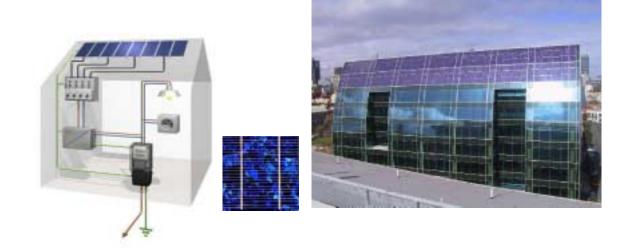
Best Practice Guidelines for Solar Power Building Projects in Australia



Prepared by

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THE UNIVERSITY OF NEW SOUTH WALES

RENEWABLE ENERGY INDUSTRY DEVELOPMENT (REID 7) PROGRAM

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PV Roadmap Network PVPS consortium BCSE members Planning NSW Australian Local Government Association Building Council of Australia Property Council of Australia Sustainable Energy Development Authority of Victoria NSW Sustainable Energy Development Authority

Disclaimer

These Best Practice Guidelines have been developed in consultation with a broad range of external organizations with an interest in building integrated photovoltaic (BiPV) applications. The report aims to facilitate the development of high quality BiPV projects. The guidelines are not intended to replace existing energy, environmental or planning policies, Australian standards or legislation at local, state and federal government levels.

The guidelines are designed as a <u>guide only</u> for designers, developers, tradesmen, building owners, planners, financiers and related practitioners. It is recommended that before proceeding with projects, parties should first seek and obtain their own independent professional support and advice.

Neither the Business Council for Sustainable Energy (BCSE), the project authors, contributors, Commonwealth of Australia through the Australian Greenhouse office, employees, agents and advisers can accept any liability arising from any reliance which may be placed upon the information contained in this publication. Similarly, no responsibility can be accepted arising in any way from any errors or omissions from the guidelines.

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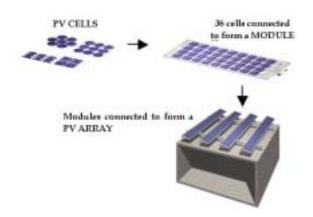
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1 INTRODUCTION

1.1 What is Solar Power Building integrated photovoltaics?

Photovoltaics, PV for short, is what most know as solar panels and is derived from the words "photons" of light rays from the sun and "volts", as in electrical currents. PV cells are made of a semi-conductor material, often crystalline silicon, that is stimulated by photons of sunlight to generate an electrical current. Often solar photovoltaic panels can be confused with solar hot water panels that harness the sun's heat energy to heat water for typically domestic use. PV cells generate direct current (DC) power. As depicted in figure 1, thirty-six PV cells are typically joined together to make a PV module (or panel). A PV array is formed when modules are connected together. The technology is very practical as a building material or integrated as an external building element known as building integrated photovoltaics (BiPV).

Figure 1 – Indicative PV Cell to Module to Array diagram (source: M.ART Martin van der Laan <u>www.laan.demon.nl</u>)



1.2 Why solar power on buildings?

Photovoltaic (PV) power systems installed on the surfaces of buildings allow the possibility of combining energy production with other functions of the building envelope including structural support, weatherproofing, shading, insulation or solar thermal collection. Cost savings through these combined functions can be substantial. Additionally, no highvalue land is required, no separate support structure is necessary and electricity is generated at the point of use. The latter contributes directly to the building occupants' electricity requirements while also avoiding transmission and distribution losses and reducing capital and maintenance costs for utilities. Integrating the photovoltaic power system into the architectural design, however, offers more than cost benefits. It also allows the designer to create

environmentally benign and energy efficient building, without sacrificing comfort, aesthetics or economy, and offers a new and versatile building material.

1.3 Nature of the Guidelines

This publication is a guide that assists in identifying, developing and implementing appropriate solar power building projects in Australia. Its nature is similar to the Australian Wind Energy Association (AusWEA) Guidelines for Implementation of Wind Energy Projects and it is supported by the Business Council for Sustainable Energy (BCSE). The guidelines are not definitive and projects require evaluation on their individual merits. There is no prescriptive timeframe, schedule or checklist that can be universally applied to all BiPV projects equally. Project proponents need to investigate specific issues that relate to a particular site and address these accordingly. The guidelines cover technical, whole building design issues and planning considerations.

1.4 Implementation and dissemination

BCSE intends that proponents of BiPV projects will be able to use these guidelines as a benchmark to help in determining project viability. Adherence with the guidelines is voluntary but BCSE urges its members and responsible practitioners to take them into account in their activities. BCSE also encourages local planning authorities to recommend these Best Practice Guidelines are adhered to by recognising that this will help foster appropriate and successful BiPV project outcomes.

The guidelines are to be widely distributed within the PV industry, building construction groups, design professionals, building financiers and planning authorities and can be made freely available to other organisations and individuals electronically on request or at cost as a paperback copy. The content may be reviewed periodically to take into account changing circumstances, and comments on the content of the guidelines are welcome. The guidelines can be downloaded from www.bcse.org.au

1.5 Structure of Guidelines

The guidelines are structured to allow different stakeholders to identify information that is relevant to them. Section 2 provides a stakeholder checklist that highlights important questions and considerations that are indexed to the main sections of the guidelines. A summary page, "BiPV relevance to different practitioners" is provided for building owners and prospective clients: designers/architects; financiers/prospective investors; construction workers, roofers, tradesmen, foremen, transport drivers; electricians and electrical utility personnel; and planning officers.

The guidelines provide step-by-step information on issues and core considerations for the following phases of BiPV projects. These include:

PHASE ONE	Feasibility and Evaluation
PHASE TWO	Detailed Design
PHASE THREE	Implementation
PHASE FOUR	Compliance & Commissioning
PHASE FIVE	Monitoring and Maintenance
PHASE SIX	Decommissioning

Within these phases, the guidelines aim to assist the reader to:

- develop a design concept
- select appropriate sites
- formulate a project team
- produce detailed designs
- evaluate BiPV options
- construct and install a BiPV system
- connect and configure a BiPV system
- maintain BiPV system performance and upkeep
- retrofit a BiPV system
- dismantle and dispose/recycle a BiPV system

1.6 Stakeholders

As early as project conception, the project developers should have a keen appreciation of the various stakeholders that are likely to be consulted or involved. Stakeholders are likely to include the following parties:

Building/Land Owners

BiPV projects occur only if the person who owns the building or site is supportive. Building/Land Owners often need to be convinced of the values BiPV can bring to a project. For example, in new buildings, it is easier to identify the cost benefits when PV is considered as an integral part of the overall design. With retrofit options, PV (particularly when used as a shading device) can often avoid upgrading mechanical cooling systems and generate power when the building most needs it. BiPV can also be effectively marketed to prospective building owners and its sustainable building credentials used to create a competitive advantage over other building developments. The Building/Land Owner needs a clear understanding of the project concept, the design process and associated risks.

Local Planning Authorities

Without local planning approval, BiPV projects do not progress beyond the drafting board. State Planning law designates local councils to reconcile urban landuse options in the interests of the public good. Protection of cultural amenity by preserving heritage is a key consideration under planning discretion. It is important, therefore, to consider development control plans (DCPs) during early design conception and provide the relevant information to planning officers on aesthetics, building compliance, electricity grid network integration, and importantly, guaranteeing adequate solar access. Increasingly, local governments also require new buildings and major renovations to meet energy performance criteria. These may include consideration of solar access and use of renewable energy systems. BiPV systems may be accepted as contributors to a building's energy performance.

State & Federal Government

The Renewable Energy (Electricity) Act passed in December 2000 requires electricity retailers and large consumers to purchase an additional 9500 GWh per year of renewable energy by 2010. Energy generated from accredited renewable energy sources such as wind, hydro, solar and biomass is tracked through the allocation of tradeable Renewable Energy Certificates (RECs) at a rate of one REC per MWh. This is regulated by the national Office of the Renewable Energy Regulator (ORER) and new generators are required to register with ORER (www.orer.gov.au) to claim their REC entitlements. State and Federal governments also provide funding support programs from time to time that offer incentives and rebates for PV applications. Of particular relevance at present is the PV rebate program (PVRP) for residential systems as described in Appendix A3.

Power Utilities

Power retailers are obligated to purchase renewable energy under the Renewable Energy (Electricity) Act (2000), as described above. Hence, they may be interested in purchasing RECs from BiPV systems. In any case, BiPV owners will need to sign an agreement with their electricity retailer, detailing the tariff conditions applying for PV generated electricity. Another otion is to onsell your RECs to REC agents.

Most power retailers also offer commercial and domestic customers the choice of purchasing, at a premium, a percentage of renewable energy through Green Power Schemes (www.greenpower.com.au).

Network Service Providers

PV power that is connected to the electricity grid will need to interface with Network Service Providers (NSP) who own and maintain the distribution network assets. NSPs may be a transmission or distribution company, an electrical utility or a small grid owner/operator normally regulated under the Electricity Act, as applicable in each state.

Under the National Electricity Code (NEC), NSPs must give generators access to the network services provided by the networks forming the national grid. This is overseen by the National Electricity Market (NEM), Australian Competition and Consumer Commission (ACCC) and National Electricity Code Administrator (NECA). In those states not connected to the NEM (ie TAS, WA and NT), access to transmission networks is controlled by the state/territory energy utilities. To enter the NEM, a generating company must obtain a generator's license by applying to, and registering with, the National Management Electricity Market Company (NEMMCO). A pre-requisite for registration is a connection agreement with the NSP. BiPV owners will need to sign an agreement with their local NSP covering connection conditions.

Details on RECs and metering can be found by downloading *Development of a Standard Grid Connection Agreement for Small Grid-Connected Renewable Energy Systems, January 2003* www.acre.ee.unsw.edu.au/anzses2002/ANZSES_Std <u>ConnAgreeUNSW.pdf</u>

Financing Organisations

Whilst BiPV can be cost comparative to expensive commercial cladding materials, such as polished marble or high tech glazing products, there is often a need to source finances externally to fund BiPV developments. This is in part due to PV not being considered as a subsidiary cost of the whole building in terms of S/m^2 . Similarly, if building costs start to blow out as modifications and issues emerge during construction, PV can be the first item to be omitted. In many cases, the building developer has a build / on-sell mentality that does not encourage consideration of the longer-term benefits of PV. Potential BiPV owners should therefore seek financing organisations, which have an interest in longer term investments and sustainable development.

Buildings can expect their PV to function for at least 20 years or more. Hence, they will be likely to operate in a much more price volatile energy market than is currently the case. This issue should be considered when arranging finance. Some mortgage suppliers provide reduced interest rates for buildings which meet high energy performance criteria, on the basis that the owners will be less exposed to energy price rises and will have lower energy bills. The lower interest rate can effectively pay for the BiPV system well within the mortgage life.

From an environmental risk perspective, financing organisations are beginning to re-position a portion of their investment capacity towards less carbon intensive activities. This, and marketing themselves through environmentally sensitive activities, provides opportunities for prospective BiPV developers to negotiate financial assistance that incorporates PV as part of the whole building cost structure.

Community Groups & General Public

In many instances, BiPV is one of the easier technologies for community groups and the general public to embrace. There are certainly positive advantages in being able to see BiPV installations from street level that the local community can identify with and proudly promote to the visiting public. Often, however, BiPV systems placed on roof surfaces can go unnoticed. This aesthetic invisibility can be warranted if heritage characteristics would result in visible PV being out of place.

2 BIPV RELEVANCE TO DIFFERENT PRACTITIONERS

2.1 CLIENT – BUILDING OWNER

BiPV relevance for building owner

The Building Owner / Client of a building project makes the final decision on whether PV is to be part of the overall design, irrespective of the scale of the project. This decision is governed by factors such as cost, paybacks, value added benefits, in terms of how the PV is applied as part of the overall energy solution, and building aesthetics. A critical factor often is the owner's commitment to sustainable building and to its long-term environmental impact. In such instances, cost may have a lesser role to play in decision making, however, the owner in all cases shows a commitment to environmental responsibility. Building owners clearly need to be convinced by those advising them about most aspects of BiPV. The following questions are particularly relevant.

BiPV checklist for building owner

⇒	How do I determine the cost and payback value of BiPV?	<u>Page 26</u>	
•	What subsidies and rebates are available?	<u>Page 45</u>	
•	What are the product options and their physical characteristics such as colour, size, transparency, flexibility etc?	<u>Page 19</u>	
⇒	How durable are the products and what warrantees apply?	<u>Page 35</u>	
⇒	What performance outputs are possible?	<u>Page 16</u>	
⇒	How much does my location and my building design matter?	<u>Page 16</u>	
⇒	Can I remove or add to my PV system in future?	<u>Page 18</u>	
•	Can I use PV to shade the building so it requires less artificial cooling?	<u>Page 22</u>	
•	Is local Council approval necessary? Will the local council cause problems in approving this or will they look at it more favourably?	<u>Page 31</u>	
+	Are there any additional risks in having PV on my buildings – is it likely to cause problems in future or affect other appliances I may have?	<u>Page 47</u>	
+	Will it delay construction and do I need specialist trades on site to install?		
•	What should I consider with monitoring and maintenance?		
•	What do I need to know about my metering and PV system upkeep/maintenance?	<u>Page 49</u>	
•	Is my building insurance going to cover any risks and will it impact upon the premium?	<u>Page 25</u>	
•	What level of solar access is required for good performance output and is the neighbourhood going to affect this in the short and long term?	<u>Page 17</u>	
+	Can unwanted heat be captured and used as part of an integrated design, for example, to pre-heat water or air?	<u>Page 29</u>	
⇒	What should I know when communicating with:		
	 Architects & Designers 		
	 Planners 	Dage 26	
	 Construction Building companies 	<u>Page 36</u>	
	 PV installer 		
	 Utility & PV owner 		
	 Local Community 		

2.2 DESIGNER – ARCHITECT

BiPV relevance for architects

Including PV in building projects, to a large extent, depends on the knowledge of the architects and designers about this technology (as a building material), its aesthetic qualities, construction detailing, weathering, durability, solar access limitations, performance, products, warranties and cost. The designer is also interested in how PV can be made part of a holistic design solution in terms of the energy equation as well as the overall building aesthetics. Architects develop briefs and advise clients about such options and need to be well informed about BiPV economics, including value-added benefits, greenhouse gas (GHG) emission avoidance, interconnection with the grid or storage, reliability and risks associated with system failures. Whilst architects need to be aware of all these issues, their technical information needs may be mininal. A greater emphasis, especially during the early concept stage is more likely to be on the aesthetic, construction, durability, weathering and solar access limitations.

BiPV checklist for designers - architects

•	What are the product options and their physical characteristics such as color, size, transparency, flexibility etc?	<u>Page 19</u>
•	What solar access and mounting requirements dictate its optimal performance?	<u>Page 16</u>
•	How can the products be detailed for required weather protection when used as external cladding?	<u>Page 18</u>
*	What heat outputs are possible and how can it be used as part of an integrated design?	<u>Page 29</u>
•	How durable are the products and what warrantees apply?	<u>Page 35</u>
•	What performance outputs are possible and what allowances need to be made for locating balance of system (BOS) components such as wiring, inverters and meters?	<u>Page 30</u>
*	What considerations apply to their design eg. ventilation of spaces, egress when inverters are used etc.	<u>Page 31</u>
How do I determine the cost and payback value of BiPV?		<u>Page 26</u>
⇒	What subsidies and rebates are available?	
⇒	What are the building compliance requirements for PV?	
⇒	➡ What are the electrical compliance requirements for PV?	
⇒	What should I consider with monitoring and maintenance?	<u>Page 34</u>
⇒	How do I make contact with the PV industry?	<u>Page 45</u>
⇒	What should I know when communicating with:	
	 The Developer &/or Client 	
	 Local Council &/or Planners 	De re 20
	 Construction &/or Building companies 	<u>Page 36</u>
	 PV installer 	
	 Utility &/or PV Owner 	
	 Local Community 	

2.3 FINANCIER

BiPV relevance for financial institutions

There is increasing interest from householders and commercial building operators in integrating PV systems into buildings. Financiers may be called on to provide finance for the entire building or for the addition of a BiPV system and hence will need to understand the basic principles of BiPV system operation, including their likely impact on energy bills and on building value. Some financial institutions have already put in place favourable policies for dealing with energy efficient buildings, on the basis of reduced energy bills, improved occupant well-being and long term increased property value. BiPV systems can be used as part of the energy efficient features of a building and hence fit the above criteria. They can also create revenue streams from electricity sales, peak load reduction benefits and Renewable Energy Certificates (RECs). These guidelines will assist financiers in assessing BiPV proposals and in developing financing products that appeal to prospective customers and encourage the appropriate installation of BiPV systems.

BiPV checklist for financiers

•	Do you have the relevant information to be able to assess the costs and benefits of the BiPV, including likely reductions in your customer's energy bills?	<u>Page 26</u>
→	Have you cited evidence that the proposed BiPV fulfills all local development control plans (DCPs)?	<u>Page 31</u>
⇒	Is your proposed BiPV project likely to meet building and electrical standards?	<u>Page 50</u>
•	Have you assessed contracts or agreements available or entered into by your client for power purchase or RECs sale?	<u>Page 26</u>
⇒	Have you assessed system performance and installation warranties?	<u>Page 35</u>
•	What aesthetic, environmental, lifestyle and economic values are likely to accrue to the building as a result of the BiPV system?	<u>Page 46</u>
What strategies are in place to ensure continued solar access so that these benefits are not lost?		<u>Page 31</u>
•	Do you have a range of financing options you can discuss with your customer? How might your organisation go about developing new options for this application?	<u>Page 23</u>
•	What are the maintenance implications?	<u>Page 34</u>
•	Where do I go for further advice?	<u>Page 45</u>
•	 What should I know when communicating with: The Developer &/or Client Architect &/or Engineer Construction &/or Building companies PV installer Utility &/or PV Owner Local Community 	<u>Page 36</u>

2.4 BUILDING CONSTRUCTOR

BiPV relevance for a construction worker, roofer, tradesman, foreman, transporter etc

Solar power panel products sometimes seem high risk for building constructors to consider installing, but this does not need to be the case. Whilst solar PV power systems are not cheap items and need to be handled and installed with care, they can be just as, if not, less challenging than putting in a lift system, a spa or a high quality glazing product. There is specialised and accredited know how involved, but once understood, this knowledge can provide construction companies and construction workers with a skills base and understanding that could potentially provide them with a competitive edge in the building market.

When installing PV in new buildings, building construction schedules need to work in harmony with the PV installation. Ensuring roof trusses, flashings, insulation, sarking, support structures, electrical connection points, waterproofing and other building materials are completed to a satisfactory standard prior to PV module installation can significantly improve the likelihood that projects will run on time. Efficient co-ordination by the site manager/foreman is also important. For example, there is a need to think through packing, delivering and unpacking solar components, particularly for large projects and especially if the available building site area is restrictive. Often scaffolding and lifting equipment used for completing cladding or roof structures can also be used to install the solar panels. Teaching tradesmen handling procedures to avoid breakage or damage requires similar attention. Some solar panels are more flexible and durable than others so it is important to follow the recommended instructions from the product supplier or PV expert.

BiPV checklist for building constructors

•	➡ What should the contract schedule consider between the PV supplier and the construction company?	
•	How do we find out how best to handle delivery of the PV system to site and on site?	<u>Page 32</u>
•	What are the various phases involved in installing BiPV?	<u>Page 16</u>
⇒	When do I need skilled tradesmen and what should I expect from them?	<u>Page 32</u>
•	How much training is involved? Is accreditation required to complete the works? What does that involve?	<u>Page 32</u>
•	Do roof penetrations and partial shading of the PV modules matter?	Page 31
•	What should be done if a panel or solar product is damaged, broken or doesn't work?	
•	What is involved in commissioning the system and maintaining it prior to building sale?	
•	➡ What are the building compliance requirements for PV?	
•	➡ What are the electrical compliance requirements for PV?	
⇒	How do I make contact with the PV industry and seek further information?	Page 45
•	What should I know when communicating with:	
	The developer/clientArchitects/designers	
	 Planners 	<u>Page 36</u>
	Electrician	
	PV installer	
	Utility/PV owner	
	 Local community 	

2.5 ELECTRICIAN

BiPV relevance for electricians

Building integrated PV (BiPV) installations must comply with relevant standards for AC and DC wiring and grid integration. There may also be specific requirements for metering or other aspects required by the local electricity utility. For correct performance and safe installation of BiPV, an electrician will need a detailed understanding of solar principles and of the characteristics of PV systems. These guidelines provide both information and contact sources for electricians, to give them an understanding of the technology and its installation requirements. Electricians, however, involved with BiPV installations should consider completing the training necessary to become an accredited installer. Most electricity utilities, as well as government grant agencies, require BiPV systems to be installed by an accredited installer. See the BCSE website (www.bcse.org.au) for a list of accredited installers and training information.

BiPV checklist for electricians

•	Are you familiar with the basic principles of PV system operation, especially their electrical characteristics?	<u>Page 19</u>
•	Are you familiar with both the DC and AC wiring requirements for PV?	<u>Page 21</u>
*	Are you familiar with the grid connection requirements of AS 4777, as well as any separate electricity utility requirements?	<u>Page 33</u>
•	Have you been told whether or not you are to install the panels, as well as wire them?	<u>Page 33</u>
⇒	Have you or the installer, if separate, completed an accredited installer's course?	<u>Page 32</u>
•	If you are to install the panels, has the architect, building developer or owner given you clear directions on their placement? If not, are you aware of the key requirements to ensure maximum output and solar access?	<u>Page 30</u>
⇒	Do you know who to contact for further information?	<u>Page 45</u>
•	If another sub-contractor is to install the panels, have you discussed with them how you will coordinate your tasks and what arrangements have been made for placement of the wiring?	<u>Page 33</u>
•	What should I know when communicating with:	
	 The Developer &/or Client Architect &/or Engineer Planners Construction &/or Building companies PV installer Utility &/or PV Owner Local Community 	<u>Page 36</u>

2.6 ELECTRICAL UTILITY PERSONNEL

BiPV relevance for electricity utility personnel

Interest in integrating solar power in buildings (BiPV) is increasing and electricity utility personnel will be called on to advise on issues such as appropriate electrical connection requirements, power purchase agreements and metering. Some of these details, including interconnecting small PV systems to the grid via inverters, are covered in electrical guidelines or standards; others, such as power purchase agreements with householders, may be included under existing internal utility policies. For innovative or large systems, however, specific arrangements with the developer will need to be made. Electrical utilities also have the opportunity of incorporating BiPV systems into their own plans for green power, Renewable Energy Certificates, distributed generation, network planning and demand management strategies. Hence, they need an understanding of the PV system's electrical characteristics, likely performance by time of day and over a year and, in the longer term, the implications of many BiPV systems in a given area. This document is aimed at assisting electricity utility personnel in making more informed decisions when considering BiPV and encouraging their incorporation into sustainable electricity system plans.

BiPV checklist for utility personnel:

Are your personnel familiar with AS 4777 series of standards concerning grid connection of energy systems via inverters?	l <u>Page 33</u>
Does the utility have existing standard arrangements concerning PV systems? Do these include safety requirements, metering, power purchase, RECs and inspection? If not, what is the procedure to follow through on these issues?	
Does the proposed system fall within existing guidelines covered above? If norwhat are the main differences? What are the procedures for dealing with them?	
Do you have adequate data to assess the energy, green power, RECs and system load values of the BiPV system and any network implications, such as harmonics?	
➡ Who will you contact to find out more?	
 What should I know when communicating with: The Developer &/or Client Architect &/or Engineer Construction &/or Building companies Planners Electrician PV installer Local Community 	<u>Page 36</u>

2.7 PLANNING OFFICER - LOCAL GOVERNMENT

BiPV relevance for a planning officer

Building developments require approval by local government authorities prior to their commencement. The approval decision is guided by design guidelines and local development control plans (DCPs). In the majority of local DCPs, guidance on solar power in buildings (BiPV) is not provided. The planning authority also oversees compliance of building codes and standards during the construction phase and at completion of the building development. This document is aimed at assisting planning officers in making more informed decisions when considering BiPV and encouraging its incorporation into integrated sustainable development planning strategies and guidance notes.

The planning role is particularly important in:

- encouraging the added values PV can bring to a development design, so that they are considered as part of an integrated sustainable design strategy;
- determining the visual aesthetic impact of a BiPV product against DCP and heritage controls; and
- ensuring land use plans and policies secure and guarantee continuing adequate property market access to solar radiation.

BiPV checklist for planning officers

•	Is BiPV considered within the local development controls plans? If not, what is a good approach?	<u>Page 21</u>
•	Do local planning officers have an adequate understanding of the technology and the added values that BiPV can bring as part of the whole building design?	<u>Page 19</u>
•	What visual aesthetic tolerance is there in terms of product selection and performance output?	<u>Page 17</u>
⇒	How do I assess what is a practical location for BiPV?	<u>Page 16</u>
⇒	What strategies can be used to ensure adequate solar access?	<u>Page 31</u>
•	What are the building compliance requirements for PV?	Page 50
➡ What are the electrical compliance requirements for PV?		Page 50
➡ Does the current local planning strategy encourage or discourage the use of BiPV?		<u>Page 17</u>
•	How do I make contact with the PV industry?	<u>Page 45</u>
•	What should I know when communicating with:	
	 The Developer &/or Client Architect &/or Engineer Construction &/or Building companies Electrician PV installer Utility &/or PV Owner Local Community 	<u>Page 36</u>

3 STAGE ONE – FEASIBILITY AND EVALUATION

3.1 Site selection

From the initial planning stage of a building, it is important to consider where solar panels might be sited. This requires an understanding of the climate conditions at the site, the way in which the sun's path travels across the sky during different seasons of the year (depending on latitude), and the building surfaces that are likely to receive high levels of solar exposure without too much interference from shade. Access to adequate direct sunshine is important if high power outputs are to be achieved over a year. But there is flexibility in determining site selection that can allow the solar photovoltaic panels to work well for you. The following helps to better understand these issues.

3.1.1 Orientation

In Australia, and in southern hemisphere locations, building surfaces that have a northerly aspect or orientation will be exposed to good solar irradiation. As a rule of thumb, the optimum solar panel angle is one that is orientated true north and tilted at the latitude angle of its location. For example, Sydney's latitude is 34° South of the Equator so a solar panel orientated true north and tilted 34° from the horizontal would be desirable to achieve maximum annual solar exposure. Detailed latitude angles are provided in table 1 for the major cities of Australia and highlight the difference between Darwin (12.4°) and Hobart (42.8°), but show only a 6 degrees range between Perth, Sydney, Adelaide, Canberra and Melbourne.

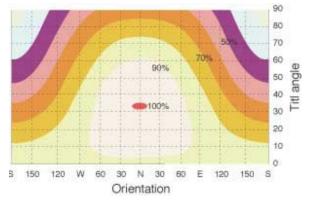
Figure 1 – Latitude angles of major Australian cities [see references for a latitude website search engine]

CITY	Darwin	Brisbane	Perth	Sydney
Latitude	12.4°S	27.5°S	31.9°S	33.8°S
CITY	Adelaide	Canberra	Melbourne	Hobart
Latitude	34.9°S	35.2°S	37.8°S	42.8°S

Solar panels do not have to be optimally orientated to gain adequate outputs. Invariably, compromises with building design features, such as roof angle will be required. For instance, the internal comfort demands of the building and time of use tariffs may favour systems that shade north-westerly exposed surfaces and generate power in the afternoon to reduce the need for artificial air-conditioning and peak load power purchases. This is particularly relevant in commercial buildings. Further discussions on this are provided in section 4.1. Similarly, figure 3, representing a band from south of Sydney through Canberra and Adelaide at 35°S latitude, shows the effect of orientation and elevation on solar panel power output, expressed as a percentage of the maximum possible output. Note that a reasonably

wide range of tilt and orientation angles will still result in useful output.

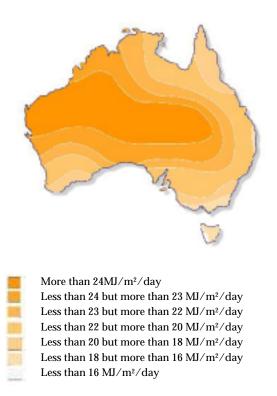
Figure 2 – Chart for latitude $35^\circ S$ and effect of orientation and tilt on PV output (as a % of the optimum)



3.1.2 Australian Solar resources

Australia has an abundance of solar irradiation, so much so that the average solar energy falling on the country in just one day provides more than 25 times the energy used in one year. Figure 3 shows isorads (contours) of the annual average daily solar energy available in megaJoules per square metre per day ($MJ/m^2/day$) for a fixed solar collector facing north and tilted to the latitude angle for near optimum year round performance.

Figure 3 – Solar energy availability in Australia (after 'Australian Solar Radiation Data Handbook', 1995, ERDC).



As an example, the solar energy available in Western Victoria on an average day (18.1 MJ/m^2 /day) would provide about 1 kWh (kilowatt hour) of electricity from two square metres of solar panel with an overall efficiency of just 10%. This is ample to light 4 rooms for 10 hours each using fluorescent lighting. One kilowatt hour equals 3.6 megaJoules (1.0 kWh = 3.6 MJ).

3.1.3 PV module shading

Good PV power performance requires access to adequate direct solar irradiation. Some PV module technologies (see section 3.3.1) such as amorphous silicon can cope more effectively with shading of PV modules. However, commonsense suggests that sites should avoid unnecessary obstructions that reduce sun exposure both from the building itself and surrounding objects. It is also important to consider the potential for shading from trees that grow over time, new building developments and general infrastructure provision such as utility cabling, chimneys and street pylons. Further discussion on solar access issues is provided in section 3.1.6. Partial shading of just a small portion of a photovoltaic surface can have a disruptive effect on its electrical power output, especially if the photovoltaic modules are wired in series to increase the system voltage. This means that the current in individual strings travels through each module. In this 'chain' of modules, the current is only as high as the current produced by the weakest module. A single shaded module will limit the current produced by the unshaded modules. Section 4.3.2 explains how the impact of shading can be minimised through smart electrical PV system configurations.

3.1.4 Soiling of panels

Soiling of PV modules can threaten power performance output but sensible site selection can normally avoid any noticeable losses. There are some instances that require forethought. Notably, in Australia, the sap from gum trees and falling tree debris can be a nuisance and care should be taken to avoid these eventualities or have in place a prescribed means of cleaning the panels. Normal dust build-up is cleaned up by rain, however, the build up of soiling from bird faeces and dirt or contaminants from construction dust, natural dust storms and sulphuric fumes from building exhausts can pose problems, especially on horizontal PV modules. Acidic and sulphuric fumes create a dirt layer, which reportedly is very difficult to remove. Other instances have been reported including a PV system installed on a German railway station that was being contaminated by dust pollution from breaking trains (Haeberlin and Graf, 1998).

Invariably, the rough grain of the front glass cover of PVs encourages self-cleaning during rainfall. It is not

uncommon for PV performance to improve slightly the next clear day after rain. Not surprisingly, panels that are tilted less than 20 degrees from the horizontal (such as in Northern Australia) are less likely to selfclean and may require an occasional clean. Consultation with the PV supplier is often a prudent approach to ensure the owner knows what might be involved in reducing the build-up of PV module soiling. Various products, such as PV Guard, can be used to prevent birds sitting on the panels and keep them in a more pristine condition.

3.1.5 Grid infrastructure

For Building integrated PV (BiPV), the general approach is to be connected to an electricity distribution network, where possible. This grid tied approach avoids the need for on site storage. In essence, the grid is used as a battery storage device exporting excess building power to the grid network during solar power generation and at other times importing power conventionally. The availability or under capacity of grid infrastructure can present added value for BiPV projects. Either at the periphery of grid networks or in high capacity areas, PV can be situated to offer a strategic distributed generation role and reduce the stress on the existing grid infrastructure. In any grid tied BiPV project, it is important to understand the grid infrastructure characteristics and the service providers that you will come in direct contact with when connecting your system. Site location can be a useful bargaining tool in this instance.

Of course, where grid is not available, BiPV can provide the building's electricity or can connect into an alternative power source. An electricity storage facility would normally be required for such independent operation.

3.1.6 Potential planning constraints

All significant building projects require sign off approval from the local planning authority whose decision is guided by planning legislation, building standards and local development control plans (DCPs). In many cases, local authorities do not have either a working knowledge of solar power products nor guidance provisions that developers and project proponents can follow. The guidelines below identify key issues that planning officers should consider.

Potential planning constraints can impact on prospective site locations for various reasons. The following bullet points are indicative of issues that might arise when developing a design and seeking planning approval.

 Existing built form, especially if of historical significance, can be protected by heritage planning controls. These controls can influence the visible (aesthetic) constraints of the BiPV project, including visibility from the street;

- The planning officers may have a lack of understanding of the product, in terms of texture, aesthetics and building and electrical standards. This can delay approval;
- An adequate level of solar access needs to be secured for the longer term so that the generation capacity of the PV is not unduly compromised; and
- In this respect, approving a PV system location predicates the future heights of surrounding buildings and may conflict with local development control plans (DCPs).

3.2 Holistic building integrated design concepts

In achieving a sustainable built environment, an integrated/holistic approach to design, construction, operation and deconstruction is required. This implies that all parties involved in the process are engaged at the pre-design stage of the building and thereafter work to optimise performance and outcomes. The builders, owner, architects, design consultants (including engineers) and tenant representatives should all contribute to the optimizing the process from the earliest stage.

The design process should address social, cultural, economic and environmental impacts. Technologies such as photovoltaics should be considered part of a sustainable building solution rather than an afterthought, both in terms of performance and architectural design. In terms of performance, good solar efficient design creates opportunities for minimizing energy demand. Photovoltaics needs to be matched against residual energy demand, opportunities for peak demand lopping and avoiding greenhouse gas emissions on a whole building and whole of life basis.

PV can also be integrated into existing buildings as part of a retrofit program or just as an add-on. In all cases, performance and anticipated outcomes should be considered as well as architectural aspects.

3.2.1 Building design evaluation

As already mentioned, there are two levels of design evaluation for buildings. Firstly, building performance is evaluated against targets (standards or codes or even client imposed goals). At both the design and post occupancy stages, evaluations are normally conducted to determine such performance. Owners, are advised to expect this in the brief. A number of assessment tools are used for this purpose. These tools should be selected as part of the targets (measures and methods of measurement). The second level of evaluation is much more qualitative. Architects evaluate the architectural quality of a project, including BiPV aesthetics. A good BiPV project enhances the architectural quality of a building.

3.2.2 PV as part of a holistic building design outcome

The architectural character of a building is very important to all parties from local government through to the community at large, including owner/occupiers. It is prudent to carefully consider both the architectural integration (the manner in which the PV adds to or detracts from the architectural quality of the building) as well as the way that PV has been integrated into the building. Whereas the former deals with issues of design quality, the latter deals with construction. A number of "good design" characteristics have been developed by IEA (IEA Task 7, 2002) and are summarised in Table 2 below. These criteria are not mutually exclusive but provide a basis for questioning and comparing architectural quality of BiPV projects.

Table 2 – Key design issues for architects and associated practitioners (Criteria developed by <u>IEA Task 7</u> participants).

Naturally Integrated

The PV system is a natural part of the building. Without PV, the building would be lacking; the PV system completes the building.

Architecturally Pleasing Based on good design, does the PV system add eye-

catching features to the design?

Well Composed

The colour and texture of the PV system should be in harmony with the other materials. In addition, a specific design of the PV system, such as frameless modules, can be integrated to blend into the building fabric.

Dimension, Harmony and Composition

The sizing of the PV system matches the sizing and dimension of the building.

Well Contextualised

The total image of the building should be in harmony with the PV system. On an historic building, tiles or slates will probably fit better than large glass modules.

Well Engineered

This does not concern the water tightness of the PV roof, but rather the elegance of design details. Have details been well conceived? Have the amount of materials been minimised? Are details convincing?

Innovative New Design

PV is an innovative technology, which can inspire innovative creative thinking by architects. New ideas can enhance the PV market and add value to buildings.

3.2.3 Structural engineering issues.

In designing a BiPV system one should also carefully consider the structural loading due to 'dead load' (consequence of system weight) and 'live load' (consequence of factors such as wind). A structural engineer should be consulted if a system is designed from components. If a supply and install contract is entered into with a manufacturer, structural warrantees from the installer should be required. Waterproofing, if poorly installed, can also lead to other problems.

3.3 Technical pre-design considerations

PV technology is evolving and maturing rapidly as PV demand grows. Since the mid 1990s, the world PV market has grown by an unprecedented 30% each year, driven by large government BiPV programs, especially in Europe and Japan. In 2002, grid connected PV. mostly installed on buildings. comprised over 60% of the PV market growth for that year. With this, there are numerous products and PV technologies that are commercially available. The International Energy Agency (IEA) publishes data on national PV progress and can be sourced from www.iea-pvps.com. The IEA task 7 program (PV in the Built Environment) has published a range of BiPV design concepts available through the above website and also maintains a database with over 400 products and projects from around the globe. This is found at www.pv.database.com and provides an excellent reference for design concepts and pre-design considerations.

The following section provides a summary of the key PV cell technologies and their performance attributes. The information is given in simplistic terms but covers some of the important issues that need to be considered when thinking about selecting a PV technology selection.

3.3.1 PV cell technology

There are numerous PV technology options for different climatic and locational circumstances, including a range of colour, textural and malleable PV cells. Solar cells can be separated into four categories, according to their crystalline structure. A short description and some features of the PV types typically used for building applications follows, with the different types illustrated in figure 4.

Mono-crystalline silicon cells

These cells are made from very pure mono-crystalline silicon. The silicon has a single and continuous crystal lattice structure with almost no defects or impurities. The principal advantage of mono-crystalline cells is their high efficiency, typically around 15 per cent or higher, although the manufacturing process required to produce mono-crystalline silicon is complicated, resulting in slightly higher costs than other technologies.

Different manufacturing methods are used. depending largely upon the Czochralski method of growing, or pulling a perfect crystal that has a solid, cylindrical shape. EFG - Edge-defined Film-fed Growth has become popular, where the cells are cut from an octagon, so as to allow higher packing densities in modules. Another approach deposits grown films of crystalline silicon onto a low cost substrate. The cost of silicon ingot sawing is eliminated and the quantity of silicon per PV module can be reduced significantly. A third approach is a string ribbon technique, where two high temperature strings are pulled vertically through a shallow silicon melt and the molten silicon expands and freezes between the strings.

A major cost component of a conventional photovoltaic module is the processing of the silicon wafers, electrical interconnection and encapsulation. There are many methods under development to try to reduce these costs. A new Sliver Cell[™], developed by the Centre for Sustainable Energy Systems at the Australian National University and under production by Origin Energy, is produced using special micromachining techniques, requiring the equivalent of two (rather than sixty) silicon wafers to convert sunlight to 140 Watts of power. The thin slivers are bi-facial and can be spaced out as required within a glass encapsulant to alter its translucent properties.

Figure 4 - Different PV cell types

Mono-Crystalline Silicon

Conventional PV module, typically a very dark blue, indicating high light absorption

Poly Crystalline Silicon

Typically a variegated bright blue, but also available in a range and combination of colours such as grey, magenta and cyan

Amorphous Silicon

Reddish-black appearance, very flexible and durable

Titanium Dioxide

Often known as the Grätzel cell and can be used as a clever window product

Sliver Cell[™]

These are strips of mono-crystalline cells that require 90% less silicon for the same power output









Poly- or multi-crystalline silicon cells

Poly-crystalline (also called multi-crystalline) cells are produced using ingots of multi-crystalline silicon. In the manufacturing process, molten silicon is cast into square or rectangular ingots, which are allowed to cool so as to form large crystals. These ingots are then cut into very thin wafers and assembled into complete cells. New manufacturing methods also use the approach of grown films of poly-crystalline silicon on a low cost substrate. Such substrates have included a metallurgical grade silicon sheet, stainless steel, ceramics and quartz glass, using a variety of growth techniques to deposit silicon films onto these substrates. Poly-crystalline cells are cheaper to produce than mono-crystalline ones, due to the simpler manufacturing process. They tend to be slightly less efficient however, with average efficiencies of around 12-13 per cent, although new processes are attaining higher efficiencies.

Amorphous silicon cells

Amorphous silicon cells are composed of silicon atoms in a thin homogenous layer, rather than a crystal structure. Amorphous silicon is produced by deposition onto a substrate (rather than wafer sawing) so the cells can be thinner. For this reason, amorphous silicon is also known as a 'thin film' PV technology. Amorphous silicon can be deposited on a wide range of substrates, both rigid and flexible, which makes it ideal for curved surfaces and 'fold-away' modules. Amorphous cells are, however, less efficient than crystalline based cells, with typical efficiencies of around six per cent., However, they require less material and are therefore cheaper to produce. Their low cost makes them ideally suited for many applications where high efficiency is not required and low cost is important. For instance, their early market has been in appliances such as calculators and watches.

Other thin films

A number of other promising materials such as copper indium diselenide (CIS) and cadmium telluride (CdTe) are now being used for PV modules. The attraction of these technologies, compared to silicon technologies, is that they can be manufactured using relatively inexpensive industrial processes. They also typically offer higher module efficiencies than amorphous silicon. Some of the raw materials required, are less abundant than silicon and there are lingering concerns over the environmental toxicity of some of the elements used. However, it is possible that these issues can be overcome with careful manufacturing, recycling and disposal processes.

Some of the new thin film technologies being released use layers of different cell types, in order to capture a wider range of solar radiation and hence increase efficiencies. These are known as tandem or stacked cells.

Dye-sensitised solar cell (DSC)

Dye-sensitised solar cell (DSC) technology is best considered as artificial photosynthesis. It performs well under indirect radiation, cloudy conditions and partial shade. DSC technology has been dominated by the Grätzel titanium dioxide (TiO_2) cell.

Particles of titanium dioxide are coated with a photosensitive dye and suspended between two electrodes in a solution containing iodine ions. When this dye is exposed to light energy, some of its electrons jump on to the titanium dioxide particles, which are then attracted to one of the electrodes. At the same time, the iodine ions transport electrons back from the other electrode to replenish the dye particles. This creates a flow of electrons around the circuit. Efficiencies over time are still to be established, but technically could reach around 10 per cent or more. The cells are very effective over a wide range of sunlight conditions.

Table 3 - Summary of the performance characteristics of	the
most notable PV technologies (IEA PVPS Programme, 200	3).

PV technology type	Market Share of PV Module Product -ion (%)	Surface area for a 1kWp system (m ²)	Typical efficiency	Maximum efficiency recorded outdoors
Mono- crystalline (m-Si)	55%	8	13 - 17%	22.7% ± 0.6
Poly- crystalline (p-Si)	33%	10	11 - 14%	15.3% ± 0.4
Amorphous silicon (a-Si)	4%	17	6 - 8%	10.4% ± 0.5
Cadmium telluride (CdTe)	2%	14	7 - 10%	10.7% ± 0.5
Copper indium diselenide (CIS)	3%	11	8 - 12%	13% ± 0.6
Gallium arsenide (GaAs)	1%	5	20%	25.1% ± 0.8
Titanium dioxide (TiO ₂)	2%	20	5%	10%

Over 85% of the PV sold internationally is based on crystalline silicon wafers. The photovoltaics industry is one of the most rapidly growing industries worldwide, with an annual growth rate exceeding 30% for most of the past decade. Annual sales now stand at around 500 MW, are valued at over US\$1 billion and are expected to more than double by 2010. PV module costs have fallen from around US\$60 per Watt in 1975 to around US\$2-3 per Watt and are expected to fall below US\$2 per Watt by 2010. Photovoltaic power systems are already cost competitive against diesel and other options for many off-grid applications and are expected to be competitive against main grid power in many countries by 2015. Table 3 above compares the typical efficiencies of PV technologies on the market today and looks into the future, by seeing what can be achieved in the laboratory. The first column indicates the percentage market share of PV module production by PV cell type.

3.3.2 PV cell and module manufacturing

The solar cell is the basic unit in a \overline{PV} system. An individual solar cell can vary in size from about 1 cm (½ inch) to about 15 cm (6 inches) across and typically produces between 1 and 2 Watts. This is hardly enough power for the great majority of applications. The power is increased by connecting cells together to form larger units called modules.

The cells are welded in series to form a string of several solar cells. Standard modules use around 36 solar cells and have a peak rating (Wp) of around 60 Watts, although the trend is to higher ratings. For large modules (150 Wp), two cell strings are employed and can be connected at the back to electrical junction boxes. Thin-film materials such as amorphous silicon, CIS and cadmium telluride can be made directly into modules. The cell material is sputtered onto a substrate, either glass, polyamide or stainless steel, and interconnected to a module by laser.

A PV module is composed of interconnected cells that are encapsulated between a transparent cover and weatherproof backing as shown in figure 5. The modules are typically framed in aluminium for mounting, although frames may not be required for building applications. The PV module is the basic building block of any PV power system. The term 'solar panel' is often used to refer to a PV module. The same expression, however, is also used in reference to solar water heating systems, so to avoid confusion, 'photovoltaic' or 'PV' module is preferred.

Figure 5 - PV module layered structure.



Source: Martin Van Der Laan (M. ART).

Solar cells are laminated to protect them from the external environment. On the front, a tempered, low iron-content glass is usually used. This type of glass is relatively cheap, strong and stable. Furthermore, it has a high transparency, good self-cleaning properties and prevents the penetration of water, water vapour and gases. On the rear side, a thin polymer sheet is usually used. The sheet should also prevent the penetration of undesirable vapours and gases. For bifacial modules, which can generate electricity from front and rear, or when extra strength or semitransparency is required, glass is used at the rear. To provide adhesion between the different components of the module, the cells are sandwiched between thin sheets of ethyl vinyl acetate (EVA). The encapsulant should be stable at elevated temperatures and under UV exposure. The stability of the encapsulant is one of the major contributors to the expected lifetime of the module. To improve the strength and rigidity of the module, it can be framed using aluminium, although this is usually not necessary for BiPV applications. Some of the crystalline silicon PV module manufacturers now guarantee a lifetime of 20 years for their modules.

Typical power module sizes are 0.5 x 1 metres and 0.33 x 1.33 metres. However, modules for building applications tend to be larger and, for special projects, modules of any desired size can be produced. Amorphous silicon can be deposited directly onto building components, e.g. window glass, metal sheets, plastics and roof tiles. Standard rectangular modules can be delivered with or without frame. Frameless modules, or laminates, can essentially be processed as normal glass panes. The thickness of glass-Tedlar laminates is generally 8 mm. Glass-glass laminates are typically at least 10 mm thick. Tedlar is used to provide back reflection and a high transmissivity toughened glass acts as a superstrate.

3.3.3 Climatic effects – temperature, ventilation, relative humidity etc

With each of these discrete technologies comes different responses to climatic effects. For most PV technologies, except amorphous silicon, the hotter the air temperature the lower the efficiency. PV modules work very well during high sun but relatively low ambient temperatures (eg. below 25°C). Most PV cell technologies also generate less power during overcast (diffuse) climate conditions.

PV modules generate direct current (DC) electricity and this power is rated by the manufacturer against Standard Test Conditions (STC). STC measures panel performance in artificial conditions. It replicates ambient air temperature of 25°C, solar irradiation intensity of 1000 Watts per square metre (W/m²) and half times the thicknesses of the earth's atmosphere at the equator. This is comparable to a clear noon day at approximately 40° latitude. Modules may be rated as 100 Watts under STC and fall within actual performance of +/-5%. Given that Australia experiences a higher number of air temperature days above 25°C, there is likely to be more frequent temperature derating of power output, especially during the height of summer. In addition, when operating on a roof or flat surface, PV modules can reach an internal temperature of between 50-75°C, causing further derating.

Consequently, it is important to consider the climatic influence on different PV types and where they are likely to be sited. Natural ventilation can be used through good design to cool the PV module to a more desirable operating temperature. This is particularly true of PV walls. The building can be designed to draw hot air through and out of the top of the building, thus providing a cooler environment in which the BiPV system can operate. Amorphous silicon modules may be preferred in high temperature applications, despite their lower overall efficiency, since their performance is not as sensitive to temperature.

Other climatic effects such as relative humidity and the salt air conditions of coastal regions can encourage moisture build up and corrosion. This is especially true for PV modules that are poorly sealed, an unusual occurrence today. The wires feed into a panel, called a junction box. This device should be either watertight or allow accumulated moisture from condensation to drain.

3.3.4 PV system sizing

As with selecting the power and torque of a car to pull a speedboat and trailer, there are some key considerations when determining PV system size:

- System size is firstly influenced by the available PV surfaces, orientation and access to useful solar energy;
- Power output is, in turn, relative to the solar resource of the site, climatic characteristics and the technology used;
- The selection and wiring of adjoining modules and resultant power output will be impacted by shading conditions;
- The DC power generated from the system will work at a lower-than-rated power output when air temperatures are high, irradiation intensity is lower than expected, or when dirt and contaminants cover the modules; and
- When the DC power is passed along wires to the inverter and converted to alternating current (AC) there is a power loss that can

range from 5 to 20% depending on conditions, the length of wiring and the technology used.

The following example illustrates some considerations involved in sizing a system:

A residential house in Canberra has 32 m² of roof space facing true north at an optimum tilt angle of 35° from the horizontal (note that many houses have a roof angle of only 25°). There is good solar access, clear from trees, street poles and the chimneystack to avoid shading. A covenant may be necessary from the local Government to avoid future multi-story houses shading the north face. With mono-crystalline silicon cells, there is sufficient space for 4kWp to be installed. Given system losses, the inverter is 3.6kVA representing 90% of peak rated power. A larger inverter would be more costly and would result in the inverter working at sub-optimum conditions for longer periods of time. Given Canberra's high irradiation intensity, the AC power output over the year would total 6,400 kWh, providing net surplus energy generation, especially if it is an energy efficient home.

3.3.5 Mounting options

The mounting options for BiPV are numerous and depend on surface constraints. These include surface tilt angle, the bearing capacity of roof joists, PV's role in weatherproofing and the influence of natural occurrences such as wind loads, snow, ice and hail and lateral loads in earthquake prone areas. Many of the mounting approaches ensure overly secure fixtures and support frames as required by building codes.

Other options can allow the PV to be mounted to shade the building so it requires less artificial cooling. This can be via conventional or specially designed sun shades. Similarly, the building design can help to dispel hot air away from the panels to improve their operating environment. An air gap of between 5-10 cm behind the PV module can encourage natural ventilation and cooling, thus improving PV power performance. BiPV products can be designed for use as skylights or windows, with the level of transparency set by appropriate cell spacing or by the use of translucent thin film products.

3.3.6 PV wiring issues

While good orientation and clear solar access are desirable, thought needs to be given to the wiring that links the PV power generator to an electrical load or distribution network. PV modules generate DC electricity. Electrical standards require DC wiring to be heavily insulated and both cables and switches are more expensive than conventional AC wiring. Thus most installations limit the DC wiring run to the inverters to maximise the use of AC wiring. Often sections of PV wiring are exposed to the natural elements, thus requiring waterproofing and UV resistance in line with electrical standards. Wiring should also be uncluttered and easily accessible to simplify maintenance. Placement of the wiring during roof and wall construction makes final installation and interconnection simpler.

3.4 Financial and financing considerations

3.4.1 PV system costs and energy values

When assessing cost effectiveness and arranging finance, the initial capital cost of the PV is of primary importance. Cost estimates should include installation, displacement building costs, and the value of generated electricity. There may also be grants, Renewable Energy Certificates (RECs) or other incentives available, which will reduce costs or increase revenue. Increased building value or rental income may also be applicable.

Prices for electricity generated will depend on your retail contract. Some retailers offer net metering, whereby the electricity retailer agrees to charge only for the amount of electricity used above that generated over a given period. Your PV electricity is thus valued at a retail tariff rate. If your PV system generates more than you use, you will be offered a buy-back rate. For residential systems, this is typically equivalent to the retail tariff. For commercial or industrial systems, it may be equivalent to the bulk supply tariff (which is lower than the retail tariff) or something in between. However, net metering is not always offered. You may instead be paid at one rate for all electricity used by the building.

Electricity distributors are increasingly concerned about the rapid rise in summer peak loads. This places a strain on the network and can lead to substantial upgrade and peak supply costs in some areas. Electricity distributors do not currently provide general incentives for summer peak load reduction. BiPV systems, however, have the potential to reduce network load or supply peak power and can therefore be valuable both to the distributor, and the retailer. This issue should be raised when approval is being sought for grid interconnection. As the problems escalate, these network and peak supply values may be given credit.

In all cases, appropriate arrangements must be made with the electricity network provider and an electricity retailer before installation goes ahead. PV installers should not assume that electricity retailers will automatically want to purchase electricity generated, or that they will allow net metering.

3.4.2 Renewable Energy Certificates (RECs)

Electricity retailers need to purchase RECs each year, and may be interested in buying them from the PV owner. RECs can also be traded privately. Current RECs prices typically range from \$25-\$35 per MWh for PV and can be claimed for a five year period. For a 1 kilowatt PV system in Sydney, RECs may be worth a total of around \$170-240. PV companies may offer higher RECs rates to purchasers of their systems.

3.4.3 Ownership – building, roof, PV, electricity – implications for finance options

Photovoltaic systems have low running costs but relatively high initial capital costs. The PV owner, therefore, must consider the best options for capital cost repayments. For BiPV systems on new residential buildings, it would normally make sense to consider the PV cost as part of the building cost and include it in the mortgage. Building retrofits can also do this. Including PV in a mortgage, however, may require the bank or financing institution to know about PV and is willing to agree to its inclusion. Insurance issues will also need to be considered. There are an increasing number of financial institutions and insurance companies, which are supportive of renewable energy initiatives and offer attractive mortgage rates. It may, therefore, be worthwhile shopping around for finance.

The building owner may not always be the PV system owner. In some cases it may make better financial sense for the PV to be owned by the electricity retailer or by a third party. The building element into which the PV is placed (ie the roof) may therefore be fully owned or leased by a third party, with suitable access arrangements with the building occupants. A third option is for the PV system to be financed by a third party and a lease arrangement made with the building owner. This will enable so that the system to be paid back over time. For non-residential buildings in particular, it may be worthwhile exploring a range of possible options to achieve the best financial return.

3.4.4 Prices vs building materials

Some BiPV products can take the place of a standard building component, such as a roof, wall, skylight or window element. When calculating costs, the BiPV cost should therefore be offset against savings in conventional material requirements and installation. When used as a façade element, BiPV costs may be no more than marble, sandstone or other feature materials. Standard roof and wall materials, however, tend to be cheaper and may be in the range \$20 - \$200 per m². This compares with window and curtain wall materials that can range from \$200 - \$500 per m². These costs compare with current PV costs of \$600 - \$1200 per m². These prices continue to fall in real terms and can also be lower for large orders.

3.4.5 Other values to consider.

Other added values include:

- enhancing the building's value by the presence of BiPV elements;
- synergies with other forms of energy, such as heating and cooling, where the BiPV element adds to insulation value, space heating or to shading;
- prestige and marketing opportunities;
- architectural merits and aesthetics;
- consumer satisfaction for those that desire for environmentally sound products;
- customer satisfaction for those that desire for increased energy autonomy; and
- contribution to triple bottome line.

Customers will place different values on the above. A building developer, however, will be aware of the client's interests and may find that some of these values are highly rated. Often they may make up for the added cost of BiPV installation.

The amortised cost of electricity from PV systems depends firstly on the eventual net system cost. This takes account of displaced building components such as grants and financing. Energy buy-back rates can then be negotiated.

For instance, for a 1 kilowatt peak (kWp) PV system costing \$12,600 installed and producing an average of 4 kilowatt hours (kWhs) per day for 20 years, the electricity cost would be around 50c/kWh if maintenance and discount rates over the 20 years are included. With the grants and RECs currently available, the capital cost can be reduced to around \$8,000, so that the electricity cost would be around 30c/kWh. If building materials and costs are displaced, the net capital cost could be further reduced.

How cost effective this is for you will depend on the alternative cost of electricity, including your assessment of how this might change with time. For instance, PV system outputs, and increasingly electricity tariffs, will be higher in summer. In some cases (i.e. for retirees), the customer may be happier to expend capital now, so as to reduce future energy bills.

The other values listed above will improve cost effectiveness for the client, but may be more difficult to include in monetary analyses. It may be possible, however, to do so for specific buildings or customers, for example where a value can be placed on the building's reduced overall energy needs or improved ambience; where marketing opportunities can be captured; or where greenhouse gas reduction requirements or energy performance ratings are necessary due to internal or external policies.

Life-cycle greenhouse gas emissions from gridconnected wafer silicon-based PV systems are around 100kg CO_2 equivalent per MWh. This compares with emissions of around 900kg per MWh from black coal fired power. Hence, the PV system cited above would displace approximately 23t of CO_2 emissions over its lifetime. Thin film PV technologies have even lower emissions.

3.5 Early dialogue and consultation

Early dialogue is essential, right from the building design concept stage. All too often, PV can be processed as an afterthought. This can isolate PV from the building design and leads to the solar component being dismissed when difficulties arise and costs go beyond the budget set down for the project. The following provides a brief guide to the consultation process.

3.5.1 Project team and stakeholders

With new building projects, the developer works to deliver building projects on budget and time in accordance with building standards and planning laws. The project design is typically crafted by an architect or building design specialist in close consultation with the client (land/building owner). The developer may also be the owner wishing to on-sell the building once completed. Through this arrangement, the fundamental relationship is that between the architect/designer and the developer/ building construction company. Conceptualisation of the design and financing is the very first step. It is at this very early stage that a PV expert should be engaged to work with the building client and architect to advise on integration possibilities. From a technical and financial perspective, the PV expert can provide various BiPV product and design scenarios.

Discussions with the local planning authority is also vital at the concept stage. This ensure that, when the final building design is submitted for approval, PV is not a surprise component that presents new evaluation skills that could slow a planning officer's assessment of the building.

As PV involves an electrical element, the relationship between the building and the electricity service provider is imperative. Potential barriers and difficulties should be identified through consultation with the network service provider with a view to developing a contractual agreement. Bargaining may include reducing the building's total energy demand through prudent design and selecting energy efficient appliances. Together with the PV system, this may reduce the capital outlay of the network service provider in supplying electricity to the site. Gains of this sort could help in brokering deals on metering costs for the PV system and a buy back arrangement that increases the value of the PV's output against electricity retail costs.

Once a building design concept that includes BiPV is defined, it is prudent to draft a schedule of works and identify where training and expert assistance will be required. It is also advisable to determine how the PV installation timing will coordinate with electricians or other services required on site. New BiPV design projects can often be unique, with the developer having no working knowledge or experience of the technology. This can create undue uncertainty and is why schedule planning is so important. Consultation should be carried out with the architect, an independent PV expert, the PV system tenderer and the developer/ building construction team.

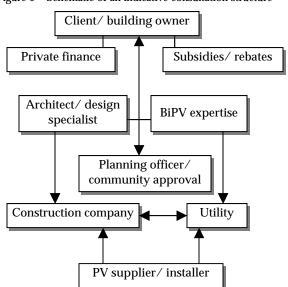
The approval of design and construction rests with the planning, survey and building inspection officers, who monitor the building's development on behalf of the community as a whole. Once planning approval has been given, structural, mechanical and electrical engineering service companies should be closely coordinated with the numerous building trades to ensure the building is completed efficiently, on schedule and within a prescribed cost.

The above description could give the impression that BiPV is a complex and costly addition to a building project. This need not be the case, since for small residential systems, approvals are standardised and straightforward while installation can be completed in half a day. If appropriately co-ordinated, larger, individually designed systems can be readily accommodated with little change to the building schedule.

3.5.2 Consultation structure

The following schematic (figure 6) provides an indicative structure for consultation. Note again that for standard small residential systems, PV suppliers or installers will provide the necessary expertise.-, They may also handle all intermediate negotiations and might offer independent financing.

The client/building owner may not pursue a BiPV project without access to private finance and/or public subsidies and rebates. Again, early consultation between the architect/design professional, a BiPV expert and the client is critical for developing options from the early concept phase. Details of a preferred project plan can then be submitted in conjunction with community and planning consultation as part of a Building or Development Application.



The construction company, the network service provider (utility) and the PV supplier and installer are co-ordinated by the project architect assisted by the PV expert's advice.

3.5.3 Tender documentation and assessment.

Particularly for large projects, the client, architect, builder and planning authority are often brought together to establish a BiPV project consortia. Independent PV expert advice is often a prudent investment at this early stage to evaluate the design options, draw up tender specifications and assess the PV tender documentation. In essence, the key aim is to secure the services of a PV related company or companies to, for example:

- Design or follow a design plan
- Ensure supply of the BiPV products
- Train on-site tradespeople involved in installing or arranging expert installers
- Make suitable arrangements for grid interconnection
- Supervise installation and complete certification and commissioning
- Set up a PV monitoring process and display, where required
- Advise on, or conduct, routine maintenance.

Figure 6 - Schematic of an indicative consultation structure

4 STAGE TWO – DETAILED DESIGN

4.1 Detailed evaluation of building characteristics

4.1.1 Building energy performance;

At an advanced design stage of a building, a series of comprehensive performance evaluations/simulations are conducted for the whole building. This includes heating, cooling, lighting and other such energy needs. At this stage, much more information is available on building design, structure and services. It is therefore appropriate to conduct a more advanced performance evaluation of the PV system to tie in with the performance of the building. Environmental/service engineers working on the design are able to conduct this as long as the design brief allows for this to occur. Often a comprehensive building assessment including material use, biodiversity impacts, water, waste and other indicators is possible. Hence the life cycle role of PV can be assessed. Moreover, a 'carbon neutral' requirement is often built into a building brief to demonstrate that over the life of a building the PV inputs contribute to this requirement.

4.1.2 Network interconnection;

Network interconnection is a key benefit of BiPV which uses the distribution grid to export power. Early consultation with the network provider and electricity retail supplier is highly recommended. Further information on network requirements can be obtained from A5 BiPV codes and standards. Details on network interconnection can be found by downloading Development of a Standard Grid Connection Agreement for Small Grid-Connected Renewable Energy Systems, January 2003 www.acre.ee.unsw.edu.au/anzses2002/ANZSES Std ConnAgreeUNSW.pdf

4.2 Design integration options

Photovoltaics can be placed in the building envelope with varying levels of physical integration. A very useful database of products and projects from IEA participating countries, of which Australia is one, can be found at <u>www.pvdatabase.com</u>. Custom and proprietary systems can be categorised into three main architectural applications:

- Roofs, including skylights;
- Façades and walls; and
- Sunshade or rain-screen elements.

Various integration approaches are possible within these broad categories. Notable examples and concept characteristics are provided below.

4.2.1 PV Roofs

Flat roof systems use the roof space in a similar way to ground based remote area power systems (RAPS). PV modules are discrete from the building, yet take advantage of unused roof area. Mounted PV module systems do not provide an essential building material function but impose additional weight to the roofing structure. They are, however, very easy to install on a range of roof types, can add insulation value and protect the roof area that it covers.

Figure 7 represents a roof PV integration system retrofit on top of the historic Queen Victoria Markets in Melbourne.





From an engineering perspective, the fixed wind resistant mounted panels on the roof require additional load to be considered. It is also necessary to ensure that the watertightness, drainage and insulation properties of the building's roof membrane are not compromised. In addition, there is a need to consider wind generated uplift forces, and as a consequence, this may restrict suitable available roof area. For a standard system, these aspects will have been taken care of by the PV supplier and will be understood by accredited installers.

Figure 8 – Swiss Electric Plug & Power^ ${\rm TM}$ system on a residential roof in Sydney previously marketed by Pacific Solar.



Sloped roof systems, commensurate with residential buildings, offer optimised tilting of PVs. The products from PV Solar Tiles (figure 11 and 12) and EPV, Shell, MSK, Electrowatt, Solrif, Uni-solar and Photowatt, shown in figure 9 from DEMOSITE in Lausanne,

Switzerland, are module integrated mounting profiles where the roof accommodates the pre-existing module dimensions.

Figure 9 – Mounting products displayed at DEMOSITE in Lausanne, Switzerland (<u>www.demosite.ch</u>)



PV shingles, however, are complimentary roof tile materials, as evident with products from Braas, Sunslates and Sunnytile (see figure 9). These are less visually intrusive and conform to conventional roofing materials, despite a trade off in efficiency output.

Other examples characterise the versatility of PVs to blend into the existing cultural building context and remain aesthetically unobtrusive. Figure 10 shows a 166 kWp BiPV system at the Kogarah Town Square Development in Sydney. In this instance, Unisolar amorphous PV roof sheets are industrially glued to a conventional spandek roofing system.

Figure 10 – Unisolar amorphous PV at Kogarah Town Square, Sydney



From an Australian BiPV product base, Peter Erling's PV Solar Tiles are the first, and so far the only solar tiles to be designed and made in Australia. The unique design of PV Solar Tiles allows them to be

fully integrated into the building, replacing the original roof material and becoming a part of the roof.

Recent solar tiles consist of a toughened glass solar laminate. The edges of the glass are protected and sealed by a long life gasket, and surrounded by a durable frame. During installation, the tiles are joined side by side on the roof by a coverstrip that is screwed to the roof battens, fastening each tile in up to eight locations. The solar tiles are supported by specially ventilated steel battens spanning the rear surface of the tile, This allows the tiles to be walked on, just like the rest of the roof surface. Airholes in the batten allow air to move more easily through the roof behind the PV tiles. This provides a cooler environment in which to operate and allows warm air to be collected for space heating.

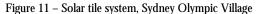




Figure 12 – Customised solar tiles used in keeping with the original character of a late 19th Century Paddington terrace



4.2.2 PV Façades

Energy yields are typically lower for **wall and façade applications**. This is due to sub-optimal orientation and shading influences from surrounding buildings. Nevertheless, PV applications on façades can optimise the available surface area and displace conventional façade cladding materials. Ventilation strategies within the building can be optimised to dispel hot air around the PV system, especially in summer periods.

Opaque PV modules installed as PV window awnings and louvres provide shielding from direct sunlight while allowing diffuse light to penetrate the interior spaces of the building. This utilises both the wall and window areas of a building's façade. It has been demonstrated that west orientated applications, although sub-optimal for annual PV output, effectively reduce the demand for air-conditioning, particularly on summer afternoons. Various integration strategies can be employed to maximise PV façade applications. Figure 13 is a southwest oriented PV louvre system in Tokyo, Japan (northern hemisphere) which helps to shield the building's façade from intense summer afternoon sun while providing diffuse natural light into office spaces. This is also very architecturally appealing and innovative.

Figure 13 – Louvre system at a Steel Headquarters SBIC Building in Tokyo, Japan



4.2.3 Translucent PV

PV atrium designs are more progressive architecturally in that it balances passive and active solar outcomes with possibilities for harnessing translucent PV/glass technologies (figures 14 and 15). They are one of the most cost effective applications for PV, especially for commercial or light industrial buildings that are used predominantly during the day. Their dual function also places them under the PV/ cogen category, as discussed in <u>Section 4.2.4</u>.

Figure 14 - Melbourne University translucent façade



The system shown in figure 15 harnesses the translucent properties that PV provides, creating curved or dynamic surfaces as a fundamental construct of the building. Architecturally, this presents new design options for working with a variety of support structure materials and complimentary building textures, as shown in figure 15 below. Here wood and steel are combined to achieve an attractive and functional building design. Importantly, the architect can control and experiment with a building's natural light to transform the colour and feel of its internal spaces as the sun's position alters during daylight hours.

Figure 15 - ECN, The Netherlands



4.2.4 PV/ Thermal (PV/ T)

Depending on the technology used, PV cells convert approximately 6-18 percent of incoming irradiance into electrical energy. The rest is reflected, re-radiated, or lost as low temperature heat. The build-up of heat provides an impetus to remove unwanted heat from behind the PV modules by using a fluid flow to utilize thermal energy. There has been considerable interest in this concept, which is known as combined PV / Thermal (PV/T) systems or PV cogeneration (PV cogen). In any BiPV cogeneration system, the usefulness and timing of the thermal energy produced is crucial. The thermal energy can be:

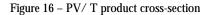
- transferred via a heat exchanger to hot water systems;
- used in conjunction with air source heat pumps;
- used to heat thermal mass;
- stored in underground pebble beds or phase change materials; and,
- used to preheat incoming air in cold seasons for buildings with high ventilation requirements.

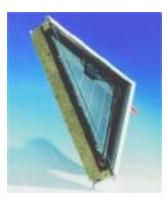
The heat produced from BiPV cogeneration system is low temperature. While this can be used directly for the processes above, it is not useful for generating electricity or in any high temperature industrial process applications. There is a large variation between system types and the climatic conditions in which they run. Within these large variations, ratios of thermal output to electrical power production are in the order of 1 - 3:1.

PV/T systems in buildings can span a wide range of technologies as discussed below.

PV/ T modules

In this configuration, PV cells are generally pasted on to a typical flat plate solar thermal collector and act as the absorber. The heat transfer mechanisms utilized by these modules either use air or heat transfer liquids.





Concentrator technologies

Small arrays of PV cells are placed at the focal point of mirrored parabolas or troughs and are hence exposed to high sun concentrations. They can therefore produce high electricity outputs, but require active cooling due to the high temperatures generated. Although typically used for power systems rather than building applications, some concentrator systems that are currently being developed use fresnel lenses to achieve a concentrator effect with a flat product surface. These have been used for roof tiles and related building products.

A combined heat and power system, (CHAPS),developed at the Australian National University (ANU) Centre for Sustainable Energy Systems, combines hot water and electricity generation into a single unit, maximising the energy available from the roof space (figure 17). A CHAPS system has been installed on a new campus residential block. It comprises 8 rows of 24 m long parabolic mirrors that track the sun on a single axis and reflect light onto strips of high efficiency monocrystalline silicon solar cells at about 35 times the normal solar intensity.

Figure 17 - CHAPS system



The solar cells cover 7.5 m² and convert around 15% of the sunlight into electricity that is delivered to the building and the local electricity network through a 40kVA grid-connected inverter. The balance of the solar energy creates heat that, rather than being wasted, is collected as hot water in 13m³ thermal storage tanks. It provides about 80% of the hot water needs of the residential campus building bathrooms, kitchens and laundry, and about 30% of the winter heating requirement via a hydronic floor heating system.

PV/ Daylighting Systems

In this category, pinholes are made in the PV cells using lasers (in the case of thin film applications). Alternatively, cells are simply spaced apart in order to achieve a desired light transmission. This is described in <u>section 4.2.3</u>. Since larger amounts of incoming radiation penetrate these systems, they act as combined electricity and daylighting systems.

BiPV/ Thermal applications

These have generally been placed in vertical façade installations where the PV array acts as a second skin to the building façade. Forced or natural convective airflows can be used in the cavity that is formed.

There are various BiPV façade buildings that utilise the airflow in the cavity behind the PV modules. This can help to increase the stack effect in a commercial building or alternatively, thermal energy can be captured and used as ventilation air preheating or for direct space heating. Two excellent examples of this type of system are in place on the European Laboratory for Structural Assessment (ELSA) building façade in Ispra, Italy, and in the Doxford solar building in northern England.

Both these buildings used holistic design to incorporate the benefits of PV façades for cogeneration. Incoming thermal energy can be vented to the outside, captured as a fluid or captured in the mass of the building structure. These types of systems have also been experimentally used in smaller commercial and residential roofs. The decreased installation angles serve to decrease the velocity of the natural convection found behind the modules., However in most latitudes, increased insulation on the tilted surfaces can serve to offset this deficiency in energy production.

4.2.5 Non Building Structures

Whilst BiPV is relevant to building applications, there has been substantial growth integrating PV on nonbuilding structures within the built environment. Larger scale examples include PV noise barrier applications, lighting systems such as the Olympic Boulevard (figure 18), car parking, bus shelters, petrol stations and railway station applications.

Figure 18 – Sydney Olympic Solar Boulevard



This increases prospective urban applicability of integrated PV systems such as shade structures and distributed generation, and provides architectural design opportunities for innovative city streetscapes.

A summary of Australian BiPV and related PV projects are provided in <u>Appendix 7</u>.

4.3 BiPV system detail

Architects, PV installers, engineers, planners and construction workers all requirehigh quality and detailed guidance on the chosen BiPV design. Detailed profiles, specific building locations, product dimensions, assembly and electrical configuration should be clearly represented in architectural drawings and complimented with step-by-step procedural instructions.

The following is a brief summary of BiPV system detail. BiPV system detail stems from the preplanning and pre-design/feasibility stages described in section 3, once a particular integration design (section 4.2) has been selected.

4.3.1 BiPV product information

Appendix A2 provides a list of BiPV suppliers and service companies in Australia and overseas. The

following information is also typically available for most BiPV products.

PV module or panel characteristics

Standard testing conditions (STC) are conducted on each commercial PV module and international testing is performed to certify the rating and legitimacy of the PV. Below is a table providing characteristics for a Seimens 50W p module.

MODEL	SM-50
Typical Peak Power	50 W
Guaranteed Min. Peak Power	47.5 W
Voltage at Peak Power	17.1 V
Current at Peak Power	2.92 A
Current at Operating Voltage	3.12 A
Operating Voltage	15 V
Weight	6.3 kg

Typically the module will include the following:

Materials:	Polycrystalline silicon cell Tempered high transmission glass Anodised aluminium frame	
Encapsulant:	Silicon sealing Ethylene Vinyl Acetate (EVA)	
Back: Junction Box:	White coloured Tedlar for external screw terminal connections	

Balance of systems (BOS) is the term to describe parts of the photovoltaic system other than the PV array including switches, controls, meters, inverters, the supporting structure for the array and storage components, if any.

A rough system sizing calculation Excel spreadsheet is available for purchase fromfrom BCSE and is a useful reference point.

4.3.2 BiPV location specifics

Encouraging sympathetic operating conditions can dramatically help performance output and ease maintenance. This includes PV designs that assist natural ventilation and cell cooling. Similarly the balance of system components such as wiring, inverters and meters need to be both accessible and protected from rain and sun exposure. The specific electrical configuration and building plan layout can significantly impact on the required wiring runs, DC to the inverter and AC to the load. Clumsy layout and wiring installations can create major headaches if there is an ensuing fault in the system. It is prudent to carefully think through the electrical system layout when preparing a building plan. For example, it is important to locate and install accessible inverter systems, key wiring junctions and monitoring equipment so that they can be replaced or maintained safely and efficiently.

4.4 Planning approval

For small-scale BiPV systems on existing buildings where the structural integrity of the building is unchanged, planning approval is unlikely to be necessary. Council approval and inspection will be necessary, however, for new buildings or where the BiPV is to replace existing building elements. An increasing number of councils have sustainable energy strategies or development controls. Council planners, nevertheless, may not be familiar with PV. They may require evidence from the builder and electricity utility that the PV system is structurally sound.

Where there are no council planning codes for sustainable development or PV, a more detailed case may need to be made.

Of particular concern is the need to ensure that future development will not shade the PV. This may require covenants over the land, or preferably, solar access guidelines. This report, and the <u>contact lists</u>, may be useful references for councils that wish to develop solar access development codes, and gain an understanding of the issues relevant to BiPV.

In addition, BiPV design should allow for appropriate placement and wiring of the inverter. The aim of the design should be to minimise DC wiring while ensuring that the inverter is located in a secure and sheltered spot, as close as possible to an electricity meter board. The inverter should not be unduly exposed to the weather or to direct sun. Key questions include:

- What visual aesthetic tolerance is there in terms of product selection and performance output?
- How do I assess the most practical location of BiPV?
- What strategies can be used to ensure adequate solar access?
- Does the current local planning strategy encourage or discourage the use of BiPV?

4.4.1 Communication with the Planning officer(s)

The level of knowledge and understanding of BiPV differs among Councils and Planning Officers. This guideline explains the BiPV product, design and performance. It may be appropriate to include a detailed specification as part of the design drawings. A 'Statement of Environmental Effects' will also explain the requirements of most Development Control Plans. A Shading/Overshadowing analysis normally addresses any adverse implications based on the type of application.

4.4.2 Visual attributes (aesthetics);

Councils often argue against BiPV on the grounds that it diminishes architectural character. However, increasingly, Councils are recognising that a well designed BiPV adds to the architectural quality of a building. With the development of new and innovative PV materials and the wide variety of nonreflective coatings now available, BiPV integrated buildings can enhance the quality of both urban planning and building design.

For heritage precincts, particular care needs to be taken to conserve and retain the existing character of the buildings. The architect may need to demonstrate that BiPV can be sensitively integrated into such buildings. There are many historical buildings around the world where BiPV has been successfully integrated, and these could serve as useful examples when approaching Councils for approval.

4.4.3 Solar access;

Most Development Control Plans (DCP) require adequate solar access (and daylighting) to primary living areas for health reasons. Solar power systems typically require minimum solar access between 9am and 4pm.. DCPs require that new building developments do not overshadow neighbouring houses or reduce the amenity of neighbouring properties.

Geometric models and computer tools are often used to analyse shadows and determine adequate levels of solar access. Consideration of existing and prospective shadow effects, including natural objects such as fast growing trees, is important if solar access is to be assured. Partial shading can have a dramatic effect on output performance if standard electrical configuration of, for example, crystalline silicon panels is used. Roof penetrations should have been planned and clearly identified from the outset. Unnecessary shading and reduction in available surface area can occur if sighing of, for example whirlybirds and skylights, is done retrospectively.

Local authorities are guided by DCPs and may not provide adequate consideration of PV systems. Consultation with PV experts is encouraged if there is a likelihood solar access is being threatened.

4.4.4 Development control plan (DCP) compliance.

It is important to demonstrate that the proposed BiPV fulfills all local development control plans (DCPs) and electrical standards. Early consultation with the local authority will assist lines of communication and help planners assess the project concept from a more informed viewpoint.

4.5 Contractual considerations

Contractual arrangements between the construction company/building developer and the PV product and service provider are of paramount importance. Other contractual arrangements need to be secured between the owner of the PV system, owner of the building and the electricity company that will negotiate network interconnection, metering and purchase of exported power. The building owner can often be the same person, but in the case of a unit apartment, it is the body corporate.

Further contractual arrangements are associated with liability and insurance of the building during construction. Insurance companies are unlikely to have a working knowledge of PV systems and may individually assess the risk associated with installation, theft and component replacement due to damage from natural events. Given its electrical characteristics, PV can be negatively perceived as a fire hazard, and this can unduly affect building structure insurance premiums. There is no overarching guidance or insurance industry protocol for considering this at present. What is important is that all building code certifications are passed on. These might include compliance with, for example, building and electrical standards for fire, structural load and weatherproofing. For small systems, many insurance companies already include PV in their list of allowed building components. They may also offer the standard insurance cover, as long as installation standards are met and the systems are suitably attached or become an integral part of the building.

The owner of the PV system's output will also need to register with the Office of the Renewable Energy Regulator (ORER) if they wish to claim RECs. This process can be simplified if the PV supplier, electricity utility or grant-funding agency has procedures already in place.

5 STAGE THREE – IMPLEMENTATION

5.1 Project scheduling

There are a number of identifiable phases in installing BiPV. The following provides a summary of indicative issues and stages:

5.1.1 Product Storage and delivery;

Delivery and storage of products and appliances is a costly item in building construction. This can often stretch budget planning where the building works lag behind product delivery. Delays can occur through inclement weather, underestimating construction completion phases and set backs from product defects, breakage and re-ordering replacements. Delays in completing roof trusses and building inspections will also result in additional storage costs and could compromise warranties of products with a shelf life where the expiry date is breached.

5.1.2 Building site schedule of works;

BiPV systems should be installed by skilled and qualified tradesmen to ensure that all building and safety regulations are complied with and expensive breakages and accidents kept to a minimum. A skilled tradesman should hold an accreditation that is recognised by both BCSE and the product manufacturer. To reduce costs, briefing sessions and tradesman's instructions should be well-organised and other building works distractions do not interrupt training sessions.

The degree of difficulty in co-odinating roofers, electricians and BiPV specialists depends on the complexity of the building and PV project detailing. Often, a BiPV specialist will be consulted on site scheduling and preferred conditions for installing a PV system. Works can also be dovetailed to co-incide seamlessly with overall building construction. However, careful forward planning and good communication is needed to avoid unnecessary delays.

5.2 Installation training guidance

The degree of guidance required again depends on the project complexity and the expertise of the installer. In many instances, products are accompanied by instructions, but these can often be incomplete and may not conform to Australian building standards. It is often worthwhile to schedule training sessions to inform both building tradesmen and electricians of BiPV requirements. The BiPV installer should have a clear understanding of the building process and have an up-to-date knowledge of the latest developments in BiPV installation. It is recommended that BCSE accredited installers are used.

5.2.1 Personal Safety Precautions

Installers should wear suitable personal protective clothing and employ safe work practices and equipment. Before starting work, the construction team should review safety procedures and inspect all equipment and building materials.

In particular, workers must be physically fit for the task, employ appropriate safety practices and ensure weather conditions are appropriate. The condition of all safety equipment should be checked in advance.

5.2.2 Safety requirements for work on roofs

As required by law, approved guarding or safety lifeline systems must be used when working at a height of 1.8 metres or more. Always check for overhead wires and observe adequate clearances. Precautions must also be taken to prevent tools and materials from falling off the roof. They should be fixed by ropes or put in bags to prevent them from falling. . Care should be taken to avoid stepping on fixed PV Modules. Never run or jump on laminates.

5.2.3 Handling precautions

- Do not touch electrical wiring or the junction box as PV modules generate electricity when exposed to the sun. While single modules do not generate dangerous levels of electrical current by themselves when connected in series with other modules, dangerous voltages can be reached.
- Do not step or walk on modules. This may cause premature failure;
- Do not scratch the PV module surface;
- Do not drop tools and or any other materials onto module. Try to keep module surfaces from coming into contact with any other materials or elements;
- Do not install when raining or when the module surface is wet;
- Do not lift or carry a PV module by hooking a wire rope around the Junction Box. It is not strong enough to hold the weight of a module;
- Do not touch PV module frames in direct sunlight as they can become extremely hot to touch;

5.2.4 Electrical Safety instructions

- Do not open the Junction Box on the back or front of modules as this will expose the electrical connections. Only appropriately trained electricians should access the junction box as the long-term reliability of the unit could be compromised.
- Do not disconnect. As PV modules produce electricity when illuminated the module could be damaged or cause electric shocks.
- Do not insert any metal pieces such as hairpins into connectors. This can cause electric shock
- Do not break or cut DC cables. Ensure all cable ends are insulated.
- All cable connections must be completed.

5.2.5 Electrical Testing

Prior to installation, the site electrician should check the occasional module. Factory tests are carried out on each individual module and test results are recorded for future reference.

5.3 Health and Safety check list – OH & S requirements

Accredited installers should be conversant with Occupation, Health and Safety (OH&S) requirements and these should compliment known building OH&S standards. PV systems are electrical components and, hence, require careful handling. On delivery, ensure that the product is unpacked and carefully inspected for breakages. Ensure that suitable equipment and clothing and that products are handled under accredited supervision. Site access, scaffolding and safety harnesses should all follow compliance requirements.

6 STAGE FOUR - COMPLIANCE AND COMMISSIONING

Installation involves both fixing the PV unit to the building and connecting the electrical components. BiPV systems must meet standards for both aspects.

Once installed and exposed to light, the PV system will generate electricity and must be treated with care. There should be no need to specifically maintain the system after commissioning.

6.1 Structural compliance

BiPV systems must comply with both the standard building codes and specific electrical standards. For standard PV systems, the PV supplier will require information on the type of building, where the BiPV is to be installed (e.g. on a tiled roof of 25 degree pitch), and whether the site is cyclone prone. The PV kit will be delivered with detailed installation instructions and the appropriate fasteners and cabling. Warranties may be voided if installation is not carried out in accordance with these instructions. This is because PV systems have been developed to meet specifications for structural integrity and wind loading.

For purpose-built BiPV systems the building designer will need to work with the PV supplier to ensure that installation meets all building codes.

6.2 Electrical safety

Correctly installed PV systems pose no increased risk to the builder or owner. PV modules are stringently tested to meet a range of adverse weather conditions such as rain, hail, ice and temperature fluctuations. Interconnecting wires and plugs are well insulated.

Installation codes cover wind loadings and can be specified for cyclone prone conditions. Electrical codes cover safety aspects including automatic disconnection from the grid in the event of PV system or grid failure. However the building's wiring diagram should specify DC wiring placement, since DC electricity has different characteristics to AC electricity. This will be of particular benefit to emergency services personnel and future renovators.

Key Questions:

- Are there any additional risks with PV systems?
- Are you familiar with the basic principles of PV system operation, especially their electrical characteristics? Are you familiar with both the DC and AC wiring requirements for PV?
- Are you familiar with the use of Uninterrupted Power Supply (UPS) systems, battery banks or hybrid diesel emergency generator systems to maintain essential electrical supply during power outages?
- Are you familiar with grid connection requirements for AS 4777, or any other separate electricity utility requirements?

The PV installer will be required to submit a wiring diagram to the local electricity utility (local utility) and to provide evidence that all components meet Australian standards. Once the system is installed, details must be confirmed with the local utility before interconnection can be made. Special signs indicating that a generator is connected to the grid must be placed on all meter boxes. This will alert maintenance personnel and emergency workers.

6.3 Calibration of BiPV system

The PV installer will check that expected system output is met, but will not connect the system to the grid without the necessary local utility approvals. In some cases, the utility will allow the installer to connect the PV into existing meters. In other cases, the utility itself will install a separate meter and commission the system by connecting it to the meter.

6.4 Sign off

The builder or customer may be wise to seek and retain a signed statement that the installation was carried out by a certified installer and that the work has been completed as per specification. The PV supplier will typically provide a checklist of items for commissioning, including the appropriate position of switches, switch testing, current tests, display operation, component integrity checks, safety notices and availability of wiring diagrams.

The PV system owner will also be required to sign appropriate contracts for interconnecting to the grid and selling any surplus electricity. In addition, evidence that building insurance extends to the PV system will need to be provided to the local utility.

7 STAGE FIVE - MONITORING AND MAINTENANCE

7.1 System monitoring

The installation of monitoring systems will depend on the interests of the owner. Most inverters provide a display of system output and maintain a history for some period of time, such as a month. This information can usually be downloaded to a computer if the appropriate hardware and software is installed. In addition, the electricity utility may also maintain a record of system performance, depending on the metering used.

For large systems, some form of monitoring is recommended, so that the system owner can ensure it is operating to specification and any problems can be quickly identified. It may also be useful to maintain a history of performance in case of future tariff negotiations.

7.2 Recommended monitoring

Guidance on monitoring specifications are detailed in <u>Appendix A6</u>. Ensuring regular data logging and alerts for system outages are very important. Similarly, public display of PV system generation and commensurate greenhouse savings can add community value to a project especially if compliments by a clear description of the building

7.3 Indicative component lifetimes – PV, inverter, meters, frames, wiring

PV modules are typically covered by 20-year warranties, or longer. Where installed in frames supplied by the PV manufacturer, the frames may also be covered by this warranty. Under normal conditions, however, a PV system owner can expect the PV modules to operate for 20 or 30 years, with perhaps only a small reduction in performance with time.

Inverters contain electronic components and are more susceptible to heat, dust and operating wear and tear. Typical lifetime is around ten years, but this is increasing with newer technology. Wiring lifetimes are similar to standard household wiring, but should be checked if any system problems arise or if the inverter is replaced. Meters usually remain the property of the electricity utility and will be replaced as necessary, although they are usually expected to last several decades.

7.4 Display options

Many PV system owners will be interested in their system's output and would like to have a handy display of current and historical performance. While this is usually available on the inverter and the electricity meter, a display inside the building can have more immediate impact, both on PV acceptance and on awareness of energy generally. In corporate buildings, where the PV is being used for promotional and other reasons, highly visible public displays can be used. This will require wiring from the inverter.

7.5 Recommended maintenance checklist

The PV system installer, through the supplier, should provide the owner with a checklist for routine maintenance, with contact numbers and receipts kept in case of system failure.

The maintenance schedule will include a description of standard inverter display conditions, such as green lights and conditions that indicate problems – e.g. yellow or red lights. Australian Standards require that the system is automatically disconnected from the grid in the event of failure. Reconnection may need to be manually carried out. System circuit breakers should be routinely inspected, in case they have tripped.

The PV modules may need occasional visual inspection for signs of damage, dirt build-up or encroaching shade. Rain will often help clean the PV modules.Panels can be hosed down to remove dust, or cleaned with soapy water and sponge if necessary. For the latter, care must be taken that cleaning is not undertaken if panels are cracked and that appropriate safety measures are followed for working on roofs or other exposed areas.

It can often be beneficial to periodically inspect fixtures such as screws, as well as checks for corrosion. The system supplier/installer should have provided a detailed checklist for such inspections. In the event of system failure or under performance, a certified inspector, preferably the installer or PV supplier, should be called on to check the system.

8 STAGE SIX – DECOMMISSIONING

8.1 Re-use and recycling options / recommendations

There is currently no formal procedure for re-use or recycling of PV products. However, there is a market in used PV modules and in future recycling may also be established. PV modules are typically covered by 20 to 25 year warranties, but can last longer than this. Hence, if a system is being dismantled, opportunities for re-sale or re-use of the PV component should be actively sought.

Both PV manufacturers and PV system distributors may be useful initial points of contact. If the PV

modules no longer work, recycling of frames and glass is possible and should be pursued. The PV module also contains silicon wafers and a range of metals. These can be valuable and may be recycled, but may require PV manufacturers to have established dedicated facilities.

Even with cadmium telluride PV modules, known to be the most sensitive of PV semi-conductor materials, the environmental risk from landfill leaching is minimal (Fthenakis, 2004). The estimated atmospheric emissions of 0.02g of Cd per GWh of electricity produced during all the phases of the modules' life, are extremely low, and recycling the modules at the end of their useful life completely resolves any environmental concerns.

KEY QUESTIONS

DEVELOPER/CLIENT

What should I know as a DEVELOPER/CLIENT when communicating with:		
Architect/engineer	Construction or building company	Financier
 What is their PV expertise? Will their design plans encourage energy and resource efficiency? Is PV part of the holistic design? If the PV was taken away from the building would it be missing something? Are they able to complete the PV system design or will a special designer be needed? 	 Have they worked with PV before? Do they have appropriate accreditation if they are installing the PV? How strong is the electrical team? Is there a willingness to be up skilled in learning about BiPV? Do they have the flexibility and track record in scheduling and completing quality innovative building projects at cost and on time? 	 Have they an understanding of the technology? Do they have an appropriate way for determining the financial risk? Is there an understanding that the PV is a part of a holistic building design and thus cost? Is there a willingness for the financier to promote sustainable building projects?
PV installer/ Electrician	Utility/PV owner	Planning officer/ Community
 Are they BCSE accredited or equivalent? Can the PV supplier/ installer guarantee price if the project is delayed? Is the product sourced from overseas and are the cost influenced by foreign currency exchange rates? How long does the warranty of each product last? Who is responsible for breakage and damage to site, on-site and once the building is commissioned? How long would it take to install? How strong is the electrical team? Is there a willingness to be up skilled in learning about BiPV? Do they have the flexibility and track record in scheduling and completing quality innovative building projects at cost and on time? 	 Has the utility dealt with grid connected BiPV before? Is PV as a distributed generator going to add value to the existing distribution network? Can a low energy building design be used to leverage a positive connection agreement with the network service operator/utility? Is the electricity company trying to overcharge for metering equipment for the PV ? Have you negotiated a good buy back rate for the PV and secured the RECs? 	 Is the community aware of what PV is and what it looks like? Do they know the difference between a solar hot water system and a solar PV power system? Is there a perceived fear that the PV system might adversely affect the cultural heritage of the community? Is there a chance that solar access and future development might be compromised in the completion of the project? Is there a positive feeling for the use of PV? Can PV be used to promote a positive message when submitting the building g project design to the How doe the PV project comply with DCP and planning controls?

ARCHITECT/ENGINEER

Developer/Client	Construction or building company	Financier
 What is their PV expertise? And knowledge Are they aware of and committed to delivering sustainable buildings Is PV part of the cost plan? Do they know that there are rebates and subsidies for incorporating technologies such as PV? Do they know of all the costs and benefits including value-added opportunities for BiPV? 	 Have they worked with PV before? Do they have appropriate accreditation if they are installing the PV? How strong is the electrical team? Is there a willingness to be up skilled in learning about BiPV? Do they have the flexibility and track record in scheduling and completing quality innovative building projects at cost and on time? 	 Have they an understanding of the technology? Do they have an appropriate way for determining the financial risk? Is there an understanding that the PV is a part of a holistic building design and thus cost? Is there willingness for the financier to promote sustainable building projects?
PV installer/ Electrician	Utility	Planning officer/ Community
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CONSTRUCTION OR BUILDING COMPANY

What should I know as a CONSTRUCTION OR BUILDING COMPANY when communicating with:		
Developer/Client	Architect/engineer	Financier
 What is their PV expertise? And knowledge Are they aware of and committed to delivering sustainable buildings Is PV part of the cost plan? Do they know that there are rebates and subsidies for incorporating technologies such as PV? Do they know of all the costs and benefits including value-added opportunities for BiPV? 	 What is their PV expertise? Will their design plans encourage energy and resource efficiency? Is PV part of the holistic design? If the PV was taken away from the building would it be missing something? Are they able to complete the PV system design or will a special designer be needed? 	 Have they an understanding of the technology? Do they have an appropriate way fo determining the financial risk? Is there an understanding that the PV is a part of a holistic building design and thus cost? Is there a willingness for the financier to promote sustainable building projects?
PV installer/ Electrician	Utility	Planning officer/ Community
 Are they BCSE accredited or equivalent? Can the PV supplier/ installer guarantee price if the project is delayed? Is the product sourced from overseas and are the cost influenced by foreign currency exchange rates? How long does the warranty of each product last? Who is responsible for breakage and damage to site, on-site and once the building is commissioned? How long would it take to install? How strong is the electrical team? Is there a willingness to be up skilled in learning about BiPV? Do they have the flexibility and track record in scheduling and completing quality innovative building projects at cost and on time? 	 Has the utility dealt with grid connected BiPV before? Is PV as a distributed generator going to add value to the existing distribution network? Can a low energy building design be used to leverage a positive connection agreement with the network service operator/utility? Is the electricity company trying to overcharge for metering equipment for the PV ? Have you negotiated a good buy back rate for the PV and secured the RECs? 	 Is the community aware of what PV is and what it looks like? Do they know the difference between a solar hot water system and a solar PV power system? Is there a perceived fear that the PV system might adversely affect the cultural heritage of the community? Is there a chance that solar access and future development might be compromised in the completion of the project? Is there a positive feeling for the use of PV? Can PV be used to promote a positive message when submitting the building project design to the local authority? How doe the PV project comply with DCP and planning controls?

PLANNING OFFICER

Developer/Client	Architect/engineer	Financier
What is their PV expertise? And knowledge Are they aware of and committed to delivering sustainable buildings Is PV part of the cost plan? Do they know that there are rebates and subsidies for incorporating technologies such as PV? Do they know of all the costs and benefits including value-added opportunities for BiPV?	 What is their PV expertise? Will their design plans encourage energy and resource efficiency? Is PV part of the holistic design? If the PV was taken away from the building would it be missing something? Are they able to complete the PV system design or will a special designer be needed? 	 Have they an understanding of the technology? Do they have an appropriate way fo determining the financial risk? Is there an understanding that the PV is a part of a holistic building design and thus cost? Is there a willingness for the financier to promote sustainable building projects?
PV installer/ Electrician	Utility	Construction or Building Company
Are they BCSE accredited or equivalent? Can the PV supplier/ installer guarantee price if the project is delayed? Is the product sourced from overseas and are the cost influenced by foreign curreny exchange rates? How long does the warranty of each product last? Who is responsible for breakage and damage to site, on-site and once the building is commissioned? How long would it take to install? How strong is the electrical team? Is there a willingness to be up skilled in learning about BiPV? Do they have the flexibility and track record in scheduling and completing quality innovative building projects at cost and on time?	 Has the utility dealt with grid connected BiPV before? Is PV as a distributed generator going to add value to the existing distribution network? Can a low energy building design be used to leverage a positive connection agreement with the network service operator/utility? Is the electricity company trying to overcharge for metering equipment for the PV ? Have you negotiated a good buy back rate for the PV and secured the RECs? 	 Have they worked with PV before? Do they have appropriate accreditation if they are installing the PV? How strong is the electrical team? Is there a willingness to be up skilled in learning about BiPV? Do they have the flexibility and track record in scheduling and completing quality innovative building projects at cost and of time?

FINANCIER

➡ What should I know as a FINANCIER when communicating with:		
Developer/Client	Architect/engineer	Construction or building company
 What is their PV expertise? And knowledge Are they aware of and committed to delivering sustainable buildings Is PV part of the cost plan? Do they know that there are rebates and subsidies for incorporating technologies such as PV? Do they know of all the costs and benefits including value-added opportunities for BiPV? 	 What is their PV expertise? Will their design plans encourage energy and resource efficiency? Is PV part of the holistic design? If the PV was taken away from the building would it be missing something? Are they able to complete the PV system design or will a special designer be needed? 	 Have they worked with PV before? Do they have appropriate accreditation if they are installing the PV? How strong is the electrical team? Is there a willingness to be up skilled in learning about BiPV? Do they have the flexibility and track record in scheduling and completing quality innovative building projects at cost and on time?
PV installer/ Electrician	Utility	Planning officer/ Community
 Are they BCSE accredited or equivalent? Can the PV supplier/ installer guarantee price if the project is delayed? Is the product sourced from overseas and are the cost influenced by foreign curreny exchange rates? How long does the warranty of each product last? Who is responsible for breakage and damage to site, on-site and once the building is commissioned? How long would it take to install? How strong is the electrical team? Is there a willingness to be up skilled in learning about BiPV? Do they have the flexibility and track record in scheduling and completing quality innovative building projects at cost and on time? 	 Has the utility dealt with grid connected BiPV before? Is PV as a distributed generator going to add value to the existing distribution network? Can a low energy building design be used to leverage a positive connection agreement with the network service operator/utility? Is the electricity company trying to overcharge for metering equipment for the PV ? Have you negotiated a good buy back rate for the PV and secured the RECs? 	 Is the community aware of what PV is and what it looks like? Do they know the difference between a solar hot water system and a solar PV power system? Is there a perceived fear that the PV system might adversely affect the cultural heritage of the community? Is there a chance that solar access and future development might be compromised in the completion of the project? Is there a positive feeling for the use of PV? Can PV be used to promote a positive message when submitting the building project design to the local authority? How doe the PV project comply with DCP and planning controls?

PV INSTALLER/ELECTRICIAN

➡ What should I know as a PV INSTALLER when communicating with:		
Developer/Client	Architect/engineer	Construction or building company
 What is their PV expertise? And knowledge Are they aware of and committed to delivering sustainable buildings Is PV part of the cost plan? Do they know that there are rebates and subsidies for incorporating technologies such as PV? Do they know of all the costs and benefits including value-added opportunities for BiPV? 	 What is their PV expertise? Will their design plans encourage energy and resource efficiency? Is PV part of the holistic design? If the PV was taken away from the building would it be missing something? Are they able to complete the PV system design or will a special designer be needed? 	 Have they worked with PV before? Do they have appropriate accreditation if they are installing the PV? How strong is the electrical team? Is there a willingness to be up skilled in learning about BiPV? Do they have the flexibility and track record in scheduling and completing quality innovative building projects at cost and on time?
Financier	Utility	Planning officer/ Community
 Have they an understanding of the technology? Do they have an appropriate way for determining the financial risk? Is there an understanding that the PV is a part of a holistic building design and thus cost? Is there willingness for the financier to promote sustainable building projects? 	 Has the utility dealt with grid connected BiPV before? Is PV as a distributed generator going to add value to the existing distribution network? Can a low energy building design be used to leverage a positive connection agreement with the network service operator/utility? Is the electricity company trying to overcharge for metering equipment for the PV ? Have you negotiated a good buy back rate for the PV and secured the RECs? 	 Is the community aware of what PV is and what it looks like? Do they know the difference between a solar hot water system and a solar PV power system? Is there a perceived fear that the PV system might adversely affect the cultural heritage of the community? Is there a chance that solar access and future development might be compromised in the completion of the project? Is there a positive feeling for the use of PV? Can PV be used to promote a positive message when submitting the building project design to the local authority? How doe the PV project comply with DCP and planning controls?

UTILITY

Developer/Client	Architect/engineer	Construction or building company
 What is their PV expertise? And knowledge Are they aware of and committed to delivering sustainable buildings Is PV part of the cost plan? Do they know that there are rebates and subsidies for incorporating technologies such as PV? Do they know of all the costs and benefits including value-added opportunities for BiPV? 	 What is their PV expertise? Will their design plans encourage energy and resource efficiency? Is PV part of the holistic design? If the PV was taken away from the building would it be missing something? Are they able to complete the PV system design or will a special designer be needed? 	 Have they worked with PV before? Do they have appropriate accreditation if they are installing the PV? How strong is the electrical team? Is there a willingness to be up skilled in learning about BiPV Do they have the flexibility an track record in scheduling and completing quality innovative building projects at cost and o time?
Financier	PV installer/ Electrician	Planning officer/ Community
 Have they an understanding of the technology? Do they have an appropriate way for determining the financial risk? Is there an understanding that the PV is a part of a holistic building design and thus cost? Is there willingness for the financier to promote sustainable building projects? 	 Are they BCSE accredited or equivalent? Can the PV supplier/ installer guarantee price if the project is delayed? Is the product sourced from overseas and are the cost influenced by foreign currency exchange rates? How long does the warranty of each product last? Who is responsible for breakage and damage to site, on-site and once the building is commissioned? How long would it take to install? How strong is the electrical team? Is there a willingness to be up skilled in learning about BiPV? Do they have the flexibility and track record in scheduling and completing quality innovative building projects at cost and on time? 	 Is the community aware of what PV is and what it looks like? Do they know the difference between a solar hot water system and a solar PV power system? Is there a perceived fear that the PV system might adversel affect the cultural heritage of the community? Is there a chance that solar access and future developmer might be compromised in the completion of the project? Is there a positive feeling for the use of PV? Can PV be used to promote a positive message when submitting the building project design to the local authority? How doe the PV project comply with DCP and planning controls?

APPENDICES

A1 Glossary and abbreviations

- **Alternating current (AC):** Electric current in which the direction of the flow is reversed at frequent intervals. In Europe and Australia, this occurs 100 times per second (50 cycles per second, i.e. 50 Hertz (Hz)) and 120 times per second in the USA. This is the opposite of direct current (DC).
- Ancillary services: Resources used to maintain power supply quality such as reliability, voltage and frequency stability and waveform purity.
- Australian Greenhouse Office (AGO): Australian government office responsible for greenhouse gas matters within the Department of Environment and Heritage.
- **Balance of systems (BOS):** The parts of the photovoltaic system other than the PV array including switches, controls, meters, power-conditioning equipment, the supporting structure for the array and storage components, if any.
- **BCSE:** Business Council for Sustainable Energy is a lobby group and business network for sustainable energy businesses in Australia
- **Building integrated photovoltaics (BiPV):** The harnessing of solar power technologies as a part of, or attached to, the external building skin.
- **Clean Development Mechanism (CDM):** Intended to help industrialized countries achieve their Kyoto Protocol emissions reduction targets while helping developing countries achieve their sustainable development goals. Emission reductions resulting from CDM projects will be available, at least partially, to the project funders.

Cogeneration: The simultaneous production of electricity and heat, usually for commercial or industrial use.

- DCP: Development Control Plan produced by Local Planning Authorities/Councils
- **Direct current (DC):** Electric current in which electrons are flowing in one direction only. This is the opposite of alternating current (AC).
- **Distributed resources:** Small-scale generating, storage or demand management plant, sometimes referred to as micropower and typically connected into the electricity distribution, rather than transmission, network. These can include photovoltaic power systems, wind generators, batteries or other storage devices and appliances, such as solar water heaters, which reduce electrical load on the distribution network.
- **Emissions trading:** A mechanism to control the increase in greenhouse gas emissions by setting emission limits, allocating permits and allowing emitters to trade permits amongst themselves as a means of achieving the lowest cost emission reductions overall.
- **Energy payback time**: The time required for any energy producing system or device to produce as much useful energy as was consumed in its manufacture and construction. For PV the energy payback time is approximately 2 to 4 years.
- **Final annual yield:** Total photovoltaic energy delivered to the load during one year per kilowatt of power installed. Unit: kWh per annum per kW installed.
- **Fossil fuels:** Energy sources derived from ancient plant and animal matter trapped on the earth's surface over geological time. These include coal, oil and natural gas, all of which are non-renewable over any human timeframe.
- **Greenhouse gas emissions:** Emissions of gases which collect in the atmosphere and contribute to the Earth's "greenhouse" effect. Increasing concentrations of gases, such as carbon dioxide, methane and nitrous oxide are currently producing an enhanced greenhouse effect because they are accumulating at a rate faster than they can be dispersed. The combustion of fossil fuels is considered to be a major cause of this enhanced effect, which in turn is expected to contribute to higher average global temperatures over the next century.
- **Grid-connected distributed photovoltaic power system:** System installed on consumers' premises, usually on the demand side of the electricity meter. This includes grid-connected domestic photovoltaic power systems and other grid-connected PV power systems on commercial buildings, motorway sound barriers, etc. These may be used for support of a utility's distribution grid.
- **Installed power:** Power delivered by a photovoltaic module or a photovoltaic array, under standard test conditions (STC). See below for an explanation of STC. Also called STC output power. Unit: Watts peak (Wp).

Inverter: Device that converts direct current (DC) into alternating current (AC).

- **I-V curve:** A graphical presentation of the current (I) versus the voltage (V) from a photovoltaic cell as the load is increased from the short circuit (no load) condition to the open circuit (maximum voltage) condition. The shape of the curve characterizes cell performance.
- kWh: Symbol of kilowatt-hour, unit of energy (power expressed in kW multiplied by time expressed in hours).
- **Load:** The amount of electric power that is being consumed at any given moment. Also, in an electrical circuit, any device or appliance that is using power. The load for a utility company varies greatly with time of day and to some extent with season.
- **Off-grid domestic photovoltaic power system:** System installed in households and villages that are not connected to a utility's distribution network (grid). Usually a means to store generated electricity is used which is most commonly lead-acid batteries. Also referred to as stand-alone photovoltaic power systems (PV-SPS) or remote area power supplies (RAPS).
- **Peak power:** PV modules are rated by their peak power output. The peak power (or nominal power) is the amount of power output a PV module produces at standard test conditions (STC). Unit: Watt peak (Wp).
- **Performance ratio:** Ratio of the final yield to the reference yield calculated on the annual or monthly or daily performance. The reference yield is the theoretically available energy on an annual, monthly or daily basis per kilowatt of installed power.
- **Photovoltaic effect:** The process of photons of light exciting a semiconductor material to produce an electric current of volts, thus producing electricity from sunlight.
- **Photovoltaic power system:** A system including photovoltaic modules, inverters, batteries (if applicable), and all associated installation and control components, for the purpose of producing solar photovoltaic electricity. Also commonly referred to as PV or photovoltaics.
- PV: Abbreviation of photovoltaics and depending on the context, can refer to cells, modules or systems.
- **PVRP:** Photovoltaic Rebate Program run by the Australian Greenhouse Office providing financial incentive for small scale BiPV projects in Australia.
- **RECP:** Renewable Energy Commercialisation Program run by the Australian Greenhouse Office providing financial support for the commercialisation and showcasing of renewable energy technologies in Australia.
- **Renewable energy:** Energy sources recently derived directly or indirectly from the energy of the sun, the earth's core, or from lunar and solar gravitational forces that are renewable over short timeframes. These include solar, wind, biomass, tidal, wave, hydro and geothermal energy.
- **Sequestration:** Removal and storage of greenhouse gases from the atmosphere through the growth of vegetation or through technological means such as injection of the gases underground.
- **Standard test conditions (STC):** The testing conditions used to measure photovoltaic cells' or modules' nominal output power where the irradiance level is 1000 W/m², with the reference air mass 1.5 times the solar spectral irradiance distribution and a cell or module junction temperature of 25°C.
- **Vertically integrated utilities:** Where generation, transmission, distribution and retailing of electricity are combined in a single organization. A vertically integrated utility could also consist of generation, electricity transport (transmission and distribution) with no retail functions, or of only electricity transport.
- Watt (W): SI unit of power. Symbol is W. One Watt is equal to one Joule per second, with 1kWh equaling 3.6 MJ. Multiples like kW (1000 W) or MW (1000 kW) are also used. In this publication, it is understood to be power output under standard test conditions (STC). Also written Wp (peak Watt) by PV professionals to mean peak power at STC.

A2 BiPV directory

There are two main locations to find out how to contact your local PV industry. The Business Council for Sustainable Energy (BCSE) is the representative sustainable energy industry body and hosts PV accreditation. Accredited PV installers can be found at:

www.bcse.org.au under the installing renewables section.

The Australian Greenhouse Office (AGO) hosts a Renewable Energy Industry Database of over 500 entries <u>www.greenhouse.gov.au/renewable/reis/reid/index.html</u>

A3 BiPV relevant subsidies and rebates

Under the <u>National Greenhouse Strategy</u>, all Australian States and Territories support the increased use of renewable energy. The Australian Greenhouse Office (AGO) has responsibility for delivering a number of renewable energy programs, including this site. The AGO has policy responsibility for the <u>mandatory target</u> for an additional 9,500GWh of electricity to be produced from renewable sources by the year 2010, and a number of financial incentives for the production and use of renewable energy.

To implement the mandatory target for renewable energy the *Renewable Energy (Electricity) Act 2000* was passed by Parliament. Under the Act a Regulator has been appointed and the <u>Office of the Renewable Energy Regulator</u> established. Roles of the Regulator include accrediting renewable energy generators and determining baselines for existing generators; ensuring that renewable energy certificates are validly issued; imposition of penalties and conducting audits. Other Commonwealth support for business, including renewable energy businesses, is delivered by the <u>Department of Industry, Tourism and Resources</u>.

 Relevant current programs for BiPV include:

 Photovoltaic Rebate Program (PVRP)

 - solar power your house - supporting the renewable energy industry

 Renewable Remote Power Generation Program (RRPGP)

 - supporting renewable energy in remote areas

 Renewable Energy Equity Fund (REEF)

 - provides venture capital for small innovative renewable energy companies

 Mandatory Renewable Energy Target (MRET)

 - sourcing an additional 9,500 GWh of Australia's electricity from renewable sources

Previous grant programs included: <u>Renewable Energy Industry Development Program</u> (REID) <u>Renewable Energy Commercialisation Program</u> (RECP) <u>Renewable Energy Industry Program</u> (REIP) <u>Renewable Energy Showcase</u>

State and Territory renewable energy programs Some State and Territory Governments have also implemented measures to increase the uptake of renewable energy – click on the relevant state/territory organisation below: <u>Australian Capital Territory</u> <u>New South Wales</u>

Northern Territory Queensland South Australia Tasmania Victoria Western Australia

A4 Added values offered by PV (summary of report that can be downloaded from IEA PVPS website www.iea-pvps.org and www.oja-services.nl/iea-pvps/products/rep1_09.htm)

The perceived benefits of PV, over and above the electricity generated, depend to some extent on the perspective from which it is viewed. For instance [Watt *et al*, 1999]:

- a building owner may be interested in offset building costs, enhanced property value and improved rental prospects, compared to the investment made;
- a building occupier may attribute value to visual appeal and green image, as well as to reduced power bills, increased self reliance and reliability of supply;
- to the community, the value may be determined by visual amenity, enhanced property values, local employment, reduced power outages or brown-outs, safety and reduced local and global pollution levels;
- for the nation, the value may be determined by employment creation, pollution reduction, energy self reliance and impacts on fossil fuel requirements.

Some of these values are based on perceptions or preferences that are difficult to define or quantify. They are, however, a key component of energy system choice and are particularly important when introducing new technologies into the marketplace. The added values available for architects and builders using BiPV have been detailed in the main report. The following provides a summary of values that may be significant to the wider community and hence, may influence choices.

A4.1 PV Values for Governments

A4.1.1 Net energy benefits and greenhouse gas emission reductions

Greenhouse gas reduction strategies are becoming key energy policy drivers in industrialized countries. PV is one of the most attractive and versatile emissions free electricity technology options suitable for use in the built environment.

Estimates of the time required for rooftop PV systems to "pay back" the energy used in their manufacture range from 3 to 8 years using existing technology [Alsema, 1998]. Hence, with existing technology, PV systems can be expected to generate at least 3 times, and most probably more than 10 times, the energy required for their manufacture over their lifetime of operation. Expected reductions in PV manufacturing energy requirements will reduce energy payback periods to less than 2 years. Hence, if PV is used to power PV component factories, it can operate as a "solar breeder" technology, with a sustainable long-term future.

The emissions reduction benefits offered by PV depend on the technologies used and the energy sources being displaced. In Australia, PV is calculated to release around 104 g CO2 equivalent per kWh produced, compared with 932 g per kWh for existing black coal fired electricity plants and 439 g from combined cycle gas plants [BHP, 2000]. Hence emissions are reduced by 85% or more compared to coal fired generation, making PV an attractive long term option for sustainable energy supply.

A4.1.2 Clean air targets

Clean air programmes have been put into place in many countries, usually on a regional basis and aimed at local air pollution. Programmes typically target local emissions from vehicles and combustion of coal and biomass. More recent clean air policies acknowledge global issues and incorporate greenhouse gas reduction strategies. For instance, the NSW air quality management plan deals with local, regional and global issues.

NO_x and SO_x trading is already being used as a part of clean air policies in some countries and offers opportunities for PV to play a role. Where PV generation displaces coal fired power generation, NOx emissions are halved and SOx emissions are reduced by 90% [BHP, 2000]. Clean air policies are already beginning to impact on standby generation, with restrictions on the use of plants using diesel or waste fuel, thus creating opportunities for PV.

A4.1.3 Energy supply security

The installation of photovoltaics on household, commercial and light industrial buildings can reduce peak electricity demand and improve short-term energy supply security. PV can also contribute to long-term energy supply security by reducing reliance on depleting fossil fuels, by increasing the use of indigenous resources and by diversifying fuel sources. With Australia's high levels of coal use and export and high per capita greenhouse gas emission levels, the challenge of reducing emissions and diversifying away from fossil fuels is an important long-term supply security issue.

A4.1.4 Industry development and employment growth

Although still relatively small, the PV industry is growing fast. The scope for PV use is widespread, in both urban and rural areas and thus there are opportunities for new manufacturing and service industry development and associated professional and trade level employment creation in urban and regional areas.

A4.2 Values for Utilities

Smaller scale generation, connected into the electricity distribution, rather than the transmission, network is referred to as distributed generation and includes building integrated PV systems. Table A4.1 summarizes some of the benefits offered by distributed generation, termed "micro-power" by the authors.

Benefit	Description
Modularity	By adding or removing units, micropower system size can be adjusted to match demand.
Short lead time	Small-scale power can be planned, sited, and built more quickly than larger systems, reducing the risks of overshooting demand, longer construction periods, and technological obsolescence.
Fuel diversity and reduced price volatility	Micropower's more diverse, renewables-based mix of energy sources lessens exposure to fossil fuel price fluctuations.
"Load-growth insurance" and load matching	Some types of small-scale power, such as cogeneration and end-use efficiency, expand with growing loads; the flow of other resources like solar and wind, can correlate closely with electricity demand.
Reliability and resilience	Small plants are unlikely to all fail simultaneously; they have shorter outages, are easier to repair, and are more geographically dispersed.
Avoided plant and grid construction, and losses	Small-scale power can displace construction of new plants, reduce grid losses, and delay or avoid adding new grid capacity or connections.
Local and community choice and control	Micropower provides local choice and control and the option of relying on local fuels and spurring community economic development.
Avoided emissions and other environmental impacts	Small-scale power generally emits lower amounts of particulates, sulfur dioxide and nitrogen oxides, heavy metals and carbon dioxide, and has a lower cumulative environmental impact on land and water supply and quality.

 Table A4.1:
 Eight Hidden Benefits of Micropower [Lovins & Lehmann, 2000]

A4.2.1 Reduced infrastructure costs and network losses

Distributed generation can offer reduced costs for infrastructure, such as line capacity and peak load generation facilities, as well as reduced network operating and maintenance costs. It can also serve to delay or eliminate the need for network augmentation. This is an important benefit, particularly where networks span large distances, where high load growth in some areas is leading to grid constraints or where lines are reaching the end of their expected life [Outhred & Watt, 1999]. Generation close to load centres also reduces network losses, which can be as high as 25% of electricity distributed through long rural lines.

A4.2.2 Reduced financial risk

Another key advantage of decentralized PV systems over traditional centralized supplies is the lower risk it offers in upgrading capacity. The ability to follow load growth more closely, by adding incrementally to supply, reduces the period of over-capacity which inevitably follows the installation of a large system, and hence also the period of low prices experienced until load growth catches up. In periods of uncertainty, the risks associated with under-utilized assets may add considerably to the costs.

A4.2.3 Capacity credit and peak lopping

Compared to central PV stations, decentralized systems smooth output fluctuations and provide a better match to loads, therefore providing a higher capacity value from the utility point of view. For commercial and industrial customers, the capacity value that can be placed on a PV system is as important as its energy value, since billing often has a strong demand component. Where air conditioning loads contribute significantly to peak demand a positive correlation can be expected with PV output. The value of PV could therefore be higher in areas with a summer peaking load. Similarly, PV generation augments electrical supply and helps in dealing with additional appliances and building loads that may come from improved living standards and changes in the building's function.

A4.2.4 Green Power

Green Power products have emerged as one means for utilities to offer differentiated products to domestic and business customers, with the intention of gaining new customers or increasing customer loyalty. Australian schemes are certified and labeled to distinguish levels of greenhouse gas reduction.

A.4.3 Values for Customers

Improved thermal comfort and soundproofing, reduced energy demand charges and interesting building design features are all of importance to customers. In addition, customer surveys around the world increasingly show an interest in the impacts of energy systems on the environment and on quality of life. Some customers are also interested in increasing their own energy self-reliance, others in portraying a clean image.

A4.3.1 Non-intrusive qualities

Compared to almost all other electricity generators, PV is noiseless, produces no on-site emissions, is relatively maintenance free and can be installed in a wide range of locations. Combined with its modularity, these characteristics make PV attractive for household, community or urban use, particularly as a replacement for diesel or petrol generators, but increasingly as a non-intrusive supplement or replacement for grid power.

A4.3.2 Image

For commercial customers especially, but also for residential customers, on-site PV generation creates a strong green and high-tech image. This makes PV attractive for use in corporate buildings, housing developments at the high end of the market and for any person or group wishing to demonstrate environmental credentials.

A4.3.3 Energy independence

PV obviously offers the opportunity for increased or total energy self reliance. In addition, the use of distributed PV systems can conceivably mitigate the onset and/or the effect of power outages caused by high summer demand or severe weather [Perez *et al*, 1997; Perez, 1998].

It should be noted that grid connection guidelines in many areas require the PV system to disconnect when grid power fails. This removes the emergency benefit for both the customer and the utility, unless self-operation of PV systems is allowed when the grid fails, with a manual inverter switch-over.

The value of PV for general energy independence and in emergency situations is increased when storage is included in the system. However, storage increases the system cost and complexity. Nevertheless, many commercial, institutional and industrial buildings already include battery storage uninterruptible power supply (UPS) systems for emergency power supply. Hence, connection of a BiPV system to the UPS battery system can extend emergency power availability. An 80 kWp building integrated photovoltaic power system installed in a commercial building in Brisbane provides added value by feeding its output through a UPS system which supports the building's computer equipment [Wren & Barram, 2000].

A4.3.4 Customer preferences

Marketing of the first generation of houses with PV was, perhaps understandably, been undertaken in a low key way. PV systems on houses in the Newington Solar Village near the Sydney Olympic site were placed so as not to be generally visible. However, recent Australian government grants for BIPV systems have had to be modified following overwhelming customer demand. For the next generation of BIPV product, therefore, it would seem that customers require attractive, multifunctional PV products and that marketers must provide substantially more information on all aspects of their systems, so that customers can appreciate all features.

A4.3.5 Electricity supply costs

In Australia there are an estimated 10,000 off-grid residences and up to 60,000 off-grid holiday homes. For these customers, the option of BiPV systems may save considerable costs otherwise associated with grid extension or with fuel delivery for gas or diesel based power systems. Low maintenance requirements are also an important factor for remote locations.

For grid connected customers, the values offered by PV, combined with current grant programs and renewable energy targets, can make PV financially attractive. With current cost reduction trends, PV is expected to be able to supply electricity at costs equivalent to grid power by around 2015, even without considering other values.

Table A4.2:	Summary of Non-Energy Benefits Which Can Add Value to PV Systems [IEA-PVPS, 2000/4]
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	Summary of tool Energy Benefits which can ridd value to 1 v Systems [IERT 1 v15, 2000, 1]
Category	Potential Values
Electrical	kWh generated; kW capacity value; peak generation and load matching value; reduction in demand for utility electricity; power in times of emergency; grid support for rural lines; reduced transmission and distribution losses; improved grid reliability and resilience; voltage control; smoothing load fluctuations; filtering harmonics and reactive power compensation.
Environmental	Significant net energy generator over its lifetime; reduced air emissions of particulates, heavy metals, CO_2 , NO_x , SO_x - resulting in lower greenhouse gases, reduced acid rain and lower smog levels; reduced power station land and water use; reduced impact of urban development; reduced tree clearing for fuel; reduced nuclear safety risks.
Architectural	Substitute building component; multi-function potential for insulation, water proofing, fire protection, wind protection, acoustic control, daylighting, shading, thermal collection and dissipation; aesthetic appeal through colour, transparency, non-reflective surfaces; reduced embodied energy of the building; reflection of electromagnetic waves; reduced building maintenance and roof replacements.
Socio-Economic	New industries, products and markets; local employment for installation and servicing; local choice, resource use and control; potential for solar breeders; short construction lead-times; modularity improves demand matching; resource diversification; reduced fuel imports; reduced price volatility; deferment of large capital outlays for central generating plant or transmission and distribution line upgrades; urban renewal; rural development; lower externalities (environmental impact, social dislocation, infrastructure requirements) than fossil fuels and nuclear; reduced fuel transport costs and pollution from fossil fuel use in rural areas; reduced risk of nuclear accidents; symbol for sustainable development and associated education; potential for international cooperation, collaboration and long-term aid to developing countries.

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A5 BiPV codes and standards

Local Government Authorities (LGAs) rely on nationally developed building codes that delineate required safebuilding practices. Building inspectors are concerned with the proper construction of safe buildings:

- regulation of public safety;
- health; and
- amenity in buildings.

Accepted variations:

- tropical cyclonic north;
- various earthquake prone areas;
- snowfields of New South Wales, Victoria and Tasmania; and
- bushfire prone areas of the south-east and far south-west.

BCA96 – performance based building codes – sustainability goals, energy efficient benchmarking and standards - "deemed to satisfy requirements".Until recently, a lack of Australian standards for BiPV have not encouraged the uptake BiPV development, with a reliance on:

- nternational standards;
- Existing national building codes, electrical & wiring standards;
- Code, standards and guideline development for Australia; and
- Stand alone systems batteries hybrid systems (AS 4509.2)

AGO have assisted with the development of Australian standards in this area and now there are a number of very helpful Australian standards giving guidance on PV array installation, (AS/NZS 5033) and AS 4777 which covers the installation and characteristics of inverters used for grid connected PV systems. Module standards have been revised and the old AS2915 standard has been withdrawn and IEC standards for modules have been adopted as they are the most widely accepted and most useful standards (See IEC 61215, IEC61646 and IEC 61730, listed below.) PV modules should have a minimum 10-year warranty, and other components and design shall meet relevant Australian Standards. PV array installation shall meet AS/NZS 5033. BiPV stems across architecture, electrical engineering, device physics, structural engineering, construction industry, architecture and planning. The current status of codes for BiPV include:

AS 1170	Minimum design loads on structures.
AS 1170.2 Part 2	Wind loads.
AS 1319	Safety signs for the occupational environment.
AS 1530	Methods for fire tests on building materials, components and structures.
AS 1530.4 Part 4	Fire resistance tests of elements of building construction.
AS 1768	Lightning protection.
AS 1931.1 Part 1	High voltage - Test techniques - General definitions and test requirements.
AS 1940	Storage and handling of flammable and combustible liquids.
AS 2279	Disturbances in mains supply networks.
AS 2481	All-or-nothing electrical relays (instantaneous & timing relays).
AS/NZ 3000	Electrical installations – Buildings, structures and premises "SAA Wiring rules".
AS 3008	Selection of Cables.
AS 3100	Approval & test specification - General requirements for electrical equipment.
AS 3300	Approval & test specification - General requirements for household & similar electrical
	appliances.
AS 3595	Energy Management Programs.
AS/NZS 3131	Approval and test specification – plugs and socket outlets for use in installation wiring.
AS 4777	Grid connection of energy systems via inverters. Part 1 installation, Part 2 Inverter
	requirements and Part 3 protection requirements.
AS/NZS 5033	Installation of Photovoltaic (PV) Arrays.
IEC 61215	Crystalline silicon terrestrial photovoltaic (PV) modules: Design qualification & type approval
IEC 61643	Low voltage surge protective devices
IEC 61643-12 Part 12:	Surge protective devices connected to low voltage power distribution systems—Selection and
	application principles
IEC 61646	Thin film terrestrial photovoltaic (PV) modules—Design qualification and type approval
IEC 61730-1 Part 1:	Photovoltaic module safety qualification: Requirements for construction

A6 Monitoring equipment and parameters

Procedures for monitoring the energy performance of PV systems are well established. In Europe the Joint Research Centre (JRC) of the European Commission developed guidelines for use in EC funded projects. These were widely used internationally and then used as the basis for developing IEC 61724 (1998-11) "Photovoltaic system performance monitoring - Guidelines for measurement, data exchange and analysis". This recommends procedures for the monitoring of energy-related photovoltaic (PV) system characteristics, and for the exchange and analysis of monitored data.

The following is a guide only for developing a wishlist of monitoring parameters for determining the outside climatic characteristics and the performance of the PV system from the modules through the inverter and to the grid at time-step intervals. These include:

- PV solar generator Voltage (V);
- DC current to each inverter;
- Earth to solar generator Voltage (V);
- Primary Voltage (Grid Voltage-V);
- Primary Current (AC current supplied to grid in amps (A));
- Primary Power (AC power supplied to grid in Watts);
- Ambient Temperature (°C);
- Heat sink Temperature (°C);
- Transformer Temperature (°C);
- Total Energy (produced since installation in kWh);
- Voc (open circuit voltage);
- Vmax (maximum power point voltage);
- MPPT maximum power point tracking window start; and
- MPPT- maximum power point tracking window end;
- Inverter run time.

The data should be logged at least every 15 minutes to a file that is suitable for importing into Excel or accessed for Web-based display purposes. Reports that are extracted from the monitoring system should be capable of being produced in spreadsheet format for easy of analysis and reporting.

Weather station and logging software to be inclusive of the following:

- Isolation sensor for measuring both global and diffuse irradiation (W/m²);
- Ambient temperature (°C);
- Relative Humidity (%);
- Wind Speed (metres/second);
- Rain Gauge (millimetres);
- Wind direction (True direction, in degrees, referenced from true north usually averaged over a period of ten minutes);

Data logger, weather station enclosure, support hardware, software, modems and other sundry supply equipment such as uniterupted power supply (UPS) system to ensure monitoring continues during blackouts; Communication to the weather station should be preferably configured as a dedicated line modem.

A7 Summary of Australian BiPV case studies and other relevant PV projects

Summary of major projects, demonstration and field test programmes in Australia Last updated: November 2004 – please advise if there are missing or incorrect information and the pdf can be updated

Shoulharbour Workers' Club

Date plant start up: 2003 Objectives:

- Building of a new \$3 million verandah, which fronts the eastern and northern facades of the original club building. The verandah's eastern and northern roofs incorporate solar panels "photovoltaics" or "PV" for short that generate up to 22 kilowatts of electricity in full sunlight. In a year, they'll generate about 25,000 kilowatthours enough to power 4 typical Australian houses.
- The PV system incorporates clear glass laminate panels that filter the light coming through the roof onto the verandah below. The laminated panels were manufactured by BP Solar in Germany while the other style of PV used was made at BP's Homebush plant, Sydney.

Project Architects: Caroline Pidcock Architects and Richard Goodwin Project management: Big Switch Projects

Chadwick Centre, Brisbane

Date plant start up: 2002

Technical and economic data: AU\$ 740,000 grant to Forrestor Kurtz Properties and Integrated Energy Services for a 60kW BiPV array on a commercial building.

Objectives:

- To demonstrate the feasibility of using PV as the energy source for a UPS
- To achieve significant cost offsets through BiPV integration and use of PV electricity for a UPS.

Main accomplishments until the end of 2002/problems and lessons learned: Project completed in 2002

Demonstrated significant reduction in cost of PV through offsets in building integration and UPS hardware. Funding: Australian Government RE Commercialisation Program

Project management: Integrated Energy Services

BiPV system for the heritage-listed Queen Victoria Market, Melbourne

Date plant start up: 2002

Technical and economic data: AU\$ 750,000 RECP grant plus Council funds. 200 kWp installed so as not to detract from the heritage buildings producing 250 MWh of green electricity per year Objectives:

- First large PV array for an industrial market-type building
- Long term performance monitoring by the University of Melbourne's Green Building Research Group
- Educational purposes

Main accomplishments until the end of 2002/problems and lessons learned: Concept developed and funding granted in 2000, System installation commenced 2002; Commissioning completed April 2003

Funding: Australian Government RECP, Melbourne City Council

Project management: Installation by BP Solar Australia, Utility - Origin Energy

Griffith EcoCentre

Date plant start up: 2001

Technical and economic data: 4.3 kWp system. AU\$ 33,000, with 80% PVRP rebate. Objectives:

- To provide environmental eduction at the Centre
- To demonstrate PV on community buildings

Main accomplishments until the end of 2002/problems and lessons learned: The system provides 7.8 MWh per annum.

Funding: Australian Government PVRP, Stanwell Corporation

Project management: EnviroPower, Stanwell Corporation,,QLD Environmental Protection Agency

CSIRO Energy Centre

Date plant start up: 2001

Technical and economic data: SEDA provided AU\$ 250,000 for 30kW of PV and 250kW of renewable energy generation, plus a loan of AU\$ 200,000 to STI towards a demonstration DSC array.

Objectives: To assist in the commercialization of renewable energy technologies.

Main accomplishments until the end of 2002/problems and lessons learned: The building is largely completed and PV system installation has commenced. Commissioning expected in 2003.

Funding: SEDA - NSW Renewables Investment Programme, CSIRO

Project management: CSIRO, Sustainable Technologies International, BP Solar, Pacific Solar

Remarks: Difficulties experienced with some aspects of the PV installation by building sub contractors. Need for certified installers.

Renewable Remote Power Generation Programme

Date plant start up: 2001

Technical and economic data: Up to AU\$\$ 264 million available to 2010, allocated on the basis of diesel fuel excise paid by public generators in each State. Grants up to 50% of costs, for renewable energy generation components. Objectives:

- To substitute renewable energy generation for diesel use in off-grid areas and reduce greenhouse gas emissions
- To assist the Renewable Energy Industry
- To meet infrastructure needs of indigenous communities

Main accomplishments until the end of 2002/problems and lessons learned: Sub-Programmes are now operational in all States and Territories. 1,036 systems installed to end 2002, including 1 MWp of PV.

Funding: Grant funding provided by Australian Greenhouse Office, topped up in some States.

Project management: Separate programmes operating in each State and managed by the State governments.

Demonstration thin-film CSG technology

Date plant start up: 2001

Technical and economic data: AU\$ 2 million project, of which AU\$ 1 million provided by RECP Objectives: To demonstrate CSG technology in 4 grid-connected rooftop systems Main accomplishments until the end of 2002/problems and lessons learned: Project is running to programme. Funding: Pacific Solar Pty Ltd, Australian Government RECP

Project management: Pacific Solar Pty Ltd

Full commercialisation of Plug&Power[™]

Date plant start up: 2001 Technical and economic data: AU\$ 1 million (RECP – AU\$ 0.5 million) Balance of systems (BoS) hardware to be configured for mass production & sale. Objectives:

- To develop new packages & hard tooling for BoS components
- To develop Plug&Power[™] for cyclonic regions
- To develop sales & marketing tools
- To monitor six Plug&Power[™] sites

Main accomplishments until the end of 2002/problems and lessons learned: Project is running to programme. Funding: Pacific Solar Pty Ltd, Australian Government RECP Project management: Pacific Solar Pty Ltd

Caboolture Regional Environmental Centre

Date plant start up: 2000 Technical and economic data: 5 kWp system, costing AU\$ 52,000. PVRP rebate of 60%. 3 x 1.6 kW grid interactive inverters Main accomplishments until the end of 2002/problems and lessons learned: The system is roof mounted and provides around 7.3 MWh per annum. Funding: Stanwell Corporation, Australian Government PVRP Project management: Choice Electric Company, Stanwell Corporation, QLD Environmental Protection Agency

Titania Dye Sensitised Solar Tile and Wall Panel manufacturing facility

Date plant start up: 2000 Technical and economic data: AU\$ 2.5 million (RECP-AU\$ 1 million) The facilities will be capable of producing 10 000 m² of Solar Wall Panels annually. Objectives:

- To validate manufacturing processes
- To enable the first phase (500kWp) start-up

Main accomplishments until the end of 2002/problems and lessons learned: World's first DSC manufacturing facilities installed in Queanbeyan.

Funding: Sustainable Technologies International Pty Ltd.

Australian Government - RECP

Project management: Sustainable Technologies International

BiPV cladding of the Melbourne University Alan Gilbert building

Date plant start up: 2000

Technical and economic data: AU\$ 755000 RECP grant + University funding.

Objectives: To demonstrate the application of building-integrated PV power generation on a large scale.

Main accomplishments until the end of 2002/problems and lessons learned: Systems design completed by STI and Ove Arups.

Funding: Australian Government RECP, Melbourne University Private Ltd

Project management: Melbourne University Private

PV Rebate Programme

Date plant start up: 2000

Technical and economic data:

Grants of AU\$ 5 000 per kWp for households and AU\$ 10 000 for community buildings.

To date, 4 MWp installed on 3 760 systems with over AU\$ 21 Million provided in grants

Objectives: To stimulate the use of PV on residential and community buildings

Main accomplishments until the end of 2002/problems and lessons learned: 40% of installations, comprising 48% of installed PV capacity, have been on grid connected buildings.

Funding: Australian Government funded, with State Government administration

Project management: Australian Greenhouse Office and State energy agencies

Remarks: Demand in the grid-connected market picked up quickly. The programme was over subscribed and money was rationed for some months. The Government has announced continuation of the programme for 2 years, with lower grant levels.

Wetlands Project - Homebush Bay 64kWp

Date plant start up: 2000

Technical and economic data:

64 kWp PV grid-connected and battery backup system sited on the Homebush Bay wetlands.

800 SX80 Solarex PV modules, three 20 KVa AES string inverters, 240 volt DC 1000 Ampère battery backup

Objectives: To pump water from 40 ponds once every three days during the summer and less frequently in the winter to mitigate mosquito infestations and the build up of algae blooms. The tilt of the array is 15 degrees, to maximize summer output.

Main accomplishments until the end of 2002/problems and lessons learned: Positioned slightly east of north, a carefully constructed galvanized steel custom-made frame was designed on a 45 degree slope without detracting from the historic munitions building.

Funding: Waste Services and Olympic Co-ordination Authority (OCA)

Project management: Waste Services and Olympic Co-ordination Authority (OCA), Advanced Energy Systems (AES) of Perth, Solar Technology Australia (SOLARTECH).

Citipower Solar Pioneers Programme

Date plant start up: 2000

Technical and economic data: AU\$ 60 000 REIP grant plus contributions from customers and Citipower.

Objectives: To help accelerate the commercialization and uptake of PV, assist in increasing sales of Australian made equipment and to enable participating customers to make their own contribution to the reduction in Australia's greenhouse emissions.

Main accomplishments until the end of 2002/problems and lessons learned: 50 systems, with a capacity of 5,6 kW, are installed. Most of the systems are rated at 1 kWp. One system is installed on a secondary school, the remainder on residential properties.

Funding: Citipower, customers, Australian Government - Renewable Energy Industry Programme Project management: Citipower

GreenGel battery

Date plant start up: 2000

Technical and economic data: AU\$ 1 Million RECP grant + funding from the companies involved Objectives: Commercialization of a long life deep cycle lead acid battery for off-grid renewable energy systems. Funding: Australian Government RECP, BP Solar, Battery Energy South Pacific, CSIRO Project management: BP Solar

220 kWp Diesel Grid Feed Sun Farm for the Anangu Pitjantjatjara Lands, South Australia

Date plant start up: 2000

Technical and economic data:

AU\$ 1 million RECP grant + funding from ATSIC and SA Government

 $10 \ x \ 22 k Wp \ PV$ concentrator dishes, which operate and feed power directly into the local grid, supplying 20% of the daily load

Objectives:

- To reduce diesel consumption and greenhouse gas emissions.
- To develop an air-cooled concentrator dish technology particularly suited to remote and arid locations where cooling water is in limited supply.

Main accomplishments until the end of 2002/problems and lessons learned: Installation largely completed in 2002. Commissioning expected in 2003

Funding: Australian Government RECP, Pitjantjatjara Council Inc, South Australian Division of State Aboriginal Affairs

Project management: Pitjantjatjara Council

Peak lopping in off-grid diesel systems using PV

Date plant start up: 2000

Technical and economic data:

AU\$ 0,5 million RECP grant + 1,25 million via the RRPGP programme and funding from NT PAWA

Flat-plate PV modules at Bulman Aboriginal community (55kWp) and Kings Canyon tourist site (225kWp), connected to diesel-powered grids via inverters.

Objectives:

- To demonstrate the large scale commercial viability of PV peak lopping in remote diesel grid systems
- To lower operating costs and reduce greenhouse gas emissions
- To reduce diesel consumption.

Main accomplishments until the end of 2002/problems and lessons learned: Early studies have shown good correlation between peak load and solar insolation, which will allow maximum benefit to be gained by addition of PV.

Funding: Australian Government. RECP, RRPGP.

Power and Water Authority of the Northern Territory. NT Centre for Energy Research, Project management: PAWA

All-plastic PV roof tile

Date plant start up: 2000

Technical and economic data: AU\$ 135 000 RECP grant, AU\$ 20 000 from NSW SEDA + funding from the companies involved.

Objectives:

To develop an extruded frame for PV laminates and a low cost pluggable PV junction box.

To market and promote the product to architects, BIPV installers, home renovators and financiers.

Main accomplishments until the end of 2002/problems and lessons learned: The new Solar Tile is already being used in Sydney, using BP Solar's 85 Wp Saturn cell PV laminates, under a contract to developer MIRVAC for the Newington Solar Village stage 2. 79 homes are now being built, each with 12 tiles, making a 1 kWp PV system. Funding: Australian Government RECP, NSW SEDA, PV Solar Energy Pty Ltd, Utilux Pty Ltd and BP Solar Australia

Project management: PV Solar Energy Pty Ltd

Solar Sailor

Date plant start up: 2000 Technical and economic data: AU\$ 1 million RECP grant + company funding. 108-seat multi-purpose catamaran capable of running on solar and wind energy with CNG or LPG back-up Objectives:

- To construct, test and demonstrate commercial viability
- To showcase the solar wing, a solid-aerofoil sail with an embedded array of PV cells that utilizes solar and wind energy separately or in combination

Main accomplishments until the end of 2002/problems and lessons learned: Solar Sailor is operated commercially on Sydney Harbour and is in high demand.

Funding: Australian Government. RECP, Solar Sailor Holdings Ltd, Project management: Solar Sailor

Commercialisation of an efficient solar electric charge controller

Date plant start up: 2000

Technical and economic data: AU\$ 125 000 RECP grant + company funding.

Objectives: To repackaging the technology in a more commercial form, lower unit costs and develop effective marketing strategies and materials.

Funding: Australian Government. RECP, Plasmatronics Pty Ltd, Project management: Plasmatronics

Solar Kogarah

Date plant start up: 2000

Technical and economic data: AU\$ 1 million RECP grant, AU\$ 200 000 from NSW SEDA + Council funding 148 kWp of UniSolar PV modules on the roof and 12 kWp glass/glass BP PV modules over the entrance and lobby. 59 SunPower 1.5 – 2.5 kW inverters are used.

Objectives:

- To establish a major building demonstration site for specific solar energy products and BIPV in an inner city town centre.
- On-site marketing and promotion of solar energy in urban environments

Renewable energy training services.

Main accomplishments until the end of 2002/problems and lessons learned: The PV systems been installed and was commissioned in 2003. The utility EnergyAustralia is responsible for the PV component of the building. BiPV modeling by SOLARCH, UNSW

Funding: Australian Government RECP, NSW SEDA, Kogarah Council Project management: Kogarah Council

Project management: Kogarah Council

NSW Solar in Schools Programme

Date plant start up: 1999

Technical and economic data: AU\$ 0,5 million provided jointly by NSW SEDA, the Department of Education and Training and Integral Energy

Objectives: To increase awareness and knowledge of PV systems.

Main accomplishments until the end of 2002/problems and lessons learned: 18 schools were provided with 1 to 1,5 kWp roof mounted PV systems.

Funding: NSW SEDA, Dept of Education & Training,,Integral Energy

Project management: Integral Energy

20 kWp grid-connected solar PV trough concentrator

Date plant start up: 1999

Technical and economic data: AU\$ 300 000 REIP grant + University and company funds Parabolic trough-shaped mirror to concentrate the sun's energy onto a line of high efficiency PV cells.

Objectives: To demonstrate and evaluate the commercial potential of PV concentrator technology, especially for use in diesel powered mini-grids in rural and remote areas.

Main accomplishments until the end of 2002/problems and lessons learned: System commissioned. Funding: ANUTECH

Project management: Australian Government. REIP, ANUTECH Pty Ltd, Solahart Industries Pty Ltd and Western Power Corporation

Sydney Superdome Solar System

Date plant started up: 1999

Technical and economic data: 70 kWp amorphous silicon roof integrated array, comprising 1176 X 77 Wp modules on a steel frame with an 8° tilt, 19 X 4 kW inverters and optic fibre monitoring link.

Objectives: To demonstrate a large roof-integrated array and supply 1000 of EnergyAustralia's PureEnergy customers. Funding: EnergyAustralia, via contributions from PureEnergy customers

Project management: EnergyAustralia in conjunction with SEDA, Abi Millenium, Olympic Co-odinating Authority

Olympic Boulevard PV Lights

Date plant start up: 1999

Technical and economic data: 1520 laser grooved crystalline silicon modules on 19 towers. Grid connected.

Objectives: To provide lights, signage, shelter and shade, plus a high profile demonstration of PV power.

Main accomplishments until the end of 2002/problems and lessons learned:

Won the Inst of Eng 1999 Eng Excellence Award for Project Development.

Provides 160,000 kWh/year

Funding: Australian Olympic Co-ordinating Authority

Project management: EnergyAustralia

Newington Solar Village

Date plant start up: 1998-2000

Technical and economic data: 629 X 1 kWp grid connected rooftop systems (c-Si cells) in a high density residential estate.

Objectives:

- To develop and demonstrate standardized, easy to install BiPV systems in commercial housing.
- To investigate network issues involved with a high density of small PV arrays.

Main accomplishments until the end of 2002/problems and lessons learned: Valuable trade and professional experience, understanding and skill development.

Funding: PV costs included in house prices.

Project management: Pacific Power, BP Solar.

Western Plains Zoo

Date plant start up: 1998

Technical and economic data: Grid-connected 50 kWp mc-Si array.

Objectives: To demonstrate PV for its Green Power customers and gain installation & operational experience.

Main accomplishments until the end of 2002/problems and lessons learned: Trees surrounding site.

Funding: Advance Energy via its Green Power customers, SEDA

Project management: Advance Energy

Queanbeyan Energy Depot

Date plant start up: 1998

Technical and economic data: Grid-connected 50 kWp mc-Si array, comprising 720 X 77 Wp modules.

Objectives: To gain installation & operational experience with larger scale PV systems.

Main accomplishments until the end of 2002/problems and lessons learned: Difficult sloping site, with non-ideal orientation.

Funding: Great Southern Energy via its Earth Saver customers and SEDA. Project management: Great Southern Energy

White Cliffs Solar Power Station

Date plant start up: 1998

Technical and economic data: Grid-connected 42 kWp concentrating array with 14 X 20 m² tracking dishes. Objectives: To refurbish a concentrating solar thermal system with PV.

Main accomplishments until the end of 2002/problems and lessons learned: Produces 70,000 kWh/an.

Funding: Advance Energy & Solar Systems.

Wilpena Pound Solar Power Station

Date plant start up: 1998

Technical and economic data: 100 kWp ground mounted mc-Si array in hybrid configuration with 440 kW diesels, 400 kWh battery bank, 125 kVA inverter /charger plus innovative remote monitoring & controls Objectives: To gain experience with and demonstrate a stand-alone community sized PV based power system.

Main accomplishments until the end of 2002/problems and lessons learned: The PV/battery system typically supplies all daytime load. Funding: South Australian government, Electricity Trust of SA. Project management: ETSA Power

Singleton Solar Farm

Date plant start up: 1997-98 Technical and economic data: Grid-connected 400 kWp array of 3,312 a-Si and 3456 mc-Si panels on steel frames at 30° N tilt. 5 X 50 kW and 36 X 4 kW inverters are used. Objectives: To gain experience with large grid connected arrays and system components. Main accomplishments until the end of 2002/problems and lessons learned: Largest central PV power station in Australia. Produces 500,000 kWh/an, supplies 6,000 PureEnergy customers Funding: EnergyAustralia, via contributions from PureEnergy customers, SEDA, Singleton Shire Council. Project management: EnergyAustralia

Homebush Business Park PV Power Station

Date plant start up: 1997 Technical and economic data: 11.2 kWp c-Si array, comprising 140 X 80 Wp panels and a 10 kW inverter. Funding: EnergyAustralia via its PureEnergy customers. Project management: EnergyAustralia

Foreshore Park PV Power Station, Newcastle

Date plant start up: 1996 Technical and economic data: 6.5 kWp array on a historic railway shed, comprising 80 X 83 Wp and 16 X 64 Wp mc-Si modules with a 5 kVA inverter. Objectives: To demonstrate a grid connected building integrated PV system. Main accomplishments until the end of 2002/problems and lessons learned: Very careful design required to fit heritage listed building requirements. Funding: EnergyAustralia via its PureEnergy customers. Project management: EnergyAustralia

National Innovation Centre PV Power Station

Date plant start up: 1996 Technical and economic data: 10 kWp array at Australian Technology Park. Main accomplishments until the end of 2002/problems and lessons learned: 120 X 83 W mc-Si modules and 10 kVA inverter. Funding: EnergyAustralia via its PureEnergy customers. Project management: EnergyAustralia

60L Green Building, Carlton

Owner: Green Building Partnership Commissioned: 2002 Configuration: 64 x 0.15kW PV Total Capacity: 0.01 MW There is also a website about this building: <u>www.60lgreenbuilding.com</u>

A8 Useful websites

Key PV sitesInternational Energy Agency (IEA) PVPS Program and Task Reportswww.iea-pvps.orgIEA Task 7 - PV in the Built Environmentwww.task7.orgAustralian and New Zealand Solar Energy Society (ANZSES)www.anzses.orgInternational Solar Energy Society (ISES)www.ises.org/UNSW PV Centre www.pv.unsw.edu.au and www.pv.unsw.edu.au/links/othersites.asp

Search engine for latitudes and longitudes of Australian cities and towns Charles Sturt University - <u>http://life.csu.edu.au/geo/findlatlong.html</u>

Bureau of Meteorology <u>http://www.bom.gov.au/climate/</u>

Business Council for Sustainable Energy (BCSE) <u>www.bcse.org.au</u> - Australian industry members directory Other industry players can be found at AGO <u>www.greenhouse.gov.au/renewable/reis/reid/index.html</u>

<u>PV Databases</u> <u>www.pvdatabase.com</u> <u>www.demosite.ch</u>

PV System sizing guide

BCSE (2004) PV Grid connect systems (non-UPS) Guidelines No2, September 2004 www.bcse.org.au/docs/Solar%20Accreditation/accreditation%20forms/For%20Accredited%20Installers/GridCon_install_V2.pdf.

Your Home Design Guide and PV www.greenhouse.gov.au/yourhome/technical/fs47_4.htm

Life cycle analysis of PV

Life cycle impact analysis of cadmium in CdTe <u>www.nrel.gov/cdte/pdfs/cdte_lca_review1.pdf</u> Life cycle analysis of Amorphous Silicon modules <u>www.umich.edu/~nppcpub/research/pv.pdf</u> Life cycle costs of PV systems <u>www.sandia.gov/pv/docs/LCcost.htm</u> Environmental life-cycle assessment of multicrystalline silicon www.chem.uu.nl/nws/www/publica/95057.pdf

BiPV Simulation Tools

PVsyst	www.pvsyst.com
PV design Pro-G	www.mauisolarsoftware.com
PV*Sol	www.valentin.de
Solar Pro	<u>www.lapsys.co.jp/pro/pro_english.html</u>

<u>City Guide on PV Potential and Issues</u> http://pvcityguide.energyprojects.net/

About Solar Power

www.greenhouse.gov.au/renewable/power/grid.html www.greenhouse.gov.au/yourhome/consumer/cg7b.htm www.howstuffworks.com/solar-cell.htm

Real Projects

www.kogarah.nsw.gov.au/asset/1/upload/Town_Square_Fact_Sheets_ENERGY1.pdf www.newingtonvillage.com.au/healthy.html#Clean

Solar Power in the Built Environment www.fbe.unsw.edu.au/research/ www.pvresources.com/en/top25bipv.php

<u>Solar lights</u> <u>www.solarg.com.au/</u>

Australian Standards www.standards.com.au

Connecting to the Grid

UNSW (2003) Development of a Standard Grid Connection Agreement for Small Grid-Connected Renewable Energy Systems, January 2003 <u>www.acre.ee.unsw.edu.au/anzses2002/ANZSES_StdConnAgreeUNSW.pdf</u> <u>http://www.pv.unsw.edu.au/documents/SmallGridCnectFinalReport.pdf</u>

US Interstate Renewable Energy Council US Department of Energy (DOE) Photovoltaics See how a PV cell works US National Renewable Energy Laboratory (NREL) US NREL - National Centre for Photovoltaics (NCPV) NCPV virtual library www.irecusa.org/connect/library.html

www.eere.energy.gov/pv/videos/pv3.mov

www.nrel.gov/ www.nrel.gov/ncpv/ www.nrel.gov/ncpv/libbody.html

<u>Australian Competition and Consumer Commission (ACCC)</u> <u>www.accc.gov.au</u> Australian government organisation responsible for ensuring compliance with the Trade Practices Act 1974.

National Electricity Code Administrator (NECA) www.neca.com.au

NECA is a company aimed at promoting the effectiveness, efficiency and equity of the national electricity market.

National Electricity Market Management Company (NEMMCO)

www.nemmco.com.au

The body corporate responsible for the administration and operation of the wholesale National Electricity Market (NEM) in accordance with the National Electricity Code.

Building Integrated Photovoltaics (BiPV) for Commercial and Institutional Structures: A Sourcebook for Architects www.nrel.gov/ncpv/pymenu.cgi?site=ncpv&idx=3&body=infores.html

Solar Buildings, US Department of Energy www.eren.doe.gov/solarbuildings/integrated.html

The Dawning of Solar Electric Architecture from the National Center for Photovoltaics (US), part of the National Renewable Energy Laboratory (NREL). Includes reports on projects in different countries www.nrel.gov/ncpv/documents/worldreport.html

Solar Electric Buildings On-line document with many examples of BiPV buildings <u>www.nrel.gov/ncpv/documents/seb/</u>

US DOE Million Solar Roofs Project www.eren.doe.gov/millionroofs/

Sustainable by design Cool tools for sustainable building design www.susdesign.com/

Most Attractive PV Projects in the World <u>www.pvportal.com/stats/nicest/chartn2.html</u>

BiPV (Building Integrated PV) Photo Album Kenji OTANI's Photovoltaics Room www.etl.go.jp/etl/divisions/~k.otani/data/bipvphoto-e.htm

A9 Bibliography – Key reference publications

MAIN REFERENCES FROM THE IEA can be downloaded from the following <u>link</u>. <u>www.oja-services.nl/iea-pvps/products/index.htm</u>

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Prasad D.K. and Snow M. (2005) *Designing with Solar Power - A sourcebook for building integrated photovoltaics (BiPV).* International Energy Agency (IEA), Images publishing, Melbourne. ISBN 1 86470 717 7

Sick F. and Erge, T. (eds.)(1996) *Photovoltaics in Buildings, design handbook for architects and engineers,* IEA Task 16 Solar Heating and Cooling Energy Systems, James and James, Glasgow ISBN 1 873936591

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