lacks urgency in increasing minimum energy efficiency and thermal performance requirements for buildings. Whilst the Fellow was in Europe (April 2012) the Victorian government was considering scrapping 6 Star energy ratings in lieu of 5 Star indicating this as a useful method of cutting government red tape. [206] This blip on progress towards more sustainable built environments indicates a lack of awareness and consideration for the long term consequences of stalling improvements in thermal performance and energy efficiency. Consequences not only relate to carbon emission mitigation but also to affordability of utility bills for building occupants and long-term financial benefits for householders. [207]

A great deal of excellent work towards sustainable building design and construction is being undertaken by Department for Climate Change and Energy Efficiency, Green Building Council Australia (GBCA), Australian Sustainable Built Environment Council (ASBEC), Building Designers Association of Victoria (BDAV), Australian Institute of Architects, building designers, architects, builders, engineers, building surveyors, educators, researchers and many others.

Generating the political will to adopt more stringent mandatory requirements more quickly is the key to accelerating environmental benefits, carbon mitigation, energy affordability, thermal comfort and long-term financial benefits for Australians.

The European Union and UK have the political will to make this happen quickly even in the midst of economic crisis. They realise the consequences of inaction or slow action would have serious environmental and economic ramifications for 2050 and beyond.

7.2.2 Investigate the development of Net or Nearly Zero-Energy Building definitions and the implication for regulatory reform

Action:

Understanding the range of definitions and the way in which European national codes will be gradually strengthened towards the more stringent requirements of these nZEB definitions is an area of interest to Australian regulatory bodies and ultimately the Australian construction industry.

Outcomes and recommendations:

The European Member States will be drawing up national plans for increasing the number of nearly Zero-Energy Buildings and these will need to include:

- A definition of nearly Zero-Energy Buildings, reflecting national, regional or local conditions including a numerical indicator of primary energy use, expressed in kWh/m² per year
- Intermediate targets for improving the energy performance of new buildings by 2015. [208]

There are many challenges ahead for Europe in defining nearly Zero-Energy Buildings (refer to Section 6.7.5).

This report includes a summary of the challenges and variables currently being discussed and does not attempt to deliver a recommendation.

Skills deficiencies that require further education to enable the successful implementation of nZEB buildings are:

- Training in energy efficient building design for designers, engineers and architects
- Trade skills for construction of nZEBs, including all building trades
- Training of 'greenskills' professionals in calculation methodologies and ongoing building monitoring to enable the difference between calculated and actual building performance to be identified and addressed
- Training in post-occupancy commissioning and maintenance.

7.2.3 Investigate EU rating processes

Action:

Comment and compare the two rating processes: Passivhaus and Minergie®.

Outcomes and recommendations:

Both Passivhaus and Minergie® rating methods and tools are extremely effective in achieving energy efficient and thermally comfortable buildings. It should be noted that Minergie-P® and Minergie-P-ECO®, are those that are comparable in energy efficiency to Passivhaus standard. Minergie A® Buildings are those that seek nZEB status. The methodologies have been used to build many buildings; 20,000 Passivhaus buildings in Europe[209], 1500 Minergie-P®, 280 Minergie-P-ECO® and 30 Minergie A® Buildings in Switzerland[210]. Extensive monitoring and research has been undertaken proving the effectiveness of both.

The advantage of Minergie® is that to meet the Minergie-P® standard, building costs cannot exceed 10 per cent of total building costs. The intention is to ensure feasibility and increased uptake of the standard. This is a voluntary standard and there are now more than 1800 Minergie-P® and Minergie-P-ECO® buildings in Switzerland (population less than eight million).

Another difference between Minergie-P® and Passivhaus is that the latter treats solar gain with less importance than low U-values (high R-values) and being air tight. Minergie-P® requires the main facade to have an orientation from southwest to southeast and be 30 per cent transparent. [211]

The main disadvantage of the Minergie® energy label, tools and resources for adoption in Australia, is language. The information is available in only German and French. Examples of Minergie® buildings adapted and constructed for warmer climates were not identified by the Fellow.

The Passivhaus standard has all resources available in English language. It is used extensively in the UK and many parts of Europe. The standard not only applies to the cooler European climates but also works for warmer countries including Spain and Portugal, parts of which have similar climates to

Melbourne. The Passive-On project is a completed research and dissemination project which worked to promote Passivhaus and the Passivhaus Standard in warm climates.

Passivhaus buildings have been built in hot climates. For example, the 204House in Lafayette, Louisiana, USA was certified by Passive House Institute US in 2010. The climate is hot and humid so an Energy Recovery Ventilation (ERV) and an efficient air-conditioner provide cooling and dehumidification. The house is reported to be comfortable for the occupants and have energy bills averaging less than $25 per month. [212]

For these reasons (English language resources and availability of Passivhaus case studies in warm and hot climates), Passivhaus would be the preferred option for Australian practitioners to try, develop and monitor in Australia.

Melbourne appears to be the Australian city with the most interest in trialling Passivhaus principles with Grocon, Studio 505, Sustainable Built Environments and Passive House Pty Ltd (Peter Steudle and James Anderson) all active in this area.

- Government support for educational resources and dissemination of information about prototype Passivhaus Australian buildings is recommended.
- Greenskills students will benefit from information disseminated by architects, builders and engineers involved in the design, construction, monitoring and building management of the first Passivhaus buildings constructed in Australia.
- Tours of Passivhaus buildings will also be useful for students and practitioners to see the buildings in action and experience the level of thermal comfort and indoor air quality that can be achieved. Any preconceived ideas about poor indoor environmental quality in airtight buildings can then be reconsidered.

7.2.4 Affordable solutions in sustainability for new and renovated building developments including innovative materials and methods to improve sustainability

Action:

Disseminating information on these findings.

Outcomes and recommendations:

In conjunction with multi-disciplinary learning, educational tools that facilitate broader knowledge beyond a single discipline's area of expertise will lead to improved collaboration and project outcomes. For example, life-cycle costing, pay back calculations and cost-optimisation methodologies should be introduced and studied by all greenskills participants, not just the cost estimators.

It is recommended that the Advanced Diploma of Building Design (Architectural) course advisory committee consider developing an additional unit on cost estimating (including life-cycle costing, pay back calculations and cost-optimisation methodologies).

It is also recommended that industry (designers, architects, engineers, cost-estimators and builders) involved in prototype sustainable buildings be encouraged (and funded by government) to share learnings on life-cycle costing, pay back calculations and cost-optimisation methodologies.

New innovative building materials for improved thermal efficiency, energy efficient service equipment and on-site energy generation products are all expensive. With time, increasing energy costs and more stringent building regulations will drive increased demand for higher performance sustainable buildings and the products that can achieve this. It is only when products become mass-produced that prices become affordable. Therefore, ongoing support for research is essential for materials, equipment and prototype buildings.

The use of innovative materials and products should be used and tested in new thermally efficient prototype buildings in Victoria to assess their suitability and effectiveness under local environmental conditions.

Prototype refurbishment projects are also required so that thermal comfort and performance data can be collected and interpreted. Analysis is required to determine the most effective materials in terms of thermal performance, practicality, ease of installation and cost. This research is necessary to enable building owners to make cost optimal decisions when upgrading existing building stock to achieve improved thermal performance.

7.2.5 Skills to implement a successful collaborative and multidisciplinary learning environment for building design, engineering, building and construction trade students

Actions:

- Disseminate learnings to teachers regarding multidisciplinary projects
- Implement multidisciplinary learning strategies in the new Integrated Technology Hub.

Outcomes and recommendations:

By visiting universities in Denmark and Germany the Fellow was able to evaluate three multidisciplinary projects for greenskills students and discuss multi-disciplinary problem based learning methodologies.

Erasmus Project – VIA University College, Horsens, Denmark

The Erasmus project allowed students to experience a working environment where collaboration was the key to success. The experience was extremely valuable in preparing students for industry.

Problem-based learning PBL, Aalborg University, Aalborg, Denmark

The benefits of multi-disciplinary project work based on the Aalborg model for Problem Based Learning were:

- Working processes are similar to working in modern organisations
- It develops analytical, methodical and transferable skills
- It develops learning motivation
- It is student oriented
- It decreases drop-out rates
- It meets the new qualification requirements for collaboration, communication and problem solving.

Visit to Digital Days at University College Nordjylland, Aalborg, Denmark

Digital days were a three day intensive multi-disciplinary Building Informatics Project. The students were using software relevant to their discipline to analyse and create digital models for a proposed four storey oncology building project. Trades students also participated by building prototype building elements.

The benefits of this intense project could be seen as the students were very actively engaged. Communication between the disciplines was the key to success and prepares students for the workplace where all greenskills participants require excellent communication skills to collaboratively design and build highly energy efficient buildings.

Madrid Solar Decathlon 2010 Team Wuppertal- University of Wuppertal, Germany

Every few years university teams from across the world compete in the Solar Decathlon. The teams design and build solar houses to suit the climatic conditions of the city where the competition is held. The houses were made open to the public and competed in ten categories. Primarily the buildings are required to demonstrate their self-sufficiency and energy efficiency.

The creation of the Wuppertal Solar Decathlon building enabled an amazing multidisciplinary learning experience for all the students and lecturers involved. Additionally, 190,000 visitors had the opportunity to visit and learn from the many buildings displayed at the Decathlon competition in Madrid. The building now located in Wuppertal continues to be an educational resource to students and visitors.

A team of students from the University of Wollongong and Illawarra TAFE has won a place to enter the Solar Decathlon to be held in China in August 2013. The building will be built in Wollongong and then shipped to Datong, about 300 kilometres from Beijing.

Solar Decathlons are tremendous learning opportunities for the decathletes who participate and also for homeowners, building professionals, teachers and greenskills students who can visit and compare an impressive range of extremely efficient buildings.

Disseminate learnings to teachers regarding multidisciplinary projects.

- Distribute report to the VABSN members – managers and teachers involved in delivery of the Advanced Diploma of Building Design (Architectural).
- Provide an information session at a meeting of VABSN members.

Implement multidisciplinary learning strategies in the new Integrated Technology Hub.

- In conjunction with managers and teachers at BHI, develop and implement a multidisciplinary learning strategy for 'greenskills' students in the new Integrated Technology Hub, opening late 2013/ early 2014.

8. Recommendations

Government – Federal, State, Local

- Continue to encourage and support the construction, commissioning and monitoring of exemplar prototype buildings.
- Continue to develop on-line documentation regarding exemplar buildings including virtual tours, the decision making process, life-cycle costing / pay back calculations, cost-optimisation methodologies, project successes and problems/failures, handover, defects rectification and building facility maintenance.
- Increase the stringency of thermal performance regulations and clearly state the dates that these will become effective to allow industry to prepare.
- Carefully consider the implementation of nZEB or ZCB strategies.
- Consider and plan for regulatory systems to ensure indoor air quality levels in new and retrofit projects meet the health and productivity requirements of occupants.
- Support Australian Universities and TAFEs to compete in Solar Decathlon competitions.
- Consider hosting a Solar Decathlon in Australia so that exemplar prototype buildings can be displayed for public education.

Industry

- Encourage employees to participate in greenskills training and education.
- Share learnings on life-cycle costing, pay back calculations and cost-optimisation methodologies.
- Educate clients regarding the long term cost benefits of energy efficient building design.
- Share learnings on handover, defects rectification and building facility maintenance.
- Trial innovative materials in building design and share learnings.

Professional Associations

- Continue to encourage and deliver professional development and life-long learning to enable professionals, practitioners and tradespeople to build knowledge in new technologies, materials, construction methods and compliance for energy efficient buildings.

Education and Training – TAFE and University

- Introduce multidisciplinary learning to improve communication between all greenskills participants. Box Hill Institute will pilot this activity in the new Integrated Technology Hub scheduled for occupancy in late 2013/ early 2014.
- Introduce problem-based projects for greenskills students.
- Expand the range of educational resources regarding exemplar sustainability projects.
- Increase awareness of the principles of indoor air quality and thermal comfort in conjunction with energy efficient buildings.
- Introduce thermography as a learning tool into greenskills courses.
- The Advanced Diploma of Building Design (Architectural) course advisory committee consider developing an additional unit on cost estimating (including life-cycle costing, pay back calculations and cost-optimisation methodologies).

- Increase emphasis on life-cycle costing, pay back calculations and cost-optimisation methodologies.
- Increase content and emphasis on handover, defects rectification and building facility maintenance.
- Increase opportunities for student excursions to exemplar buildings.
- Plan, design and enter building proposals for Solar Decathlon competitions.

Community

- Open House activities to enable the public to visit sustainable buildings are important for community education and these activities should continue to be encouraged and supported.
- The community should be encouraged to participate in life-long learning by offering relevant greenskills short courses, certificates, diplomas and degrees.
- Support the concept of having a Solar Decathlon in Australia so that exemplar prototype buildings can be displayed for public education.

International Specialised Skills Institute

- Continue to support research in sustainable building design and construction.

Further Skills Deficiencies

- Passivhaus training.
- Heat recovery ventilation systems and energy recovery ventilation.
- Geothermal heat pump technology.
- Photovoltaic modules including BIPV.
- Calculation methodologies and ongoing building monitoring to enable the difference between calculated and actual building performance to be identified and addressed.
- Post-occupancy commissioning and maintenance.

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