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Modelling economic viability of facade-integrated photovoltaic applications in non-domestic buildings

Nilmini Weerasinghe[1] and Rebecca Jing Yang[1]

[1]*RMIT University, 124 Latrobe Street, Melbourne, VIC, 3000*
E-mail: rebecca.yang@rmit.edu.au

Abstract

Building-integrated photovoltaic technology (BIPV) is a promising renewable energy technology which generates electricity onsite. Due to the advancement of technology, BIPV enables the transformation of untapped facades into electricity generators with standard material design objectives. This is simply an alternative option for producing substantial electricity onsite, in particular for buildings with limited rooftop areas in dense urban areas. However, facade-integrated photovoltaic (PV) systems are often disregarded by stakeholders for various reasons, including their high cost, lack of performance and lack of information. A common myth is that photovoltaic facades are expensive, but there are success stories in the building industry. Understanding the economic viability of such applications is required to inform decision-makers of their successful deployment. This study employs an innovative approach to the examination of the economic performance of existing BIPV facade systems based on a lifecycle approach and the multi-functionality of the technology. This study proposes a model including the following direct and indirect economic parameters: i) standard net present value (NPV) ii) standard levelized cost of energy (LOCE), iii) standard discounted payback period iv) advanced NPV, v) advanced LCOE and vi) advanced discounted payback period. 28 facade-integrated PV applications in non-domestic buildings were selected based on i) availability of the required information ii) location (11 western countries) and iii) recent completion (2009 – 2018) for comparative analysis. The case studies use three module technologies: amorphous silicon (a-Si), crystalline silicon (c-Si), and copper indium gallium selenide (CIGS) with system capacities of 1-700 kW. According to the results, the average standard LCOE and advanced LCOE are 0.71 and (0.31) (negative) AUD/kWh, the average value of standard and advanced NPV are (3,668) (Negative) and 6,327 AUD/kW and standard and advanced payback period are 42 years and 5 years, respectively for the cohort. Low cost, system efficiency and financial incentives contribute to the achievement of economically favourable projects. The study reveals that quantifying direct and indirect benefits facilitates the disclosure of the actual value of BIPV applications. More importantly, recent projects are nearer to producing economic benefits than past projects. We believe that the dissemination of reliable information among stakeholders will dispel the myths or fears surrounding BIPV. The results of this study can be used to inform decision-makers of the economic performance of BIPV systems and accelerate their penetration in facade-integrated PV applications in dense urban areas.

1. Introduction

With the enormous potential of harnessing solar energy, PV applications are recognized as the promising technology to generate substantial electricity onsite in buildings. The integration of PVs in building components such as facades, windows, roofs, shading and balconies enables the harvesting of substantial solar energy while achieving net or almost zero energy targets (Shiraz et al., 2019; Shukla et al., 2017). It is, in effect, transforming a building to a mini power plant where the building is self-generating energy at the same time as distributing the excess to the grid. Although there is a trend towards increasing use of PVs, building-integrated photovoltaic (BIPVs) is one of the slowest growing renewable energy technologies. Compared with other PV applications globally, BIPV represents a small segment of solar PV application, contributing only 2 % of total world PV generation in 2015 (PV Sites, 2016). There is reluctance to deploy BIPV systems due to various issues, such as their technical complexity, lack of awareness, availability on the market, lack of building codes and regulations and high costs (Curtius, 2018; Bonomo et al., 2016). The economic value of BIPV systems has become one of the main obstacles in the decision-making process and different arguments are proposed to estimate and quantify the economic performance of these systems. Therefore, there is an urgent need to evaluate the economic performance of BIPV projects, and the aim of this study is to assess the economic performance of facade-integrated PV applications in non-domestic buildings.

A range of PV facade types is available, including cladding, curtain walls, windows, warm facades, cold facades, and balconies (Shukla et al., 2017; SUPSI 2015). These applications are appropriate alternative solutions to harvest significant amounts of solar energy, particularly for buildings with limited rooftops in urban areas. The ample space of facades has huge untapped potential to produce substantial electricity onsite (Shiraz et al., 2019). Facade PV systems are installed at the design stage or the retrofitting stage to provide a full or substantial share of the energy demand in buildings (IEA, 2016). Due to continuous technology advancement in the industry, new features of modules including colour, efficiency, size and transparency have emerged, providing an aesthetic appearance and satisfying building material requirements (Gholami et al., 2019; Shukla et al., 2017). BIPV applications have recently been acknowledged as building materials and as a source of clean electricity generation (Bonomo, et al., 2016). However, there are obstacles in the delivery of successful BIPV applications (Gholami et al., 2019; Bonomo, et al., 2016). A common myth is the adverse economic indicators of PV applications.

Many studies have evaluated BIPV system performance, in particular its economic viability (Gholami et al., 2019). The significance of the present paper is that economic performance is evaluated in a lifecycle approach and the multifunctionality of the technology is considered using six economic parameters. A model is proposed to assess system performance including the following direct and indirect economic parameters: i) standard net present value (NPV) ii) standard levelized cost of energy (LOCE), iii) standard discounted payback period iv) advanced NPV, v) advanced LCOE and vi) advanced payback period. The advanced metrics are indirect economic values where the opportunity cost of replacing conventional materials is added to the estimation. Comparative performance analysis was conducted for 28 facade-integrated systems located in 11 different countries and using three module technologies. The objective of this paper is to understand the economic performance of existing facade-integrated PV systems and learn from actual stories. The outcome will inform decision-makers of the economic performance of systems and accelerate the penetration of BIPV.

2. Methodology and data

Unlike other economic evaluations, this paper considers lifecycle assessment and the multi-functionality of BIPV applications to evaluate their economic viability. A model is proposed to assess the economic feasibility of BIPV projects due to their complexity. The model was developed in the MATLAB programming language. The model employs six parameters, i) standard LCOE, ii) advanced LCOE, iii) standard NPV, iv) advanced NPV, v) standard discounted payback period and vi) advanced discounted payback period to assess economic performance. Advanced values signify the opportunity cost of replacing building materials as indirect measures. A detailed discussion of these parameters is included in Section 3.

The model was then executed using 28 BIPV project cases. Illustrative facade-integrated PV case studies were identified. Although more BIPV projects are available, 28 projects were chosen based on i) availability of the required information ii) location (western countries) and iii) recent completion (2009 – 2018) to maintain the accuracy of the output. Extensive document analysis was conducted to identify the BIPV project details. Publicly available BIPV project details, mainly published on websites by various PV installers and architects, BIPV project databases, books, industry reports, blogs and newspaper articles were reviewed. Table 1 highlights the details of the key materials used to ascertain the BIPV project details.

Table 1: Document Analysis

Type of publication	Examples and reference
BIPV database	• BIPV database managed by Swiss BIPV Competence Centre (SUPSI) • PV database for urban PV applications managed by a 'joint venture' between the PV-UP-SCALE project and the IEA PVPS Task 10 project • Eurac organised by Institute for Renewable Energy • Solarfassade.info
Website (suppliers/architects)	• Web site of multinational BIPV supplier Onyx Solar • Website of ISSOL Green Architecture • BIPV Austria (Ertex Solar, 2016)
Books	• Building Integrated Photovoltaic (BIPV) in Trentino Alto Adige (Maturi and Adami, 2018)

Figure 1 illustrates the key characteristics of 28 facade-integrated PV projects selected for this study. The case studies were grouped based on module type, building function, system capacity, construction stage, method of finance and country. The projects included three BIPV technologies: amorphous thin film (a-si); crystalline technology (c-si); and copper indium gallium diselenide (CIGS). Nine projects used crystalline technology, 18 projects used amorphous technology and one project used CIGS technology. The projects were categorized based on building function. The non-domestic buildings are 16 commercial buildings (CO), 6 educational buildings (ED) and 6 apartment buildings (RE). The systems included capacities of 1-700 kW, but most system capacities were less than 50 kW. The facade can be integrated at the design stage or the retrofitting stage of a building's lifecycle. In the cohort, 19 projects were installed at the initial construction stage and 9 projects were applied at the retrofitting stage. The projects used self-financed and full and partially financed methods. 22 projects were self-funded while another 6 projects received financial incentives to build the systems. We selected BIPV projects in 12 western countries and grouped them based on region: Australia, European countries and the USA. Most (24 projects) were in Europe.

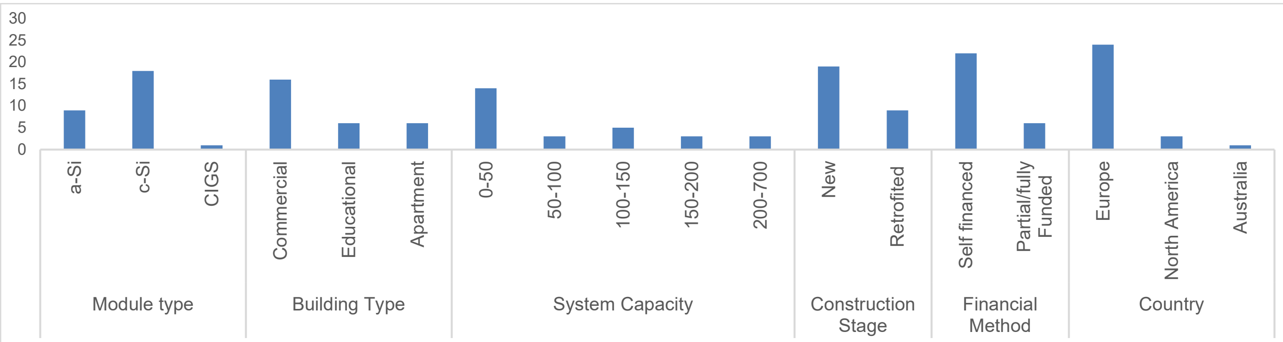

Figure 1: Characteristics of facade-integrated PV projects

3. Parameters and process of evaluation

As stated previously, economic performance was assessed, reflecting both the lifecycle approach and the multi-functionality of the application. Therefore, the BIPV economic cases were evaluated on six parameters: i) standard LCOE, ii) advanced LCOE, iii) standard NPV, iv) advanced NPV, v) standard discounted payback period and vi) advanced discounted payback period. LCOE reveals the cost comparison of systems, while NPV provides a comparison of total cost and revenue generation over project life. The discounted payback period shows the time for investment recovery. Advanced parameters cover the opportunity cost of replacing conventional building materials as an indirect benefit to investors or building owners. The study applied two types of economic parameters to identify direct and indirect values considering both multi-functionality and lifecycle aspects. The definitions of the parameters are provided in the following sub-section.

3.1. LCOE parameters

Standard LCOE: LCOE is an assessment of lifecycle energy cost, which can be applied to any energy technology (Darling et al., 2011). It is an indicator of the different means of the cost associated with energy production as a rate to cost per kWh. In the present study, LCOE denotes lifecycle cost over lifecycle electricity generation and the unit is AUD/kWh. Capital cost, lifecycle maintenance cost and lifecycle inverter replacement cost are cost categories, and financial incentives are added as benefits as lifecycle costs. Life cycle energy generation is calculated by using average annual electricity generation over project life combined with annual system energy degradation. LCOE is generally compared with the electricity price. An electricity price below LCOE implies that the cost of energy production is higher than that of national energy production, which is a negative indicator (IRENA, 2016). When the LCOE value is higher than the electricity price, the system is unproductive, as the energy production cost is more expensive than purchasing from the national grid.

Advanced LCOE: The advanced LCOE parameter includes the opportunity cost of replacing building materials as an income source. Although it is an additional cost element beyond the standard LCOE, it is a specific cost that is compulsory to account for the multi-functionality of systems. All the costs and revenues are similar to standard measures, with the exception of the material replacement value, which was added as a benefit. This is a one-time occurrence value in the initial stage. The value of the material benefit is projected using conventional building material costs (see Section 3.4). The price of standard building/facade material is multiplied by the area of the BIPV system to compute the opportunity cost of building material replacement.

3.2. NPV/kW parameters

Standard NPV/kW: NPV is the most common economic parameter in project evaluation. NPV is the sum of discounted cash flows (cash inflows and outflows), where the total cost and overall benefits are accounted for. The NPV calculation combines both lifecycle cost and lifecycle revenue components. Lifecycle costs are maintenance costs, inverter replacement cost and initial capital cost. Two lifecycle revenues are identified: 1) annual energy bill savings and 2) income gained by selling excess electricity to the grid. Energy bill savings is the payment of the electricity bill for the amount of energy consumed by the BIPV application. Annual average electricity generation and electricity price are used to quantify the annual energy bill savings. As discussed in the LCOE parameter, annual energy production degradation is accounted in the calculation. Further, the annual electricity price change over a project's life is embedded in the calculation. Secondly, income is generated by selling energy to the grid or utility suppliers which is paid off through a feed-in tariff (FIT). Further, financial incentives received in the initial year and during the project life are counted as a benefit. NPV values are expressed as a ratio of NPV over system capacity to ensure a better comparison of projects. Positive NPV is economically favourable, as the total cost is recovered within the lifecycle. Negative NPV signifies that building owners are unable to regain their total investment from revenue generation during the project's life.

Advanced NPV/kW: Advanced NPV conveys the multi-functionality of the application, similar to the calculation of the advanced LCOE parameter. The opportunity cost of replacing traditional building materials is added as a benefit element in the advanced NPV/kW. This is a once-off cost incurred during the initial stage.

3.3. Discounted Payback period parameters

Standard payback period: The discounted payback period is a common indicator that assesses the length of time over which the investment can be recovered. The initial cost is deducted from income over a period to estimate the number of years when the project can fully pay off the initial investment (Rai et al., 2015). The discounted payback period is quantified according to the time value of money. The main revenue sources are energy bill savings and income from selling excess electricity to the grid. Capital cost, inverter replacement cost and maintenance cost are lifecycle cost categories in the discounted payback period equation. Rebates or financial incentives are included as economic benefits. The rule of thumb is that investment is favourable when the payback period is short, as building owners often dislike long payback periods.

Advanced PB: The advanced payback period is estimated by adding material replacement value to the standard discounted payback period. This enables us to understand the importance of the additional benefits of replacing traditional building materials to recover costs.

3.4. Data inputs

Economic parameters include multiple costs and income components such as capital cost, material replacement cost and inverter replacement cost. The following sections provide the definitions and sources of the cost categories. The capital cost symbolizes the hardware and soft costs of a BIPV system in the initial stage of the project. The hardware cost includes the cost of physical systems, including BIPV modules, inverters, electrical equipment and cables. Soft costs include installation, direct labour costs, administrative activities, transportation and procurement (Strupti, 2017). This cost was available as a total cost in the project details. However, the capital costs of eight projects were unavailable. Therefore, a proxy capital cost was assigned based on 1) supplier databases 2) total construction value of the building and 3) similar projects in the same location and with the same module type.

Lifecycle operation and maintenance (O&M) denotes the costs incurred during the operational stage of the project's lifespan, including general cleaning, monitoring and performance evaluation. These costs are often hidden in the documents. Based on the details available for existing projects, the study assigned 1% of total capital cost as the O&M cost. Inverter replacement is a significant cost incurred during a project's lifecycle. The cost of 8.4 AUD per kW was assigned for inverter replacement, as stated in the report of National Renewable Energy Laboratory (NREL) (Fu et al., 2018). In the present study we made the following assumptions for inverter cost elements: that the cost was constant for subsequent replacements; inverter replacement was performed every 10 years (Fu et al., 2018); during the lifecycle, an inverter was replaced twice; it was a string inverter type for the above-mentioned cost.

In general, BIPV projects may span 30 years and longer (Gholami et al., 2019). In the present study, 30 years for the project lifecycle was considered. The annual degradation rate varies generally from 0.5% to 1.5% based on the module type (James et al., 2012). We used the minimum value of 0.5% for this estimation. Electricity price, FIT and the annual rate of change of electricity price were identified. Electricity prices and FIT were not available for many BIPV projects. Therefore, the electricity price for the year in which the project commenced was taken from country-specific documents and databases. Electricity prices change annually. We therefore reviewed the statistical data on electricity prices over a 10-year period and the average growth rate was taken as the annual rate of electricity price change expressed as a percentage. Moreover, counties have different FITs which change over time. The study reviewed the FITs in 11 countries at different time intervals and assigned a project-related FIT value based on the year the project began. In this study we assumed that FIT is a constant during the project life. The discount rate of a project is a significant factor governing the decision to invest in the project. The real interest rate, which is the lending interest rate adjusted for inflation, was adopted in this study. The country-specific real interest rates were taken from tradingeconomics (2018) and IndesMundi (2018) statistical databases. Since the available data were in different pricing formats, currencies were converted to Australian currency as at December 2018.

The opportunity cost of the material benefit was estimated from the average value of standard building material costs. As a wide variety of facade materials is commercially available, we considered the most common facade materials in non-domestic buildings. The most common materials in non-domestic buildings that can be substituted for BIPV modules are glazing, plastered concrete or cladding materials. Therefore, the cost of curtain walls (aluminum framed with glass) was taken to compare BIPV facade replacement in the non-domestic buildings. The prices of building materials vary from country to country. The projects were located in 12 countries which were categorized as 1) North America 2) Europe and 3) Australia. Material costs of three regions were identified and the average value was allocated for the calculation, as shown in Table 2.

Table 2: Building material cost based on region

Building Material	Australia	North America	Europe
Curtain wall - aluminium frame with glass	897.5AUD/ m^2 725-1070 AUD/ m^2 (Rawlinson guide, 2018)	1056.8 AUD/ m^2 650 – 817.5 USD/ m^2 (Rsmean, 2018)	1272AUD/ m^2 470-1140 €/m^2 (SUPSI, 2017)

4. Comparative analysis of BIPV case studies

This section discusses the results of the performance of selected facade-integrated PV systems using six economic parameters.

4.1. LCOE

LCOE is the cost of energy generation over a project's life. Figure 2 shows a comparison of standard and advanced LCOE values with electricity prices. According to Figure 2, LCOEs are less than their electricity prices in five projects. A lower value demonstrates that a project is cost-effective, as the cost of energy generation is lower than the current cost of electricity. LCOEs are higher than the electricity prices in the remaining 23 facade applications, indicating the high cost of energy production compared with national production. This is economically unfavourable, as system owners can purchase electricity at a lower price from the external grid. The lowest LCOE value, which is the most cost-effective project in the cohort, is a newly constructed commercial building in Europe. The LCOE value is also below the electricity price. However, this project received a financial incentive in the initial stage to fully pay off the capital cost. The project with the second most significant cost advantage is a commercial building in north America installed in 2014. This project was self-financed and spent the lowest amount of the cohort to install a kW system. The highest LCOE value, which is the most expensive energy production per 1kWh unit, applied to an apartment building in Australia. The system, which has a 5kW capacity and was built in 2016, cost the most in the cohort to implement.

LCOE based on financial incentives was also examined. Based on the results, four partially or fully funded projects in the cohort yield economically favourable LCOE values, as LCOE values are lower than the electricity rate. A European building and a north American commercial building which subsequently received 45% and 33% financial incentives are not economically favourable LCOE because the projects required high capital costs to implement the systems and generated 1kWh of electricity. This indicates that financial incentives are not the only promising indicator for achieving favourable economic advantages.

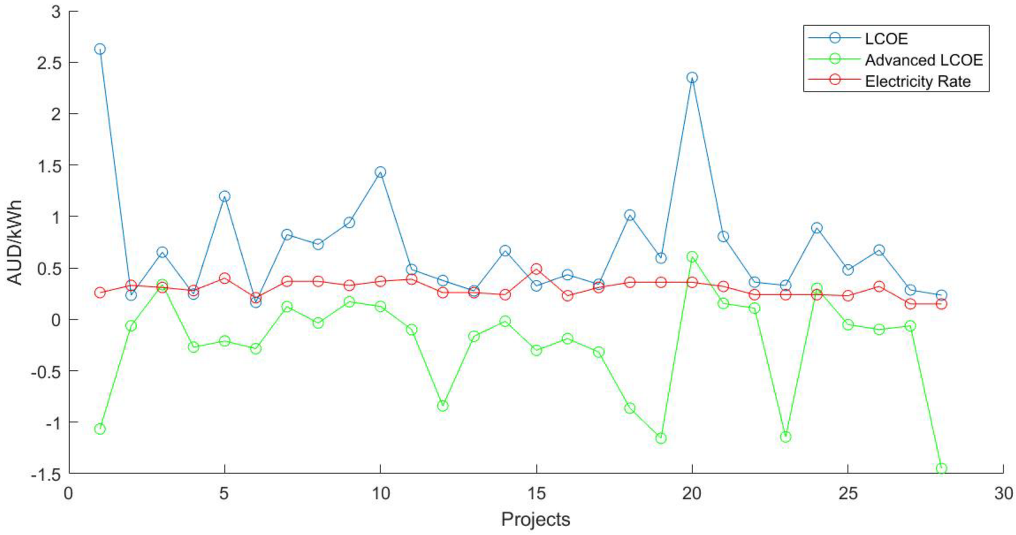

Figure 2: LCOE parameter distribution compared to electricity price

According to the advanced LOCE measure, 25 projects yielded favourable LCOEs. The cost of energy production was less than their national electricity prices. More importantly, 20 projects received negative LCOE values. This demonstrates that onsite energy production is a revenue generation unit, not a cost item. The opportunity cost of replacing building materials has facilitated to recover the lifecycle cost. The lowest advanced LCOE value, which was for the most profitable project in the cohort, is a commercial building in north America which covers 882 m^{2}. The system spent less to install a 120kW system and the opportunity cost of material replacement is very high. The highest cost of energy generation in the cohort was for an apartment building in Europe. This system indicates a high cost to generate energy, and it is higher than the electricity price.

As shown in Figure 2, the LCOE values range from 0.17 – 2.63 AUD/kWh, and most of the projects lie between 0.34 - 0.86 AUD/kWh. According to the results, facade-integrated PV systems spend on average AUD 0.71 to produce an energy unit of 1kWh. Advanced values are distributed between (1.45) (negative) – 0.61 AUD/kWh, with most ranging between (0.31) (negative) – 0.12 AUD/kWh. The average advanced LCOE value is (0.24) (negative) AUD/kWh. 25 Facade-integrated PV systems are economically favourable according to the advanced LCOE, while 5 projects are economically favourable according to the standard measure. In comparison with the standard parameter, the advanced LCOE parameter offers economically favourable performance. Therefore, this indicates that projects yield positive performance when real benefits are quantified and assessed.

4.2. NPV parameters

NPV/kW is the discounted cash inflow and outflow of a project for the unit of capacity (kW). Figure 3 depicts the value distribution of two NPV/kW parameter categories, based on the method of financing. As highlighted in Figure 3, five facade-integrated PV projects show positive NPV values. The income from energy bill savings, feeding back to the grid and financial incentives assists to recover the investment during the project’s lifecycle. Importantly, five projects received financial incentives of 100%, 60%, 45%, 33% and 30% of the capital cost. On the other hand, other 23 projects record negative NPV values, due to the high cost of capital and insufficient electricity generation to recover the cost.

The highest NPV value recorded is for a commercial facility in Europe. The building is a partially funded system of 100kW. The building produces 30% of the building’s energy demand. This system represents the lowest cost of adoption and highest energy generation per kW among the other buildings in the cohort. Low cost and high efficiency result in high NPV values. The lowest NPV, which is a negative value, is for an office building of 100 kW covering 2,340 m^2. The building had a facade system installed in 2012 and it is one of the most expensive projects in the cohort. It uses a high cost 1kW system and generates low energy per square meter. Moreover, Figure 3 further exhibits that the NPVs of recent BIPV projects are closer to the marginal line than aged systems. This is a sound indicator for potential investors.

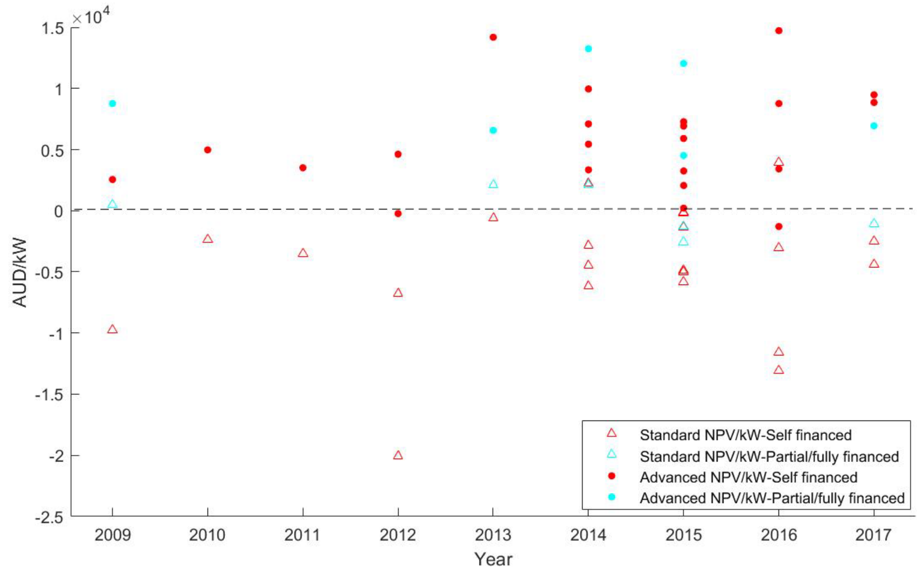

Figure 3: NPV parameter distribution vs. method of project finance

The advanced NPV parameters resulted in different value distributions, although all 26 projects showed positive advanced NPV values. As stated in relation to the LCOE parameter, buildings generate substantial opportunity costs when facades are replaced with PV modules. The highest advanced NPV is for the same building that showed the highest standard NPV parameter. Significant factors contributing to high NPV are the opportunity cost of material replacement and high system efficiency. Energy generation from a 1kW module in this building is comparatively higher than the other systems. In contrast, an apartment building in Europe installed in 2016 showed the lowest advanced NPV value. Which is negative. The high capital cost caused this decline in NPV value.

Standard NPV values are distributed between (20,091) (Negative) – 3,934 AUD/kW and the average value is (3,668) (Negative) AUD/kW. According to the results, average negative NPV in this cohort is an adverse alarm for potential system adopters. However, the advanced NPV values range from (1,291) – 14,729 AUD/kW and the average value is 6,327 AUD/kW. As shown in Figure 3, the advanced NPV values have shifted upward compared to standard NPV values. The main reason for this change is the opportunity cost of replacing traditional building materials. The positive NPV is yielded by the advanced performance parameters.

4.3. Payback period parameters

The payback period is the most important financial indicator in project evaluation, particularly for renewable energy projects, as decision-makers like to be able to estimate the time over which they will recover their investment. Figure 4 depicts the results for discounted payback periods and advanced discounted payback periods. The payback period was calculated up to 50 years. As illustrated in Figure 4, five projects recover the investment within the project lifecycle, similar to NPV. One project has a one-year payback period. The main reason for the short payback period is the financial support, which means that the capital cost is fully paid off. The rest of the projects require more than 14 years to recover the cost, and the payback period is more than 30 years for 21 projects. Significant reasons for a longer payback period are the high cost and lower efficiency of the systems.

Lower system efficiency signifies that these projects produce relatively low energy generation per kWh.

In the evaluation of the advanced payback period, all but four projects showed a one-year payback period. This highlights that the opportunity cost is sufficient to recover the capital cost in the first year. In addition, BIPV is less expensive than conventional materials. An office building in Europe showed more than 50 years for payback. This facility also received a lower advanced LCOE value. The main reasons for a longer payback period are the high cost to produce 1kWh energy, the high cost to install a 1kW system and low efficiency.

As shown in Figure 4, the advanced payback period shows a significant change to the standard payback period. The average standard payback period for this cohort is 42 years, signifying that the investment cannot be recovered within the project's lifecycle. Based on this estimation, it is concluded that building owners have applied BIPV despite the payback period. The average advanced payback period in this cohort is 5 years, which is favourable for building owners, who prefer the shortest possible payback period.

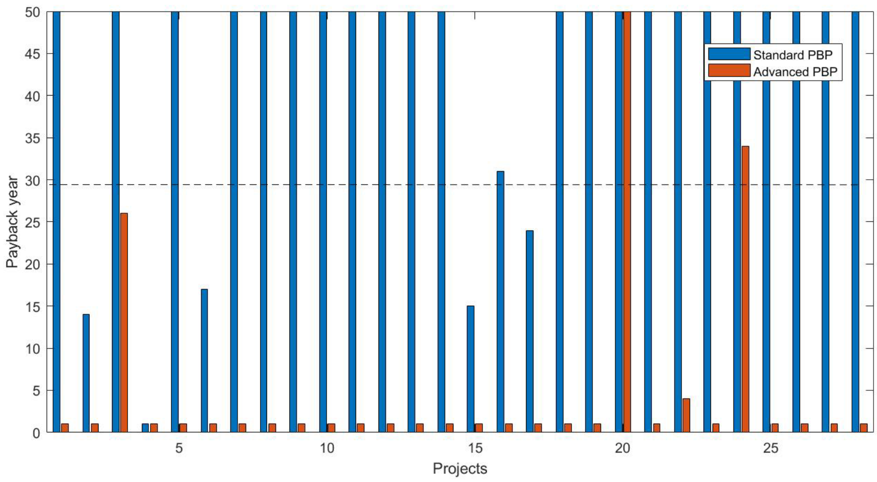

Figure 4: Discounted payback period distribution

5. Discussion and Conclusions

The objective of this study was to assess the economic performance of facade-integrated PV systems. The paper took an innovative approach to estimate economic parameters, adopting the lifecycle approach and the multifunctionality of the technology. A model was developed, and six economic parameters based on the direct and indirect benefits were proposed to assess the economic performance of existing facade-integrated applications. The six economic parameters are: i) standard NPV ii) standard LOCE iii) standard discounted payback period iv) advanced NPV, v) advanced LCOE and vi) advanced discounted payback period. The best BIPV configuration is an LCOE which is lower than the electricity price, a positive NPV value and a short payback period. Based on our study of the direct economic (standard) parameters, five facade systems are revealed as economically favourable in the cohort. According to the advanced economic parameters, 25 projects are becoming economically viable, with the exception of three systems which have longer payback periods, adverse LCOE and negative NPV. The results of the advanced parameters establish favourable economic performance compared with the standard parameters. The values distributions between standard and advanced measures exhibit significant variances. The average standard and advanced LCOE is 0.71 and (0.31) (negative) AUD/kWh, respectively. The average values of standard and advanced NPV in the cohort are (3,668) (Negative) and 6,327 AUD/kW. The standard and advanced payback period is 42 years and 5 years, respectively. The standard parameters demonstrate adverse economic performance while the advanced parameters show favourable economic performance. Therefore, facade-integrated PV products are economically favourable when both direct and indirect benefits are quantified. The findings also show that costs, system efficiency and financial incentives contribute to the achievement of economically favourable projects, because the 28 facade-integrated PV systems resulted in different value propositions based on the key characteristics of the projects, including their cost, efficiency, and method of financing. The crucial problem with economic evaluations is the lack of empirical data. Most of the data were real, but some data were assumptions based on previous projects' experiences and academic references. Due to space limit, the paper focuses on a direct economic analysis perspective (LCOE and NPV). It should be noted that in the future study, the intrinsic value of BIPV such as building performance benefits, productivity gains if an office building, rentability through energy rating uplift, mitigating local substation stress, embedded energy asset etc. should be explored.

With the growing requirement of sustainable applications, the owners of most new and retrofitted buildings are interested in integrating renewable technologies. Facade applications are a proven technology to achieve sustainability in buildings and even generate energy credits. Facade-integrated systems have vast potential for energy generation to meet building energy demand without compromising aesthetic appearance and functionality. Due to transformations in the industry, high energy efficiency, architectural possibilities and standard material requirements are no longer obstacles (Gholami et al., 2019; Bonomo, 2016;). Therefore, there will be immense growth in facade-integrated applications in the near future. The value of BIPV systems is one of the critical factors to increase their deployment. The lack of understanding of the true benefits of BIPV may be the main reason for the low BIPV market growth. We believe that understanding the real value of BIPV applications will help in accelerating BIPV penetration in the industry. Disseminating reliable information among stakeholders will remove the myths or fears about BIPV. Therefore, this may be the appropriate time to invest in facade-integrated PV projects in buildings.

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