УДК 330.322.55
JEL Classification G11, Q20, Q56
DOI https://doi.org/10.33146/2307-9878-2025-2(108)-59-66

Estimating the Financial Payback Period for Renewable Energy Investment – A Quasi-Systematic Review

Collins C Ngwakwe[1]

Abstract. *Accounting and finance discipline is intricately connected to the global campaign and advocacy for sustainable energy alternatives that balance costs and environmental sustainability. This paper aims to use the literature review to estimate the financial payback period for renewable energy investment. Thus, it encourages the financial investment of renewable energy and the use of renewable energy to assist in sustainable energy adoption. The paper applied a quasi-systematic review to explore the concept from prior literature data. Findings from the final selected empirical literature show different financial payback periods (FPP) and energy payback time (EPBT). In particular, residential solar PV technology has an estimated expected financial payback period of 7 to 15 years, giving an average FPP of 12 years. Correspondingly, residential solar PV technology has an associated energy payback time of 1 – 4 years with an average EPBT of 2.5 years. Large-scale (or utility) PV technology has an expected FPP of 3 to 12 years, with an average of about 7.5 years. The associated energy payback time (EPBT) for large-scale (or utility) PV technology ranges between 1 and 5 years, with an average EPBT of 3 years. For off-grid photovoltaic systems (for rural areas), there is an expected FPP of 4 – 6 years, which gives an average of 5 years. Similarly, an associated EPBT of 2 – 4 years gives an average EPBT of 3 years. The paper offers insight into financial payback and energy payback for users and investors in making renewable energy alternative investment choices. The results of this study are expected to help consumers and investors make effective decisions about investing in renewable energy. Incorporating data on the financial payback periods of renewable energy and energy payback times into business school lectures and sustainability projects will improve stakeholders' understanding of renewable energy investments.*

Keywords: *financial payback period, energy payback time, renewable energy investment, Solar PV technology, environmental accounting.*

Received: 20 May 2025 | **Revised:** 30 May 2025 | **Accepted:** 1 June 2025 | **Published:** 10 June 2025

Suggested Citation
Ngwakwe, C C. (2025). Estimating the Financial Payback Period for Renewable Energy Investment – A Quasi-Systematic Review. *Oblik i finansi*, *2*(108), 59-66. https://doi.org/10.33146/2307-9878-2025-2(108)-59-66

---

[1] **Collins C Ngwakwe**, Graduate School of Leadership, University of Limpopo, Polokwane, South Africa.
ORCID 0000-0002-6954-8897
E-mail: collins.ngwakwe@ul.ac.za

Оцінка терміну фінансової окупності інвестицій у відновлювану енергетику – квазісистематичний огляд

Коллінз Нґвакве[1]
[1] *Університет Лімпопо, м. Пітерсбург, Південно-Африканська Республіка*

Анотація. *Бухгалтерський облік та фінансова дисципліна тісно пов'язані з глобальною кампанією та адвокацією альтернатив сталого розвитку енергії, які балансують між витратами та екологічною стійкістю. Мета статті – оцінити термін фінансової окупності інвестицій у відновлювану енергетику і, таким чином, сприяти впровадженню сучасних технологій сталого розвитку. В роботі використано квазісистематичний огляд результатів попередніх досліджень. Результати на основі аналізу емпіричної літератури показують різні терміни фінансової окупності та час окупності енергії. Зокрема, технологія сонячних фотоелектричних систем для житлових приміщень має очікуваний термін фінансової окупності від 7 до 15 років, із середнім показником 12 років. Натомість, технологія сонячних фотоелектричних систем для житлових приміщень має термін окупності енергії від 1 до 4 років із середнім показником 2,5 року. Великомасштабні (або комунальні) фотоелектричні системи мають очікуваний термін фінансової окупності від 3 до 12 років, із середнім показником близько 7,5 року. Термін окупності енергії для великомасштабних (або комунальних) фотоелектричних систем коливається від 1 до 5 років, із середнім показником 3 роки. Для автономних фотоелектричних систем (для сільської місцевості) очікуваний термін фінансової окупності становить 4–6 років, при середньому показнику 5 років. Натомість термін окупності енергії для цих технологій становить 2–4 роки, із середнім показником 3 роки. Очікується, що результати цього дослідження допоможуть споживачам та інвесторам приймати ефективні рішення щодо інвестування у відновлювану енергетику. Включення даних про фінансові терміни окупності технологій відновлюваної енергії та терміни окупності енергії до лекцій бізнес-шкіл та проєктів сталого розвитку покращить розуміння зацікавленими сторонами інвестицій у відновлювану енергетику.*

Ключові слова: *фінансовий термін окупності, термін окупності енергії, інвестиції у відновлювану енергетику, технологія сонячних фотоелектричних систем, екологічний облік.*

INTRODUCTION

Due to the substantial capital required to invest in renewable energy, such as solar power plants, stakeholders are primarily concerned with accurately estimating the payback period (Singh et al., 2024). Contemporary corporate motivation for engagement with and investment in environmental responsibility is rooted in legitimisation, compliance, stakeholder satisfaction and the potential financial benefits of environmental investment. The financial sentiment is inclined to the original goal of the business corporation, which, according to Friedman (1970), is to make a profit for the owners of the business whilst complying with the rules that guide business. In his New York Times article, Friedman wrote his doctrine of corporate social responsibility wherein he opined that the sole desires of the owners of business are:

> *"There is one and only one social responsibility of business – to use its resources and engage in activities designed to increase its profits so long as it stays within the rules of the game, which is to say, engages in open and free competition without deception or fraud." (Friedman, 1970, p. 17)*

However, with time, consumers, shareholders, and modern business owners have begun shifting their ideology toward the corporation's objectives. Whilst hoisting profit as the central focus in line with Friedman's philosophy, contemporary corporate owners appear to have seen the need to expand the rule of compliance enunciated by Friedman. Perhaps Friedman's (1970) doctrine may also have a bearing on the modern stakeholder theory of business and the objective of business, which expands the objective of business to encapsulate other appendages that together nurture the business value and hence the business capacity to make a sustainable profit. It can thus be argued why many scholars and critics may have viewed Friedman's doctrine as solely inclined to profit. However, a critical deconstruction of the doctrine's facet "*without deception*" would suggest accommodating stakeholders' views of corporate responsibility. It can thus be logically argued that a business that operates "without deception" would not offer products and services whose operations undermine social accountability and environmental responsibility – the preservation of nature and society. This is because products and services produced and sold for profit purposes whilst trampling on the environment and society's wellbeing are undeniably tantamount to corporate deception – which, when decoupled, would suggest that the products and services do not offer sustainable value to the consumers, stakeholders and the society at large.

Whilst a few years ago, it did seem like global corporate environmental responsibility campaigns and advocacy were regarded as costly engagements that bring little or no value for business owners, but, currently, environmental and social responsibility has grown beyond being optional for corporate considerations to being a modern corporate competitive and resilient strategy. Accordingly, sustainability strategies of the modern corporation pervade social, environmental and governance strategies, which have been proven by research as good drivers of corporate financial and competitive value (Xie et al., 2019; Ghosh & Singh, 2025). According to empirical research, short-term and long-term values are implicit in corporate social and environmental engagement and investment (Bhuiyan, 2025).

Existing research has focused on diverse social and environmental variables and their catalysing effect on financial value. This paper contributes to existing literature and focuses slightly on a different stance on one element of environmental responsibility (which is investment in renewable energy) and gauging their potential payback period.

The problem of this paper, thus, is that although renewable energy is the popular, fast-growing renewable energy alternative globally, some countries and regions appear to be slow in the adoption and installation of renewable energy. Amongst others, one of the top reasons adduced for the slow adoption of renewable energy in some countries and regions draws from the lack of or skeletal information for investors and consumers about the cost of building and operating renewable energy and the period of cost recovery (Firdaus & Amrina, 2025).

RESEARCH OBJECTIVE

Therefore, based on the above problem, this paper aims to use the literature review to estimate the financial payback period for renewable energy investment. Thus, it encourages the financial investment of renewable energy and the use of renewable energy to assist in sustainable energy adoption. The results of this study will are expected to help consumers and investors facilitate renewable energy investment decisions.

LITERATURE REVIEW

This section presents a brief review and discussion of the key concepts contained in the title and objective of this article. The main concept is the financial payback period (FPP) of renewable energy investments. Although the FPP is the key concept, the energy payback period (EPBP) is also connected to the concept of the financial period; hence, EPBP is also mentioned in this paper to buttress the discussion on the estimation of FPP.

Conceptual Review

Before proceeding to the literature review, this section presents a brief conceptual review of the central concept that is pivotal to the objective of this paper, namely, the payback period. Although a novice investor may hastily acquire an asset such as renewable energy asset, however, the growth in cost-benefit awareness, even among average education citizens, makes it imperative to present a guide that provides a guided estimate of a window of the period within which investors in renewable energy may expect to realise their cost of investment in renewable energy. Understanding the concept of a payback period of renewable energy investment is much needed within the current dispensation when many households and rural areas patronise renewable energy in search of a more constant and cheaper energy source.

Financial Payback Period (FPP) and Energy Payback Time (EPBT)

The payback period can be reached at the time when financial returns from a renewable energy investment are equal to the initial investment. The total cost of renewable energy investment over the yearly cash flows (annual total cost saving) can be used to compute a basic payback period. A straightforward technique for assessing the investment's feasibility and worthwhileness is the payback period. In renewable energy investment analysis, the project's overall cost includes the setup fee as well as any component replacements that may be required. The annual cash flow represents the total cost savings of energy use compared to traditional energy consumption (Mahlia & Chan, 2011). To calculate the financial payback period of investments in renewable energy, we can use the following formula:

$$\text{FPP} = \frac{TCRI}{ACF} \qquad (1)$$

Where:

TCRI = total cost of renewable energy investment;

ACF = annual cash flow from renewable energy investment.

However, a discounted cash flow method will be more appropriate to generate a better view of when an investment in renewable energy will provide the payback to the cost of investing in renewable energy. In addition, it will be more conservative and prudent to ensure that the analysis includes the foreseeable cost of parts replacement and servicing to the initial cost.

Hence, the modified formula for the payback period to renewable energy investment after consideration of discounted cash flow and additional cost of parts replacement and servicing would be:

$$\text{FPP} = \frac{TCRI}{\sum\frac{DACF_n}{(1+r)^n} + \ldots\ldots \frac{DACF_Z}{(1+r)^Z}} \qquad (2)$$

Where:

TCRI = total cost of renewable energy investment;

DACF= discounted annual cash flow from renewable energy investment;

year 0 (zero) or period 0(zero) of discounted cash flow (DACF);

z = (last year or last period of DACF).

On the other hand, the Energy Payback Time (EPBT) is crucial when evaluating various renewable energy systems. It shows how long it takes the renewable energy to produce as much energy as it takes to produce it. Estimating the system's embodied energy is necessary to calculate the energy payback period (Bhandari et al., 2015)

Accordingly, calculating and determining the payback periods is a basic financial tool for comparing renewable energy options in renewable energy investment and usage. Therefore, an investor or user of renewable energy can determine the payback period for an investment in renewable energy by understanding all the cash flows for the investment spare parts service, the financing costs and available budgets for energy needs. After analysing the payback period, the potential financial gain can be concluded from a renewable energy investment if the renewable energy lifetime exceeds its payback period (Breyer et al., 2009). For this important decision imperative, this paper provides a glimpse into the Financial Payback Period (FPP) of renewable energy investments to assist investors and users in investing and using renewable energy wisely to balance the energy provision need with the cost-benefit trade-off, which enables the selection of option that provides renewable energy which returns the cost of investment faster than others.

Empirical Literature Review

According to Kashani et al. (2015), finding the right time to install a particular renewable energy system and determining the worth of well-timed investments require an appropriate investment valuation method. Although the ability to handle uncertain investment timing is provided by real options analysis, the current real options models have theoretical limitations when making decisions regarding investments in building energy improvements. Kashani et al. (2015) developed a new real options model to assess investment options for renewable energy systems under uncertainty while also addressing the theoretical shortcomings of existing real options models. This model, which is both theoretically sound and practically helpful, is specifically designed for the context of building energy improvement investment decision-making (Kashani et al., 2015). In related research, Gorshkov et al. (2018) created a mathematical model to calculate the discounted payback period of investments made to lower the energy resources required for building development. The obtained equations enable the computation of the estimated payback period for energy-saving investments accounting for the size of the investment, the estimated or actual value of the energy-saving effect achieved in the dynamics of energy carriers tariff growth, the discounting of future cash flows, and a loan repayment period and value. By comparing different energy-saving options according to their economic feasibility, the suggested mathematical model makes it possible to select the best option in a timely and effective manner.

Bhandari et al. (2015) performed a meta-analysis and systematic review of embedded energy payback time and energy return on energy invested for thin-film and crystalline silicon photovoltaic systems. They found that the embedded energy variation among the various PV types was larger than the efficiency and performance ratio variation. This suggests that embedded energy rather than efficiency will be the primary determinant of the relative ranking of the EPBT of various PV technologies in the future. In search of energy payback time and using the International Energy Agency's inventory data as a guide, Tsuchiya et al. (2020) examined the energy payback time (EPBT) derived from using PV systems and found an inadequate performance. The EPBTs significantly outperformed the expected value-based solar radiation calculations based on actual power generation at the sites. Energy recovery was impossible at one location because the EPBT even outlasted the PV panel's lifespan. Regarding the energy return on investment (EROI), it was clear that the investment income was not enough to pay for ongoing operating expenses, indicating a negative return on investment. On the other hand, the low and erratic demand for power in these regions seemed to make diesel power generation more appropriate. A higher demand for electricity, as well as better management and maintenance, would be necessary for a more effective PV system to function (Tsuchiya et al., 2020). Other researchers apply the machine learning model toward estimating the payback time. For instance, Singh et al. (2024) applied an optimized XGBoost machine-learning model to forecast solar power generation. Their paper presented a novel approach to estimate the payback period of a 10MW solar power plant. Their approach began by predicting the temperature and Global Horizontal Irradiance (GHI) at a temporal resolution of one hour. They applied the predicted values to calculate the expected power output of a single solar panel with the specified properties. Thereafter, their derived expected output was scaled for the entire plant to estimate the total power generated for the entire year at an hourly resolution. Plant investments consider several expenses, such as panels, land acquisition, upkeep, wiring, and equipment. Compound interest on the initial investment (compound monthly) and monthly loan repayments were also considered. By considering various scenarios, they calculated the payback period by adjusting for variables like interest rates, land costs, panel efficiency and maintenance costs (Singh et al., 2024).

Delapedra-Silva et al. (2022) examine the literature on the financial assessment of RES projects published between 2011 and 2020 and critically evaluate the reviewed works. Four techniques were used to evaluate RES projects: (i) levelized electricity costs, (ii) return on investment approach, (iii) real options analysis, and (iv) traditional metrics based on net present value internal rate of return and payback period. A quantitative analysis was conducted considering factors such as the authors' relevance productivity by nation and the journals most pertinent to these groups. The primary features of the five most cited articles in each group were then qualitatively examined. The findings of Delapedra-Silva et al. (2022) demonstrate that the more conventional approaches are still frequently employed for RES project financial evaluation. However, to address the intricate aspects of financial evaluation and comparison of RES projects, levelized cost and real options techniques are becoming more vital for application (Delapedra-Silva et al., 2022). Others, such as Shekar et al. (2025), examine how building orientation affects the viability of residential rooftop photovoltaic systems in the Arctic climate, supporting the European Union's call for solar-ready buildings that are tailored to the region through the innovative use of 3-dimensional modelling solar simulation and thorough economic analysis. The study shows how discount rates and orientation greatly impact the system's economic feasibility. According to the economic analysis, grid parity in the Levelized Cost of Electricity and positive Net Present Value for all azimuths are found for solar PV installation preferences ranging from 0° to 359°, and discount rates are between 3 and 7%. For azimuths in the 70°–270° range at a 3 percent discount rate and in the 120°–200° range at a 5 percent discount rate, the results also demonstrate favourable Discounted Payback Periods.

The policy implications of installing residential photovoltaic (PV) solar systems in Ghana and Jamaica were examined by Shand et al. (2025), who also emphasized the significance of policy frameworks in influencing the sustainable energy landscape. Using a multipronged approach, the study assesses the feasibility, economic viability and potential obstacles to residential PV solar adoption by combining a risk assessment with System Advisor Model (SAM) analysis, which shows promising energy production potential in both regions with significant economic benefits. According to financial evaluations, residential PV systems can provide affordable energy solutions with competitive payback periods and positive returns on investment. Based on some assumptions, Firdaus and Amrina (2025) estimated that an LCOE amounting to 73.05 US$/MWh would have a payback period of 9 years, with an Internal Rate of Return in the range of 5.88%. They found that the Net Present Value (NPV) of the same project's net cash flow, which is discounted at an assumed WACC of 5%, would be US$0.35 million. They conclude that additional assumptions may be added to compute the Return on Investment (ROI). They conducted the analysis with assumed straight-line depreciation for the main solar assets running over 30 years, with the power inverters running over a 12-year life span. They further assumed that the revenue gained is accumulative and would be invested in an account with a simple interest earning of 2% annually (Firdaus & Amrina, 2025).

RESEARCH METHOD

The key aim of this study is to use the literature to identify the payback period for renewable energy investment and focus on PV solar energy systems for households and rural areas. The paper applied the quasi-systematic literature review and/or assessment approach to achieve this aim. Borrowing from the work of Peterson et al. (2008), this approach involves indicating research questions, engaging in a literature search and selecting closely related past studies to retrieve the relevant data to map the results in alignment with the research objective and questions. The quasi-systematic review (or semi-systematic review) integrates some aspects of both systematic and non-systematic (a middle ground approach), which offers a more structured review than a conventional narrative literature review, yet by being less rigid than would be required for a full-fledged systematic review (Snyder, 2019; Rodrigues et al., 2013). A quasi-systematic review is often applied when researchers attempt to evaluate issues around a rapidly evolving study field with little or no established protocol. Table 1 presents the article search criteria and index where searched. The two key search indices used were Google Scholar and Google. Of these, 40 related literatures were scanned, and 24 were downloaded. A total of 12 articles were scanned in Google, and out of these, 7 were downloaded.

Table 1. Articles Search

Literature source	Number of literatures scanned	Selection criteria for scanning	Articles downloaded for screening
Google Scholar	40	Mentions payback in the title	24
Google	12	Mentions payback in the title	7

The following questions assisted in screening the prior articles for inclusion:

- Did the article contain a payback period on the title;
- Did the article contain specific findings on the number of Financial Payback Period;
- Did the article contain an Energy Payback Time (EPBT) specific number in the findings.

Table 2 presents the article screening – selection and dropping criteria. A total of 31 were screened (with a payback focus), 13 had a specific payback period or time indicated, and 18 were screened and dropped as they had no specific payback period. Hence, a total of 13 articles were selected for use.

Table 2. Articles Screening

Renewable energy technology type reviewed	Total articles screened for payback focus	Articles with specific payback period or time	Articles without specific payback period or time (dropped)	Total article used
The Solar PV technology (for residential)	10	6	4	6
The Solar PV technology (large scale or utility scale)	12	4	8	4
Off-grid photovoltaic systems (for rural areas)	9	3	6	3
Total	31	13	18	13

Table 3 shows the criteria under which articles were finally housed according to the sub-sections of renewable energy type, which is divided into financial payback and energy payback for three classes of PY technology renewable energy (the Solar PV technology for residential; the Solar PV technology (large scale or utility scale); and the off-grid photovoltaic systems (for rural areas).

Table 3. Review Criteria

Renewable energy technology type reviewed	Associated Financial Payback Period (FPP)	Associated Energy Payback Time (EPBT)	Final selected literature
The Solar PV technology (for residential)	ü	ü	6
The Solar PV technology (large scale or utility scale)	ü	ü	4
Off-grid photovoltaic systems (for rural areas)	ü	ü	3
Total Number of Final Selected Literature			13

FINDINGS AND DISCUSSION

Table 4 presents the findings from the review of the selected literature to understand the expected financial payback period of renewable energy investment. While examining the selected literature, not only was the Financial Payback Period (FPP) for solar PV renewable energy technology unravelled, but the literature also provided the associated Energy Payback Time (EPBT). Within the scope of this paper, only three solar PV technologies financial and energy payback searches were undertaken. These are Solar PV technology (for residential), Solar PV technology (large scale or utility-scale), and photovoltaic systems (for rural areas). Based on the thirteen (13) empirical literature whose findings were used, the data in Table 4 indicate that for solar PV technology (residential), there is an expected financial payback period (FPP) of between 7 – 15 years, which gives an average of 12 years as shown on the graph in (Figure 1).

According to the data in Table 4 and Figure 1, Solar PV technology (residential) has an expected financial payback period (FPP) of 7 – 15 years, which gives an average of 12 years, as shown in Figure 1. Similarly, there is an associated Energy Payback Time (EPBT) of 1 – 4 years, giving an average EPBT of 2.5 years. Furthermore, for solar PV technology (large scale), there is an expected FPP of between 3 -12 years and an average of about 7.5 years. There is an associated Energy Payback Time (EPBT) of 1 – 5 years, giving an average EPBT of 3 years. In the same vein, for off-grid photovoltaic systems (for rural areas), there is an expected FPP of 4 – 6 years, which gives an average of 5 years. Similarly, there is an associated Energy Payback Time (EPBT) of 2 – 4 years, giving an average EPBT of 3 years.

Table 4. Findings from the Literature Indicating Payback Periods

Renewable energy technology type	Associated Financial Payback Period (FPP)	Associated Energy Payback Time (EPBT)	Sources
The Solar PV technology (for residential)	Around 7 – 15 years	Around 1 – 4 years	Raw (2025) Soly (2025) Tesla (2025) Zientara, B (2025 Jelle et al. (2012) Kato et al (1998)
The Solar PV technology (large scale or utility scale)	Around 3–12 years	Around 1– 5 years	Moore et al (2008) Bhandari et al (2015) Sewchurran & Davidson (2021)
Off-grid photovoltaic systems (for rural areas)	Around 4 – 6 years	Around 2 – 4 years	Tsuchiya et al (2020) Feron et al (2016) Breyer et al (2009)

Following the findings of Kashani et al. (2015), it may not be easy to find the right time to install a specific renewable energy option. In addition, determining the feasibility of well-timed investments requires using an appropriate investment valuation method. However, not all current or potential investors and users of renewable energy are conversant about the time it takes a renewable energy investment to payback financially or energy-wise. Hence, this paper contributes to the environmental management accounting literature by rummaging through the literature to unravel the payback period of renewable energy, focusing on PV energy systems for households and rural areas.

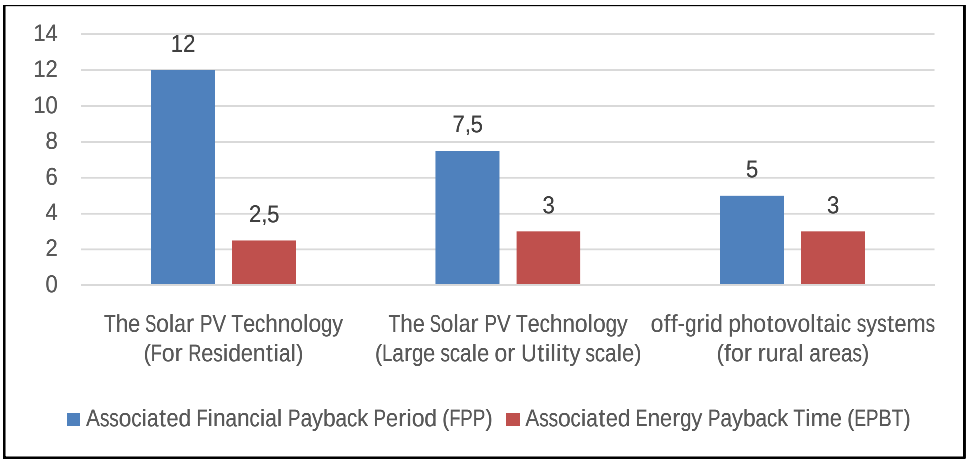

Figure 1. Financial & Energy Payback Periods of PV Investments

In conclusion, therefore, given the richness of the vast land area, rich solar radiation, and international support for green energy usage, the adoption and usage of photovoltaics (PV) as a source of renewable electricity energy supply is fast spreading in developing countries (Tsuchiya et al., 2020). However, it does not necessarily follow that abundant solar radiation, vast land area, and foreign support may translate to a positive Financial Payback Period (FPP) and Energy Payback Time (EPBT). In some cases, like in the empirical case of Tsuchiya et al. (2020), there is evidence that some solar energy investments in vast land areas within huge solar radiation areas and with overseas support may not automatically achieve a positive Financial Payback Period and Energy Payback Time.

CONCLUSION

This paper provides an overview and insight into what potential investors and users of renewable energy might expect when planning renewable energy investment and usage. Findings from the empirical literature show that solar PV technology (residential) may give a financial payback period of around 7 – 15 years with an associated Energy Payback Time of around 1 – 4 years. Solar PV technology (large scale) is expected to give a financial payback period of around 3 -12 years with associated Energy Payback Time (EPBT) of around 1 – 5 years. In the same vein, the off-grid photovoltaic systems (for rural areas) are expected to give a financial payback period of 4 – 6 years with associated Energy Payback times of 2 – 4 years.

This paper contributes uniquely to the environmental accounting literature as it offers a novel presentation not often common in accounting literature, presenting financial and energy payback for users, investors, academia, and researchers. Given that this paper focused only on the solar energy aspect of financial payback and energy payback, the paper offers an agenda for further researchers to expand this review research to another aspect of renewable energy. It is also important for academics in business schools to integrate renewable energy financial payback time and energy payback period in sustainable finance lectures and projects to enhance balanced financial and investment insights regarding renewable energy investment by managers in business classes.

4 References

Bhandari, K. P., Collier, J. M., Ellingson, R. J., & Apul, D. S. (2015). Energy payback time (EPBT) and energy return on energy invested (EROI) of solar photovoltaic systems: A systematic review and meta-analysis. *Renewable and Sustainable Energy Reviews*, *47*, 133-141. https://doi.org/10.1016/j.rser.2015.02.057

Bhuiyan, T. (2025). Impact of ESG (Environmental, Social, Governance) on the Financial Performance of US Firms: A Sector Based Approach (Doctoral dissertation, Murdoch University). Retrieved from https://researchportal.murdoch.edu.au/view/pdfCoverPage?instCode=61MUN_INST&filePid=13178586940007891&download=true

Breyer, C., Gerlach, A., Hlusiak, M., Peters, C., Adelmann, P., Winiecki, J., ... & Gashie, W. (2009, September). Electrifying the poor: highly economic off-grid PV systems in Ethiopia – a basis for sustainable rural development. In *Proceedings 24th European Photovoltaic Solar Energy Conference, Hamburg* (pp. 21-25). Retrieved from https://www.researchgate.net/publication/303158602_Electrifying_the_poor_Highly_economic_off-grid_PV_systems_in_Ethiopia_-_a_basis_for_sustainable_rural_development

Delapedra-Silva, V., Ferreira, P., Cunha, J., & Kimura, H. (2022). Methods for financial assessment of renewable energy projects: A review. *Processes*, *10*(2), 184. https://doi.org/10.3390/pr10020184

Feron, S., Heinrichs, H., & Cordero, R. R. (2016). Sustainability of rural electrification programs based on off-grid photovoltaic (PV) systems in Chile. *Energy, Sustainability and Society*, *6*, 1-19. https://doi.org/10.1186/s13705-016-0098-4

Firdaus, A., & Amrina, U. (2025). Estimating the cost of producing grid-connected solar PV in Indonesia. In *BIO Web of Conferences* (Vol. 159, p. 03004). EDP Sciences. https://doi.org/10.1051/bioconf/202515903004

Friedman, M. (1970). A Friedman doctrine – The Social Responsibility of Business Is to Increase Its Profits, *New York Times Magazine,* September, 13. Retrieved from https://www.nytimes.com/1970/09/13/archives/a-friedman-doctrine-the-social-responsibility-of-business-is-to.html

Friedman, M. (2007). The Social Responsibility of Business Is to Increase Its Profits. In: Zimmerli, W.C., Holzinger, M., Richter, K. (eds) Corporate Ethics and Corporate Governance. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-70818-6_14

Ghosh, M., & Singh, M. P. (2025). Unveiling sustainable practices in financial institutions: A bibliometric analysis cum meta-analytical review on enhancing financial performance. *Corporate Social Responsibility and Environmental Management*, *32*(2), 2295-2316. https://doi.org/10.1002/csr.3064

Gorshkov, A. S., Vatin, N. I., Rymkevich, P. P., & Kydrevich, O. O. (2018). Payback period of investments in energy saving. *Magazine of Civil Engineering*, 2(78), 65-75. https://doi.org/10.18720/MCE.78.5

Jelle, B. P., Breivik, C., & Røkenes, H. D. (2012). Building integrated photovoltaic products: A state-of-the-art review and future research opportunities. *Solar Energy Materials and Solar Cells*, *100*, 69-96. https://doi.org/10.1016/j.solmat.2011.12.016

Kashani, H., Ashuri, B., Shahandashti, S. M., & Lu, J. (2015). Investment valuation model for renewable energy systems in buildings. *Journal of Construction Engineering and Management*, *141*(2), https://doi.org/10.1061/(ASCE)CO.1943-7862.0000932

Kato, K., Murata, A., & Sakuta, K. (1998). Energy pay-back time and life-cycle CO2 emission of residential PV power system with silicon PV module. *Progress in Photovoltaics: Research and Applications*, *6*(2), 105-115. https://doi.org/10.1002/(SICI)1099-159X(199803/04)6:2%3C105::AID-PIP212%3E3.0.CO;2-C

Mahlia, T. M. I., & Chan, P. L. (2011). Life cycle cost analysis of fuel cell-based cogeneration system for residential application in Malaysia. *Renewable and Sustainable Energy Reviews*, *15*(1), 416-426. https://doi.org/10.1016/j.rser.2010.07.041

Moore, L. M., & Post, H. N. (2008). Five years of operating experience at a large, utility-scale photovoltaic generating plant. *Progress in Photovoltaics: Research and Applications*, *16*(3), 249-259. https://doi.org/10.1002/pip.800

Petersen, K., Feldt, R., Mujtaba, S., & Mattsson, M. (2008, June). Systematic mapping studies in software engineering. In *Proceedings of the 12th international conference on Evaluation and Assessment in Software Engineering* (pp. 68-77). Retrieved from https://dl.acm.org/doi/abs/10.5555/2227115.2227123

Raw, A. (2025) Average payback period for Solar Panes. Retrieved from https://www.dwellow.co.uk/blog/solar-panel-payback-period

Rodrigues, S. A., dos Santos, R. P., Arnaud, L., & de Souza, J. M. (2013). Critical Factors in Mobile Learning: A Quasi-Systematic Review. *International Association for Development of the Information Society.* Retrieved from https://files.eric.ed.gov/fulltext/ED562290.pdf

Sewchurran, S., & Davidson, I. E. (2021). Technical and financial analysis of large-scale solar-PV in eThekwini Municipality: Residential, business and bulk customers. *Energy Reports*, *7*, 4961-4976. https://doi.org/10.1016/j.egyr.2021.07.134

Shand, J., Glakpe, E., & Ivey, C. (2025). Policy implications of implementing residential PV solar energy systems in developing regions. *Energy Policy*, *196*, 114414. https://doi.org/10.1016/j.enpol.2024.114414

Shekar, V., Abraham, D., Caló, A., & Pongrácz, E. (2025). Determining the optimal azimuth for solar-ready buildings: Simulating for maximising the economic value of solar PV installations in Lapland, Finland. *Renewable Energy*, *241*, 122357. https://doi.org/10.1016/j.renene.2025.122357

Singh, T. R., Prajapati, A. H., & Kumar, N. (2024, December). Dynamic Payback Period Estimation for Solar Power Plants Through ML Based Solar Power Generation Forecasts. In *2024 International Conference on System, Computation, Automation and Networking (ICSCAN)* (pp. 1-5). IEEE. http://dx.doi.org/10.1109/ICSCAN62807.2024.10894689

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of business research*, *104*, 333-339. https://doi.org/10.1016/j.jbusres.2019.07.039

Solly (2025). What is the average payback period of solar panels in South Africa?. Retrieved from https://soly.co.za/solar-panels/payback-period/#:~:text=In%20practice%2C%20it%20may%20take,on%20the%20factors%20mentioned%20above

Tesla (2025). Solar Panel Payback Period. Retrieved from https://www.tesla.com/learn/solar-panel-payback-period

Tsuchiya, Y., Swai, T. A., & Goto, F. (2020). Energy payback time analysis and return on investment of off-grid photovoltaic systems in rural areas of Tanzania. *Sustainable Energy Technologies and Assessments*, *42*, 100887. https://doi.org/10.1016/j.seta.2020.100887

Xie, J., Nozawa, W., Yagi, M., Fujii, H., & Managi, S. (2019). Do environmental, social, and governance activities improve corporate financial performance?. *Business Strategy and the Environment*, *28*(2), 286-300.

Zientara, B (2025). Solar panel payback period and ROI. Retrieved from https://www.solarreviews.com/blog/how-to-calculate-your-solar-payback-period