Building Integrated Photovoltaics: What is the potential for this PV technology?

Building Integrated Photovoltaics (BIPV), as the name suggests, describe a PV system where solar PV modules are integrated within a building's envelope, as oppose to conventional PV systems where modules are mounted on the top of existing roofs. BIPV products have been commercially available since the 1990s in Europe, but have not played a major role in the global PV market. However, Tesla's recent release of aesthetically pleasing and competitively priced BIPV solar tiles has again captured the public's imagination. GSES thought it opportune to highlight the benefits of BIPV systems and what the future may hold for these applications.

Benefits of BIPV

BIPV systems are the more aesthetic option for PV installations, as modules in a BIPV system are designed to blend in with the surrounding building envelope, giving the installation a more subtle, unobtrusive appearance. There are various BIPV solutions for a variety of building types and applications. The modules within the BIPV system also can serve a multitude of functions, from acting as sunshade only to forming a part of the building envelope and acting as a barrier to the elements, as exemplified by Tesla's solar tiles.

BIPV can also increase the value and prestige of a building, improving marketing opportunities and equity value of the property. BIPV also serves to increase customer satisfaction for occupiers who want to be more environmentally friendly or have more energy autonomy.

Aesthetics

One of the key drivers for BIPV is to improve the aesthetics of buildings with PV. BIPV usually has a homogenous appearance, and blends in discretely with the design, or is a feature of the design itself. This is particularly important for public places or heritage buildings, where the conservation of the architectural character forms part of the development application requirements.

Figure 1: *Solar tiles subtly integrated into a roof. (Courtesy: Nu-Lok Roofing Systems.)*

Flexibility of BIPV Application

BIPV modules can be integrated in a multitude of innovate ways to achieve functional and aesthetically pleasing designs, in a way which reduces the physical limitations on the use of traditional PV modules. BIPV tile replacements, such as Tesla's solar tiles and Nu-lok's Integrated Solar Inserts (figure 1), is only one of the many integration designs of BIPV systems. Other popular types of BIPV include solar windows, façades (Figure 2), pergolas, parking lots (Figure 3) and skylights (Figure 4).

Figure 2: *Photovoltaic solar curtain wall at Suntech HQ. (Source: Suntech)*

Figure 3: *Solar modules integrated into the awnings of a shopping centre in St Aunès, France. The 1.15 MWp system comprises 12 shading structures, each of which is 85 m in length, and shade 816 car spaces while reducing the air conditioning bill of the shopping centre. (Source: Sunvie.)*

Since BIPV is not limited to spacious rooftops like conventional PV modules and can be built into the cladding, skylight, windows, façade etc. of a building, this opens up a range of new opportunities for the installation of PV. For example, Onyx Solar has developed a range of innovative BIPV products that even includes walkable PV floors. These design would allow buildings which are unsuitable for conventional rack mounted PV systems, such as tall commercial buildings with limited roof space, to utilise façade space to generate electricity.

Figure 4: *Semi-transparent photovoltaic atrium. (Source: Issolsa)*

Multifunctional

A key benefit of BIPV is that the BIPV installation performs the function of the building material it is replacing, such as protection from the elements and natural lighting, while also functioning as electricity generators. BIPV designs may also have more desirable thermal properties compared to glazed surface, with portions of the energy incident on the BIPV modules converted to electricity instead of transmitted into the building as heat.

Barriers to BIPV

Despite the benefits of BIPV, its uptake has been limited thus far for a range of reasons, including capital cost, complexity of the planning, design and installation procedures, performance issues, building and electrical standards, and the lack of economies of scale.

System Cost

BIPV systems are generally more expensive than typical roof mounted systems due to the cross-disciplinary nature of its design and install, the resultant additional complexity in their installation, and BIPV systems not yet available in the mass market. While Tesla founder Elon Musk claims that "It's looking quite promising that a solar roof will actually cost less than a normal roof before you even take the value of electricity into account", it is of interest to note that the shingle and concrete roof tiles that Tesla's solar shingles have been designed to imitate are more expensive than the typical cold-rolled steel sheeting that makes up a large proportion of Australian roofs. However, this may not be a significant barrier as the aesthetics of high end products is likely to align better with customers who are interested in BIPV systems.

Complexity

The design and installation of a BIPV system is more complex than traditional roof mounted systems. It is important for a business is considering offering BIPV systems to understand that the planning, design and implementation of a BIPV system requires the cooperation of several different trades, including electricians, roofers, façade or cladding specialists, architects, engineers etc. (Figure 5). Training specifically in the field of BIPV will be required.

However, as this market evolves, it is likely that contractors will begin to accumulate expertise in this product and be able to improve efficiencies and reduce costs.

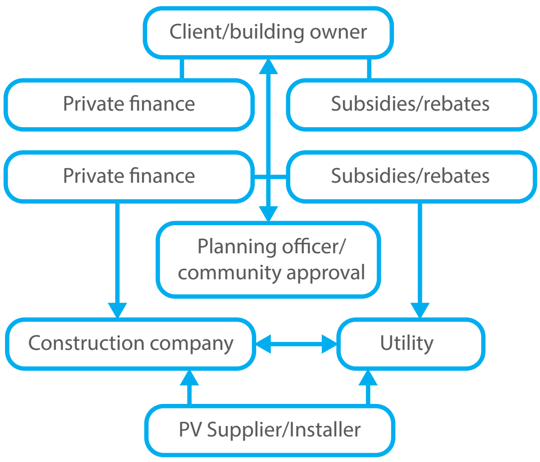

Figure 5: *Example of the cooperation required between different parties involved in the planning, design and installation of BIPV systems.*

System Performance

The design brief of the BIPV system may also limit the BIPV systems performance, since systems may be designed to meet architectural criteria, rather than maximising PV output. This means that optimal positioning of the modules in terms of their tilt and orientation may not be possible, resulting in the output of the system, and hence the financial return, being lower than a conventional roof mounted PV system of the same capacity. The architect would need to have a good understanding of the requirements of PV systems in order to design a building which meets customer expectations.

A BIPV system may also experience more partial shading. Partial shading is likely on non-planar surfaces, or where protruding objects are installed on building surfaces. PV production losses because of shading may be mitigated with the use of micro inverters or DC-DC optimisers, but this will increase the cost of the system.

BIPV systems may experience higher operating temperatures if they are installed flush against the building surface as opposed to backing onto a ventilated space. The lack of adequate airflow under PV modules will decreases the efficiency of the modules, and may also contribute to accelerated module degradation, reducing the lifetime of the system. Again, this is a consideration that needs to be accounted when selecting BIPV products and designs.

Codes and Standards

Since the installation of BIPV includes both installing the modules into the building envelope and connecting the electrical components, the installation must meet the requirements of the standard building codes and specific electrical standards. BIPV for installation on a building must prove that the PV component meets all fire testing compliance. Given that all BIPV DC wiring is installed within the roof or wall cavity, the installation of BIPV requires close attention to fire safety to ensure that an electrical fault in the system cannot cause a fire within the roof or wall space. The Standards and guidelines for the installation of PV, and therefore BIPV, are well established in Australia. However, requirements such as installation of a DC isolator adjacent to the array and enclosing of all dc cables in roof cavity in HD conduit may require innovative solutions.

Economies of Scale

A limitation within the BIPV market is that there are very few 'off the shelf' options available. Most designs are customised and therefore, until the market expands, the BIPV market will struggle to achieve any economies of scale. This is compounded by the fact that BIPV is not suited to utility solar, and is only cost effective on new buildings or buildings which require other retrofits/rectifications. However, with renewed interest, BIPV product may eventually be deployed on a larger scale, enabling cost reductions in both product and labour as the industry gains more experience and capacity.

Future Markets

Recent studies have predicted a global BIPV market growth from about $3 billion in 2015 to over $9 billion in 2019, and to reach $26 billion by 2022. Of these figures, BIPV roofing is forecast to be the largest player. Another study predicts that BIPV will shift away from prestige buildings towards zero-energy buildings, which are expected to make up the bulk of this market growth, followed by commercial and residential buildings. It is important that the required expertise is developed in preparation for the large scale deployment of BIPV within the PV market.

GSES welcomes feedback on technical papers and other resources available on www.gses.com.au, please contact GSES by email at info@gses.com.au or by telephone on 1300 265 525.