LOW COST BUILDING-INTEGRATED PHOTOVOLTAICS (BIPV) FOR AUSTRALIAN RESIDENTIAL AND COMMERCIAL/INDUSTRIAL ROOFTOP POWER GENERATION

Final report: project results and lessons learnt

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# Table of Contents

Table of Contents.................................................................................................................................... 2
Executive Summary ....................................................................................................................................... 3
Project Overview ....................................................................................................................................... 4
Project summary ....................................................................................................................................... 4
  Project scope ....................................................................................................................................... 6
  Outcomes ............................................................................................................................................. 7
  Transferability ..................................................................................................................................... 9
  Conclusion and next steps ................................................................................................................. 10
Lessons Learnt ....................................................................................................................................... 11
  Lessons Learnt Report: Impact of market dynamics on technology................................................. 11
  Lessons Learnt Report: Complexity of decision makers and influencers involved in BIPV........... 13
Executive Summary

This project aimed to develop low cost building integrated photovoltaic (BIPV) roofing for mass market residential and commercial applications on Australian buildings. As one of the largest suppliers of roofing material in the world, BlueScope sought to develop BIPV to reduce the total installed cost of traditional roofing and rooftop PV, improve aesthetics, improve convenience to the building owner and enable the building supply chain to capture value and develop skills and capacity in the delivery of renewable energy.

Three prototype systems were successfully developed and installed as in market prototypes on both residential and commercial buildings. The prototypes were designed to optimise the integration of flexible thin film PV technologies and balance of system components to deliver a superior and cost effective complete system solution. As such, an evaluation of flexible thin film PV (CIGS) technology was undertaken analysing efficiency, lifespan and encapsulation to determine its suitability for rooftop BIPV. In addition to this, BlueScope evaluated and developed in-factory integration processes and designed roofing profiles to be mass production ready.

Throughout this development process, BlueScope engaged extensively with key influencers and decision makers across the building market supply chain. In addition, a range of commercial suppliers and partners supported the development of the BIPV roofing systems or contributed components and services to enable the successful installation of the 3 prototype systems. As such there have been many insights and design iterations to improve the proposed designs and their cost effective installation on Australian residential and commercial buildings.
Project Overview

Project summary

This project aimed to develop low cost building integrated PV roofing for use on mass market residential and commercial buildings in Australia. BlueScope embarked on achieving this goal by completing the following activities:

- Installation of a PV Evaluation Facility at its R&D site in Port Kembla, NSW as shown in Figure 1. This enabled the performance monitoring of flexible thin film technologies in Australian conditions and comparison to a glass covered crystalline silicon system. Flexible thin film technologies are easily integrated to the surface of a steel substrate, but are not used extensively in the rooftop PV market in Australia. This evaluation facility enabled testing & validation of manufacturer performance guarantees and to explore options to optimise the PV and balance of system design for a BIPV solution.

- Evaluated the suitability of flexible thin film PV (CIGS) technology to determine its suitability for integration with building components and undertook lifespan evaluations of flexible encapsulations.

- Partnered with a leading Industrial Design consultancy to design two BIPV roofing profiles which were low cost, easy to install, aesthetically acceptable to the market and optimised system integration. One of these profiles is a photovoltaic thermal roofing profile.

- Developed in-factory integration processes to assist in achieving low cost objectives.

- Prototyped and tested the roofing system on a ‘laboratory’ scale test facility as shown in Figure 2 and Figure 3 and undertook in market installations in both Residential and Commercial building applications.
• Undertook extensive in market engagement with consumers, builders, developers, architects, building designers, roofing fabricators, engineering consultants and renewable energy industry members to develop and evolve the prototype systems.
• Undertook an evaluation and development program for inverter technologies with the aim of allowing for improved compatibility with flexible thin film PV in order to support the electricity grid and to enable battery integration.

By undertaking these activities, BlueScope hoped to achieve the development of low cost, durable, reliable and performance optimised BIPV prototypes that would be suitable for commercial evaluation and manufacturing scale up and eventual mass deployment on Australian residential and commercial buildings.
Project scope

BlueScope is a leading Australian manufacturing company that sells over 200 million m² of roofing materials per annum, with approximately 60 million m² of that being solid in the Australian market. As such, BlueScope was well placed to develop BIPV due to its well established channel to market, leading product testing facilities and strong fit with ongoing enhancements of our COLORBOND® roofing product.

The combination of BlueScope’s unique market position in roofing and the strong adoption of rooftop PV in the Australian market was a key driver in the development of a BIPV solution. BIPV presents an opportunity to reduce total installed cost, and improve aesthetics and convenience to the building owner and building supply chain. Whilst the PV market will be a long term sustainable market, BlueScope believed that by developing BIPV solutions a range of barriers could be overcome to encourage broad mass market adoption in the new build and renovation market across both residential and commercial buildings. Some of these barriers included: aesthetics, reliability, total installed cost, convenience of install at the time of build and grid load management. In addition to this, at the time of development there was no global example of a steel based BIPV solution optimised and suitable for the Australian market.

In developing BIPV, BlueScope has sought to utilise design & innovation as a lever to develop the skills and capabilities of the building markets’ manufacturing supply chain. The emphasis on low cost BIPV meant relying on the existing supply chain for fabrication along with up-skilling of existing trades and service providers to attain cost savings in installation. In order to up skill trades, BlueScope developed installation guidelines (Figure 4) that were utilised by the supply chain to guide efficient and safe installation. Additionally, by designing the BIPV for installation by the existing supply chain it enables them to capture value from the emerging growth in the renewable energy sector.

![Figure 4: Example of installation guidelines](image)

Finally, by building the test Facility, BlueScope also wanted to gain an understanding of the performance of BIPV panels in Australian conditions, which can often be far harsher than those in Europe or America.
Outcomes

BlueScope successfully designed and deployed in-market prototypes of two different BIPV products. The first is a horizontal styled residential BIPV system as shown in Figure 5 and Figure 6. The second is a BIPV-Thermal system as shown in Figure 7 and Figure 8, which has the additional functionality of capturing warm and cool air via a novel air channel system to provide heating and cooling to the building while cooling the PV for higher efficiency. The latter was prototyped in both a residential and commercial application. Both of these BIPV solutions utilised flexible thin film PV technology which was in-factory integrated following the fabrication of the roofing material and utilised the existing supply chain to fabricate and install the system. The BIPV-T system also contained a variety of sensors, fans, ducting and a control system designed by a leading Australian fan company. This ensured that the warm or cool air being ducted into the building was useful and offered improved comfort to the occupant.

To undertake the prototype installations, BlueScope worked with existing building supply chain participants including: roof fixers, electrical contractors and accredited solar professionals. Through detailed engagement, prototyping and testing, BlueScope has built an intimate understanding of the skills and capabilities required to deliver BIPV in the Australian market, and has worked with members in the supply chain to test and evolve a variety of business model options. One of BlueScope’s primary objectives was to support the development of skills and capabilities of existing roll formers, builders, developers, roof fixers and contractors to cost effectively supply and install
BIPV steel roofing. The prototype products that have been developed can enable this transition to begin.

![Figure 7: BIPV-T commercial installation](image)

![Figure 8: BIPV-T residential prototype installation](image)

To advance commercial readiness, BlueScope developed the two BIPV profiles to be mass manufacturable using a roll forming process, and also developed cost effective in-factory integration processes that can be adapted depending on the size and geographic location of the market.

Throughout the project and development process there have been some fundamental shifts in market dynamics and technology improvements which have influenced the likely commercial success of the BIPV solutions developed. Firstly, the strong reduction in installed cost (in $/W) of traditional roof top PV since the commencement of the project over 3 years ago has been significantly greater than originally estimated (i.e. sub $0.50c/W with very low fully installed costs). Thus, closing the cost differential between traditional roof top PV and BIPV has proven very challenging, particularly with the use of flexible thin film technologies which have not yet attained the desired degree of manufacturing efficiency and scale to drive a desirable price point. The thin film manufacturer market has also consolidated considerably since this program of work started, with only a few of the original manufacturers surviving. To optimise BIPV to achieve optimal installed efficiency required influencing these suppliers, and when the market began to consolidate this proved to be very difficult. It also meant the profile designs were fluid, often having to change to accommodate different PV module sizes from different suppliers.
There remain some surprising challenges in PV buying behaviour that are unique to BIPV. Whilst BIPV provides many attractive attributes including aesthetics, convenience and efficiency it also forces a buying decision at the point of build, with a product that is broadly thought of as an after build (retrofit) product. Of the 1.4 million households who’ve installed rooftop PV, we believe only a small percentage of these were installed during the new build process. This dynamic may change with time but remains a hurdle which marketing and product positioning strategies will need to overcome to drive adoption.

**Transferability**

BlueScope’s development efforts in BIPV profiles have uncovered a range of commercial and technical learnings that are relevant to any BIPV development in the market. Much of this knowledge has been extracted and imparted across the building market supply chain.

BlueScope approached sharing knowledge internally and externally through a combination of innovative partnerships and through traditional means. Internally, more traditional means of communications have been used through project team meetings, monthly stakeholder updates, presentations, open days, and workshops. Externally, BlueScope has worked collaboratively with a range of partners, suppliers and key influencers and decision makers within the building market supply chain to share its learnings around the design, manufacture, supply and installation of its BIPV products. For example, in undertaking in-market prototype installations of the BIPV-Thermal roofing system BlueScope hosted the owner of the property to provide his thoughts on the design and performance of the system and how it would offer value to the household. Roofing and solar installation companies were involved in design reviews and also completed a number of trial installations at BlueScope’s innovation facilities, as shown in Figure 9. Further, installation training guides were developed to enable safe and efficient installation.
Funded under a separate agreement and in partnership with University of Wollongong’s Sustainable Building Research Centre, BlueScope developed a tool to calculate the thermal output of the BIPV-Thermal system for use in any geographic location in Australia. The outputs of this thermal model were translated into a ‘Payback Estimator’ and ‘Design Guide’ which was developed for builders, building designers, architects and specifiers to understand the value and economics of the BIPV-T system and how to optimise the design for performance.

Conclusion and next steps

The development of BIPV products for Australian buildings has unveiled a range of benefits and opportunities for the Australian energy system and the building market supply chain.

In delivering a number of prototypes, BlueScope has built an intimate understanding of the skills and capabilities required to manufacture, supply and install BIPV. In addition, a range of barriers and challenges associated with the adoption of BIPV and associated limitations have been identified including: how buildings are designed; building ownership structures; purchasing behaviour; fabrication and integration; and a variety of other technical issues. Additionally, some of the existing building and solar installation practices have been found to be unconducive to the efficient installation of BIPV. By undertaking this project, BlueScope has developed a broad inventory of knowledge that could assist the Australian market to overcome these barriers to the adoption of BIPV.

The development of the thermal attributes of the BIPV-T system offers positive benefits in terms of potential reduction of building energy load and improved energy efficiency. BlueScope, with its partners, has built a robust understanding how the thermal energy is captured and how to utilise it most efficiently in buildings for maximum energy efficiency. In addition, detailing around design integration has been explored and the cost benefit of thermal energy capture in roofing creates the opportunity to translate this functionality to other building applications. Overall, use of this IP could benefit the Australian energy system more broadly.

BlueScope’s work with flexible thin film PV manufacturers has raised the profile of this technology in the Australian market and built additional technical knowledge on its suitability and application in Australia. BlueScope led the accreditation process for two manufacturers of thin film technologies for use in the Australian market and worked closely with one of the largest solar retailers and installers to develop expertise in its efficient installation. BlueScope’s investment in these areas is likely to provide broader benefit to the market.

BlueScope is uniquely positioned to share its learnings across its direct customer base which fabricates roofing for a large share of the residential and commercial building market. Imparting this knowledge through this channel to market can only stimulate efficient delivery of BIPV.

In terms of next steps, to progress the BIPV products to a commercially viable stage, further profile optimisation is required, manufacturing of the system would need to be scaled substantially to improve product costs, and the supply chain needs to be enabled to more cost effectively assemble and install the systems to be competitive with existing alternative technologies. Furthermore, significant cost reductions (in $/W) for flexible thin film technologies are essential to achieve a competitive market alternative to incumbent technologies, which comparatively have seen a significant reduction in their cost over the life of the project.
Lessons Learnt

Lessons Learnt Report: Impact of market dynamics on technology

Project Name: Low Cost Building Integrated Photovoltaics (BIPV) for Australian residential and Commercial/Industrial rooftop power generation

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Key learning

Changing market dynamics in the solar industry have had a significant impact on this project and BlueScope has learnt two primary lessons. Firstly, sourcing flexible thin film PV from start-up companies in a similar innovation/technology readiness stage to BlueScope’s developments has proven very challenging. The ability to influence technology development is particularly difficult when the market is still developing, volume is small and the PV manufacturer is still trying to meet their internal commercial hurdles. It was found that developing alignment with these companies was challenging and was not always conducive to achieving the desired outcome. Additionally, due to market and company dynamics there was a significant contraction in the number of manufacturers of flexible thin film PV over the duration of the project, which made developing an integrated BIPV design difficult.

Secondly, shifts in market dynamics can accelerate or change the adoption of technology, which was the case with the roof top PV market. Scale up of thin film PV manufacturing did not progress at the anticipated rate of production, nor were the expected projected cost curves or module efficiencies achieved within this project timeline. In parallel to this technology struggling to grow volume, high demand for traditional PV technologies saw rapid reductions in price and installed cost over the duration of this project. A technology agnostic approach may have enabled a pivot to alternatives technologies that may have been more cost effective and efficient.

Implications for future projects

In terms of the implications for future projects, there are a few strategies BlueScope might more consciously deploy moving forward:

- Develop better risk mitigation strategies associated with utilising technologies that are in a start-up or early phase of commercialisation.
- Maintain flexibility and perspective on other available technology options and their cost and competitive supply targets.
- Ensure the product development process is sufficiently agile to pivot or change direction in line with market changes.
Knowledge gap

N/A

Background

Objectives or project requirements

One of BlueScope’s objectives was to develop an optimised BIPV roofing product for residential and the commercial/industrial rooftop market. At the beginning of the project BlueScope identified flexible thin film PV technologies as a highly compatible technology with steel. Furthermore some of the performance attributes of flexible thin film PV, combined with the attractive manufactured cost curve of the technology, increased its appeal.

As such, the roofing profile design was heavily influenced by the form factor of the thin film PV panels. To adhere the panels directly to the steel required a flat wide pan surface of at least 380mm. BlueScope identified all of the flexible thin film PV suppliers and engaged them directly to evaluate their commercial readiness, product performance and appetite for collaboration and entry into the Australian BIPV market. In this time, the number of manufacturers contracted substantially via insolvency and merger and acquisition, such that only one major supplier was left.

Whilst the objectives of this stage of the project were met, the resultant technology choice did not reach its forecast potential in both performance and price, and has therefore impacted the overall economics of the developed BIPV product.

Process undertaken

BlueScope had developed the concept roofing profiles and progressed to detailed design prior to the fundamental shifts in the PV market and the contraction in the number of flexible thin film PV suppliers. As such, it continued the product development process to produce two BIPV roofing profiles which were optimised for a flexible thin film technology.
Lessons Learnt Report: Complexity of decision makers and influencers involved in BIPV

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Key learning

In a typical commercial development there are a suite of key influencers involved in the design, specification and construction of a project. These influencers and decision makers include the client and depending on the type of ownership structure or development model there is usually a developer, who may contract an architect or building designer, an ESD consultant and engineers who may then tender the construction to a builder who has a suite of subcontracted staff such as electrical, roofing and plumbing contractors.

The final specification of a BIPV system requires the appropriate influence of some or all of these entities. Due to the complexity of this product, now containing both energy generation and thermal energy functionality (with regard to the BIPV-T system), there are more decision makers required in the specification process, as it affects more than just the roof design. BlueScope has learnt that if a product includes structural, energy generation and mechanical services features the system needs to be specified early in the project such that major changes to the building are not necessary later in the design process. It also means there is a much higher degree of scrutiny on the product and it requires very credible tools and the provision of sufficiently detailed information to enable to the system to specified and designed into the building.

In addition to this, each of these entities has expressed concern or reluctance to be the ‘first to move’ with a new product like this. Generally, they are seeking detailed case studies and demonstrations that are independently proven or validated, before they consider adopting any innovation.

Implications for future projects

The complexity of decision making and material selection is something that BlueScope is generally familiar with, given the complexity of the supply chain for building products. However, in the innovation space, BlueScope would likely adjust its innovation development and collaboration model to work more closely with the likely influencers of the new product. Whether through traditional partnerships, co-creation, collaboration agreements or other commercial approaches, BlueScope can see the value in earlier and deeper involvement with direct and indirect customers to enhance both the product design and market entry strategies required to drive successful adoption.
Knowledge gap

N/A

Background

Objectives or project requirements

During the in-market installations, BlueScope undertook intensive engagement with companies in the building market supply chain, to seek feedback on the product design and identify potential prototype sites. There were two instances where BlueScope pursued detailed design with two different clients but, due to reasons outside of both parties’ control, the projects were not implemented and the BIPV product was not utilised.

As a result of this phase of work, BlueScope set out to understand:

- The decision making processes for specifying new advanced building products
- The key influencers and design makers by building segment
- The tools and materials these decision makers would require to specify the system

Whilst these were not specific deliverables or requirements for these activities as part of this project, they were essential to build a commercial business case for the products.

Process undertaken

Once the design of the prototypes was finalised, BlueScope engaged a suite of parties to identify a prototype opportunity. This process involved face to face meetings and interviews, sharing of detailed design information, review of building drawings and working across a range of decision makers involved in the building design to assess the suitability of the prototype system for that building. Throughout this process, BlueScope received feedback and insights which fed into the product design and marketing strategy.