IJFBS
Finance & Banking Studies

Finance & Banking Studies

IJFBS, VOL 10 NO 3 ISSN: 2147-4486
Contents available at *www.ssbfnet.com/ojs*

https://doi.org/10.20525/ijfbs.v10i3.1288

A Case Study of Green Energy Roofs in Taiwan Using Financial Analyses

Meng-Yi Liu
Department of Risk Management and Wealth Planning, Takming University of Science and Technology, Taipei, Taiwan

Dan Lin
Corresponding Author: Department of Banking and Finance, Takming University of Science and Technology, Taipei, Taiwan

Abstract
As part of the low-carbon policy and development in Taiwan, the Bureau of Energy introduced the "Green Energy Roofs Project" in 2017, which encouraged homeowners to install green energy roofs. However, the incentives of homeowners and solar photovoltaic operators to participate in this Project were low. The aim of this study is to propose and evaluate alternative models for investing green energy roofs. The contributions of this study are that, first, we consider factors such as risk management schemes and crowdfunding that have not been considered in evaluating green energy roofs project. In addition, this study provides a solution to Taiwan government's current dilemma about how to encourage homeowners to install green energy roofs. This study adopts five common investment appraisal methods (including payback period, discounted payback period, net present value, internal rate of return and profitability index) to evaluate four different models for investing green energy roofs. The results show that when homeowners are fully responsible for installation costs of green energy roofs with partial funds borrowed from banks and with consideration of risk management, the homeowners have better investment returns. Therefore, the Taiwan government could consider the alternative strategy proposed in this study for promoting green energy roofs so that the country can move a bigger step forward towards the goal of being nuclear-free.

Keywords: *Green Energy Roofs; Investment Decisions; Solar Photovoltaic System*

JEL Classifications: *G31; G38*

Introduction

Environmental concerns have become a worldwide issue that increasingly led to various environmentally friendly practices. Green energy roof technology is one way of efficiently utilizing natural resources and solar energy to reduce environmental impact of a building. The Bureau of Energy in Taiwan introduced the “Green Energy Roofs Project” in 2017. The goal of Taiwan government is to have energy supply from renewable resources by 20 percent in 2025. In addition, the Taiwan government aims to install at least 3 gigawatts of roof solar power generation capacity across the country (Executive Yuan, 2019). The Green Energy Roofs Project encourages homeowners to generate their own electricity and install local distributed energy systems (DES), which provide better power reliability and resilience, less emissions and higher cost efficiency (Liao, 2017).

The principle of Green Energy Roofs Project is “zero funding from homeowners and zero subsidies from governments” (Bureau of Energy, 2019). The Project is executed by local authorities serving as a platform that consolidates homeowners who are willing to install green energy roofs and qualified solar photovoltaic operators who will rent the roofs of homeowners, install solar photovoltaic energy power facilities and are responsible for maintaining the facilities. The homeowners, on the other hand, will sell/supply any excess power to the grid under a feed-in tariff, which according to the principle of the “Green Energy Roofs Project” will be kept at a fixed rate for 20 years since the date of installation.

Green energy roofs have many beneficial effects such as having nuclear-free homeland, carbon sequestration, improved air quality, stormwater management, seasonal energy savings, aesthetic city landscape, stable electricity supply, minimizing the urban heat island effect, and enhancing the membrane longevity of the rooftop (Feng and Hewage, 2018). Many leading cities worldwide, such as Hong Kong, Melbourne, Toronto, and Berlin, have been encouraging the construction of green energy roofs through initiative programs and policies by municipalities and local governments that typically provide financial support or tax abatements (Shin and Kim, 2019).

However, a green energy roof is not without its flaws. For example, it adds extra weights to the building structure, may cause the membrane to fail, involves high construction and maintenance costs, may cause water leakage problems, and is highly affected by weather conditions (Shin and Kim, 2019). Therefore, despite the perceived benefits of “zero funding from homeowners”, the incentives of homeowners to participate in this Green Energy Roofs Project in Taiwan are low. The solar photovoltaic operators also have a low incentive to participate in this Project because of low profit margin.

Wu and Smith (2011) conduct a case study on the economic benefits (in terms of return on investment, ROI) of applying a green roof on a future pharmacy building at the University of Utah. The authors find that although green roofs have larger initial capital investment than alternatives such as black roofs and reflective roofs, the green roofs have positive net present value and 100% ROI, and are better investment than the other roof alternatives. Shin and Kim (2019) adopt a benefit-cost analysis of the green roof initiative projects in Jung-hu, Seoul by considering eight benefit and six cost items. They find that green roof initiative projects have economic viability. However, factors including climate, urban form, economic conditions and government regulations can affect the results. Mahdiyar et al. (2020) analyze the financial feasibility of green roofs installation in Kuala Lumpur, Malaysia using Monte Carlo simulation where social and private factors are considered and the net present value and discounted payback period across various scenarios are analyzed. The authors conclude that the green roofs are financially feasible if all private benefits are attainable and suggest that as green roofs have social financial benefits, the government should provide incentives for green roof installers, for example, by providing partial financial support for the initial costs.

Accordingly, the objective of this study is first to analyze the benefits and perceived problems with the current Green Energy Roofs Project. Then, we propose alternative investment models for green energy roofs and conduct financial analyses to compare these models. This study adds to the literature by considering factors such as risk management schemes and crowdfunding that have not been considered in evaluating the feasibility of green energy roofs projects in previous research. Finally, a suggestion of the best model is made.

Based on five common investment appraisal methods (including payback period, discounted payback period, net present value, internal rate of return and profitability index), we find that when homeowners are fully responsible for the installation costs of green energy roofs with partial funds borrowed from banks and insurance incorporated for managing risks, the homeowners get better investment returns. Therefore, this study makes a contribution by providing a solution to Taiwan government's current dilemma about how to encourage homeowners to install green energy roofs. The solution can also help the government achieve its goal of becoming nuclear-free by 2025.

Literature Review

The Green Energy Roofs Project

The Green Energy Roofs Project adopts "zero funding from the public, zero subsidies from governments". The Project is carried out firstly by local governments to select qualified solar photovoltaic operators who can assist homeowners to install solar photovoltaic systems on their roofs. Homeowners who generate power via the rooftop solar photovoltaic systems can use the generated power themselves first and sell/supply any excess power to the grid under a feed-in tariff, which according to the principle of the "Green Energy Roofs Project" will be kept at a fixed rate for 20 years since the date of installation.

Benefits of Green Energy Roofs Project

The benefits of Green Energy Roofs Project can be analyzed from three perspectives, the homeowners, the solar photovoltaic operators, and the government. The benefits to participating homeowners include, first, before installing green energy roofs, the structural safety of the roof will be checked and enhanced. Secondly, after installing the green energy roofs, the indoor temperature can be lowered by 2 to 3 degrees Celsius. Thirdly, there is no down payment when installing the green energy roofs. Fourthly, solar photovoltaic energy power facilities are installed and guaranteed by qualified operators that are selected by local governments. Lastly, smart meters are installed at the same time to keep homeowners informed about power consumption and therefore can help them conserve energy (Liao, 2017).

As for the solar photovoltaic operators, because the Project is backed by the central government policy, they can become authorized operators and increase business opportunities. In addition, feed-in tariffs can ensure reasonable profit income for solar photovoltaic operators.

From the government's perspective, this Project helps Taiwan move one step forward towards the goal of becoming nuclear-free by 2025. The Project can also ensure stable power supply. As solar power is generated mostly at midday, it can help ease out the high power demand during that time. In addition, green energy production can help improve air quality by reducing the usage of fossil-fuel burning generators and create more investment and job opportunities.

Perceived Problems with Green Energy Roofs Project

There are several reasons for low intention to participate in the Green Energy Roofs Project by homeowners and solar photovoltaic operators. From the perspective of homeowners, the first reason is that the electricity prices are relatively low in Taiwan compared to that in other countries (Liang, 2017). Hence, there is little incentive for the public to install renewable energy systems to lower their electricity bills. The electricity prices in Taiwan are based primarily on the cost of power generation, whereas in countries like Germany, feed-in electricity tariffs are introduced to promote clean energy (Chang, 2020).

The feed-in tariffs in Taiwan are also falling gradually every year. Therefore, the incentives of homeowners to install green energy roofs are lowered. Moreover, despite the promise of structural safety check of roofs before installation, homeowners fear that the prolonged heavy weight of green energy roofs may affect the safety of building structures and cause leakage problems. After installing the green energy roofs, the original lifestyle of homeowners may also be affected because they can no longer plant trees and flowers or hang clothes on their roofs. Some homeowners are even concerned about the "feng shui" of their houses being disrupted by the green energy roofs.

As for solar photovoltaic operators, they prefer large-scale commercial projects to Green Energy Roofs Project which is targeted at residential homeowners. The reason is that large-scale commercial green roof projects are more profitable in economic terms due to fixed personnel and administration costs.

Accordingly, the Taiwan government faces some obstacles in promoting the Green Energy Roofs Project to homeowners and solar photovoltaic operators. Prior study by Chen and Liu (2014) analyzes four investment models for green energy roofs including: (1) installation costs fully paid by homeowners; (2) installation costs paid by homeowners with 20% as down payment and 80% being borrowed from banks; (3) 10% of the installation costs each paid by homeowners and solar photovoltaic operators, and the rest of the costs (80%) being financed through bank loans taken out by solar photovoltaic operators; and (4) installation costs fully paid by solar photovoltaic operators. To add to the literature, this study considers the option of crowdfunding in green energy roofs investment. Also, this study considers risk management schemes in investment models that are closer to real investment situations. In the next section, we propose three alternative models for encouraging the installation of green energy roofs in addition to the original model under the Green Energy Roofs Project. Then, these investment models are evaluated based on five common investment appraisal methods.

Methods

Four Investment Models of Green Energy Roofs

This study compares four investment models of green energy roofs, whereby the first model follows from the Green Energy Roofs Project. The other three models are proposed by this study and incorporate the risk management concepts in the models. Table 1 provides a summary description of the four models.

Model 1

Model 1 is the Green Energy Roofs Project implemented by Taiwan's Bureau of Energy. In this Project, the installation costs of green energy roofs are paid by solar photovoltaic operators. By providing the roofs, homeowners can gain a certain percentage (about 10 percent) of the feed-in tariff. The concept of this model can be exemplified by homeowners "lending out" their roofs to solar photovoltaic operators who gain from feed-in tariff, that will be kept at a fixed rate for 20 years since the date of installation. The homeowners receive "rental payment" as a percentage of feed-in tariff.

Model 2

The second model proposes that the installation costs of green energy roofs are 100% paid by homeowners so that the homeowners are compensated 100% for the renewable electricity they supply to the grid. To lower the risk of property loss to home building or solar panels due to natural disasters that is also associated with the risk of property damage or personal injury to third parties, this model incorporates risk management strategies of property insurance and third-party property damage insurance. This can reduce the economic losses due to damages to green energy roofs caused by natural disasters.

Model 3

This model also proposes that the installation costs of green energy roofs are 100% paid by homeowners. However, as installation of green energy roofs may be costly to homeowners, this model proposes a more feasible solution. That is, of the total amount of installation costs, 20% are paid as a down payment and the remaining 80% of the costs are borrowed from financial institutions at current low interest rates. In order to raise the loan-to-value ratio and lower the interest rates for homeowners, this study proposes a "Solar Life Insurance" (that is, decreasing term life insurance for green energy roof loan). This insurance serves as a risk protection for financial institutions and can therefore increase their willingness to lend out money to homeowners. The decreasing term life insurance pays out less over time as the total balance of the bank loan decreases over time and will be paid off in full at the end of the term. In addition, in model 3, we propose to include risk management strategies of property insurance and third-party property damage insurance to reduce the economic losses due to damages to green energy roofs caused by natural disasters.

Model 4

This model is a combination of model 1 and model 3 whereby the installation costs are paid by third parties (not homeowners or solar photovoltaic operators) through crowdfunding. After deducting the maintenance fee paid to solar photovoltaic operators and risk management expenses (including property insurance and third-party property damage insurance), feed-in tariffs are then distributed to homeowners who "lend out" their roofs and investors who put the money into the installation of green energy roofs.

Table 1: Summary of four investment models for green energy roofs

Model	Descriptions
Model 1	Installation costs of green energy roofs are paid by solar photovoltaic operators. Homeowners gain a certain percentage of feed-in tariffs.
Model 2	Installation costs of green energy roofs are fully paid by homeowners. Homeowners are compensated for the renewable electricity they supply to the grid. Property insurance and third-party property damage insurance are incorporated for risk management purposes.
Model 3	Installation costs of green energy roofs are paid by homeowners, whereby 20% are paid as a down payment and the remaining 80% of the costs are borrowed from financial institutions. "Solar Life Insurance" (i.e., decreasing term life insurance for green energy roof loan) is incorporated with the bank loan. Property insurance and third-party property damage insurance are incorporated in the model.
Model 4	Installation costs of green energy roofs are paid by third parties through crowdfunding. Property insurance and third-party property damage insurance are incorporated in this model. Homeowners and investors are awarded with feed-in tariffs based on a contractual profit-sharing ratio.

Sample and Data

The statistics by Taiwan Power Company showed that the yearly power generation of solar photovoltaic energy facilities per kW in 2019 is 1,070 kWh across the country. Table 2 presents the top twelve cities/counties in yearly power generation per kW in Taiwan. These areas have yearly power generation per kW greater than 1,000 kWh. Specifically, the top five cities/counties in Taiwan are Penghu County (1,220 kWh), Kinmen County (1,199 kWh), Yunlin County (1,179 kWh), Chiayi County (1,135 kWh) and Chiayi City (1,129 kWh).

Table 2: Top 12 cities/counties in solar photovoltaic power generation in Taiwan in 2019

County/City	Capacity (kW)	Power Generation (kWh)	Daily power generation per kW (kWh)	Yearly power generation per kW (kWh)	Capacity Factor (%)
Penghu County	15,194	18,535,278	3.34	1,220	13.93
Kinmen County	8,201	9,836,614	3.29	1,199	13.69
Yunlin County	479,277	565,106,758	3.23	1,179	13.46
Chiayi County	260,176	295,378,840	3.11	1,135	12.96
Chiayi City	14,678	16,573,639	3.09	1,129	12.89
Tainan City	532,346	600,763,749	3.09	1,129	12.88
Hsinchu County	82,089	92,584,054	3.09	1,128	12.87
Kaohsiung City	448,732	500,813,853	3.06	1,116	12.74
Taichung City	244,381	260,831,295	2.92	1,067	12.18
Taoyuan City	246,195	259,119,833	2.88	1,052	12.01
Miaoli County	98,835	103,532,653	2.87	1,048	11.96
Nantou County	59,731	61,721,783	2.83	1,033	11.80

Source: Taiwan Power Company (Note: These twelve cities/counties are presented because they have yearly power generation per kW greater than 1,000 kWh.)

In this study, two cases are adopted for analyzing the above discussed four investment models. The first case (Case A) uses Yunlin County, that has the highest solar photovoltaic power generation in Taiwan main island. The second case (Case B) uses the average power generation of top 12 cities/counties in Taiwan (as shown in Table 2).

Based on the estimation by the Bureau of Energy, a green energy roof of 100 square meters (m2) has 13kWp in capacity. The installation of green energy roofs costs approximately TWD 789,100 (USD 28,333.93). The yearly power generation per kW is 1,179 kWh in Yunlin Country (Case A) and 1,120 kWh for Case B (that is, the average of top 12 cities/counties in solar photovoltaic power generation in Taiwan in 2019). The feed-in tariff rate officially announced by the Ministry of Economic Affairs in 2019 was TWD 5.9722 / kWh (USD 0.2144 / kWh). The basic information for investment appraisals of green energy roofs is provided in Table 3.

Table 3: Basic information for investment appraisals of green energy roofs

Case/ Data	Yunlin County (Case A)	Average of top 12 counties/cities (Case B)
Area of green energy roof	100	m^2
Capacity (approx.)	13	kWp
Installation costs (approx.)	789,100 (28,333.93	TWD USD)
Feed-in tariff rate (high-efficiency modules)	5.9722 (0.2144	TWD/kWh USD/kWh)
Yearly power generation per kW (kWh)	1,179	1,120
Estimated yearly power generation (kWh)	15,327	14,560
Estimated annual revenue from feed-in tariffs	TWD 91,536 (USD 3,286.75)	TWD 86,955 (USD 3,122.26)
Estimated property and third-party insurance costs[1]	TWD 915/year (USD 32.85/year)	TWD 870/year (USD 31.24/year)
Estimated green energy roofs maintenance expenses[2]	TWD 1,831/year (USD 65.75/year)	TWD 1,739/year (USD 62.44/year)

Note:

1. Property and third-party insurance costs are estimated to be 1% of the annual revenue from feed-in tariffs. The costs are estimated in reference to current green energy roof projects in the market (https://www.sunnyfounder.com/projects/214) and are adjusted in accordance with premium rates of residential fire and earthquake insurance and compulsory auto liability insurance.
2. With reference to current green energy roof projects in crowdfunding platforms, the maintenance expenses are predicted to be 2% of the annual revenue from feed-in tariffs.
3. The exchange rate is 27.85 TWD/USD based on the average bid and ask exchange rate of Bank of Taiwan on 6 July, 2021.

Investment Appraisal Methods

Following Chen and Liu (2014), this study adopts five common methods used in corporate finance for investment appraisals, including payback period, discounted payback period, net present value (NPV), internal rate of return (IRR) and profitability index (PI), to analyze the above-mentioned four investment models. The methods are summarized below.

- Payback period calculates the number of years required to recover the original investment invested in a project.
- Discounted payback period method is similar to the payback period method except that it uses the discounted cash flows.

- Net present value compares the present value of all future cash flows from the investment with the value of initial cash outflow. The investment should be accepted if NPV is greater than 0.
- Internal rate of return is the rate of return at which the NPV of the investment becomes zero.
- Profitability index is the ratio between the present value of all future cash flows and the initial cash outflow of the investment. The investment should be accepted if PI is greater than 1.

Analysis and Results

The financial analysis results of four investment models are provided in Table 4. Model 1 is the Green Energy Roofs Project implemented by Taiwan's Bureau of Energy. With this project, the homeowners do not need to pay for any installation costs and will be awarded with 10% of feed-in tariffs, guaranteed for 20 years. Therefore, this "rental" revenue is treated as the cash inflow each year. Specifically, for Case A, the rental revenue is approximately TWD 8,879 (USD 318.82) per year (or TWD 177,580 [USD 6,376.30] for 20 years which has the present value of TWD 159,183 [USD 5,715.73]). For Case B, the rental revenue is approximately TWD 8,435 (USD 302.87) per year (or TWD 168,700 [USD 6,057.45] for 20 years which has the present value of TWD 151,223 [USD 5,429.91]).

For Model 2, homeowners are responsible for the initial installation costs (TWD 789,100 [USD 28,333.93]). The discounted payback period for Case A and B are 9.40 years and 9.92 years, respectively. With the consideration of insurance costs (for risk management) and maintenance expenses, the cash flow in Case A each year is approximately TWD 88,790 (USD 3,188.15). The NPV, IRR and PI for Case A are TWD 802,551 (USD 28,816.91), 9.37% and 2.02, respectively. For Case B, the NPV, IRR and PI are TWD 722,895 (USD 25,956.73), 8.65%, and 1.92, respectively.

For Model 3, homeowners are responsible for the installation costs of green energy roofs and 80% of the funds are assumed to be borrowed from banks. Two lending interest rates are considered, 2% and 3%. Also, three types of insurance are incorporated in the model, including decreasing term life insurance for green energy roof loan, property insurance and third-party property damage insurance. Suppose the loan borrower is a 50-year-old male, the single-premium decreasing term life insurance is TWD 56,689 (USD 2,035.51), estimated based on the mortgage life insurance provided by BNP Paribas Cardif Assurance Vie, Taiwan branch. The results in Table 4 show that when the lending interest rate is 2%, four indicators (including payback period, discounted payback period, IRR, and PI) except NPV all suggest that Model 3 is better than Model 2. Similar conclusions can be reached for Case B and when 3% is adopted as the lending interest rate. That is, Model 3 has shorter (discounted) payback period, higher IRR and larger PI than Model 2. However, the NPVs of Model 3 appear to be slightly lower than that of Model 2. This finding is consistent with the result reported by Chen and Liu (2014) who show that when homeowners pay the full amount of initial installation costs that involve a large amount of initial cash outlays, the homeowners actually get the best return in terms of net present values.

Model 4 is similar to Model 1 where the homeowners do not need to pay for installation costs. In contrast, the installation fund in Model 4 is gathered from crowdfunding. After considering management fees in maintaining the crowdfunding platform and revenue distribution to investors, the roof rental revenues to homeowners are estimated to be 8% of net feed-in tariff. Specifically, the rental revenues for Case A and B are TWD 7,103 (USD 255.04) and TWD 6,748 (USD242.30), respectively. The total present value of rental revenues for Case A and B are TWD127,343 (USD 4,572.46) and TWD 120,978 (USD 4,343.91), respectively. The results in Table 4 show that the NPVs of Model 4 are lower than that of Model 1. Therefore, based on the net present value method, Model 1 is better than Model 4.

Overall, the results show that across four models, when homeowners do not need to pay for installation costs (i.e., Model 1 and Model 4), the NPVs are lower compared to that of Model 2 and 3. This finding is consistent with the results reported by Chen and Liu (2014) who find that without any initial investment, homeowners gain the least in return from installing green energy roofs. In addition, our results show that Model 3, which has considered low interest loans and risk management schemes, appears to be the best investment model, evaluated based on payback period, discounted payback period, IRR, and PI.

Table 4: Financial analyses of four investment models

Analytical method Model/Case		Estimated revenue from roof rental ($/year)	Payback period (year)	Discounted payback period (year)	NPV ($)	IRR (%)	PI
1	A	TWD 8,879 (USD 318.82)	-	-	TWD159,183 (USD 5,715.73)	-	-
	B	TWD 8,435 (USD 302.87)	-	-	TWD 151,223 (USD 5,429.91)	-	-
2	A	-	8.90	9.40	TWD 802,551 (USD 28,816.91)	9.37	2.02
	B	-	9.36	9.92	TWD 722,895 (USD 25,956.73)	8.65	1.92
3	A (i=2%)	-	4.45	4.58	TWD 700,955 (USD 25,168.94)	23.08	5.42
	A (i=3%)	-	5.00	5.16	TWD 647,317 (USD 23,242.98)	20.85	5.08
	B (i=2%)	-	5.08	5.25	TWD 621,299 (USD 22,308.76)	20.45	4.92
	B (i=3%)	-	5.81	6.02	TWD 567,662 (USD 20,382.84)	18.27	4.58
4	A	TWD 7,103 (USD 255.04)	-	-	TWD 127,343 (USD 4,572.46)	-	-
	B	TWD 6,748 (USD 242.30)	-	-	TWD 120,978 (USD 4,343.91)	-	-

Note:
1.Case A refers to Yunlin County. Case B refers to the average of top 12 counties/cities in yearly power generation per kW.
2.Descriptions of Model1-4 are provided in Table 1.
3.We use the average of one-year term deposit rate of Bank of Taiwan in 2019 as the discount rate; that is, the discount rate is 1.065%.
4. *i* in Model 3 represents the lending interest rate. Two different rates, i = 2% and i = 3%, are considered in this study with reference to the "Special Purpose Loan for Green Energy Facilities" provided by Taipei Fubon Bank.
5.The exchange rate is 27.85 TWD/USD based on the average bid and ask exchange rate of Bank of Taiwan on 6 July, 2021.

Conclusions

Green energy roofs have been acknowledged for having various economic, environmental and social effects. The Taiwan government has been promoting the low-carbon policy and introduced the "Green Energy Roofs Project" in 2017. With this project, homeowners do not need to pay for any initial installation costs. The solar photovoltaic operators "rent" the roofs of residents and are responsible for maintenance of the green energy roofs. Feed-in Tariffs (TIF) policy is adopted and the solar photovoltaic operators have a 20-year contract with homeowners. However, the incentives of residents and solar integrators to participate in this Project are low. This study therefore proposes three alternative investment models for green energy roofs and evaluates these models using five common investment appraisal methods (including payback period, discounted payback period, net present value, internal rate of return and profitability index). Specifically, Model 1 is the current "Green Energy Roofs Project" promoted by the Taiwan government. In Model 2, the installation costs of green energy roofs are paid by homeowners with the property insurance and third-party property damage insurance incorporated in the model. In Model 3, the installation costs of green energy roofs are paid by homeowners; however, 80% of the installation costs are borrowed from banks. Decreasing term life insurance for green energy roof loan, property insurance, and third-party property damage insurance are incorporated in the model. In Model 4, installation costs of green energy roofs are paid by third parties through crowdfunding. Property insurance and third-party property damage insurance are also considered in this model.

Our analyses show that when homeowners do not need to pay for installation costs (as in Model 1 and Model 4), the net present values are lower compared to the NPVs in Model 2 and 3. This may explain why the incentives of homeowners to participate in the Green Energy Roofs Project launched by the Taiwan government are low. As low interest rates are prevailing in the present state of economy, properly utilizing financial leverage through bank borrowing and managing risks through insurance, Model 3 shows better financial outcomes than Model 2 in terms of payback period, discounted payback period, internal rate of return and profitability index (even through the net present value is slightly lower than that of Model 2). In fact, Model 3 appears to be the best investment model of the four. Therefore, in conclusion, we suggest that the Taiwan government could consider changing the strategy in promoting green energy roofs by encouraging homeowners to become the owners of solar photovoltaic facilities and providing low interest loan for funding the installation costs. As a result, the homeowners would be better compensated and have greater incentives to install green energy roofs. The goal of being nuclear-free by 2025 will be more likely to be achieved by the Taiwan government.

References

Bureau of Energy. (2019, December 24). Directions for Implementation of Green Energy Roofs Project by Ministry of Economic Affairs. https://www.moeaboe.gov.tw/ECW/english/content/Content.aspx?menu_id=8715

Chang, C. (2020, February 27). Taiwan to boost renewable energy to 20% by 2025, introduce trillion-dollar investment. Taiwan News. https://www.taiwannews.com.tw/en/news/3880997

Chen, H., & Liu, G. (2014). Investment analysis of photoelectric electricity generation system on roofs. Journal of TUNGFANG Design Institute, 35, 1-10. https://10.29421/JTDU.201412_(35).0001

Executive Yuan. (2019, January 2). Green Energy Roofs project. https://english.ey.gov.tw/News3/9E5540D592A5FECD/e1dce6dc-26b6-4299-9ad2-fab723664d8e

Feng, H., & Hewage, K. N. (2018). Economic Benefits and Costs of Green Roofs. In G. Perez & K. Perini (Eds.), Nature Based Strategies for Urban and Building Sustainability (pp. 307-318). Elsevier: Oxford/Cambridge, UK. https://doi.org/10.1016/B978-0-12-812150-4.00028-8

Liang, C. (2017). Low electricity price is detrimental to sustainable development of a country. Economic Outlook Bimonthly, 172, 10-16.

Liao, G. (2017, December 21). Taiwan's Green Energy Roofs project urges the public to build a green home. Taiwan News. https://www.taiwannews.com.tw/en/news/3325380

Mahdiyar, A., Tabatabaee, S., Yahya, K., & Mohandes, S. R. (2020). A probabilistic financial feasibility study on green roof installation from the private and social perspectives. Urban Forestry & Urban Greening, 58(1). https://doi.org/10.1016/j.ufug.2020.126893

Shin, E., & Kim, H. (2019). Benefit-Cost Analysis of Green Roof Initiative Projects: The Case of Jung-gu, Seoul. Sustainability, 11(12), 3319. https://doi.org/10.3390/su11123319

Wu, T., & Smith, R. E. (2011). Economic benefits for green roofs: A case study of the Skaggs Pharmacy Building, University of Utah. International Journal of Design & Nature and Ecodynamics, 6(2), 122-138. https://10.2495/DNE-V6-N2-122-138

Acknowledgements

The authors would like to thank Professor Yu-Cheng Hsiao for his helpful advice and comments. The authors had won the championship in “The Best Enterprise Solution Competition - Taya Group’s Green Energy Roofs Challenge” in 2019.