Solar Energy Application Lab,
School of Property, Construction
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RMIT UNIVERSITY

# Building Integrated Photovoltaics (BIPV) Enabler

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# Executive Summary

There is an urgent need to explore the renewable energy resources such as solar PV which not only meet the increasing energy requirements of the world but also are environmentally friendly. The Zero Carbon Australia Buildings Plan promotes building integrated photovoltaics (BIPV), to reach a full uptake on suitable buildings by 2030. BIPV is at Technology Readiness Level 9, but adoption has been slow in Australia because it reframes distributed solar energy as a building product which needs close collaborations between the PV and building industries. It is difficult to develop a business case for a BIPV project without accessible information and value-for-money solutions

BIPV design and management is a complex process which involves requirements geophysical, technical, economical and environment factors throughout the life cycle of the system, ranging from acquiring architectural visual effects to higher solar insolation in given location, efficient energy generation and economic operation and maintenance of the BIPV system. Lack of consideration for PV integration of the building envelope in the early design phase is one of the main reasons for complicating the design and construction process of BIPV systems.

This Activity aims to translate technical complexities into a packaged, user friendly platform that integrates product, regulation, technical, economic and construction data to create the best BIPV solution for individual building projects. It intends to provide a one-stop solution for all BIPV stakeholders cross the PV, energy, building and regulatory sectors.

A product database is developed in the BIPV Enabler platform, which identified 136 important product attributes under 13 categories (i.e. product application, cell information, module information, product certificates, product test outcomes, cost, electrical aspect, thermal aspect, optimal characteristics, warranty, junction box, maintenance procedure, and integration method and packaging). Platform users can complete BIPV initial design through six simple steps: Building type and location selection, Building modelling and simulation, Product selection, Report generation, Placement and visualization, and Design optimization.

BIPV Enabler is the first specialized design tool for BIPV in Australia, especially for layman to optimise the BIPV design in conceptual design stage. This project provides the facility required to move BIVP from Commercial Readiness Index 2 to Commercial Readiness Index 3 in Australia and should accelerate market adoption of BIPV that unifies precast PV modules with the overall building outer surface, including every wall and window in both residential and commercial buildings. The project enables all BIPV products and studies to be applied in the real building market as easy as possible.

# 1. Project aim and objectives

Building Integrated Photovoltaics (BIPV) adoption has been slow in Australia because it reframes distributed solar energy as a building product which needs close collaborations between the Photo Voltaic (PV) and building industries. It is difficult to develop a business case for a BIPV project without accessible information and value-for-money solutions.

This Activity aims to translate technical complexities into a packaged, user friendly platform that integrates product, regulation, technical, economic and construction data to create the best BIPV solution for individual building projects. It intends to provide a one-stop solution for all BIPV stakeholders cross the PV, energy, building and regulatory sectors.

There are four objectives in this Activity:

- To develop a BIPV product database which provides comprehensive product information;
- To develop a BIPV design and decision-making platform;
- To validate the developed platform; and
- To conduct marking and promotion activities.

# 2. Key outcomes/achievements

BIPV is not only a solar product affected by the PV and energy sectors, but also a building product which affects the working process of all building professionals from design, to construction and operation stages, and is restricted by building and construction standards. There is a lack of BIPV product and standards awareness and cost-effective project solutions because of information gaps within and across the PV and building sectors. BIPV Enabler platform provides optimized BIPV design solutions which compile with construction codes, design, installation and maintenance options and configures easy-to-use interfaces for different stakeholders. This one-stop solution delivers value as a handy tool and professional services for users such as PV manufacturers in product promotion and building professionals in BIPV design, construction and facility management.

This project will be the market enabler to move BIVP from Commercial Readiness Index 2 to Commercial Readiness Index 3 in Australia and enable the replacement of every building, whether new or renovated, with beautiful solar panels as an easy option.

The Activity key outcomes are summarised as follows:

<u>Product database:</u>

Building design, engineering and construction regulatory requirements in relation to BIPV application were mapped out in a product database which identified 136 important product attributes under 13 categories (i.e. product application, cell information, module information, product certificates, product test outcomes, cost, electrical aspect, thermal aspect, optimal characteristics, warranty, junction box, maintenance procedure, and integration method and packaging). Local and global product information were collected under the attributes identified. Relevant information of seventy-three (73) BIPV products were collected through reaching out to BIPV product suppliers and manufacturers. The BIPV products in the database includes: monocrystalline modules; polycrystalline modules; amorphous silicon; CIGS; and Cadmium telluride

BIPV modules. The BIPV product database is linked with the simulation and optimisation modules in the prototype.

Platform development:

The prototype BIPV Enabler was developed with object-oriented programming (OOP) and Python programming language. The platform uses FreeCAD as the primary CAD tool for creating 3D building models. The user interface is segmented to six phases: 1. Initiating the project setup which include selection of the building type and project location using a map; 2. Creating the building model with the 3D geometric building shapes library or default arch and/or draft workbenches in FreeCAD; 3. Visualising the solar irradiance on the building envelope; 4. Selection of BIPV module(s) from the product database, generating report on the energy output of the BIPV design(s) and economic and environmental considerations, and automatic and manual placement of the BIPV modules; 5. Estimation of the wind load of the BIPV design; and 6. Optimisation of BIPV designs as per tilt angles, BIPV product, window to wall ratio and distance to length ratio.

The detailed development activities and outcomes of the Activity include:

(1) Improving the current weather and financial database required for calculation

The hourly weather data for locations in Australia which required to simulate the solar irradiance were integrated. The following databases were established to input the financial information required for calculations in the simulation and optimisation process:

- A database with standard energy prices and feed in tariff prices based on the states of Australia.
- A database with cost of alternative materials provided by industry experts.
- Cost of BIPV modules and their maintenance cost are included in the BIPV Product database.

(2) Building design module development

FreeCAD was used as the primary CAD tool for creating 3D building models for simulating BIPV designs. The Qt GUI framework, and Python programming was used to connect the building design with the simulation and optimisation process. The building designing process under this module is facilitated in two ways:

- Using the 3D geometric building shapes library to directly input the shape of the buildings. The building dimensions, colours and orientations can be controlled as per user requirements;
- Use of the default Arch and/or draft workbenches to create the building. The building dimensions, colours and orientations can be controlled as per user requirements.

(3) Coding assessment and optimisation method

The coding assessment of the platform consists of two process engines: 1. Simulation engine; and 2. Optimisation engine. These two engines process input data and output the alternative BIPV design options for the user.

(4) Simulation engine

The simulation consists of irradiance simulation and visualisation, BIPV Energy output simulations, cost/benefit simulation and carbon emission, wind load simulation.

(5) Optimisation engine

The Optimisation engine adopted Non-dominated Sorting Genetic Algorithm (NSGA-II) as its core algorithm to meet the demands of the multi objective optimisation problem. The optimisation process generates feasible BIPV design solutions based on design variables, objective functions and constraints defined by the user.

(6) User interfaces

The Qt GUI framework and Python programming was used to develop the platform user interfaces. The interface is developed under the following sections: 1. Project setup; 2. building model design; 3. solar irradiation simulation; 4. BIPV product selection and generation of results; 5. BIPV module placement; 6. wind load estimation; and 7. optimisation.

Platform validation:

A preliminary industry workshop was held online in August 2021 to present the preliminary version of the BIPV Enabler prototype. Case studies and test models were used to test and validate the simulation and optimisation process of the platform. Several internal workshops were held at RMIT University to test the prototype in November 2021 and April 2022 as an interim measure to refine the prototype. The final version of the prototype was tested through industry workshops in May 2022 - held in Brisbane, Melbourne, Sydney and online.

Marketing and promotion:

The BIPV Enabler web page was created to facilitate those who seek information on the BIPV Enabler project. The RMIT has published three Q1 Journal papers, three conference papers/presentations, two HDR theses and was shown in five media releases. Further, two industry partner meetings were organised to present the progress of the development of the BIPV Enabler prototype and seek feedback and comments. The BIPV Enabler tool has also been introduced in the International Energy Agency PVPS Task 15 relevant meetings as an example of BIM based BIPV design software.

# 3. Lessons learned

In undertaking the development of the BIPV Enabler Project, the following key lessons learned were made:

- The complexity of software development is beyond our initial expectation especially related to building design coordination system. Industry partners' support and engagement is important and required throughout the Project; and
- Stakeholder engagement especially in COVID situation is extremely hard during the project. This impacts our progress in organsing industry meetings, workshops and trial sessions. Although online meetings can be arranged, the communication efficiency is reduced. Instead of group meetings online, we organized many individual meetings to talk to different industry partners and stakeholders. We send trial versions to industry participants prior to the workshops, and emailed many key stakeholders demonstrating the use of the tool. This provides them extra time to explore the usefulness and issues of the tool.
- The tool uses some open-source software/databases. This added complexity in Commercialisation/licensing. Although RMIT Legal/IP team has provided instructive suggestions, we

suggest in the future similar projects should consider using software that grants a permissive license if possible.

- Software long term maintenance should be considered and is required to be sustained.

# 4. Next steps including promotion within industry and towards commercialisation

BIPV Enabler tool is free to use from June 2022-June 2023 for further feedback. From June 2023, this tool will be fully commercialized.

A BIPV forum was held at the RMIT University (8th June 2022) called for greater collaboration and engagement in this space. In particular, the BIPV forum sought to establish a stakeholder ecosystem in BIPV adoption in Australia. The forum discussed taking a value-added approach in which BIPV is not only related to PV (covering energy and performance requirement) but also other important aspects of the building industry (covering aesthetics, safety, multi-functionality and installation).

Forum participants included: key stakeholders cross the building, construction, PV and energy sectors from government bodies, property developers, design and engineering consultancy, subcontractors, NGOs, manufacturers/suppliers, and standard/test firms.

The Solar Energy Application Lab at RMIT University launched BIPV Enabler in the forum. The tool will be free to use in the first year and expected to be fully commercialised after this period.

A call to organise an Australian BIPV Alliance was canvassed on common stakeholder interests, conceptual framework, and collaborative engagement. Australian BIPV Alliance aims to enable collaborations within the entire stakeholder ecosystem across different industry sectors in addressing technical, practical, policy and standard related opportunities and issues in BIPV adoption, showcasing good practices, filling in industry knowledge gaps and providing training opportunities. Thirteen key BIPV development/research areas are proposed:

- City strategy and policy: Based on digital twin, to estimate BIPV potentials across Australian cities and support specific policy and incentive development;
- Design: BIPV Enabler is a tool for conceptual design stage; we hope to further facilitate detailed design by developing BIPV category/class under the Information Foundation Classes (IFC), digital products, and plugins in Building Information Modelling platforms;
- Installation: To demonstrate the installation process with digital technology and facilitate the labor/cost/health and safety evaluation;
- Maintenance & Repair: To explore the feasible ways to replace and repair BIPV and onsite performance evaluation;
- Fire safety /Engineering: To drive an industry agreement on BIPV fire testing process, develop Guidelines for fire safety of BIPV modules under national building regulations, and support future standard development;
- Physical demonstration/live lab: To facilitate BIPV project development in Australia, and develop a live lab at RMIT in demonstrating alternative products, and monitoring their performance;
- Performance testing: To conduct mechanical, thermal, weatherproofing, electrical and fire related test based on national /international standards. The test results will increase industry confidence to accept BIPV products.
- Product Certification: To support local certification for BIPV as a building product;
- Standardization: The project leader is a member of the National Mirror Committee for International Electrotechnical Commission (IEC) TC 82 Solar photovoltaic energy systems,

represents Australia to the development of an international standard IEC 63092 BIPV, reviews and comments on new proposed standards under IEC TC 82. Currently she is the Australian delegate in the IEC/ISO JWG 11 working on the evaluation methodology of Solar Heat Gain Coefficient (SHGC) for BIPV modules. In the future, her team will support more BIPV specific standards to be developed or amended.

- Product innovation: R&D work on BIPV product development especially on new products which can comply with building codes easily;
- Supply chain management: To develop a trustworthy supply chain of BIPV product and monitor the production line;
- Local manufacturing: To facility local BIPV manufacturing and assembly as both PV and prefabricated building products;
- Guidebook& Training: To develop industry guidebooks and provide trainings on BIPV products, design, engineering, installation and maintenance.

All of the proposed areas will lead to significant BIPV adoption in Australia and numerous commercialization and job opportunities. Currently more than 50 organizations have shown interested in collaborations. Those interested in finding out more or to collaborate on the BIPV Enabler are asked to contact Rebecca Yang, Associate Professor, Solar Energy Application Lab, RMIT University.