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Building Integrated Photovoltaics in the Context of the Australian Construction Industry

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i. Executive Summary

Building Integrated Photovoltaics (BIPV) is an umbrella term used to refer to a range of solutions to embedding solar energy generation into a range of building materials. The aim of the set of technologies is to increase the accessibility of solar electricity generation to a range of applications where conventional system design is not appropriate or compromises other design features. BIPV can be implemented as a retrofit, but is also very well situated as a technology that can be integrated into the design of new buildings.

- **Reduced cost of an installed system.** This may manifest through both reduced total labour of installation and reduced material costs (by combining with the cladding required for building construction).
- **Increased available surface area, resulting in larger overall systems.** BIPV allows for a larger proportion of surfaces such as roofs to collect solar energy over conventional systems and also enables previously unsuitable surfaces (such as windows) to become collectors.
- **Through glazing and awning applications, BIPV technologies can have a positive effect on the passive design performance of a building.** For example, the integration of PV into glazing allows for reduced SHGC coefficients (something that might be typically sought through films or treatments) while also generating renewable energy.
- **Improved integration of photovoltaic technology into a building can lead to improved aesthetics and greater market acceptance,** encouraging the further development of the photovoltaic market.

Through the benefits outlined above, particularly in regards to commercial properties, it is **significantly more feasible for buildings to become carbon neutral;** a benefit that is increasingly being realised as of value in the marketplace.

Currently the market has not achieved significant adoption of this technology. There are a number of reasons that combine to create this outcome, however the focus of this report is to emphasise the hurdles currently presented by established construction processes and gaps or shortcomings of the regulatory and certification environment that lead to significant hurdles.

In particular, this Fellowship focuses on the following issues:

1. **In Australia BIPV is rarely recognised as an option for building design.** There are only a small number of vendors in the marketplace and BIPV solutions are considered only applicable for very high-end developments. There is tremendous opportunity for the development of this industry, enabling buildings with standard design to become significantly more sustainable. The very low operation requirements of BIPV (and photovoltaics in general) make it a far more viable solution for most developments than alternatives such as cogeneration and wind.
2. **In Australia there is no distinction made between BIPV and standard photovoltaic installations in regards to certification and installation processes.** This significantly compromises the opportunities that are available through the use of this set of technologies, but also does not recognise that there are a unique set of skills required for widespread integration. The customised and once-off nature of current installations means that there is a skills hurdle in seeing the technology become more widespread.
3. Despite some consistent efforts by manufacturers, **there is little standardisation of BIPV technologies** and currently limited integration of required installation skills into training and certification programs.
4. **There is no established method for firms specialising in BIPV and PV system design to be able to integrate into building design to ensure cost effective outcomes.** As the technology is fundamentally different in its interaction with the built environment, conventional approaches are no longer applicable. Understanding how this needs to change and how European countries have successfully overcome these barriers is critical to seeing sustained growth in this field.

Recommended Outcomes

The four principle conclusions on appropriate next steps within the industry are summarised as:

- **Establishing improved communication between manufacturers and the construction industry;** specifically, the emphasis on creating a conventional language. Industry bodies can provide direction on this by promoting standardised sets of information and points of comparison.
- **Improving awareness within building designers and other professionals as to the opportunities presented by BIPV. Facilitated continuing professional development (CPD) for the appropriate trades and disciplines is an effective channel, already demonstrated successfully on a range of initiatives.**
- **Taking steps to improve clarity on BIPV in regulations.** Appropriate pre-emptive clarification of regulations for BIPV technologies will improve practice within the installer community and will help overcome resistance to technologies that are outside of the ‘standard’ practice.
- **Addressing the unique considerations that are involved with BIPV. Issues such as appropriate substrates, inverter selection and string design are dependent on the specific technologies that are being selected and can vary on characteristics of building design and climatic conditions.**

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ii. Abbreviations/Acronyms

BDAV	Building Designers Association of Victoria
BIPV	Building Integrated Photovoltaics
BAPV	Building Added Photovoltaics
NCC	National Construction Code
BCA	Building Code of Australia (now obsolete, see National Construction Code)
CPSISC	Construction and Property Services Industry Skills Council
ISS Institute	International Specialised Skills Institute
MEFL	Moreland Energy Foundation Ltd.
ISE	InstitutfuerSolareEnergiesysteme (Institute for Solar Energy Systems)
AIA	Australian Institute of Architects
DNSP	Distribution Network Service Provider
CPD	Continuing Professional Development
ESD	Environmentally Sensitive Design
ATA	Alternative Technology Association
PIC	Plumbing Industry Commission
PICAC	Plumbing Industry Climate Action Centre
SUPSI	ScuolaUniversitariaProfessionaledellaSvizzeraItaliana (University of Applied Sciences of Southern Switzerland)
ISAAC	IstitutoSostenibilitàApplicataall’AmbienteCostruito
FiT	Feed-in Tariff

iii. Definitions

Insolation

This term refers to solar radiation. It can either be direct (as in a continuous line from the sun) or diffuse (reflected from other sources; particulates in the sky, other objects). It is typically measured in megajoules/square meter, or in watt-hours/square meter.

BIPV background and definitions

Building Integrated Photovoltaics (BIPV) is an umbrella term used to refer to a range of solutions to embedding solar energy generation into a range of building materials. The aim of the set of technologies is to increase the accessibility of solar electricity generation to a range of applications where conventional system design is not appropriate or compromises other design features. BIPV can be implemented as a retrofit, but is also very well situated as a technology that can be integrated into the design of new buildings.

IEA Task 7

The potential for BIPV has been recognised for some time. In 1997 the IEA (International Energy Agency) undertook Task 7 with 'the objective to enhance the architectural quality, the technical quality and the economic viability of PV systems in the built environment and to assess and remove non-technical barriers for their introduction as an energy-significant option.'[1] The study, concluded in 2001, summarised that they expected the successful integration of PV systems into the built environment will contribute significantly to the future spread of PV in general; however this potential has yet to be realised to any extent.

Task 7 motivated the collaboration between these groups and PV system specialists, utility specialists and PV building industry and other professionals involved in photovoltaics. The primary focus of the Task was the integration of PV into the architectural design of buildings (roofs and façades) and other structures in the built environment, such as noise barriers, parking areas and railway canopies. In addition to integration issues, Task 7 also addressed market factors, of both technical and non-technical kind.

As the costs of the silicon cell component of conventional systems continue to fall (traditionally the most expensive component of solar installations) the Balance of System (BOS) is becoming proportionally a greater component of this cost. In many cases the technology type employed is a thin film (silicon, Cadmium Telluride or CIGS); however a number of applications also utilise more conventional thick substrate technologies (poly or monocrystalline silicon).[2] Recent studies [3,4] into the availability of products have demonstrated that then industry is fast approaching cost competitiveness with conventional building materials that the technologies are looking to offset, which will leave market awareness and skill sets as the primary hurdle for large scale implementation.

Range of technologies

There is an increasingly diverse set of photovoltaic technologies that are being developed for BIPV and other PV applications. This range will play an important role in the development of the industry, as different technologies may present as the most suitable for varying applications. A brief summary of the available technologies may be seen in Figure 1.

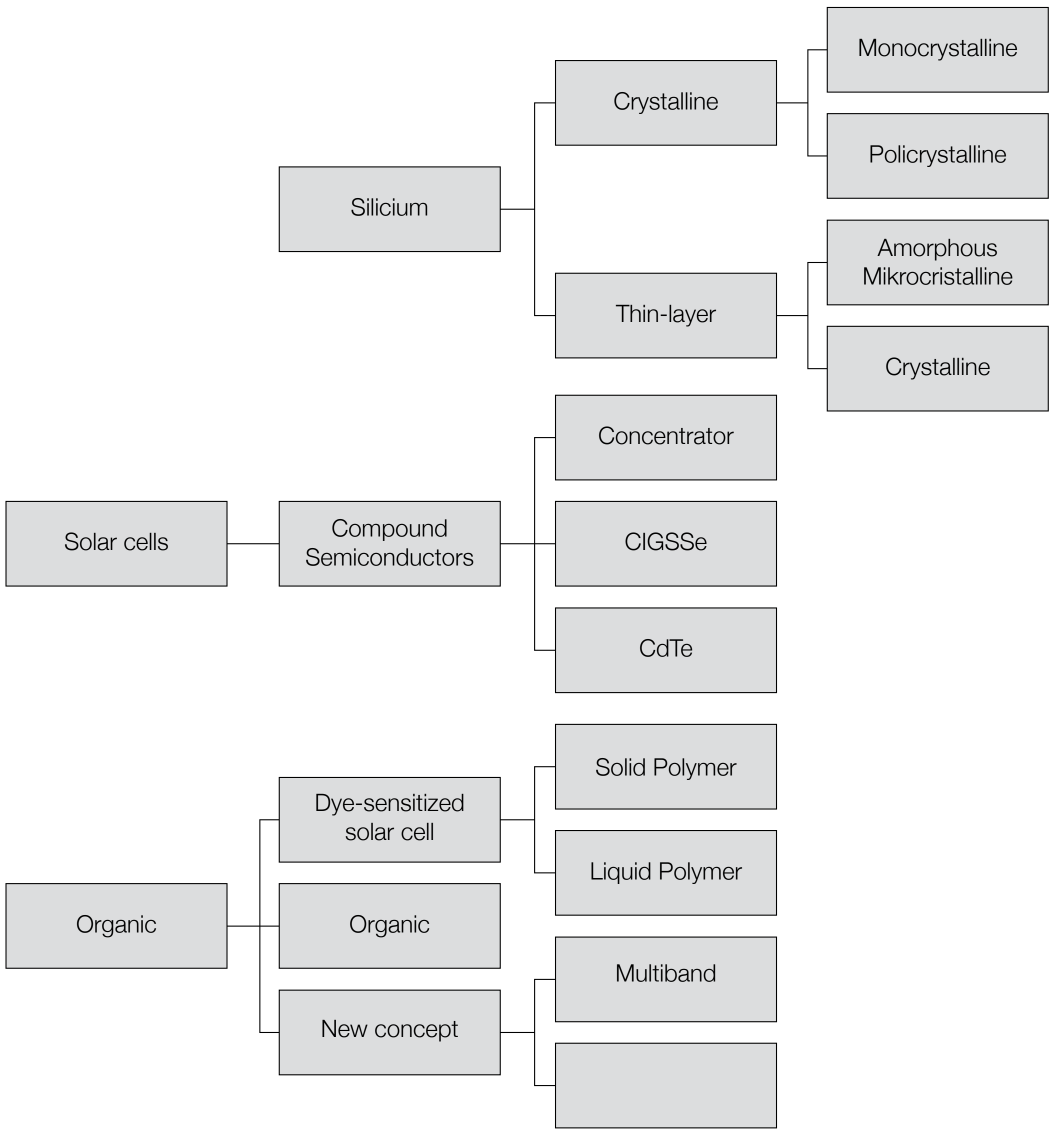

Figure 1: Current Photovoltaic Technologies

Technology Benefits

By integrating solar collection into the building structure, several opportunities are presented:

- **Reduced cost of installation due to reduced balance of system costs**. The installation can be approached from a marginal cost over conventional cladding/glazing, as opposed to entirely additive (as is the case with BAPV systems). Figure 2 demonstrates how this Balance of System (BoS) costs have shifted over the last few years (in the graph, the BoS is represented in the 'Module' component).

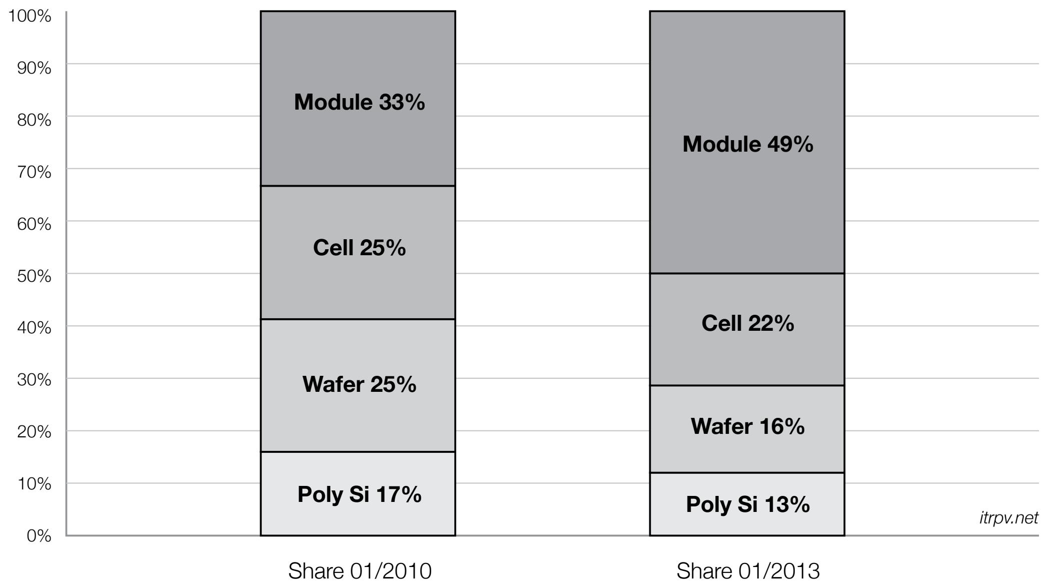

Figure 2: Demonstration of the cost of the shifting proportion of Balance of System costs [5]

- **Increased available surface area.** Conventional solar PV systems typically only have a small surface area that is suitable for their installation (essentially either unoccupied sections of flat roofs or a small proportion of the roof facing north for pitched). This area is constrained by a number of factors including guidelines around perimeters to edges and other accessibility issues. For BIPV solutions, the available area is radically increased (such as through glazed surfaces and even though a number of these surfaces may have attenuated accessibility to sunlight), the decreased cost per installed watt allows much greater flexibility in their application.
- The fact the panels are integrated into the fabric of the building means that they are subject to reduced rates of degradation. All cabling can be located behind environmental barriers and are not subject to the UV exposure and other degrading factors experienced in conventional installations. In addition, there are no additional wind loading requirements for BIPV installations that are installed within the building envelope, again reducing the costs of design and installation.

Building A - Melbourne University

- In many cases the use of **BIPV technologies can have a positive effect on the passive design performance of a building**. In cases where BIPV is used for facades and awnings, for instance, controlling the solar gain of windows will reduce cooling loads on HVAC systems at the same time as generating electricity. For glazed solutions the outcomes can be even more positive, as integration of PV into the glass allows for reduced SHGC coefficients (something that might be typically sought through films or treatments) while also providing an offset to other energy consumption.

- Through the benefits outlined above, particularly in regards to commercial properties, it becomes **significantly more feasible for buildings to become carbon neutral,** a benefit that is increasingly being realised as of value in the marketplace. The reduction in ongoing utility costs, particularly considering the upward trends in utility prices, will be of tangible benefit to building owners for the life of the installation. This is highlighted in reports such as that by the BPIE on Nearly Zero Energy Buildings,[6] where it is recognised that commercial properties in particular have issues with generating enough on-site power to meet their marginal requirements.

Longevity of systems

Photovoltaics are unique in the renewable energy field due to their extremely low maintenance and long life spans. As compared to other conventionally employed distributed energy sources, such as cogeneration or wind generation, they have virtually no ongoing maintenance and component life spans are measured in decades. For successfully integration into a building's fabric, it is important that there is no reduction in the longevity from the materials that BIPV systems seek to displace and evidence from industry indicate that this is the case.

Forms of BIPV

Roof tiles and shingles

Currently the most applicable technology for small scale developments such as residential buildings, BIPV roof tiles are similar to conventional PV except the panelling is integrated into an interlocking and expandable system. The benefits of such designs are that they may be implemented with essentially no modification to the building design.

Solar facades and awnings

Solar facades and awnings involve the use of panels for the provision of shade to external glazing. In many cases this application is very similar to conventional installations; however this is typically undertaken at the time of construction and is designed to provide the passive design benefits of shading to windows at the same time as providing generation capacity.

Solar windows

Solar windows are a range of technologies that provide either the interspacing of collection panels with conventional glazing (demonstrating a striped or checked aesthetic) or through the use of thin films to provide a transparent coating (giving the overall window a uniform, tinted look). Solar windows are particularly exciting because so much of the surface of contemporary commercial structures have such large glazing ratios. As medium to large commercial buildings typically have a positive cooling/heating ratio (meaning they expend more energy cooling than heating) there is significant opportunity to reduce overall energy consumption through the reduction in SHGC (solar heat gain coefficient) afforded by these technologies. In addition, the large glazing ratio presents significant opportunity for energy collection. Despite the fact that glazing based solutions typically have reduced collection efficiency (due to the requirement to be at least partially transparent) the overall available surface can be considered as a marginal cost on conventional glazing, therefore very large systems may be installed at a significantly reduced cost on a conventional system (if such a system was possible at all).

BIPV in Europe

BIPV is not a large sector of the market in Europe, but it has benefited from some targeted government incentives that has aided its development.[7] Currently the most significant player in BIPV is Germany. The Germans were a very early adopter of the technology type, beginning a government run program in 1999.[8] Germany has consequently developed a very high level of expertise in BIPV products and installation processes and makes an excellent case study for understanding how to best effect and up skill both the industry and the greater public. The German government has implemented a range of measures to direct this development and it will be highly illuminating to observe the impact these measures have made.

France has made significant gains after having introduced BIPV specific Feed-in Tariffs in 2006.[9] This has led to a significant development of the industry skill set and will form an excellent example of how an industry has undergone a rapid transformation.[10] Spain has long been considered a leader in solar generation [11] but up until recently its expertise has been in large field collection. Changes that have taken place in the tariff structures have led to an increased prominence of BIPV technologies and there are ongoing improvements in awareness by industry and the greater population about the benefits that it presents.

1. Acknowledgements

Mathew Sullivan would like to thank the following individuals and organisations who gave generously of their time and their expertise to assist, advise and guide him throughout the Fellowship 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.[6]

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.

1. Acknowledgements

Fellowship Sponsor

The Construction and Property Services Industry Skills Council (CPSISC) represents the workforce training and skills development needs of the construction and property services industries.

More than 1.8 million Australians work in over 526,000 enterprises within the sector. Together these workers and companies contribute greatly to Australia's infrastructure by underpinning the nation's economic and social fabric. CPSISC is committed to encouraging recruitment to meet current skill shortages and the future demand for a skilled workforce.

CPSISC is the official skills development voice of the construction and property services industries in Australia. The Council develop, manage and distribute nationally recognised Training Packages and associated training and assessment materials.

Supporters

In Australia

- Joan Whelan, Project Manager, Construction and Property Services Industry Skills Council
- Kane Thornton, Deputy Chief Executive of the Clean Energy Council
- Glenne Drover, Manager Economic Infrastructure, Department of Business and Innovation, Victorian State Government
- Ken Guthrie, Principal Project Manager, Sustainability Victoria
- Damien Moyse, Energy Policy Manager, Alternative Technology Association
- Nick Brass, Retail Manager, Energy Matters.

In Germany

- Dr Helen Rose Wilson, Fraunhofer ISE
- Dr Christian Hey, German Advisory Council of the Environment
- Mr Ruggero Schleicher-Tappeser, Sustainable Solutions
- Steffen Porschberger, LeiterBildungszentrumMünchen.

In Brussels

- Pietro Caparassio, European Photovoltaic Industry Association.

Employer Support

The Fellow would like to thank the following people at the Moreland Energy Foundation Limited (MEFL) for their time and financial support:

- Paul Murfitt, CEO
- Brad Shone, Manager Energy Strategy
- Bruce Thompson, Director of Major Projects
- Govind Maksay, Project Specialist - Residential Buildings.

Organisations Impacted by the Fellowship

Due to the focus of the research being on processes and system characteristics, the outcomes of this research have the capacity to affect a broad range of organisations involved in the implementation and operation of distributed energy. Some of the principle organisations, with associated impacts, are outlined below:

Government and Government Agencies

- Australian Buildings Codes Board (ABCB). Implications to the National Construction Code with regard to aspects of integrated energy system design that may require revision or expansion of the code.

Industry and Professional Associations

- Australian Institute of Architects. Considerations to how renewable technologies and integrated energy system design may be adopted by practitioners, such as through CPD or independent certification.
- Green Building Council of Australia. In light of the increasingly broad adoption by industry and government for the GreenStar assessment framework as a means of benchmarking ESD performance. Identify how accelerate adoption of novel technologies into the building and construction sector.
- Master Builders Association of Australia. Consultation on how builders and associated trades may look to accelerate skill building and engagement in the adoption and implementation of BIPV technologies and specifically identify where hurdles currently exist within building methodologies and processes.
- Building Designers Australia and the Building Designers Association of Victoria (BDAV). Strategically interested in considerations on how renewable technologies and integrated energy system design may be adopted by practitioners, such as through CPD or independent certification.
- Clean Energy Council (CEC). The Clean Energy Council is the leading industry body for distributed solar generation systems and is responsible for assessing and maintaining the lists of products suitable for installation (panels and inverters) and the standards and certifications for BIPV technologies.

Education and Training

- Construction, Property and Services Industry Skills Council (CPSISC). Technologically innovative platforms such as BIPV provide a suite of opportunities for development in the Australian workforce. In particular, there is opportunity to expand into active involvement in distributed energy, a rapidly expanding field that is increasingly important for building design, construction and operation.
- Plumbing Industry Commission. There are several aspects of BIPV design that overlap with traditional roles for plumbers, specifically that of roofers.

Community and Non-Government Organisations

- Alternative Technology Association (ATA). The ATA is Australia's pre-eminent non-government body in regards to distributed energy generation and is heavily involved in developing practical understanding of the application of technologies.
- Environment Victoria. Environment Victoria is an organisation committed to seeing a large-scale shift from polluting energy sources. The development of better methods of implementation and the streamlining of pathways to see broader adoption would significantly facilitate their advocacy programs.
- Moreland Energy Foundation Limited (MEFL). MEFL is a research, community engagement and advocacy organisation set up by the Moreland City Council (MCC). It undertakes research into contemporary, commercially viable energy efficiency and renewable technologies to establish objective understanding of their merits and explore alternative strategies for market adoption.

2. About the Fellow

Name: Matthew Sullivan

Employment: Head of Research, Moreland Energy Foundation, Melbourne

Qualifications:

- Bachelor of Engineering (Hons.) (Mechatronics), University of Melbourne, 2002
- Bachelor of Computer Science, University of Melbourne, 2002
- Master of Engineering (Energy Studies), University of Melbourne, 2009.

Short Biography:

Matthew Sullivan received his undergraduate degrees at the University of Melbourne before working for several years at engineering design firms in Australia and the USA. During his time in industry, he began to develop an appreciation that energy and deriving a clean and sustainable source of it, was going to become increasingly important. Sullivan returned to Australia to complete a Masters degree in Energy Studies and then began work in the sustainability and renewable energy field. He has worked for several years now for energy efficiency consultancies, most notably as a technical specialist at the Moreland Energy Foundation (MEFL) and as senior consultant with the firm Energy Return. MEFL is an organisation that coordinates extensive community engagement programs (such as the Moreland Solar Cities program) and undertakes investigations into technologies and practices. Sullivan has recently been promoted to the Head of Research for MEFL and in this role strategically directs the efforts of the organisation in a field that is evolving rapidly.

The Fellow has a strong interest in identifying technologies and composite solutions that will deliver the best outcomes within the current market context of Australian. He has been heavily involved in a number of studies that focus on the assessment of hurdles and real costs of implementation.

3. Aims of the Fellowship Program

The solar industry continues to move ahead dramatically, and although 2013 is set to be a brief hiatus on that growth, longer term trends anticipate further market expansion.[12] BIPV is expected to develop in importance [13] and, as outlined above, it presents a number of significant advantages to both building owners and the construction industry. However, thus far BIPV and related technologies have had very marginal adoption within Australia. This Fellowship aims to examine the various considerations that are needed to understand how technologies such as BIPV may be encouraged, focussing on the specific regulations, incentives and industry structures involved in bringing BIPV to a broad adoption. These insights allow for the following:

- Communication with key elements of the building and distributed energy industry to establish a consistent understanding of what BIPV is, such that decisions around the inclusion of the technology can be effectively carried through the design and build process
- Identification of shortcomings in the current certification and standards scheme, highlighting how improvements in these references will facilitate the uptake of BIPV and associated technologies
- Establishing how the current arrangement between industry, industry bodies and regulatory bodies may be improved to see accelerated uptake of BIPV and improved penetration in the market for distributed energy systems
- Exploring current incentives and identifying what incentives would be appropriate to see broader adoption of BIPV and distributed renewable energy in general.

4. The Australian Context

The situation in Australia is currently one of extremely low adoption of BIPV technologies and there is a limited existing supplier and installer base. The total number of BIPV installations is relatively small when compared to photovoltaic installations overall with no significant increase in installation rates in recent years. Where installations do take place, it is typically in instances where there is a desire for the associated building to demonstrate leading innovation in sustainability.

Technology types

The predominant technology that has been present in the Australian market is that of products integrated into roofing materials, manifesting as roofing tiles (typically targeting the residential market) and cells affixed to sheet metal (used in both residential and commercial applications). This presents a difference to the technologies being seen in Europe, which are more focused on wall and glazing applications.

Age and complexity of market

A shortcoming of the market in Australia is that there has been relatively little engagement with the broader scope of professionals conventionally employed in building design and construction. In general the BAPV industry has been established through electricians and specialist installation companies that have taken on the necessary up skilling, which the other trades have been largely unaffected. This result in instances of new buildings and homes being constructed in their entirety and then a separate team will install a BAPV post-construction. This delineation of trade practice is common in Australian industry; however it presents challenges for the more integrated approach for technologies such as BIPV.

Due to role compartmentalisation, it is difficult for manufacturers to create a solution that can have a cost-effective labour of installation.

Points of contrast to European practice

There are a number of key differences between the Australian context and that of Europe. A driving factor is the difference in manufacturing.

Difficulties facing BIPV in regards to contemporary product certification

Photovoltaic products can be installed only if they meet the requirements of the AS4777 construction code. To meet this code they are required to be certified according to IEC 62125 or 62670 international standard, which involves a range of environmental and safety testing to ensure that products will not fail under reasonable operating conditions. However, for BIPV products this testing can be inadequate for a number of reasons. The fact that BIPV is built into the fabric of the building places a lot of operational conditions that are more complex than conventional solar solutions.

The testing conditions within the IEC frameworks are not representative of the likely construction substrates for BIPV solutions, meaning it may demonstrate differences in the performance of the panels in real-world scenarios. In particular, the current IEC testing framework does not undertake transient temperature analysis of panel performance under partial shading and elevated ambient temperature conditions. Under such situations, a possible outcome is having panels that reach undesirable temperature spikes, a situation that is not screened by the standards.

SWOT Analysis

The overall objective of this Fellowship was to gather information to assist with the implementation and development of the BIPV market in Australia.

A SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis provides a useful avenue for exploring the contemporary situation of Building Integrated Photovoltaics. This analysis provides an effective means of 'mapping' the current situation and identifying opportunities for future developments.

Strengths

Note: In many cases, the strengths and weaknesses of BIPV are largely made in comparison to that of conventional distributed photovoltaic systems (BAPV).

- BIPV has the capacity to have a larger collection surface, and allows for more building types to be suitable for solar electricity generation. The technology applications in cladding and glazing in particular dramatically increase the surface area available for office buildings and high rise developments.
- BIPV can achieve cost savings beyond that of what can be theoretically achieved with BAPV solutions.[14] The capacity to offset virtually the entire cost of the substrate to building costs and the cross over between labour for install with the building process allow for cost savings unachievable with a conventional BAPV solution.
- Current lowering costs of solar PV technologies, combined with improved performance and innovation in cells and inverters, is expected to shift the emphasis of photovoltaic system design away from optimising panel placement and orientation, and towards maximising overall system size.[15] This works in favour of BIPV technologies, as they typically trade off poorer orientation while having superior coverage when compared to BAPV solutions.
- BIPV has the capacity to be both functionally and visually integrated into the fabric of a building, lowering the visual impact of have a distributed energy system installed. This factor can improve the perceived value of the system and increase the scope of buildings that would consider installing a PV system over that of a conventional system.

Weaknesses

- There is limited support for BIPV in current standards and certification material. This leads to difficulties for practitioners to implement solutions, creating a 'grey zone' of regulatory requirements.
- There are several ways that BIPV present additional complexity in building design. These complexities include the requirement for different and/or additional materials (such as the adding of heat-resistant layers), more complex characteristics of conventional components (such as window frames) and additional design elements (the circuitry required for electrical connection).
- Overall system design is significantly more complex than for conventional BAPV. This is due to a combination of factors, including more complex parts and materials (as outlined in the point above), as well as orientation and shading factors. For instance, solar PV systems respond poorly to shading, however this does not typically present a problem for BAPV solutions because the layout is typically optimised and designed to minimise shading impact. BIPV is generally designed to cover much more extensive areas, in addition to being often located in more marginal aspects. This can lead to complex shading patterns. On the most basic level, shading reduces energy generation because photovoltaic systems derive the majority of the energy from direct insolation; however partial shading of strings of panels can lead to irregularities in power output and a decrease efficiency overall.

- The requirement to have a number of different participants being educated and motivated in BIPV to carry the process through from design to installation. As noted in the outcomes of the IEA Task 7 investigations,[16] "active involvement of urban planners, architects and building engineers is required" to see extensive uptake.

Opportunities

- BIPV is still a very small segment of the photovoltaic market; however in the last few years there has been a rapid expansion of the solar retrofit industry. As discussed in the sections below, the technical skill development that this has encouraged would not present direct benefit to BIPV adoption.
- BIPV has the capacity to significantly increase the number of buildings that may achieve energy neutrality or become net exporters of energy, due to the overall increase in total possible system size. This may have broader implications for grid operation and design, and may play a role in reducing overall emissions for the building sector.
- Increased utility costs will put ongoing pressure on the development of alternative sources of power.[17,18] BIPV can be installed in such a way that power is delivered over a broader spectrum of the day, potentially allowing energy generation to better match on-site supply requirements – an effect that can partially offset poor FiT scenarios.
- The development of parallel technologies such as inverters with integrated storage and financial/ regulatory models may facilitate and accelerate technology adoption,[19] many of which create tangible improvements in the financial arguments for the technology.[20]

Threats

As with any developing technologies there are many factors that may threaten the adoption of BIPV into mainstream practice.

- Depending on how the energy industry and government respond to the changing circumstances of distributed generation, there may be increased pressure to de-incentivise the wider scale adoption of distributed energy in coming years. If this outcome develops, burgeoning technology groups such as BIPV will likely present an excessive risk for manufacturers and installers to increase capacity. This includes negative impacts on market development as represented by declining Feed-in-Tariffs (FiTs).
- Failure to establish common standards in the industry for BIPV conventions could result in ongoing challenges for designers and builders to confidently incorporate the technology.
- Due to the limited standards relating to the specific conditions of BIPV, there may be as yet unrealised hazards from including the technology in building fabric. Some of the outcomes of these hazards may induce issues regarding how the technology is perceived.
- In particular, this suite of technologies require the collaboration and buy in from a number of professionals and specialities within the construction and energy sectors, which raises the bar for adoption.

Contact points for BIPV implementation

As identified above, there are a number of critical decision points that need to be informed if BIPV (or similar technologies requiring building integration) are to be adopted. Exploring this flow can assist with highlighting key hurdles and may form the basis for establishing strategies for overcoming them.

A simplified suggested summary is outlined below:

Stage	Stakeholders	Challenges/ Opportunities	Advised Measures
Initial building concept	Developer Lead architect	Lack of awareness of BIPV solutions, lack of awareness of advantages	Improved communication of available products
Detailed Design	Developer Architects/ Building Designers Services engineers	Broad range of BIPV technologies Uncertainty of regulatory requirements Lack of design principles	Formalisation of BIPV standards Creation of BIPV specific regulations Establishment of designs to assist implementation
Building Construction	Building Engineers Roofers Electricians Glaziers Façade installers	Unclear delineation between trades in installation Poor or missing skills in implementing systems	Connecting BIPV technology solutions to discrete trades Expansion of training available for trades Amendment of relevant standards
Grid Integration	DNSP Electricians	Poor regulatory support for connection of systems larger than 30kW	Improvements to energy system regulations to streamline grid connection

5. Identifying the Skills Deficiencies

Skill deficiencies are defined as areas where there is a lack of knowledge, experience, policies, formal structures and organisations to support a successful BIPV industry in Australia.

The aim of the Fellowship was to investigate the following skill deficiencies:

1. **In Australia BIPV is rarely a recognised option for building design.** There are only a small number of vendors in the marketplace and BIPV solutions are considered only applicable for very high-end developments. There is tremendous opportunity for the development of this industry, enabling buildings with standard design to become significantly more sustainable. The very low operation requirements of BIPV (and photovoltaics in general) make it a far more viable solution for most developments than alternatives such as cogeneration and wind.
2. **In Australia there is no distinction made between BIPV and standard photovoltaic installations in regards to certification and installation processes.** This significantly compromises the opportunities that are available through the use of this set of technologies, but also does not recognise that there are a unique set of skills required for widespread integration. Presently the customised and once-off nature of current installations means that there is a skills hurdle in seeing the technology become more widespread.
3. Despite some consistent efforts by manufacturers, there is little standardisation of BIPV technologies and currently limited integration of required installation skills into training and certification programs.
4. **There is no established method for firms specialising in BIPV and PV system design to be able to integrate into building design to ensure cost effective outcomes.** As the technology is fundamentally different in its interaction with the built environment, conventional approaches are no longer applicable. Understanding how this needs to change and how European countries have successfully overcome these barriers will be critical to seeing sustained growth in this field in Australia.

Detailed outline of skill deficiencies

The skill deficiencies that have been the subject of study for this Fellowship are outlined below.

1. In Australia BIPV is just beginning to be a recognised option for building design. There are only a small number of vendors in the marketplace and BIPV solutions are considered only applicable for very high-end developments. There is tremendous opportunity for the development of this industry, enabling buildings with standard design to become significantly more sustainable. The very low operation requirements of BIPV make it a far more viable solution for most developments than alternatives such as cogeneration and wind.

There are a number of specialised skills involved in successful BIPV installation. These include:

- An inspection of the energy generation opportunities of a site. This includes being able to determine solar energy density based on orientation and surface pitch, as well as considerations of external constraints such as shading buildings and vegetation
- Capacity to design distributed solar generation systems and meet appropriate regulatory requirements*
- An understanding of passive design and the implications and opportunities presented by BIPV technologies
- A comprehensive understanding of the available technologies, including capacity to assess the important considerations of the various applicable technologies and appropriate applications
- A clear understanding of the considerations of building fabric/glazing performance characteristics and how to properly assess the suitability of a BIPV solution

- An understanding of how to develop an interface to the system that will allow ongoing operators of the site to assess and maintain the system where required
- An understanding of the steps required in establishing grid connection.*

**Note: Crossover with conventional distributed PV systems*

To a large extent the skills are present to some degree within the existing workforce; however these are generally spread across a wide range of expertise (from engineers, builders, installers, system designers and DNSPs) that the hurdles in implementation are impractical for all but the highest-budget projects. Also, the common source of information on technology of these types (PV installers) are rarely engaged during the design or retrofit of a building fabric and in any case are typically under-skilled in identifying opportunities in BIPV.

2. **In Australia there is no distinction from a certification perspective made between BIPV and standard photovoltaic installations in regards to certification and installation processes.** This significantly compromises the opportunities that are available through the use of this set of technologies, but also does not recognise that there are a unique set of skills required for widespread integration. Recent modifications to the codes have not included improved recognition of these technologies.[21] Presently the customised and once-off nature of current installations means that there is a skills hurdle in seeing the technology become more widespread.

The lack of identification of the unique opportunities and hurdles presented by BIPV contributes to the difficulties in implementation of the technology on a large scale. What is needed is a low cost and well-established methodology for considering the current range of technologies and key elements of system design at the building design stage, developed along the lines of what is currently applied in Europe for PV testing.[22] It is important that there is a consistent and effective understanding of what the opportunities and constraints of the technology are to ensure that safe and cost effective systems can be designed.

3. **Australian industry is largely unaccustomed with possibilities of BIPV.** In Australia there is very little understanding of the range of technologies that are becoming available and because solar energy has generally come from a separate field (that of electrical networks) and is retrofitted means the building industry is largely unaccustomed to considering the possibilities of BIPV. As with many other examples of technology, the public awareness of a product can play a huge role in its take up, as people become aware of the benefits it presents at the same time as becoming comfortable with any perceived risks. In cases of energy technology this is particularly important because of the significant disconnect that the general public has historically had with energy generation and supply.

The building industry itself has in general had little to do with solar technologies, and unless an organisation has set itself as a pioneer in the field it will typically have very little exposure to BIPV technologies within Australia. This lack of awareness alone is a significant barrier to more wide spread market adoption.

Economic opportunities presented by an established solar PV Industry

In Australia, the very rapid development of the PV installation industry (in conjunction with a rolling back of both primary rebates and Feed-in Tariff support) has clearly demonstrated its capacity to support jobs. However, the value chain is slender compared to countries that have a more mature and established industry. As highlighted in a recent report by Mr Schleicher-Tappeser presented at the 8th Germany California Solar Day, there is much greater depth presented by the solar industry.[23]

Below is a table extracted from this presentation:

Entity	Region
Research Institutes	International
Manufacturers of Production Plants	International
Bank and Financing Companies	Can be Local
Manufacturers – Silicon	International
Manufacturers – Wafers, Cells	International
Manufacturers – Modules	Can be Local
Traders	Can be Local
System Integrators, EPC Contractors	Can be Local
Craftsmen in the construction business	Local
Operating company	Can be Local

Please note that not all systems would have all links in the chain.

In many instances, various elements of this value chain are highly dependent on several others, meaning that development requires incremental improvement across the whole chain.

6. The International Experience

The majority of the Fellow's research trip involved meeting with various organisations in Germany. Throughout the trip the Fellow was interested in identifying key experts in a range of fields that impact the adoption of BIPV. These included policy and strategic government planning, certification, training, standards development and technological and commercial direction.

Visit One

Dr Professor Christian Hey, Secretary General of the SRU (German Advisory Council on the Environment)

The German Advisory Council on the Environment is an important institute that presents summaries of trends and provides policy advice for the German government. It has recently published a highly influential paper, Pathways towards a 100% renewable electricity system.[24] With Dr Hey, the Fellow investigated current trends with the German and European policy, with discussion on how these trends will influence government investment and regulatory reform to impact uptake of BIPV and associated technologies.

The council was established 40 years ago, comprising of a group of seven scientists and assisted by a staff of 25 persons in total. It is important to note that this body is neither lobby group nor doing research. It specifically exists to apply available research to give policy advice to the government.

The environmental advisory council has a strong standing with government and the broader public. Council has a special reputation - very good coverage, much beyond individual research papers. In particular, the paper released in 2011 on renewable energy got an enormous response. The timing of its release six weeks before the Fukishima nuclear disaster, which of course was a tragic event in itself, proved the lighting rod for a public keen to identify alternative strategies to continuing down the nuclear road that existed for German energy supply.

The report strongly criticised the approach of extending nuclear power and developed a strong technical argument for why nuclear is a barrier to renewables. The emphasis was on nuclear as an inflexible technology, requiring long construction times and operation at high capacity factors to deliver cost effective energy. Weather-dependent technologies (such as wind and solar) require a high degree of flexibility from other generators on the grid to compensate for their intermittent supply. Nuclear installations are not sufficiently flexible to form the complement to renewables. The report demonstrated that a number of scenarios showed Germany is able to provide all of its electricity needs based on renewables and at relatively low cost. This report was the first thing to be mentioned in the debate on replacing nuclear, which greatly increased its impact.

Discussion on the development of scenarios

Germany has a very strong capacity for scenario analysis, which improves the ability to make reasonable forecasts. Methodology of scenarios was centred on a least cost electricity portfolio approach, with various solutions put into merit order. Specifically the 100 per cent renewable report created a simulation of the situation in 2015. Results indicated that:

- Offshore wind will be the cheapest
- Onshore wind next
- Solar is twice as expensive and only comes in when there is not sufficient wind.

Dr Hey summarised the findings of this analysis of the various scenarios as follows. The initial scenario was to look at Germany as an 'electrical island' that would neither import nor export to the grid.

Other scenarios included opening to the European electricity market. Coming from these types of investigations, it was determined that a meaningful contribution from solar is needed in the self-sufficiency as well as the high demand scenarios. Importantly it is not needed in the high-efficiency scenario, a reflection of the current pricing structure of solar.

In these scenarios, it is worth noting that the council did not assume any radical changes in the cost of technologies. The following conditions applied to the analysis:

- Cost of solar generation is a function of global market penetration
- The council did not look at technology innovations or significant step changes in cost/efficiency
- The data used for technology prices and efficiencies came from years 2007/08
- Importantly, there is a much steeper decline of solar cost over the last few years than previously anticipated, which may impact the relative prices of generation. Global oversupply is currently a big factor - prices do not reflect cost.

For 2050, it was estimated that cost of solar is below 10c/kwh, while it is more optimistic in regards to wind. He believes that Germany has a problem is that:

- Currently invest roughly 20 billion Euro in new renewable power
- Out of this, about 15 billion Euro is in photovoltaic systems
- Three quarters of the investment goes into PV, but it has been delivering much lower proportion of value
- Overall the council is of the opinion that Germany should shift priorities in the direction of cheaper renewable resources and away from photovoltaics
- There is a widespread consensus to change the Feed-in Tariff system – need to control PV growth and encourage higher growth rates in wind energy.

At present there is around 30GW of installed solar power - most on individual buildings. Share of farm PV is increasing however. The government has set a threshold of 32GW and will not support anything above this unless a new system is put in place. However the cost if PV electricity to the end user is below grid parity, so that even if there are no government incentives there will still be significant (and likely increasing) uptake of solar as households and end users seek to reduce their overall electricity bills.

Current average production-cost-of-energy is around five to six cents per kilowatt hour in Germany, whereas currently generation from PV is around 18 cents per kilowatt hour. A question that needs to be asked is does Germany allow homes to be ‘free riders’ on the value presented to the grid? This question will need to be addressed in the future as more households reduce their total electricity demand through installed solar, but still require the infrastructure of the grid to support them during hours without solar generation. Overall the framework of support for PV will become less and less generous in Germany in the coming years.

Outcomes of discussion

Dr Hey related important developments within the solar PV and broader energy industry, highlighting that there is still substantial opportunity for increased uptake of distributed generation. He emphasised that the Government programs pursued by Germany (specifically their 100,000 roofs campaign) have been extremely successful at achieving higher levels of PV adoption. He indicated, however, that this uptake has been largely along the lines of conventional BAPV systems.

Visit Two

Mr Ruggero Schleicher-Tappeser, Director of Sustainable Strategies (a consulting advisory body)

Through his consulting firm, Schleicher-Tappeser provides a strategic overview of technological and economic trends for strategic decision makers throughout Europe. Schleicher-Tappeser indicated the importance of the prevailing trends of technological improvement and the dropping of manufacturing costs on the broader market response to embedded photovoltaic systems.

Outcomes

Schleicher-Tappeser provided the Fellow detailed insights into the specifics of the development of the solar industry in Germany, and identified a number of considerations that have played a pivotal role: [25]

- A reliable investment context with guaranteed Feed-in Tariffs for 20 years after installation
- Continuous adaptation of the FiT for new systems to market development, resulting in steady growth
- A simple scheme: no other incentives, just FiT
- No complicated permitting procedures
- Banks have learned that PV investments are low risk, thereby allowing low financing costs
- Industry and craftsmen have invested in production and training, resulting in reliable quality, low total system price (including installation).

Visit Three

Dr Helen Rose Wilson, Spectrometry and BIPV, Fraunhofer-InstitutfuerSolareEnergiesysteme (Fraunhofer ISE), Freiburg, Germany

The Fraunhofer Institute is one of the most prestigious research organisations in Germany. The institute receives a significant amount of government funding, in addition to specific funding arrangements with industry. The branch of the Institute that deals with solar energy, the InstitutfuerSolareEnergiesysteme (Institute for Solar Energy Systems) is well established within the field and contributes significantly to international research on a range of technological developments. The Institute works closely with training and certification bodies to ensure that the research is rapidly transcribed to the professional field and to keep abreast of new developments in on-ground implementation. Due to the key role that the organisation plays in the solar context, it formed a central focus for the Fellow's studies.

Within the organisation, Dr Wilson leads a number of research initiatives into facilitating the further adoption of BIPV, specifically relating to solar façades and is involved in the development of internationally recognised standards for BIPV products. Dr Wilson was able to provide the Fellow an extensive understanding of what the trends in BIPV research were, in addition to exploring the technical hurdles for further adoption.

Background

Dr Wilson is currently a member of the solar facades group at the Fraunhofer ISE. She has a background in thermal and optical characterisation of solar energy and five years ago moved to active PV systems. Dr Wilson is also:

- The coordinator of a joint project called 'BIPV systems', which brings together module manufacturers, SMA (inverter manufacturers) and system integrators. One manufacturer - Mazda PV – is exploring amorphous silicon modules in insulating glazing; micro-amorphous silicon. This is a new system and also known as tandem silicon.
- Exploring semi-transparency in glazing solutions. The innovation with these platforms is through using a transparent conductor. In conjunction with them, stripes of transparent and opaque material across several layers – a composite system – is striped so that the incoming light is angled.

Note: As the majority of the innovation taking place in Germany at the moment is in the construction of glazing based BIPV solutions, Dr Wilson's experience centres around the considerations of this subset of BIPV technologies. In many ways, the experiences noted in this subset mirror those of BIPV installations in Australia in regards to skill gaps and remedial measures.

Fraunhofer ISE (Source Fraunhofer ISE)

In Germany there is a big difference between window builders and façade builders. In the first instance, although the craft of window construction is well advanced (as demonstrated by the overall very high standard seen as compared to Australia), there has been little impetus to integrate this into other systems.

In regards to systems with integrated photovoltaics, some practitioners are extending their skills, but it is still a very small market and the drive from clients is limited. Importantly, window installers in Germany generally have no electrician skills and the channels towards adding these skills are problematic. As a comparison, in the facade builder trade, they are familiar with electricity for supplying motors for blinds etc. This presents an avenue for investigation of upgrading their skill sets to accommodate BIPV integration.

Through work done the regulations and certifications are relatively well defined. Specifically, BIPV glazing solutions seem to fall largely within the insulating glazing units - family of CEN regulations. Importantly, if the introduction of the photovoltaic element doesn't affect other issues (such as strength and safety) then it is not considered a problem from a building regulations perspective. Essentially, from the perspective of the building code windows that have the integrated BIPV technologies will become a combination photovoltaic and insulating window systems.

Roofing BIPV

There is some exploration of BIPV roofing products going on in Europe at present. Intersolar is the major manufacturer in the production of these product types in Germany. They are working with CIGS (the same as the Bluescope Steel venture). It is considered that CIGS should exceed ten per cent shortly, which will be an important stepping stone in its development towards becoming comparable to silicon based systems. The very rapid development of CIGS (significant investigation into this solution only began in 2007) does promise that good levels of efficiency may be possible. The Fraunhofer ISE complex will shortly have a warehouse reroofed with this material as a means of assessing efficacy. MR Sunstrom is the installer - they have historically done field photovoltaic systems, but they want to increase their experience in BIPV. Of note is the fact that among their installers they have a professional roofer - they had already extended their labour force to include people who had their background from the building trade.

In Europe there are two certifying bodies: CEN and CENELEC. The second relates exclusively to standards associated with electricity, whereas CEN covers areas such as building and construction. To this end, BIPV can have elements within both areas, complicating compliance. In situations where there are no established standards, the organisation DeutchesInstitut fur Bautechnik (German institute for Building Technology) is responsible for the installation of products for which there is no certification.

Overall, in Germany there is a division between federal and state responsibility when it comes to issues surrounding building construction and certification. There is a stage at which the state level is required to authorise the construction and standards, which mean the requirements for the same products might differ depending on the state. The standards and certifications are largely the extent of the information required, highlighting the importance of these.

Overall, the work that needs to be done now to improve the uptake of BIPV has strong parallels to the original German '100,000 roofs' program for PV installation. During this program, part of what was done was training electricians in the installation of BAPV systems. Obviously this is a simpler process than would present for an equivalent BIPV installation, but there are also similarities. Outcomes of this study demonstrated that many of the issues that came up were simple installation errors. There are other individuals at Fraunhofer who have been involved in training programs for system installations, for the '100,000 roof' programs and others. The Institute continues to do analysis on the outcomes of this study. The Institute also undertakes training programs for third world countries.

Another important aspect of BIPV that is being worked on now is durability testing. This is also an aspect related to certification and presents a number of specific considerations that manifest on BIPV installations. Most standards haven't reached this level yet, so there is some work yet to do on this matter. Fraunhofer ISE is recognised as a testing institute, and has the weathering equipment for doing the non-standard tests. This is an important part of how they can understand where current tests have shortcomings and where additional elements need to be considered.

In regards to technology development and research, there is an Australian/German collaboration on PV systems working on a number of the elements of BIPV design, including the Dyesol initiative.

Within the training for trades as applicable to BIPV technologies, there is a technical school at Freiburg with various branches that deal with many of the components of BIPV:

- Courses for plumbers (specifically on solar thermal systems; however there is some crossover for BIPV considerations)
- A course called solar teur (technical installer) which focuses of solar PV systems.

Outcomes

Dr Wilson related the methodologies and processes that are being pursued within the Institute and the broader solar industry for overcoming the many issues facing broader adoption for BIPV and related technologies. Specifically, Dr Wilson addressed the methods for improving standardised understanding of the technology in the construction industry; the resolution of cross-overs between the needs of the BIPV systems and addressing existing building and construction regulations; and the technological innovations being undertaken to provide products that meet these conditions and that are simple to install for the existing workforce.

Visit Four

Mr Daniel Philipp, Test Lab PV Modules, Fraunhofer-InstitutfuerSolareEnergiesysteme (Fraunhofer ISE), Freiburg, Germany

Philipp undertakes a number of the durability testing that is performed on photovoltaic systems and discussed with the Fellow characteristics of PV testing and specific considerations that might be involved with BIPV.

Philipp is a researcher in the durability testing team for the Fraunhofer ISE. He works mainly in the field of photovoltaics, although there is still important ongoing work in examining solar thermal systems. With regards to photovoltaics, a large proportion of the work that is done is the testing of photovoltaic systems to undertake the appropriate IEC tests according to standard 61215 (note that this is the standard expected by the Clean Energy Council to meet AS 4777 environmental and safety performance). This work is based on and integrated with the activities of the research groups within the Institute and form an important referral point for ongoing studies. It should be noted that the work they do does not just test the modules; they also provide feedback to the panel manufacturer if there is a failure.

The team can analyse what happens in the modules and the characteristics including chemical and physical changes in polymers, metals, components, as well as systems. The durability testing focuses on the module level – this is the key unit for examining commercial applications.

It is worth noting that the actual tests are not sufficient for lifetime assessment, or to represent an operation at different sites, because the standards were developed with different climatic emphasises to what is found in many environments (such as Australia). To this end the Fraunhofer Institute has a number of field research stations. In these locations they can run sequences that are more fitting to significantly varying climatic considerations. The Institute runs different auto monitoring sites at a range of locations, including Israel and the Canary Islands. It is interesting to see what is happening at the different places and how the systems respond. Once data is obtained of the real-world performance, the research team tries to mimic what is seen in reality and to trigger the same effect in the accelerated aging processes. As a result, the Institute has a high degree of confidence between what happens in the field due to the age impacts and what is simulated in their testing regimes.

The testing regime is changing a little bit because PV Modules are not all the same. It is noted that of late there has been a strong increase in the diversity of materials that is used in commercial PV systems. This is increasing the expected variation between simulated and actual environmental performance. Up until 2008 there have been maybe five or six suppliers. Production methods were always the same and could compare modules to each other. The number of different suppliers has increased radically from that point over the previous four years. Each new supplier brings new risks and potential for other failures that were not previously anticipated. The IEC certification standards are not sufficient to cover all of the failure mechanisms.

Part of the research work of the Institute is to determine what these other points of failure might be and how they could be reasonably included within the standard. Overall the Fraunhofer ISE does not do a great deal of testing – the majority of the commercial work is undertaken by TUV SUV and TUV Rhineland, among others. In a number of cases, companies do the tests themselves. From the perspective of the individual cells, the way they pass differs: some just meet the requirements; others are better than the requirements after the tests. It is possible that a manufacturer can have good luck – the results of the tests may not really reflect the average performance of the modules and the selection process happened to select particularly high performing modules. The tests are standardly performed on eight modules. Once certification is achieved the only thing required by the standard for continued certification is a visit to the production lines once a year. However, if the manufacturer changes anything on the module, retesting has to be undertaken. Overall, the certification procedure generally takes about three to four months.

It is reasonably well known that in many cases the standards are not sufficient to provide adequate assurance of the panels over their expected lifespan. For the Australian context, this particularly manifests with the UV aging process. For the IEC testing standards, the UV dose is 15kwh per day. In typical Australian conditions, however, this might represent one quarter or half of an actual dose. This highlights one of the many motivations for ensuring that testing standards are customised to the local environment.

In addition to undertaking the specifics of the tests, the Institute provides their customers respective advice about what they can do to improve the response of their systems to the testing. This can manifest in ways to cover missing elements in the standard. Importantly, though, they do not say what can be done to guarantee 20-year life spans, which is of particular interest to companies providing guarantees of extended performance. There won't be a standard that can be referred to and the company needs to be quite definite on how this would be achieved.

In regards to BIPV specifically, there has not been a lot of testing yet. As relayed by Dr Wilson, there is a nominal standard being developed for BIPV, however durability and performance testing is still being developed. The Institute has a specific piece of equipment that would prove advantageous to this work known as a double climatic cabinet. The two sides of the system can be operated independently and can then be combined with an artificial sun to test a very broad range of conditions. The panel (or BIPV system with substrate) is mounted between the cabinets and then the system can simulate indoor and outdoor environments. Overall this can simulate the operations of the module very well. Importantly, it becomes possible to see if there is any hazardous behaviour or damage that occurs to the panel. This test can be undertaken before or after aging testing (the accelerated aging cycle that exposes the system to prolonged UV radiation).

Outcomes

The conversations with Philipp highlighted the importance of undertaking independent assessment of solar PV modules, taking into account the specifics of the local environment. In order to provide local manufacturers, installers, end users and insurers confidence in the long term performance of the systems, independent testing should be considered a high priority for achieving robust industry standards.

Fraunhofer Testing (Source PV Tech)

Visit Five

Mr Detlef Horst Sonnabend, Distributed Energy Systems, Richard-Fehrenbach-Gewerbeschule (Richard Fehrenbach Trade School), Freiburg, Germany

Sonnabend is engaged in delivering training on a number of renewable and distributed energy technology platforms and related to the Fellow the ways in which key training institutes in Germany interface between research institutes (such as Fraunhofer) and industry to consistently improve the content of training courses. In addition, Sonnabend was able to provide insight into the structures of accreditation for German trade craft and the implications of this in relation to the introduction of new concepts and technologies.

The Richard-Fehrenbach-Gewerbeschule is a trade school for solar energy, primarily for solar thermal but also for photovoltaics. This is the largest training institute in this field in Germany. It is a member of DGS – the network of training institutions that provide certified trades education.

The School has a curriculum of quality management. There is a master plan developed to ensure that the material that is delivered to trainees is targeted to ensure graduates have the skills that are needed by industry. At intervals this master plan is revised to ensure that content is matched to the changing requirements of technology and industry. The recent revision to the master plan has only just been released. In addition, there are some technologies and products that manufacturers deliver for the school to provide specific training.

Essentially the material for the courses boils down into two areas: theory and practice. Both are weighted as critically important at the school. An area of particular focus is on maintenance training. This is an area of increasing importance as the more complex systems begin to age it is anticipated that there will be a need to significantly expand this area going into the future.

The Fraunhofer Institute is responsible for design of methodologies for practitioners that are used in the school. Generally this trade school looks to the Fraunhofer Institute or manufacturers to develop the training for a new technology. Good examples include software programs and new modules with mirror technologies. Companies are strongly motivated to provide materials and training support to the school because there is a lot of advantage to them. Due to the competitive market and the high profile that the school has in training the best practitioners, many people look at products that are being used in the School as a sign of best practice, providing a significant advantage to the companies that supply them. The School attracts many people from all over the world and there are many levels of training to cater for this variety. In regard to new technologies, the School generally reacts to the things that are presented to them by manufacturers – they need companies to present the options to them. If there is something outside of the existing standards then it is possible for the School to facilitate the development of strategies to best address the appropriate training response.

Trade crafts in Germany have three levels - apprentice, meister and then technick. All levels are supported at the School. There is a consistent drive towards excellence that motivates tradespersons to seek higher levels of education; this will ensure that they can continue to compete in the market. There is a strong recognition in German industry of the advantages of using highly skilled tradespersons.

There are a lot of training areas within the campus. Overall, the School has fuel cells, heat pumps, hydro and other technologies. It is the only institute that supports all kinds of distributed generation; however there are many other locations around the country that provide training in some of these aspects. DGS (the central authority) handles the consistency of training across the multiple schools.

Other important areas of training innovation are being pushed by Renergy. This is a training organisation located in Berlin. Their goal is to train the trainers all over the world to a high standard of installation capacity for distributed generation systems.

Visit Six

Mr Steffen Porschberger, LeiterBildungszentrumMünchen (Head of Munich Training Centre) and Max Stadler, Bildungszentrum Traunstein, HandwerkskammerfürMünchen und Oberbayern (Chamber of Crafts for Munich and Upper Bavaria), Munich, Germany

Porschberger was able to provide the Fellow a detailed insight into the training methodologies and practices as implemented in one of Germany's leading trades training facilities. The Fellow experienced the best practice in infrastructure used to develop hands-on skills for installers of solar technology and discussed the mechanisms by which the training system adapts to changes in skill requirements.

Outcomes

Sullivan was able to explore some of the methodologies that are used for engaging and capacity building within the trades in Germany. Importantly the emphasis on continuing professional development (CPD) that was exhibited at these training centres, and the high theoretical and practical expertise that was being achieved, highlighted the need for similar measures to be adopted in Australia to realize significant improvements in industrial practice.

Max Stadler and Steffen Porschberger showing the BildungszentrumMünchen

Visit Seven

Mr Pietro Caloprisco, Policy Officer, European Photovoltaic Industry Association, Brussels, Belgium

Caloprisco collates industry-wide data on solar manufacturing and installation across Europe and was able to provide the Fellow detailed trends on the direction of manufacturing.

The European Photovoltaic Industry Association was created around 25 years ago, when PV was just an emerging technology. Currently there is a lot of confusion about what this industry is actually made up of. Traditionally it was considering manufacturers; however with the changing manufacturing landscape and the significant growth in installers and suppliers, there is a need to consider new priorities. The organisation has around 200 members, plus a number of associate members that include financial institutions and consulting services. The role of the organisation is to be located in Brussels to promote legislation reform and incentives for the appropriate development of the industry. On another front, the Association undertakes extensive market research to follow the development of trends. A key emphasis of this work is to identify the main changes ahead and to ensure that the industry is not going to encounter any unforseen hurdles.

Currently it is understood that grid integration is becoming a big problem. In this regard, the Association has to rely on expertise of technology platform providers. In regards to BIPV specific technologies, the approach of the Association is to examine the elements that are going to develop the markets:

- Example of pull - have a specific Feed-in Tariff, rebates and incentives
- Example of push - development of new technology, increased regulations and performance standards
- Look at the support schemes at the national level.

In general the research corroborates the understanding that technologies like BIPV perform better where there is more support for remuneration (such as targeted Feed-in Tariffs). It is noted that it has been proven hard to standardise the product. The industry is currently still far from having a conventional suite of BIPV templates that manufacturers can then tailor to their specific features. Along these lines there is a project called 'PVtrin'. It aims to determine what minimum standards should be created at the European level.

At the highest level, Europe has the SET (Strategic Energy Technology) plan. Although it does not necessarily go into specific aspects of technology development, it outlines the road maps for each of the low carbon technologies for Europe. It aims to create an estimate of the research and development pathways for these technologies. The plan has grown to look at the pipeline of the workforce, so it should play an instrumental role in identifying how training and certification is expected to develop. At this stage the EPIA has not seen any concrete reports yet. Legislation frequently pushes innovation in Europe, so the outcomes of these plans will likely be hugely influential in the development pathways that are realised. In addition, it should be noted there is a parallel roadmap for the building sector; the fact that BIPV overlaps between these two plans may be problematic for its realisation.

The European Commission recently published a roadmap of how Europe can achieve the ambitious carbon emission reduction targets. These targets and the challenge in meeting them may be the requirement to make BIPV viable in the political sphere. Typically, pushes happen at the national level. Federal governments tend to decide if they want to go with large field solutions (closer to convention large generators), or BIPV. In recent trends, the EPIA is finding that more and more residential is being supported, which would be promising for the development of new innovation in this space.

Across Europe there is a concept of solar cities. There is a clear will here, but it is not specifically for BIPV – it is more technology agnostic, focusing instead on the broader technological options. Politically there is a desire to locate generation close to consumers and to give end users greater control over energy generation. In the future it is anticipated that there will need to be new business models to support some of these structures.

Now, the big argument is how does the industry integrate the energy. There are serious concerns on grid operations in light of ever increasing proportions of embedded renewable energy generation. Currently, a key focus is on inverter technology. There are a number of promising innovations that would allow for inverters to play a much more active role in the regulation of the grid and this may be a critical element in resolving the ongoing role of solar power.

Any discussion on the future of distributed generation needs to also include considerations for the evolution of the energy grid. There is another initiative for investigating the development of the grid where there is a high penetration of renewables. Focuses for the study explore who should bear the costs for grid development and maintenance and what is the optimal delivery of technology. As things stand, the role of intermittent renewables will have to be balanced with highly flexible dispatch generation and currently this will require gas to be included to balance photovoltaic generation.

Storage is being increasingly seen as a viable inclusion in the energy balance, but it is important to understand what the role will be and exactly how will this manifest. A clear impact that will occur is the flattening of demand. The impact of this on grid design and management will likely be enormous.

A critical consideration is, as the grid moves towards a more renewable basis, how to ensure security of supply. The EPIA is trying to look at what the key issues are that should be addressed to answer this pressing question. There are many other ways to get around the issue of unstable supply from photovoltaics: both technical and strategic. The creation of virtual grids – through centralised control of dispatch, possible with smart inverters with the capacity of storage – will allow for the aggregation of photovoltaic energy production which can then be directed to where it is needed.

Curtailment (the reduction or cutting off of input into the grid in response to oscillating supply and demand mismatch), currently a favoured method for the inclusion of intermittent supply to the grid by the conventional supply and distribution players, should be the last option.

Another measure that is being pushed is the development of better forecasting of generation. This is an example of something that should be provided by the photovoltaic industry, so that more consistent decisions can be made about supply. It will be critical to provide more communication services to the grid. A promising innovation is the development of forecasting to be provided by individual inverters, based on projections unique to the associated system.

It is not necessarily clear as to what the impacts of these actions are going to be. There are studies on different inverter technologies, in conjunction with meta studies that examine how the various innovations may be combined to best effect.

From the financial perspective, how is a system developed where compensation can be provided to entities that bear the costs for system design and maintenance? To those ends there are a number of individual projects and groups seeking to address these issues. An example would be a project called 'PV Legal' [26] – it is looking at overcoming the bureaucratic hurdles for PV adoption. Importantly, however, it is now perceived as a question of how, not if.

The EPIA is currently updating the Implementation Plan of the Solar Europe Industry Initiative,[27] which includes also a section dedicated to BIPV. As part of this exercise they are meeting with the European Construction Technology Platform leading the Energy Efficient Building European Initiative (E2B EI)[28] to gain more insights into the building sector needs and standards.

7. Knowledge Transfer: Applying the Outcomes

As the technology stands at the moment, there are few instances where BIPV is a cost-viable alternative to BAPV. However, a number of key stakeholders in the solar PV industry are already of the opinion that BIPV solutions will be the natural progression of distributed PV solutions. In light of this, there would be an advantage in Australia taking conscious steps towards facilitating this outcome. As identified in the SWOT analysis, the large number of contact points that BIPV occupies within the design and construction cycle means that it would particularly benefit from strategic implementation by government and regulatory bodies. The areas of knowledge transfer include the following:

1. Establishing improved communication between manufacturers and the construction industry
2. Improving awareness within building designers and other professionals as to the opportunities presented by BIPV
3. Taking steps to improve clarity on BIPV in regulations
4. Awareness of the unique considerations that are involved with BIPV.

7.1 Establishing improved communication between manufacturers and the construction industry

A vital step to seeing the types of technology design that will be compatible with the current Australian construction industry is facilitating channels of communication between technology manufacturers and the installers of these products. An important part of this communication is the emphasis on creating a conventional language. Industry bodies can provide direction on this by promoting standardised sets of information and points of comparison. A good method for improved communication is through the development of decision making tools, such as solar availability modelling [29] and that used in the recently concluded European 'Cost Effective Renewables' program.[30]

Among the considerations that make an impact on the ultimate design of the product are ensuring that existing delineations between trades are understood and incorporated into system design.

7.2 Improving awareness within building designers and other professionals as to the opportunities presented by BIPV

As established in international programs like that of France, active engagement with the building community can facilitate adoption. Facilitated continuing professional development (CPD) for the appropriate trades and disciplines is an effective channel, already demonstrated successfully in a range of initiatives. Consistent pressure for adoption needs to be provided from one source (such as manufacturers), which may see improvements trickle through the required steps of the design/build process, or overall strategies for engagement.

7.3 Taking steps to improve clarity on BIPV in regulations

The shortcomings of regulations in how they address BIPV can be developed in conjunction with the manufacturing sector. Although prudence is advised on leading standards development in advance of large-scale market adoption, pre-emptively driving the development of clarifications around regulations and appropriate interpretation for specific technologies, will improve practice within the installer community and help overcome resistance to technologies that are outside of the 'standard' practice. Direction can be sought from other initiatives for the pro-active development of standards in similarly rapidly developing technology areas.[31]

7.4 Addressing the unique considerations that are involved with BIPV

As identified in the SWOT analysis of BIPV, there are important considerations when incorporating BIPV into a building design. These considerations are dependent on the specific technologies that are being selected and can vary on characteristics of building design and climatic conditions.

Australia has a long history of leading research into solar energy, a tradition that still continues.[32] Ultimately, there is opportunity for the development of a BIPV manufacturing sector in Australia. Providing facility for this development would be highly advantageous to continuing the expansion of green jobs and the sustainable economy.

8. Recommendations

Overall the result of this investigation leads the Fellow to believe there is strong motivation for looking to facilitate the adoption of BIPV in the market. There are a number of avenues for action to see improved uptake of BIPV, many of which may provide outcomes that result in the building industry being more receptive and to improve the capability to deploy other innovative technologies.

The following recommendations are being pursued by the Fellow in achieving an improvement to the adoption of BIPV within Australia:

Industry

- Facilitate collaborative actions centred on improving communication pathways between manufacturers and installers. A proposed initiative that would support this is the ACCEDE proposal for the Innovation Precinct Funds.
- Clean Energy Council to pursue a revision of the Australian Standard AS5033 to accommodate the specific design and construction considerations for effective BIPV installation.

Government

- Determination of appropriate standards for BIPV installations in Australia centred on research available from international studies. These standard definitions will include definition of BIPV classes and correlation of BIPV technology with appropriate requirements of the National Construction Code (NCC). This work is sought to be done in conjunction with the Australian Photovoltaic Association (APVA).
- Undertake reform to the energy regulations and energy market to provide more incentive for distributed generation. This advocacy will form part of the ongoing efforts to redefine the mechanisms of the National Energy Market (NEM) into ways that better utilise Smart Grid technology. Advocacy will support the efforts of the Moreland Energy Foundation (MEFL), the Northern Alliance for Greenhouse Action (NAGA) and the Alternative Technology Association (ATA).
- Creation of appropriate systems for the assessment and approval of BIPV systems, including standard testing methodologies to ensure that minimum performance standards can be achieved.

Education

- Industry bodies (such as the Building Designers Association and the Australian Institute of Architects) to support and devise continuing professional development (CPD) that trains designers and trades to incorporate BIPV installations.
- Skills councils to modify to the appropriate national electrician training modules (UEENEEK135A and UEENEEK148A) to include considerations and specific characteristics of BIPV systems (specifics to be developed in consultation with workshops with manufacturers)
- Skills councils to investigate into the development of plumbing training modules to support installation of BIPV technologies (specifics to be developed in consultation with workshops with manufacturers)
- Research centres in collaboration with manufacturers to develop software tools to facilitate decision making and opportunity assessment for BIPV installation.

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