ENERGY - PHOTOVOLTAICS

INTRODUCTION

Leichhardt Council has a vision (as stated in the Leichhardt 2020+ Strategic Plan) of the 'Community and Council working together to promote and develop Leichhardt as a sustainable and liveable community'.

Key objectives in the 2020+ Strategic Plan are to 'reduce non-renewable fuels usage' and to 'reduce greenhouse gas emissions'. Photovoltaic (PV) installations can help Leichhardt achieve the stated objectives.

The aim of this discussion paper is to explain current State legislation and how Council's new Development Control Plan (DCP) relates to its controls. It will provide background information about the installation of PV systems, (worldwide) best practice examples and how to maintain the integrity of heritage items.

BACKGROUND

The Leichhardt LGA is characterised by a diversity of building stock, often heritage listed, which results in sometimes competing interests of streetscape, heritage and Ecologically Sustainable Design (ESD) principles.

Current legislation and controls

Table 1 summarises the relevant State Environmental Planning Policies (SEPP) and Leichhardt Controls regarding photovoltaic installations that currently exist.

RESEARCH

Controls in neighbouring Councils

The following DCPs have been accessed and reviewed regarding controls for the installation of PV systems on residential development:

- City of Sydney draft DCP 2010
- Marrickville Council draft DCP 2010
- Ashfield DCP 2007
- Willoughby DCP
- Woollahra

Other controls and legislation

In addition to the DCPs from neighbouring councils, the following legislative documents have been reviewed to get an understanding of what is current common practice elsewhere:

- East Perth Planning Policies and Design Guidelines
- UK Government Planning Portal (applies to London City)

TYPES OF PV INSTALLATIONS

- **Building integrated Photovoltaics**

Building Integrated Photovoltaics (BiPV) are integrated within the building itself and form part of the structure. Rather than installing PV cells on the roofs of buildings, they are integrated in the fabric of the building. Examples of BiPV can be found on the PV Sunrise website (www.pvsunrise.eu).

Table 1. Current New South Wales and Leichhardt Council legislation relating to PV installations on residential development

Legislative Document	Control	Implication
SEPP Infrastructure (2007)	37 Complying Development (2) Solar energy systems 39 Exempt development (3) Solar energy systems	The SEPP outlines controls on installation, placement, size, output and technology of the solar energy system in general and specific controls relating to heritage and conservation buildings and land. A distinction between ground-mounted and not ground-mounted systems is made, with specific controls relating to the type of solar energy system. Controls.
Leichhardt DCP – Part B Residential Development	B 2.6 - Design element 14 Using solar energy 'actively' – Energy efficient water heaters, photovoltaic (solar energy) & systems & swimming pool heating	General controls outline the panel's orientation, minimum electrical output, placement and heat build-up in roof cavities when solar tiles are to be installed. Specific controls exist for the installation of PV panels in heritage and conservation areas.
Leichhardt DCP 35 – Part B Exempt Development	3.23.3 - Photovoltaic systems (Including both panels attached to roof and photovoltaic tiles that form part of the roof itself)	Exempt Development prerequisites must be met. In addition to the SEPP requirements, specific controls are to be followed. These controls outline the PV panel's orientation, minimum electrical output, placement and heat build-up in roof cavities when solar tiles are to be installed. The installation of PV on the street frontages of heritage items or in conservation areas is not exempt development.

Advantages of BiPV are that they allow the architect of to make PV part of a building, both structurally and visually.
The power output of these PV cells can be maximised, as the they can be positioned and installed in parts of the building that allow for the highest solar irradiation. PV cells can be applied in such a way that they can serve multiple purposes, e.g. forming a shading device, as the PV panels are not transmitting light.

However, BiPV are a relatively expensive form of PV systems. Existing buildings can be retrofitted with BiPV. As discussed in Sustainability at the cutting edge (2007), Applied photovoltaics (2006) and Best Practice Guidelines for Solar Power Building Projects in Australia (2005), the integration of PV in buildings should be approached holistically, taking all factors relevant to the site into account: aesthetic impact/design, heritage/ conservation, structural changes, innovation, integration and fit for purpose. Consultation and discussion should be undertaken before construction starts.

- **Roof-mounted PV installations**

Possibly the most widely known and common form of PV installations, are roof-mounted PV systems. As the title suggests, these installations comprise PV panels that are either mounted on the roof or integrated in the roof of buildings. When fitting buildings with roof-mounted PV installations, frames will be installed on which the PV panels will be mounted. These frames allow for the PV panels to be tilted and rotated in the direction that will generate the most optimal average yearly power output. The most sophisticated frames are installed with tracking devices. These tracking devices will rotate and tilt the PV panels in the direction that will generate the most optimal power output in real time.

The advantage of roof-mounted PV systems is that they are relatively affordable and easy to install on the roof of a building, either new or existing.

Disadvantages are their visual impact once installed, especially on heritage items or in conservation areas and the maximum output of the system is dependant on the orientation and angle of the roof on which the system will be installed.

- **Ground-mounted PV installations**

Ground-mounted PV systems consist of PV panels, attached to frames, which are mounted on the ground. As with the roof mounted PV systems, the most sophisticated frames are installed with tracking devices. These tracking devices will rotate and tilt the PV panels in the direction that will generate the most optimal power output in real time

Ground-mounted PV systems are relatively affordable and easy to install.

However, a considerable area of land is needed to accommodate for a system size that can generate a substantial amount of power. In addition, this area of land needs to be free from overshadowing, and therefore high growth or general infrastructure, and is unlikely to be applied in densely populated areas.

DESIGN CONSIDERATIONS

Solar access

In order to optimise PV power performance, direct solar irradiation is needed, in accordance with a range of criteria preferably from 9am to 3pm in midwinter.

When installing PV systems, the potential for partial overshadowing needs to be considered. PV panels are to be wired to ensure that, in the event of partial overshadowing of the panel, the overshadowed portion of the PV panels is isolated from the rest of the system as partial shading of just a small portion of a PV surface can have a disruptive effect on its electrical power output.

Objects that reduce sun exposure, both from the building itself as well as from surrounding objects, should be avoided. Therefore, the potential for existing and future shading from trees, new buildings and developments and general infrastructure should be carefully assessed when PV systems are considered

Considerations to achieve optimum power output

As a rule of thumb, the optimum output for a PV panel is achieved when:

a. it is orientated true north and;

b. tilted at the latitude angle of its location.

In Sydney the latitude angle is 34° south of the Equator, which means that a PV panel orientated true north and tilted 34° from the horizontal would be ideal to achieve maximum annual solar exposure.

Figure 1 shows the effect that the orientation and tilting angle of a PV panel have on the power output, expressed as a percentage of the maximum possible output. Figure 1 applies to the area from south of Sydney through Canberra and Adelaide at 35°S latitude.

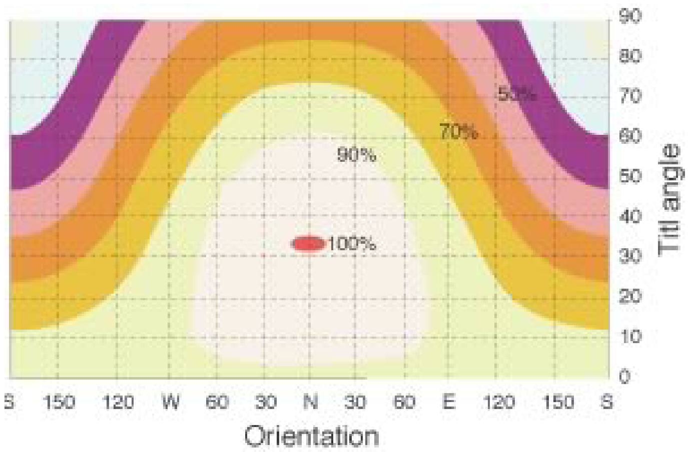

Figure 1. Power output of PV panel expressed as a percentage of maximum possible output at 35°S latitude (Source: Best Practice Guidelines for Solar Power Building Projects in Australia, 2005)

Figure 1 shows that PV panels do not have to be optimally orientated to gain adequate outputs. Research is currently being undertaken to assess the usefulness of installing north-westerly facing PV systems to address peak power demand in the afternoon. (Dr. R Corkish, 2011).

Apart from amorphous silicon PV panels, generally the following rule of thumb applies: the hotter the air temperature, the lower the efficiency of PV panels. As can be read in Applied Photovoltaics (Wenham et al, 2006), PV panels work best during high sun and relatively low ambient temperatures (e.g. below 25°C). Australia experiences a high number of days with an air temperature above 25°C. This means that there is likely to be more frequent loss of power output, especially during 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 loss of power output. It is therefore important to consider what climatic influences for the chosen location can have on different PV types.[1]

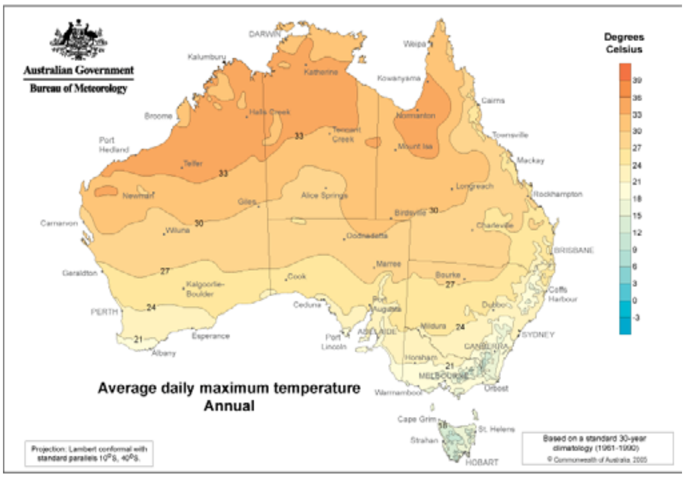

Figure 2. Annual average daily maximum temperature in Australia based on 30 year climatology (1961 - 1990) (Source: Australian Bureau of Meteorology 2008)

Amorphous silicon PV panels are more efficient when heated by the sun. The downside is that PV panels based on amorphous silicon technology have a lower maximum power output than mono-crystalline or poly-crystalline PV panels. Therefore, PV systems based on amorphous silicon technology can result in system sizes up to twice the size compared to a mono- or poly crystalline PV system to achieve comparable power outputs.

However, as Sydney has a lower average maximum temperature and a cooler and more humid climate than inland and northern Australia, mono-crystalline and poly-crystalline PV panels are suitable for installation.

The following should be considered in order to reduce the working temperature of PV panels.
Natural ventilation can be used to cool PV panels to a more desirable temperature; this can be achieved by mounting the PV panels parallel to the roof, which allows air to circulate in the space under the panels.

Cooling is particularly important for BiPV. Buildings fitted with BiPV should be designed to create natural air flow to provide cooling for the BiPV system in summer, and passive heating in winter.

Maintaining PV panels

The accumulation of dirt on PV panels can reduce power performance significantly. Dust build-up will be cleaned up by rain. However, the sap from gum trees and falling tree debris, the build up of bird faeces and dirt or contaminants from construction dust, dust storms and fumes from building exhausts can be problematic, especially on horizontally mounted PV panels. Sensible site selection can normally avoid any significant losses.

The rough grain of the front glass cover of PV panels encourages self-cleaning during rainfall. It is not uncommon for PV performance to improve slightly the next clear day after rain. PV panels that are tilted less than 20 degrees from the horizontal, are less likely to be rinsed by rain and may require an occasional clean. Various products exist which can be used to prevent birds sitting on the panels.

As discussed in Applied Photovoltaics (Wenham et al, 2006), climatic effects such as relative humidity and the salt air conditions of coastal regions can encourage moisture build up and corrosion and affect the power output or operation of the PV panel. This is especially true for PV modules that are poorly sealed, however this is an unusual occurrence today.

Recycling

As both the Best Practice Guidelines for Solar Power Building Projects in Australia (2005) and Applied Photovoltaics (2006) mention, there is currently no formal procedure for re-use or recycling of PV products.

Voluntary industry recycling guidelines are currently prepared by the American Solar Energy Industries Association (SEIA, 2011). In Europe, PV Cycle has been set up in July 2007 “to implement the photovoltaic industry’s commitment to set up a voluntary take-back and recycling programme for end-of-life-modules and to take responsibility for PV modules throughout their entire value chain” (PV Cycle, 2011).

PV installation examples

A list of examples of larger-scale PV installations in Sydney can be found below. These installations have successfully addressed and integrated PV panels and heritage:

- City of Sydney Town Hall
- Cockatoo Island
- Sydney Theatre Company

[1]Note: Sydney has a much lower average daily maximum temperature, between 21 and 24°C, compared to inland and northern Australia, between 30 and 36°C (see figure 2).

DISCUSSION

Cutting energy demand is the first and most affordable step towards reducing carbon emissions. Energy efficiency measures are to be implemented in the first instance to reduce energy consumption – these measures are to include but should not be limited to:

- the installation of low energy light bulbs;
- heating controls;
- improved insulation;
- repairing damaged windows, doors and seals;
- unblocking boarded over window openings;
- removing introduced glazing over openable windows;
- unblocking ceiling vents and flues, and;
- opening doors to reinstate air movement for cooling.

Property owners are also encouraged to reduce energy consumption by implementing behavioural changes such as turning off appliances and opening windows and doors to allow cross ventilation of rooms.

The existing controls in the Leichhardt DCP relating to PV systems are thorough and descriptive. Descriptive controls provide a good overview and are easily enforceable. However, controls that are too descriptive might limit innovative use of PV on buildings and might therefore be counterproductive.

In the following paragraphs, general design guidelines relating to the installation of PV systems, that could be considered when writing new controls, will be outlined. In order to ensure that PV systems are installed correctly, they must be installed to all relevant Australian Standards, manufacturers specifications and by a person accredited by the Clean Energy Council.

New technologies

Economy of scale is an important factor for new technologies to become economically feasible. Many integrated technologies do not yet offer the same efficiencies as existing purpose built solar panels or are only available at high costs.

BiPV have the potential to radically change the way PV installations/systems are integrated in the built environment. Rather than retrofitting existing properties with standard PV panels, a more inclusive and arguably more attractive design can be achieved once PV panels become an integrated part of buildings. Currently, BiPV are slowly integrated in large scale (re)developments. The high cost prohibits many smaller developments to be fitted with BiPV systems. With the ongoing development of PV technologies, such as thin film solar (see next paragraph), this might change in the coming years and the improvements of BiPV systems should be assessed on a regular basis.

Thin film solar panel technology is rapidly developing, and promises to be a major player in the near future. One of the advantages of thin film technology is the flexibility of the panels and design as well as the reduced amount of materials, and thus embodied energy, to manufacture them. This flexibility might lead to a better integration of solar panels in the built environment, rather than the well-known retrofitted panels that are currently common practice.

The colour of the rim/edge around PV panels has always been a point of debate. Currently, differently coloured rims for PV panels do exists, e.g. black or dark grey, which are more aestheically pleasing. In addition, the previously discussed thin film technology will allow PV panels to be integrated in roofs or designed without the need for a rim/edge, which makes installing PV panels a more aesthetically pleasing option.

Design considerations

In order to achieve the optimum output of PV panel installations, the following is crucial:

- **Solar access:** as discussed previously, solar access is the most important factor when installing PV systems. Objects that have the potential to overshadow the PV system should be avoided. The site should be carefully assessed prior to installation to limit the chance of future objects (such as growing trees, (re)developments and general infrastructure) overshadowing the PV system.
- **Placement:** a true North orientation and 34 degree tilting angle allow for an optimum average yearly output of PV panels. Research is currently being undertaken (at the University of New South Wales), to investigate if strategic orientation of solar panels might help addressing the problem of peak power load in summers;
- **Wiring:** in order to prevent overshadowing from shutting down the entire PV system, PV systems should be connected in such a way, that the parts affected by overshadowing are wired separately from the rest of the system. By doing so, the effect of partial overshadowing on the total system's output is minimised;
- **Cooling:** generally the following rule of thumb applies: the hotter the air temperature the lower the efficiency of PV panels. Natural ventilation can be used to cool PV panels to a more desirable temperature;
- **Maintenance:** a clear surface will result in higher power output and therefore a higher efficiency. Inspections of PV systems should occur regularly;
- **Recycling:** although PV panels are not widely recycled yet, programs to address recycling are currently being developed. Voluntary industry recycling guidelines are currently prepared by the American Solar Energy Industries Association (SEIA, 2011). In Europe, PV Cycle has been set up in July 2007 "to implement the photovoltaic industry's commitment to set up a voluntary take back and recycling programme for end-of-life-modules and to take responsibility for PV modules throughout their entire value chain" (PV Cycle, 2011).

HERITAGE

Due to the cultural, historical and social significance of conservation areas and heritage items, a thorough examination into feasible alternatives to reduce the overall energy use should be undertaken before a decision is made to install photovoltaic (PV) panels.

Altering the visual or structural aspects of heritage items should be avoided. Heritage aspects often can not be replaced and should be preserved. The specific cultural, historical and social significance to an area or building is often reflected in its visual and structural appearance. In order to preserve this appearance, it is important that the PV panels have a minimal visual and structural impact on the relevant building and the streetscape/urban realm in which the relevant building is placed.

Before any work to a conservation or heritage item is undertaken, it is important to have a contingency plan in place. This plan will ensure that no damage will be made to the item and will address the processes that have to be undertaken in the event that something might not go according to plan. In addition, the processes that need to be undertaken once the PV panel installation reaches its end of life are outlined in this plan.

When a contingency plan has been developed, careful considerations will have to be made as to where PV panels will be installed. In addition to the previously discussed design considerations, specific guidelines will have to be developed in order to maintain and preserve the cultural, historical and social values of heritage items, especially when a consideration will be made to install PV panels on primary frontages in conservation areas. These guidelines would address specifications relating to the item and the setting it is placed in. Recommendations to consider when installations of PV panels on primary frontages could be (but not limited to):

- Aesthetic considerations for both the streetscape/urban realm and the site/item itself;
- The effects of predicted future overshadowing;
- Protection of the existing building envelop of the building the PV panels will be installed on;
- The colour of the PV panels and the edge/rim of the panels could be sympathetic to the roof colour;
- PV panels could be prohibited on slate roofs with decorative features such as a fish scale pattern;
- PV panels could be prohibited on parapet roofs and sub roof elements;
- The pruning or removal of vegetation could be prohibited when development consent or a permit is needed;
- PV panels could be mounted parallel to the roof;
- A maximum amount of PV panels that can be installed on primary frontages;

Through technological advances, an increasing number of PV products will become more sympathetic to heritage or conservation areas. An example of one of those products is a solar roof tiles and solar roof slate, available in different colours.

These advances in knowledge and technology could assist in integrating or retrofitting heritage or conservation items with PV technology without impacting on the aesthetics, cultural, historical or social significance.

CONCLUSION

The installation of PV panels on residential development is a very complex issue. A considered approach should be taken, which will make a distinction between new development and development in conservation/heritage areas as there are different interests at stake. Heritage is of great importance the Leichhardt LGA. When PV panels on heritage or conservation items will be made exempt development or are considered, it is very important that a considered approach will be taken and strict guidelines and checklists will be developed to assure that the item's importance and significance will be maintained for both current and future generations.

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