Development of a Prototype Building Integrated Photovoltaic Design and Simulation Tool

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Australia has great potential for expanding solar photovoltaic applications in the building sector. Currently, building attached solar photovoltaic (BAPV) applications have dominated Australia's solar market (Climate Council of Australia, 2017). The contribution of Building integrated photovoltaic technology (BIPV) to the built environment and the total PV generation in Australia is very limited. The BIPV applications contributed less than 1MW capacity in Australia in 2015 – 2016 and there were very few BIPV installations for the period from 2017 – 2019 (APVI, 2016; APVI, 2017; APVI, 2018; APVI, 2019; APVI, 2020). A key reason for the lack of application of BIPV systems is there are information gaps within and across the building and PV industry sectors in relation BIPV products, building and PV standards and cost-effective project solutions (Sullivan, 2013, Fedorova, Hrynyszyn, and Jelle, 2020; Weerasinghe et al., 2021). Therefore, the design, planning, and construction process of BIPV has become complicated. It involves determining the solar irradiation levels, selecting appropriate BIPV modules, the tilt angle and azimuth angle of the BIPV modules, energy production of the system, capital costs, operation and maintenance costs, income generated by the BIPV system and reduction of greenhouse gases. Such factors will vary depending on building type, weather, location, building codes and standards, construction process, and aesthetics considerations (Gagea, Gagea and Badea, 2018). Therefore, it is important to identify the correct BIPV design that would provide the best outcome in terms of building requirement and energy generation. CAD and Building Information Modelling (BIM) software are often used for designing BIPV projects with PV simulation tools to estimate energy, economic and environmental performance (Jackia, 2018; Wijeratne et al., 2019). However, there is a lack of BIPV specific design tools which address both building and PV related requirements of BIPV projects in the early design stage. Most crucial BIPV design decisions need to be made in the conceptual design stage (Bonomo et al., 2017; Aranda-Mena and Fong, 2020). This paper presents the development of a prototype for a BIPV specific tool which can facilitate BIPV project design in the early design phase in Australia. The aim of the proposed prototype is to develop a BIPV design software with user-friendly interfaces, local BIPV product information and standard guidelines to facilitate decision making at the conceptual design stage. Figure 1 presents the structure of the proposed prototype. There are three major components considered in this platform: 1. inputs, 2. simulation processes and 3. visualization.

Inputs: There are two main data sources in the proposed BIPV design prototype, user preferences inputs and database inputs. User inputs include building-related information and BIPV related preferences. Building related information such as building dimensions, orientation, location and surrounding environmental details are the preliminary data required for the simulation process. Furthermore, a separate map view has been integrated into the proposed tool so that the user can select the exact location of the targeted building. Four main databases have been integrated into the platform namely, weather database, BIPV module database, building standards database and building material database.

BIPV envelope design can be carried out for different BIPV application types such as rain-screen façade, skylights, curtain walls and shading devices (Bonomo et al., 2017; Alim et al., 2019). BIPV product database which is arranged according to the BIPV application types is one of the major databases integrated into the tool and it provides the user with the capability to filter products based on colour, transparency, etc. Users can specify several other financial, environment and energy-related parameters before beginning the building design simulation process.

Simulation processes: There is a set of manual and automatic processes available in the tool. Building models can be designed manually using the available components or an existing building model can be uploaded to the proposed tool. Irradiance and shading simulation, life cycle energy simulation, economic analysis, carbon emission simulation are the main automatic simulation processes running on the platform. Optimization, wind load simulation and virtual reality (VR) simulation act as extra functionalities provided by the proposed tool. Functionality to customize the building design and repeat of the simulations is available in the platform. Further, the users can provide required data and run the optimization, wind load calculation and request VR simulation of the designed building model using the functionalities available in the proposed tool.

Visualization: Initially, the tool enables visualization of the uploaded building model or the newly created building model. Then, the irradiation simulation process visualizes the view of irradiation on each surface of the building based on a pre-defined colour range. Moreover, the tool enables the user to place BIPV panels manually or automatically and the building model with BIPV panels will be displayed on the platform. Automatic placement considers surface areas having high irradiation levels to place the BIPV panels and to visualize the BIPV panel placement view on the platform. The VR view functionality directs the user to a separate view where the developed building model can be viewed in VR mode.

The developed prototype has been validated with a case study to ensure the credibility. The BIPV specific tool could encourage the uptake of BIPV projects in Australia through facilitating BIPV designs in the conceptual design phase.

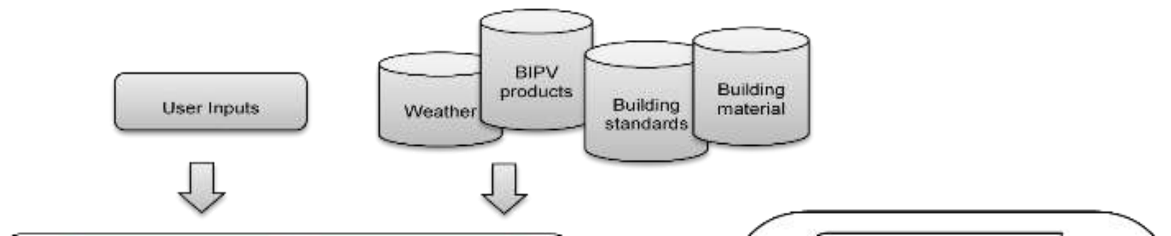

Figure 1. Structure of the proposed prototype

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