Chapter 5

Economic Impact of CO_2 Mitigation Devices in Sustainable Buildings

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Additional information is available at the end of the chapter

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Abstract

Recent innovations in residential and commercial buildings involve the integration of low-carbon devices for the purpose of mitigating CO_2 footprints. Photovoltaic (PV) modules are now commonly integrated into parts of the fabric of a building as roof tiles, asphalt shingles, facade materials or shading elements and usually blends with the aesthetics of applied buildings. This is referred to as building-integrated photovoltaics (BIPV), and when used in this way, the integrated PV modules replace conventional building envelope materials, thereby benefiting from capital cost reduction. One key aim of BIPV technology on applied buildings is sustainability, and according to recent research, 'sustainable buildings perform better than conventional buildings in terms of well-being of the occupants'. This study evaluates and assesses the economic impact of BIPV projects as a low-carbon technology on applied buildings for use by prospective BIPV investors in the building sector.

Keywords: economic impact assessments, CO_2 mitigation device, low-carbon technology, low-carbon economy, sustainable buildings

1. Introduction

This chapter provides an overview of the concept of low-carbon technologies and consequent economies of their applications. Most interestingly, a major issue with such technologies is that the curiosity to justify their economic or financial viability especially among prospective investors was elaborately treated via systematic methods of economic evaluations and experimental system monitoring/analysis. A framework of decision-making was developed based on the assessments.

1.1. Rationale behind the study

Climate change and global warming has become both scientific terms and political slogans and point to the same direction, namely the effect of industrialisation and urbanisation. At first instance, one may want to ask or find out if these are real or whether they are concepts driven by political motives towards policies and regulations in a desired inclination. Scientific investigations and research organisations like NASA have validated the reality and causes of these phenomena, a situation which now calls for effective low-carbon technologies and policies [1]. The application of such low-carbon technologies has therefore become a global recommendation by various governments as a key solution to mitigate the rising CO_2 emissions, while various governments have initiated strategic policies and guidelines towards achieving a low-carbon environment and economy. The UK Government policy paper on low-carbon technologies [2], for instance, stipulates a target of 80% reduction in greenhouse gas emissions by 2050. Meanwhile, statistics have shown that commercial/office buildings alone, account for 20% of the carbon dioxide (CO_2) emissions in the UK [3] and about 39% in the US for both domestic and commercial buildings. Also with the UK's existing building stock being replaced at a rate of 1–1.5% per annum [4], occupants of existing office buildings will need to respond to rising temperatures resulting from climate change with the possibility of temperatures exceeding comfort levels by as many as three to five working days by 2050 [3]. Therefore, there is an urgent need to extend the use of low-carbon energy technologies, and part of the strategies to encourage wider application of such technologies involves the introduction of policies [2] such as renewables obligation (RO), which provides incentives to support suppliers in the UK generate a proportion of their electricity from low-carbon renewable sources and the Feed-in Tariffs (FITs) scheme, which rewards users of small-scale, low-carbon electricity for the electricity they generate and use, and for excess electricity they export back to the grid.

Considering the level of attention at the moment on this global subject, questions and controversies begin to emerge regarding the economic viability, and one way to justify the continuous application of the technology in the building sector is by assessing their impact on applied buildings to find out whether they make economic sense with regard to initial investment cost, net benefit or payback period.

This research study assesses a low-carbon technology and evaluates its net benefit on applied building in order to find out whether the application makes an economic sense. The outcome or result of the research forms a vital decision platform for prospective investors and stakeholders.

2. Overview of low-carbon technologies and economy

An attention to both the technologies and the consequent economic outcomes on lives and the environment is very important for the present status and future trend.

2.1. Mitigation technologies

Low-carbon technologies simply refer to systems, which involve negligible or low amount of CO_2 in the process of generating a required form of energy, usually electricity for domestic

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and industrial applications. Several low-carbon energy technologies are available in the building sectors and the built environment at the moment for use in different parts of the world for mitigating carbon footprints. These include microwind turbines, building-integrated photovoltaics (BIPV), small hydro power generators and bio-tech systems. Although listed as a low-carbon energy source, categorising nuclear energy sources as low-carbon energy technology have been a bit controversial over time; however, the 2014 Intergovernmental Panel on Climate Change report identifies nuclear, wind, solar and hydroelectricity in suitable locations as technologies that can provide electricity with less than 5% of the lifecycle greenhouse gas emissions of coal power [5].

Besides the nuclear option, most other options can be applied to both domestic and commercial buildings usually for generation of electricity. It has been observed that when used in buildings, only building-integrated photovoltaics (BIPV) becomes aesthetically appealing and forms part of the applied building fabrics, while most other options could deform the building aesthetics and require large spaces for both installation and operation especially, the wind turbine.

Recent studies [6–9] and to mention but a few have involved research investigations on specific types or technologies: Ikedi, for instance, assessed the energy impact of a grid-connected, building-integrated PV (BIPV) in a commercial/office building in UK; Ronga, in a different study, conducted a comprehensive review for optimising poly-generation bio-tech systems in buildings; Santoli, in another study, conducted an energy and environmental analysis for a vertical-axis micro-wind turbine with a nominal electric power of 3.7 kW as a cost-effective energy technology for rural electrification, while Francisco reviewed small hydropower systems in Europe. These previous studies focused more on the power generation, while this present study focuses on the economic impact of such carbon mitigation devices.

2.2. Low-carbon economy

The topic of low-carbon economy can be considered as a new concept which dates from the inception of the matter of climate change with increasing carbon footprints. The logic behind this new concept lies in the fact or saying that health is wealth. In other words, a healthy environment implies a wealthy economy. Carbon emission has been identified globally as a key health challenge to lives and the environment. A low-carbon environment, therefore, implies a wealthy economy and referred to as a low-carbon economy.

Low-carbon economies offer various benefits to the environment, such as businesses, employment, health, energy security and industrial competitiveness [10].

Two different perspectives can be adopted to define or describe low-carbon economies namely:

(1) The expected economic value or benefit of low-carbon technologies on applied buildings or environment

This perspective which forms the basis for the economic evaluations in this study refers specifically to net benefit or financial savings achieved via the use of a low-carbon device to generate a particular type of required energy, which is usually electricity as in this research case study. Yearly monitoring for changes in cost of electricity before and after the installation of a low-carbon device is carried out to showcase or measure possible economic values or benefits.

(2) The projected contributions to the environment due to obtainable policies and practices

Based on this perspective, a low-carbon economy can be defined to be an economy that is an outcome of the introduction and application of low-carbon technologies, thereby resulting in some benefits such as the value of CO_2 reductions, the potential for good practice guidelines in energy production and use to minimise costs, opportunities for new knowledge and better scope of energy management [10].

The way a country or government manages the emission of carbon determines its ability to create a healthy and safe future. Countries with improved low-carbon energy production have the capacity to enhance their future economy and prosperity. How each government or country approaches and manages the challenge of carbon climate would depend to a large extent on awareness and investment towards carbon mitigation strategies. France, Japan, China, South Korea and the United Kingdom are currently best positioned in the trend of low-carbon economy. France retains the top ranking followed by Japan, South Korea and the United Kingdom. China's dramatic rise up the Index to third place is the result not only of its major investment in clean energy, but also growth in its high-technology exports. The earlier a country or government involves low-carbon technologies, the earlier they will experience greater benefits associated with sustainability and energy efficiency and so will be better positioned to provide healthier environment and wealthier economy in future.

3. Research methodology

This section explains the main research methodology applied in this study, as well as the assessment methods used. Firstly, the framework of economic assessment based on the most suitable economic method was explained. The researcher further explores and justifies the criteria for the selection of a case study and also explains the considerations adopted when selecting the most suitable and effective research methodology.

3.1. Economic assessment framework

Prior to this present study, there had been several similar attempts to develop some form of framework or method to assess the economic impact of low-carbon technologies on applied buildings. The summarised definition and principles of the process 'impact assessment' as provided by the IEA/IAIA best practice document (International Association for Impact Assessment [IAIA] and Institute of Environmental Assessment (IEA) [11] could be considered as a yardstick to weigh or compare such studies. The first criteria, for instance, could be the

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degree of compliance of the structure: aims, objectives and research methodologies of such studies with the definition standards. A further criterion could be the degree of fulfilment of critical areas of assessment required by prospective investors particularly in the areas of economy. Economic evaluations of low-carbon energy systems usually involve an assessment of the projected benefits compared to the estimated costs of the system, which implies that the actual financial benefit of a low-carbon energy system is in essence the value of energy generated.

Economic methods of evaluation considered include the following:

Payback period—The payback period is the minimum time it would take the mitigation device in the research case study to recover investment costs and can be calculated as:

Payback period = total investment cost divided by the first year

Net benefit analysis—net benefit analysis is an expression of the net difference between the benefits and costs of the technology relative to an alternative system. The low-carbon systems as applied in the case studies would be considered cost effective if the net saving or net benefit turns out positive.

Adjusted internal rate of return (AIRR)—the adjusted internal rate of return is a discounted cash flow technique, which can be used to measure the annual compound yield from the applied system in the case study, taking into account reinvestment of interim receipts at a specified rate. With this method, estimating the cost effectiveness of the low-carbon system involves comparisons of the calculated AIRR of the system to the investor's minimum acceptable rate of return (MARR). The low-carbon system would be considered to be cost effective if the AIRR is greater than the MARR.

Lifecycle cost analysis—in life-cycle cost (LCC) analysis, all relevant present and future costs (less any positive cash flows) associated with the applied system are summed in present or annual value during a given study period (e.g., the life of the system). These costs include, but not limited to energy, acquisition, installation, operations and maintenance (O&M), repair, replacement (less salvage value), inflation, and discount rate for the life of the investment (opportunity cost of money invested).

One major barrier identified in this research assessment was how to gather and assess observable/measurable data and results associated with the BIPV system in such a way as to aid existing owners and potential investors decide whether the technology makes an economic sense or positive impact. However, because of the nature of data available in the selected case study, the economic assessment is based mainly on the net benefit analysis.

3.2. Selection of the research methodology for economic evaluation

In order to select an appropriate methodology, an extensive review of similar studies was carried out [[6–9]. The methods of assessments in the studies were also examined and compared. Most of the studies were found to focus more on power generation, while this present study focuses on the economic impact of such devices. Also, most of the previous studies focused their assessment on residential or non-commercial buildings with little or no consideration to commercial/office buildings. The present adopted the use of parametric analysis of intrinsic output characteristics of the applied device together with applicable economic methods to conduct the assessments.

3.3. Identification and selection of research case study

The first step adopted by the researcher in the research methodology was to identify an appropriate and suitable case study for the economic impact assessment. The main purpose of choosing a case study is to conduct a self-experimental assessment beyond mere evaluation of secondary data from a ready source.

Because of the wide application of BIPV due to its advantages of aesthetics and installation space, the case study selected for this assessment study is a BIPV system. One key requirement for the selection of a case study in this research study is that the applied system should have a comprehensive record of system monitoring for at least a period of 1 year. Another key requirement or criteria for the selection of a case study is that it must be grid connected, which is a basic requirement for economic analysis and assessment.

The BIPV system at the Kedleston campus of University of Derby was chosen—this case study comprises a BIPV roof array with an area of 204 m^2, consisting of 72 units of ND-170E1F (170 W), Si-poly Sharp PV modules and is of a commercial/office application. However, before evaluating the selected case study, it is important to have a brief background overview of BIPV systems.

3.4. Background behind BIPV

Photovoltaics refers to the science and engineering of converting energy from the sun to electricity with the aid of special configuration of modules, panels or arrays of cells referred to as photovoltaics or PV systems.

Two basic types of PV systems can be described namely: fixed PV and tracking PV.

The earth moves round the sun in an elliptical orbit, in a counter clockwise direction on an imaginary line called its axis, tilted with respect to the plane of its orbit at an angle of about 23.4°. Due to the movement of the earth around the sun and the consequent effect on solar radiation, tracking PV systems are designed to track the sun’s movement and hence maximise solar incidence on the modules/arrays by maintaining an optimum orientation between the sun and the solar panels. The complex and usually delicate operations involved in tracking PV systems has meant that most PV applications are of the fixed category resulting in benefits of simplicity, least cost and convenience of operation.

Fixed PV systems are defined as such because the solar modules or arrays are permanently fixed at a particular angle towards the sun, with the aim of maximising solar capture. Fixed systems can be installed either as pole mounted, ground mounted or roof mounted systems.

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Pole and ground mounted PV's are usually installed remote from building envelopes, while other types of PV systems are either installed on structured framework on the roofs of buildings or integrated with the building envelope in such a way that it is referred to as building-integrated photovoltaic (BIPV). These involve the integration of the PV modules into parts of the fabric of a building as roof tiles, asphalt shingles, facade materials or shading elements. Used in this way, the integrated PV modules replace conventional building envelope materials, thereby benefiting from capital cost reduction and hence improved payback period and life-cycle cost.

3.5. Methodological evaluation of the research case study

Post-commission data of the BIPV system in the selected case study were retrieved and recorded from the system with the aid of high-performance data logger systems networked to different input and output terminals of the entire BIPV system. The first set of monitored parameters here include mean values for grid current [A], DC current [A], grid voltage [V], DC voltage [V], operating time meter change [h] and feeding time meter change [h].

The second set of parameters monitored in the system include total yield meter change [kWh], power mean values [W] and specific inverter yield mean values [kWh/kWp], where A is ampere, V is volts, W is watts and h is hours, respectively.

The BIPV system, which involves the latest grid-feedback and SMA inverter technologies, was monitored with the aid of Kyoto platform software integrated into a state–of-the-art SMA data technology (Kyoto platform is an open text computer format, which has the capability to extract large volumes of texts and data in various computer languages and this formed the basis for using the software.)

Each of the parameters was monitored on a daily basis, and this was carried out for about 1 year in order to account for the different seasons of the year namely: winter and summer. The monitoring was commenced from July 2010 to July 2011. For simplicity and evaluation purpose, the data were subsequently compressed to monthly average values for the different months of the year.

Finally, graphical representations of the data were developed and applied to deduce and assess the economic impact of the system on the applied building.

Details of these graphical information and the subsequent assessment results are presented below.

4. Results of economic evaluations

The graphical results for the total system yield denote meter change values which represent the excess energy imported into the building grid supply by the BIPV system. The mathematical product of these values measured from the graphs with the unit tariff for electricity, provides the economic earnings or financial savings for each feed back into the grid system.

For simplicity and space, the graphs below (**Figures 1–4**) show the average daily values in kWh for the first months, only of each quarter of the 1 year research monitoring. Section 5 discusses the results in detail, while the economic evaluation of these parameters is presented in the section on economic impact assessment (Section 6).

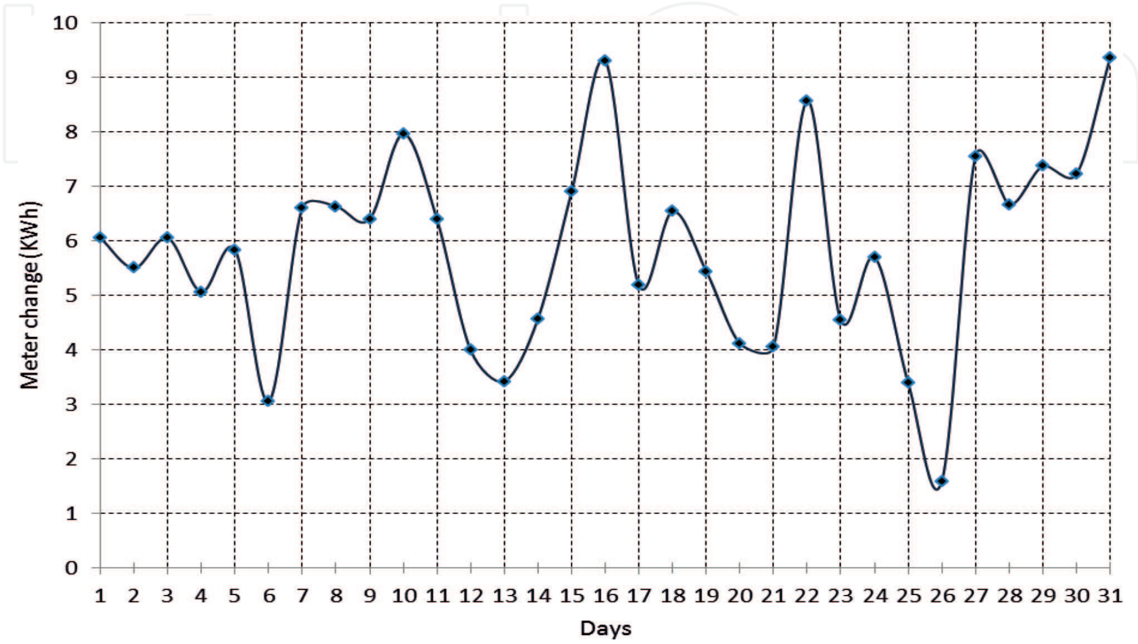

Figure 1. Total system yield—July 2010.

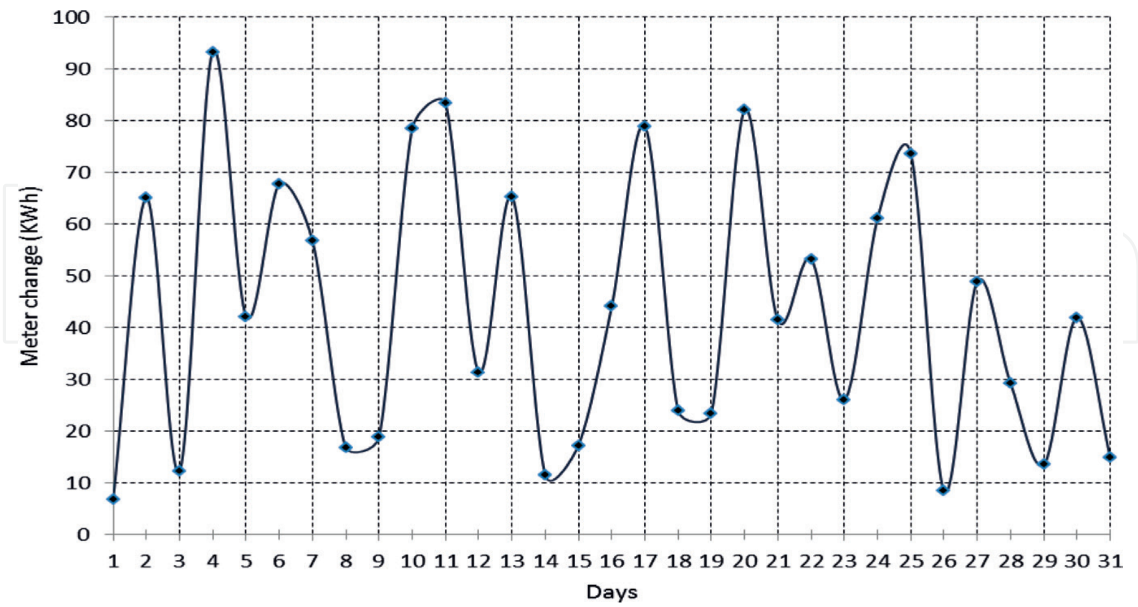

Figure 2. Total system yield—October 2010.

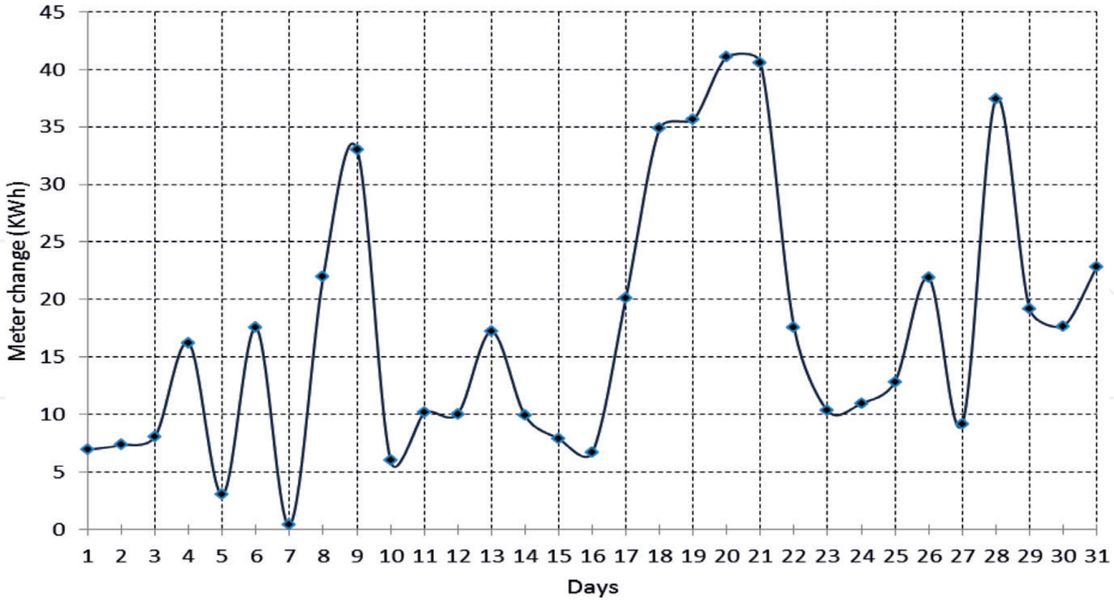

Figure 3. Total system yield—January 2011.

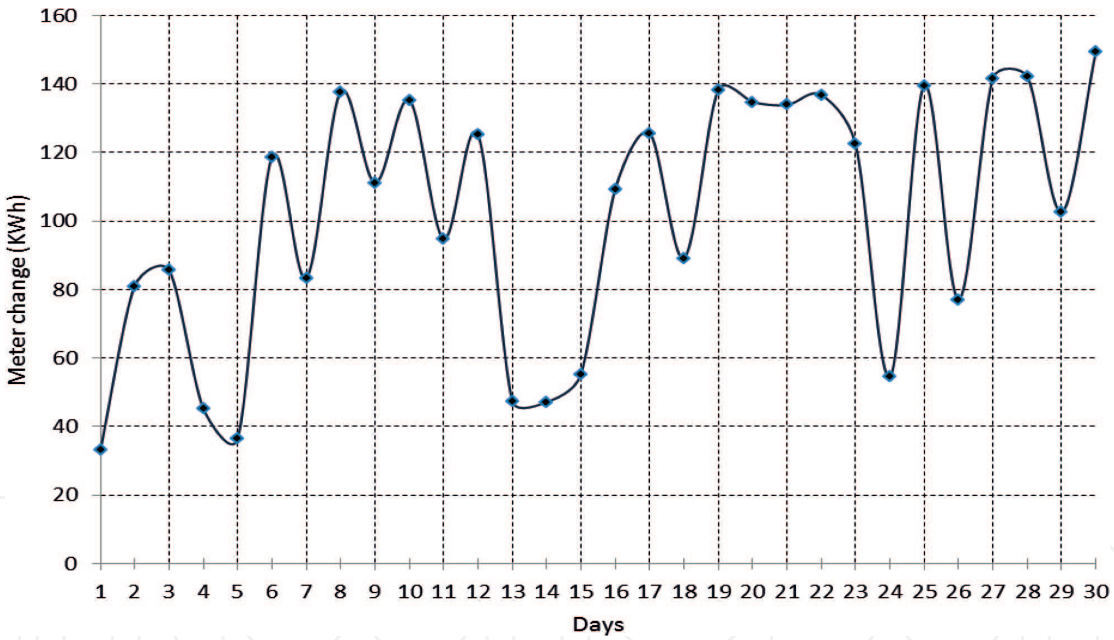

Figure 4. Total system yield—April 2011.

5. Discussion of the results of the economic evaluations

The total energy yield (**Figures 1–4**) deduced from monitored meter changes values and provides the excess energy imported into the building grid by the BIPV system. The unit for the total energy yield is kWh, while the mathematical product of these values measured from the graphs with the unit tariff for electricity provides the economic earnings or financial savings for each feedback into the grid system.

The total energy yield in principle is a product of the power contribution and time and can be expressed as:

$$\text{Total yield (Y)} = \text{power (P) kW} \times \text{time (t) h} \tag{1}$$

Substituting P for *IV*, then

$$\text{Total yield (Y)} = \boldsymbol{IVt}\ \text{(kWh)} \tag{2}$$

$$\boldsymbol{IVt}\ \text{(kWh)} \times \text{unit tarriff for electricity (£/kWh)} = \text{economic benefit (£)} \tag{3}$$

where *I* and *V* are the current and voltage, respectively.

From the graphical results for each of the respective months, it can be seen that the energy yield from the BIPV system is higher in the summer months than in the winter months. This is also explained based on the fact that the summer months are characterised by clear climatic solar conditions, which enhanced direct incident solar radiation on the BIPV panels, consequently maximising the system power and hence the total energy yield. The winter months, on the other hand, were characterised by cloudy climatic conditions resulting in diffuse solar radiations, which retard or impede the yielding capacity of the BIPV system.

The days in summer months namely May (5th and 6th), June (3rd), July (24th) 2011 recorded maximum daily energy yields of about 169.0, 180 and 175 kWh, respectively, from the BIPV, while the days in the winter months namely November (6th) 2010, December (25th) 2010 and January (20th) 2011 recorded about 51.0, 29.0 and 41.0 kWh, respectively, as the corresponding maximum in winter.

The energy yield from the BIPV system, therefore, shows a significant difference or margin between winter and summer months. This difference in the system yield at different seasons in effect has an implication on the economic or financial impact of the BIPV on the applied building at the respective periods. For instance, because the graphical results show significant increment in summer months, the excess energy imported into the building grid by the BIPV system was correspondingly high, thereby providing more economic earning or financial savings at such times.

The least recorded excess energy imported by the BIPV into the building grid within the 1 year monitoring period is approximately 0.01 kWh, which was recorded from the 1st to the 9th of the winter month of December 2010. A similar value of about 0.01 kWh was also recorded on the 7th of January 2011. In contrast, however, the highest excess energy imported by the BIPV into the building grid within the 1 year monitoring period is about 180.0 kWh, which was recorded from the system in the summer month of June.

Compared to the results of the power contribution, the BIPV system provided maximum power to the building in the month of May (**Figure 5**), while the maximum excess energy yield from the BIPV system was imported into the building grid in June.

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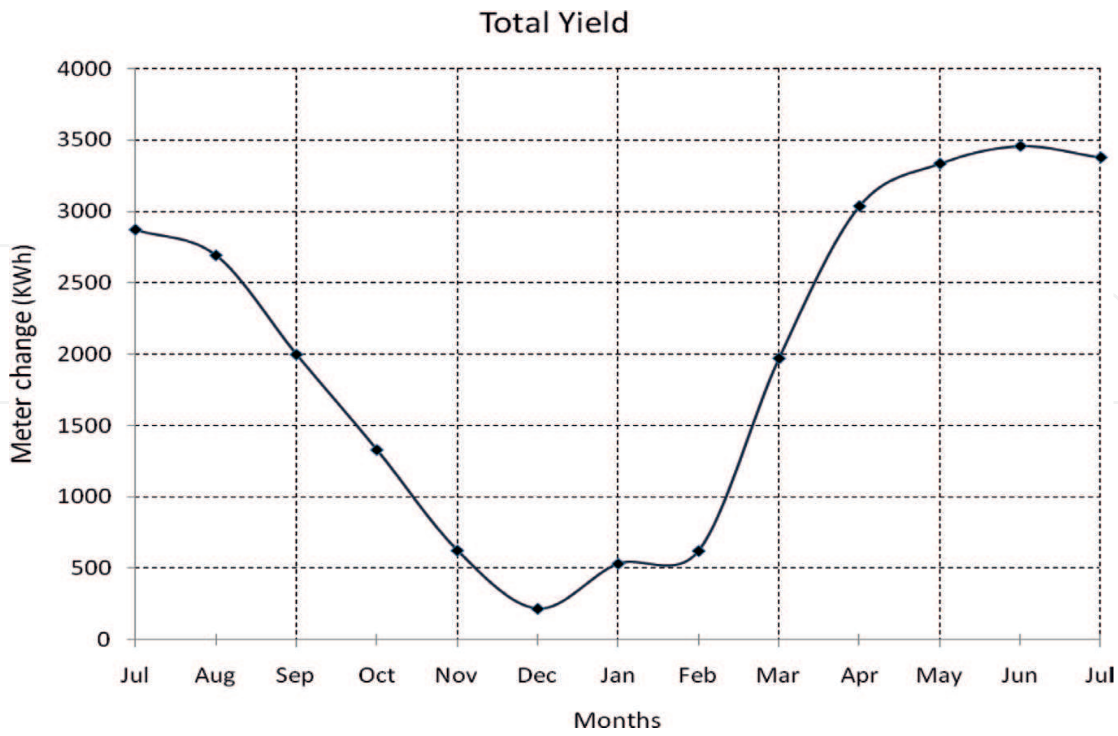

Figure 5. Monthly system total yield (University of Derby).

The graphs were based on daily values. These values were further computed into total monthly values for the purpose of the economic impact assessment in the research project (**Table 1**). The month of December with nine consecutive days recording the minimum daily energy export from the BIPV into the building grid had an overall total monthly yield of 219.59 KWh, resulting in the least financial savings of about £26.35 (**Table 1**).

Furthermore, from **Table 1**, it can be clearly seen that the system made a maximum yield of 3455.55 kWh in the summer month of June providing maximum economic benefit to the building with the highest financial savings of about £414.66 (**Table 1**). June 2011, therefore, was the most economic period of the BIPV project within the monitored period.

The explanation for the variations in the economic impact of the system at these periods obviously lies in direct relationship with the amount of direct solar radiation available to the BIPV panels at respective seasons or months of the year.

From this discussion and analysis, the following conclusions can be made:

- BIPV systems generate and feed back maximum excess energy into the building grid in the summer months. Regardless of the obtainable feed in tariff, the project, therefore, makes maximum economic returns at such times.
- It is advisable to carry out pilot or preliminary BIPV designs and base the design thresholds on the winter period when the atmospheric condition is usually cloudy and involves diffuse solar radiations. This will in practice ensure that the actual economic performance of the project does not operate below expectations.

Month	Total yield (kWh)	Financial value (£)
July	2871.04	344.52
Aug	2690.99	355.32
Sep	1997.92	239.74
Oct	1331.04	159.72
Nov	626.80	75.22
Dec	219.59	26.35
Jan	534.51	64.14
Feb	623.99	74.88
Mar	1971.33	236.55
Apr	3035.41	364.25
May	3333.16	399.98
Jun	3455.53	414.66
Total	22691.31	2755.33

Table 1. Monthly financial impact of BIPV system—University of Derby (July 2010 to June 2011).

6. Economic impact assessment

In general, two parameters were considered for use to assess the economic or financial impact of the system. The first is the ′energy cost produced′, putting into account, the initial capital costs, maintenance costs and costs of changing parts of the balance of system (BOS) components like the inverters. The second is the ′value of excess electricity exported′ by the BIPV system into the grid network of the building. The exported electricity can pay or make returns to the BIPV owners in either of two ways: reducing the overall cost of electricity imported from the grid company or generating direct cash as the selling price to the grid company.

On account of the nature of data monitored, the assessment in this study is based on the second approach, which in principle, falls under the net benefit analysis outlined in Section 3.1.

The direct financial benefit of the BIPV system can be described to be the value of excess electrical energy imported into the applied buildings. In simple mathematical notation, this can be expressed as:

$$\text{Projected benefits of BIPV systems} = \text{value of electricity generated} \tag{4}$$

In the same dispensation, the principal economic costs of the BIPV system can be expressed as:

$$\text{Estimated costs} = \text{initial costs} + \text{maintenance costs} \tag{5}$$

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Because the photovoltaic (PV) components for the systems in the study are grid connected and used as part of the building components, its economic costs and benefits are, therefore, shared between the occupants and the utility company. Also, a further benefit to the building owners (University of Derby) is that the added costs of installing and operating the systems to generate electricity are offset by the avoided costs of purchasing electricity as well as the sale of surplus electricity yield to the utility companies. In effect therefore, the entire procedures for the economic impact assessment for the BIPV system can be used to develop frameworks for rates in the form of feed-in tariffs as well as to determine an equitable rate structure for exporting or importing electricity to and from the electricity grid, respectively.

Further economic benefits in the BIPV system lies in the structural performance of the BIPV modules as a building component (for instance, as shading devices, roofs or daylight devices).

The PV modules at the research case studies, in addition to generating electricity to the building, successfully provide roofing for a significant part of the building. On the other hand, although the PV modules in the high-rise building of the University of Derby are installed on the roof area of the applied building, there is no significant structural contribution to the building because of the underlying concrete roof.

Table 1 shows the results of the parametric analysis carried out for the assessment of the overall economic impact of the BIPV system.

Figure 5 is a graph of the monthly system total yield over the entire 1 year monitoring period of the research at the University of Derby, from July 2010 to July 2011.

From **Figure 5**, the monthly values of the total excess energy yielded or exported into the building were tabulated and multiplied in each case with the unit cost of electricity in UK estimated at about 12 pence per KWh. This gives the monthly economic impact or contribution from the BIPV system directly for each of the months (**Table 1**). The values in the last column of **Table 1** (financial values), which were obtained by multiplying the respective preceding total yield values by 12 pence in each month, give the respective economic values or benefits.

From **Table 1**, firstly, it can be clearly seen that the system yielded maximum economic benefit to the building in the summer months with the highest financial savings of about £414.66 in June 2011, while the winter months yielded minimum economic impact with the least financial savings of about £26.35 in December 2010.

It is interesting to note that the total financial savings or impact of the BIPV system over the one period of the research monitoring is approximately £2755.33 (**Table 1**).

The total capital installation cost of the BIPV systems at the University of Derby was £70.674.00 (incl. VAT).

The life expectancy of the BIPV system used in the project from the manufacturers (Sharp) is typically about 25 years.

Dividing the total capital cost of £70.674.00 by the life expectancy of 25 years implies an annual capital cost of about £2826. 96.

From the principles of life-cycle analysis (10.3), if the payback period of the BIPV system turns out to be significantly less than the expected system life, the BIPV project is considered cost effective.

£2826.96 ≤ £2992.49. This implies less payback period. Hence, the BIPV system applied in this case study is considered to be cost effective.

Finally, the percentage economic impact of the BIPV system based on the value of excess electricity exported into the building therefore becomes

[2755.33/70664.00 × 100]% = 3.90% with respect to the system capital cost.

In other words, the value of the excess electricity exported or yielded into the building grid by the BIPV system has the capability to provide financial savings of up to 3.90% of the original investment cost every year.

7. Conclusions

Having conducted and discussed the result of the assessment, key features of the research outcomes which contribute both to the aims of the study and knowledge are outlined below:

1. **Financial significance:** the results of the study has shown that the value of the excess electricity exported into the building grid by the BIPV system has the capability to provide financial savings of up to 3.90 of the original investment cost every year.
2. **Added value**: from the case studies, it can be seen that before the implementation of BIPV on applied buildings, most buildings could be considered as 'consumer–only' of energy. However, with the integration of the solar panels, the BIPV in addition to generating electricity into the building, replaced part of the building roof materials, thereby providing further economic savings equivalent to the cost of the area of roofing materials, replaced by the PV panel.
3. Besides the added value to the building, the system fulfils the second definition of low-carbon economy as implied in the study via the creation of opportunities for the installation contract or jobs in the project as well as business or sales outlet for companies supplying the equipment. Another indirect way to assess the economic impact would be to quantify the financial value of the quantity of CO_2 avoided by the device from the time it started operating.
4. **Decision-making:** finally, the entire information gathered from this study can be used to appraise or criticise the continued use or application of low-carbon technologies. Some potential or prospective investors sometimes go into the investments with exaggerated or overrated expectation and get disappointed after commitment to such investments. Such information as the outcome of this study provides a preliminary idea of post-investment expectations.

In conclusion, therefore, putting into consideration the outcomes of the assessments in the study, one can reach a conclusion that low-carbon technologies, in particular BIPV, have a relatively positive economic impact on applied buildings. A downside, which could be picked as seen from the parametric analysis in the economic evaluations, is the influence or dependence of the economic contribution of the system to seasons of the year. This forms a platform of critical comparison between BIPV systems as used in this research case study with other types of low-carbon technologies. Wind turbines can also be argued to depend on climatic wind current, micro-hydro-systems on water flow at any given point and bio-systems on the volume of bio-gas flow at any given point. Apart from nuclear source, it can be concluded that most other types are not absolutely stable with respect to the measure of economic contribution over a time trend but influenced by climatic conditions of applied locations. Meanwhile in addition to being controversial as a low-carbon technology, nuclear sources are not yet applied as building-integrated low-carbon technology.

Finally, it is important, however, to always adopt credible methods of economic evaluations as outlined and demonstrated in the chapter in which the net economic benefit of the technology was paralleled with the life expectancy before making decisions on the viability of the technology as a low-carbon energy option in today's built environment and the building sectors.

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