

Article

Using an Analytical Hierarchy Process to Analyze the Development of the Green Energy Industry

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Abstract: With global climate change and resource scarcity becoming increasingly serious issues, the green energy economy is transforming on a global scale. There are an increasing number of large-scale green energy development projects. However, these are often beset with risks; thus, this study conducted an analysis of the renewable energy risks in Taiwan using the analytical hierarchy process technique. Accordingly, a comprehensive study focusing into the current energy situation and potential development is needed. Renewable energy status and the availability by its main types, including, wind, solar, thermal, and biomass energies, were critically reviewed and discussed in this study. The findings of this study include the top 10 key operating risks recognized by specific green energy companies, as well as an assessment of which risks have been addressed and which have caused losses.



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1. Introduction

With global climate change and resource scarcity becoming increasingly serious issues, the green economy is seeing transformational trends on a global scale [1]. However, with an increasing number of green energy technologies in widespread use and the growing number of large-scale development projects in this field, the identification, mastery, and management of the risks involved are becoming increasingly important in setting green energy policies and the promotion of the industry as a whole. Chassot et al. [2] find that investors' worldviews moderate the impact of perceived regulatory risk: respondents who expose strongly individualistic "free-market" worldviews are less likely to invest in renewable energy ventures with high regulatory exposure than other investors. Xu et al. [3] selected four factors to measure the development of renewable energy, economic factors, political factors, social factors, and technical factors, to predict the future development of renewable energy in various regions.

The above strand considers that the development and production efficiency of renewable energy has become more and more important in response to resource shortages. Salah et al. [4] concluded that there is an essential need to adopt a new action plan aims at addressing energy independency and sustainability. There is a need to accelerate more research and investment in the renewable energy sector to use a hybrid energy system, which can offer a better grid stability. This is the most relevant research to us. Sarkar and Sarkar [5] identified a major effect on renewable energy in a sustainable smart production system. They found that the amount of impure biofuel can be minimized by a sustainable smart production system through reduced renewable energy consumption. Sarkar et al. [6] stated that the manufacturing system in question produces defective products during extended periods of use, and those products can be reworked at a cost in order to ensure that they have an optimal energy efficiency and carbon footprint. The development of this

system is affected by the development factors of green energy risks, which, in turn, affect the production efficiency.

To ease human economic activities in light of ecosystem extinction, and to avoid the devastating and irreversible effects of man-made causes of global climate change, the UN released a sustainable development policy, entitled “Transforming our World: The 2030 Agenda for Sustainable Development”. This puts forward 17 goals to achieve sustainable development by 2030. The sustainable goals of “renewable energy and the transformation of energy supplies and demand structures”, “green finance”, and the “circular economy” have become the three major actions required by Western countries, led by the UN and the EU, to address the effects of global climate change and to slow down global warming in order to reach the 2030 sustainable development goal.

One current trend involves transforming the structure of energy supply and demand using renewable energy and smart grids. Fadaeenejad et al.’s [7] findings demonstrate that a few countries, such as China, India, and Brazil, have had proper planning and development in this technology. Tutak et al. [8] pointed out that the European Union countries should utilize more effective sustainable energy development. Brodny and Tutak [9] stated that the efficient use of financial resources could be the impetus for the EU’s economic development. For example, the EU is increasing its regional renewable energy consumption ratio by 2030 (it was up to 32% in 2018) [10]. A total of 179 countries and regions have set renewable energy consumption ratio targets; of this total, 57 have set a target of 100%. In 2017, renewable energy accounted for 70% of the new power generation investment; in 2018, renewable energy installations accounted for 26.5% of the total investment worldwide. Today, with the worldwide increase in renewable energy supply and demand, the stability of power supply and demand, the feasibility of business models, and financial risks have become fundamental issues in this field [11]. Arnold and Yildiz [12] pointed that suitable business models, specific financing concepts and advanced risk management tools to deal with issues concerning transaction costs and financial risks, are required to support renewable energy technologies investments. Although renewable energy can reduce environmental pollution, its output is unstable due to the climate. Takano et al. [13] present an optimization method for operation plans of controllable generators in micro grids that copes with the uncertainty of DREG outputs. Therefore, more funds are needed for public and private partnerships to develop renewable energy. Aleixandre et al.’s [14] aim was to analyze scientific and energy production, funding, and collaboration among countries and the most cited papers on the renewable energies topic through bibliometric and social network study of articles included in the Web of Science database. Gatzert and Kosub [15] present current risks and risk management solutions of renewable energy projects to identify critical gaps in risk transfer. As a result, identification of risk of development of renewable energy is particularly important. A comparison of the effectiveness and risks of traditional energy and renewable energy is shown in Table 1.

Table 1. The effectiveness and risks of traditional energy and renewable energy.

	Renewable Energy	Traditional Energy
Effectiveness	- Improves energy independence - Reduces environmental pollution	Power output is very stable
Risks	- Affected by the weather; the power output is unstable - Construction costs are relatively higher	Higher environmental pollution costs

This research employed the questionnaire method to investigate major risks in the development of green energy in Taiwan. The risks include political risks, administrative procedure and efficiency risks, and imperfect laws and regulations. From past experiences in Taiwan, it can be discerned that the risk of losses in green energy development may be as high as between 30% and 50%, meaning that these losses are worthy of consideration. These statistics are consistent with the risks faced by the EU in the past decade. These risks exist

at the government or policy level, and they are generally considered to be development risks and difficulties in the green industry overall.

In this research, we reviewed the literature and discovered that recent studies mainly focus on the effect of critical risks and risk management investigations in developing green energy policies, as well as problems found in the green energy industry. We found ten key operational risks related to green energy companies, and we assessed which risks were addressed and which caused losses. Moreover, we collected data on the main financing methods of the green energy companies surveyed, including the financial instruments they used. It is very important for green energy companies to thoroughly assess the risks they face. We employed the AHP technique in this research to assess the priorities in relation to identification of risk of development of renewable energy. The empirical results include some issues that may contribute to the development of operational risks. Our research fills the research gap in relation to identification of risk of development of renewable energy.

The remainder of the paper is organized as follows. In Section 2, we present a review of the literature. In Section 3, we describe our research methods, and The Analytic Hierarchy Process Method and Questionnaire. In Section 4, we present our result analysis, basic information of respondents, and key risks recognized by the regulated green energy industry and key risks recognized through the AHP technique. In Section 5, we present a conclusions and limitation.

2. Literature Review

2.1. An Introduction to the Green Energy Industry

According to estimates by Bloomberg New Energy Finance (BNEF) in 2019, the global green finance market, which means to invest in areas that have positive impacts on the environment and society, has expanded rapidly in recent years, from USD 15 billion in 2013 to USD 247 billion in 2018, and there is still a lot of room for growth. In addition, according to the Financial Standing Committee of the United Nations Framework Convention on Climate Change (UNFCCC), the annual cash flow of climate finance reached USD 510 billion in 2017. According to Bloomberg's [16] The New Energy Outlook 2020, wind and solar energy panels (also known as photovoltaics or simply as PV) are the technologies that will meet 56% of the world's electricity demand by 2050, with batteries, flexible demand, and peakers also providing support. The belief is that countries leading the way in the green energy field will reach as high as 70% to 80% of total renewable energy before hitting their economic limits, and that wind will retake the lead over solar technologies.

The Roadmap for a Sustainable Financial System, released by UNEP (UN Environment Programme) [17], together with the World Bank (WB), in November 2017 estimated that, between 2016 and 2030, the global public and private sectors could invest USD 22.6 trillion in addressing climate change needs, and that 2018 and 2019 are critical years. On the other hand, the Forum for Sustainable and Responsible Investment (SIF) in the United States estimates that ESG (Environmental Social Governance) exposure in the United States has reached USD 12 trillion, mainly due to the large involvement of public pension funds in green finance after 2017.

Compared to traditional industry investments, the development of green financial investments is novel. Taghizadeh and Yoshino [18] practiced solutions, including increasing the role of public financial institutions and non-banking financial institutions (pension funds and insurance companies) in long-term green investments. Such investments are characterized by a long project lifecycle (one or more decades), leading to an emphasis on short-term profits. Furthermore, green development can produce all kinds of financial gaps, stopping countries from promoting energy transformation and achieving their sustainable development goals. Hafner et al. [19] confirms that policy uncertainty and short-termism in the financial system are the two main investment barriers. Therefore, it is necessary to develop an appropriate financial policy framework and legal environment according to the characteristics of the green energy industry to promote the innovation and controllable risks of green financial commodities and enable green energy development. Yoshino et al. [20]

pointed out a major challenge for filling the financing gaps of green energy is the lower rate of return of green projects compared to fossil fuels. Electricity tariffs are often regulated by governments. Jiang et al. [21] analyze the direct impact of energy consumption on energy innovation and innovation transformation and reveal the net effect of green innovation transformation on economic sustainability and energy consumption.

2.2. Crowdfunding and Public Finance Interventions in Green Energy

When developing green energy technologies, the development of the financial elements of the business is an important step. Vismara [22] studied the relationship between sustainability and crowdfunding, focusing on campaigns that provide rewards for backers. Equity crowdfunding offers motivations for people to make investments in terms of size, horizon, and expectations. Vismara's research employed 345 initial equity offering samples on the UK platforms Crowdcube and Seedrs from 2014 to 2015 and provided evidence of the attractiveness of sustainability-oriented ventures in equity crowdfunding. Lam and Law [23] introduced crowdfunding as a new source of green financing and gives evidences for using crowdfunding in renewable and sustainable energy development, in comparison with other funding sources. Bonzanini et al. [24,25] presented that green credit guarantee schemes (GCGSs) and returning a portion of the tax revenue originally generated from the spillover effect of green energy supply to investors.

The report in Reference [26] says that public finance interventions in support of the development of green finance are important and should be implemented in government policies. This "involvement" mechanism is not only implemented in the financial sector but also in the real industry sector. Haščič et al. [27] used a unique dataset of investment flows to analyses the role of two categories of public interventions (finance and policies) in mobilizing flows of private climate finance worldwide and in the more specific context of flows to and in developing countries. Corrocher and Cappa [28] analyzed the factors explaining the recent boost in solar energy private investments, focusing on the role of public finance and public policy tools-feed-in-tariffs and renewable energy quotas.

2.3. Green Energy Development Risks

Wu et al. [29] studied whether the increase in a manufacturer's share of green costs would lead to the supplier increasing the greenness of the intermediate components, thereby reducing the risks. This is an important means for the manufacturer to increase their share of green costs in the cooperative process, so as to encourage the supplier's green investment. Migendt et al. [30] pointed out that green entrepreneurs continue to suffer from perceptions of higher political and technological risks, with the lower scalability and long pay-back periods involved in green investments making them unattractive ventures for financial institutions.

Lederer et al. [31] stated that the markets alone are failing to bring about sustainable practical changes, so governments must intervene to drive green energy transformation. Pegels et al. [32] pointed out that the risks of developing green energy technologies are exceedingly high; this is why rational and transparent policy processes, with continuous and systematic policy learning, and options for corrective action, are of the greatest importance.

The above literature explores the effects of critical risks and risk management investigations in developing green energy policies. However, the abovementioned authors did not consider the effects of the top 10 key operating risks for specific companies, how to address these risks, or which of them cause losses. These topics are studied and discussed in this paper.

Ning et al. [33] considered the financial concept that many green start-up ventures have inherent technological and managerial risks. They are typically financially constrained, with limited or no collateral to offer to their funders. Criscuolo et al. [34] determined that there is a dearth of knowledge regarding external financing by green innovators in relation to the overlap and timing of distinct financing modes in the business lifecycle.

To the best of our knowledge, the effects of the top 10 key operating risks recognized by specific green energy companies have not yet been assessed, despite the fact that it is vitally important to evaluate the risks that green energy companies face. Sadorsky [35] used a variable beta model to investigate the determinants of renewable energy company risk. The empirical results show that company sales growth has a negative impact on company risk, while oil price increases have a positive impact on company risk. Our proposed technique includes some issues that may contribute to the determination of operating risks, and our research fills the research gap in this regard.

2.4. Analytical Hierarchy Process (AHP) Application

AHP is a powerful and flexible multi-criteria decision-making method that has been applied to solve unstructured problems in a variety of decision-making situations, ranging from simple personal decisions to complex capital-intensive decisions in fields as diverse as management science, economics, finance, politics, and sports. Bhushan and Rai [36] focused on applying the AHP to decision-making problems; Strategic Decision Making covers problems in the realms of business, defense, and governance. Wang et al. [37] reviewed the corresponding methods in different stages of multi-criteria decision-making for sustainable energy. Gandhi et al. [38] proposed the means of combining the AHP and the Decision-Making Trial and Evaluation Laboratory (DEMATEL) approach to evaluate these SFs at the tactical, operational, and strategic levels in GSCM adoption. Wu [39] proposed a weighted keyword-based patent network (WKPN) approach, which combines Delphi technique, analytic hierarchy process, and network analysis, to overcome the limitations in order to identify the technological trends and evolution of biofuels. Aragonés [40,41] presented a top manager of an important Spanish company that operates in the power market has to decide on the best PV project to invest based on risk minimization. Dos Santos et al.'s [42] findings substantially elucidate the advancements in the state-of-the-art of the analytic hierarchy process for sustainable development. Implications for research and practice, as well as promising challenges for further research, are presented.

Wang and Xu [43] use Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis to assess the internal and external factors which affect the renewable energy technologies in Sindh and Baluchistan province. Then, the Fuzzy Analytical Hierarchy Process (Fuzzy AHP) method is used from the multi-perspective approach.

The AHP process is reliable and repeatable. Kaya et al. [44] mentioned that Multi-criteria decision-making (MCDM) methods are used as effective tools to help decision makers while solving energy problems. Ghasempour et al. [45] made a wide variety of multi criteria decision-making (MCDM) methods, investigated by various researchers, and they are presented to obtain effective criteria in selecting solar plants sites and solar plants technologies. There is not any comprehensive research providing all required criteria for decision-making for site and technology selection. Muhammad et al. [46] made a multicriteria-based equipment selection framework on the triple bottom line of sustainability in the context of the Malaysian construction industry that has been developed and tested. It reduces a set of options (or situations) into pairwise comparisons and asks for a ratio assessment of each pair. For example, to assess preferences for three features (A, B, and C), AHP sets up the three pairwise comparisons (AB, AC, and BC). The results of the comparisons are arrayed in a matrix, and values are assigned to each option. Once the values are assigned, the options can be compared or rank ordered.

3. Methodology

3.1. The Analytic Hierarchy Process Method

The analytic hierarchy progress method was devised by Saaty in the 1970s [47,48]. It is a structured technique for organizing and analyzing multifaceted or complex decisions based on psychology and mathematics. It allows researchers to determine the weights (significances) of hierarchically non-structured or particular hierarchical criteria.

An AHP has seven steps, which are described below:

1. Identifying the problem: the scope of the research problem should be expanded as much as possible, the key factors that may affect it should be included, and the problem should be clearly defined in light of these factors.
2. Listing the factors related to the problem using the Delphi Method (a forecasting process framework based on the results of questionnaires sent out to a panel of experts in multiple rounds, the responses to which should be kept anonymous, aggregated and shared with the group following each round), brainstorming, literature review, etc.
3. Establishing a hierarchy: the levels of the hierarchy can be set according to the needs of the problem. The relationships between the levels should be plausible.
4. Designing a questionnaire survey: factors at each level are compared with the factors at a higher level as a benchmark for evaluation.
5. Setting up a paired comparison matrix: this enables the relative importance of various options that need to be weighed up. The elements of a paired comparison matrix are obtained from the survey results (see Step 4). The paired comparison matrix can be established by geometrically averaging the judgment values.

$$A = \begin{pmatrix} 1 & a_{12} & L & a_{1n} \\ a_{21} & 1 & L & a_{2n} \\ L & L & L & L \\ a_{n1} & a_{n2} & L & 1 \end{pmatrix} = \begin{pmatrix} 1 & a_{12} & L & a_{1n} \\ 1/a_{21} & 1 & L & a_{2n} \\ 1 & L & L & L \\ 1/a_{n1} & 1/a_{n2} & L & 1 \end{pmatrix}, \quad (1)$$

$$= \begin{pmatrix} W^1/W^1 & W^1/W^2 & L & W^1/W^n \\ W^2/W^1 & W^2/W^2 & L & W^2/W^n \\ L & L & L & W^3/W^n \\ W^n/W^1 & W^n/W^2 & L & W^n/W^n \end{pmatrix}. \quad (2)$$

This study combines theory and experience with actual interviews via expert questionnaire design. By deploying the analytic hierarchy process, the weightings of the impacts of the 10 main risks on firms' operational performance are verified one by one. The priorities are, therefore, obtained for each individual measured indicator of the surveyed companies, which are expected to provide corporate operators with enough information to choose suitable solutions based on the objective results.

6. Calculating the priority vector and the maximum eigenvalue: after the paired comparison matrix is compiled, the eigenvalue solution method of numerical analysis is used to obtain the eigenvector or priority vector, and then the maximum eigenvalue is calculated based on this priority vector.
- (1) Discovering the priority vector:

Saaty [48,49] believed that four approximations could be used to find the dominant directions if higher accuracy was not required. Of these, the standardized geometric mean of the gradient, which is shown below, is the best method for estimating the dominant directions:

Listing the standardization of the vector's geometric mean:

$$w^i = \frac{\sqrt[n]{\left(\prod_{j=1}^n a_{ij}\right)}}{\sum_{i=1}^n \left(\sqrt[n]{\left(\prod_{j=1}^n a_{ij}\right)}\right)}. \quad (3)$$

- (2) Calculating the maximum eigenvalue (λ^{max}): First, $A \times w = w'$ (A new vector is obtained by pairwise comparison of matrix A and product dominant vector W.).

$$\begin{pmatrix} 1 & a_{12} & L & a_{1n} \\ a_{21} & 1 & L & a_{2n} \\ L & L & L & L \\ a_{n1} & a_{n2} & L & 1 \end{pmatrix} \begin{pmatrix} w_1 \\ w_2 \\ L \\ w_4 \end{pmatrix} = \begin{pmatrix} w_1 \\ w_2 \\ L \\ w_4 \end{pmatrix}. \quad (4)$$

The maximum eigenvalue λ^{max} can be calculated using the following formula:

$$\lambda^{max} = \frac{1}{n} \left(\frac{w_1}{w_1} + \frac{w_2}{w_2} + \dots + \frac{w_n}{w_n} \right). \quad (5)$$

7. Finally, the consistency index of each level is calculated. In order to determine the suitability of the questionnaire content, a consistency test with respect to its characteristics must be carried out to calculate the consistency ratio (CR). According to Saaty's theory, the consistency ratio must be less than 0.1 before it can be accepted; otherwise, the consistency index is irrelevant and an analysis of all factors and links must be re-conducted.

- (1) consistency index (C.I)

$$C.I = \frac{\lambda^{max} - n}{n - 1}, \quad (6)$$

- (2) consistency ratio (C.R)

$$C.R = \frac{C.I}{R.I}, \quad (7)$$

where the random index (R.I.), the positive inverse matrix from the assessment scales from one to nine, the consistency index values generated under different orders, and the random index values of different orders are all shown in Table 2.

Table 2. The values of the random consistency index.

Matrix Order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.58

Source: Saaty [13].

The steps of the analytic hierarchy process (AHP) are shown in Figure 1.

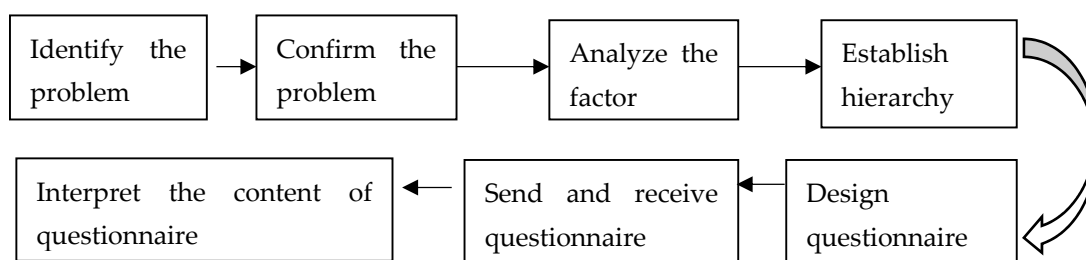


Figure 1. The steps of the analytic hierarchy process (AHP).

3.2. Questionnaire

With global climate change and resource scarcity becoming increasingly serious issues, the green economy has become a key trend in the global economy. However, due to the long duration of green energy projects, the increasing number of green energy technologies, and the concomitant number of large-scale green energy development projects, in terms of policy and industry promotion, the identification, mastery, and management of risks, are increasingly important. The questionnaire was designed by all three authors, and we compared with Lederer et al.'s [31] and Pegels et al.'s [32] previous related research, to identify some main risk for this questionnaire design. This study aimed to understand the risks faced by Taiwan's green energy industry through a questionnaire survey in order to determine countermeasures and risk management strategies.

The questionnaire had two main parts. The first involved basic information about the surveyed institutions, and the second was an investigation into the key risks and the risk management procedures in place within each institution. Through the questionnaire survey, we hope to know the risks faced by Taiwan's green energy industry, research and business response, and risk management strategies. The part questionnaire is shown in Appendix A.

This questionnaire is designed by the Analytic Hierarchy Process (AHP) to determine the relative weight of renewable energy development risk indicators through pairwise comparison of indicators. First, nine final value items of development risk indicators are established, and then the elements that compose the goal into several items are decomposed, with each evaluation item divided into several sub-projects and built up as the whole hierarchical structure step by step.

The questionnaire examined the top 10 key operating risks recognized by the respondents, which risks have been addressed, and which risks have caused losses. The basic information about the surveyed institutions included their name, their amount of capital and capital sources available to each institution, the number of employees, the green energy career development possibilities available to employees, etc. The second part pertained to risk—more specifically, the risks that these institutions have faced, as well as potential risks, risk management policies, etc. The third part enquired about the institutions' finances—more specifically, how they are financed, which financial instruments are used, their degree of capital adequacy, their main modes of providing receipts and payments, etc. This study established a hierarchy for recognized key risks, and the steps are as following.

- (1) The first hierarchy: To identify all renewable energy risks.
- (2) The second hierarchy: According to the identification of risk, list the three main criteria.
- (3) The last hierarchy: This study summarizes a hierarchical framework of risk factors affecting the development of renewable energy. There are ten secondary criteria. Each factor is described in detail, as shown in Appendix A.
- (4) Established hierarchy for recognition of key risks, as shown below in Figure 2.

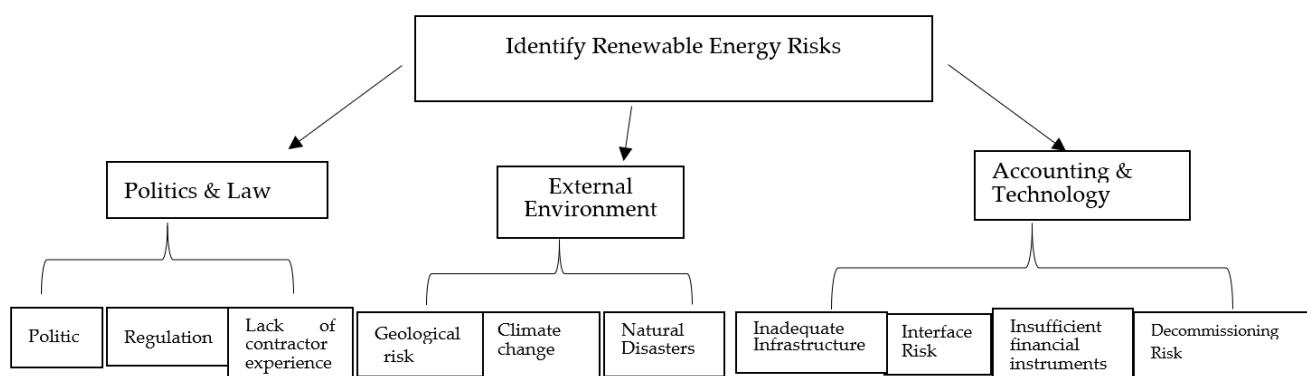


Figure 2. Established hierarchy for recognition of key risks.

3.3. The Analytic Hierarchy Process Method

This study uses the AHP technique and questionnaires to investigate the top 10 risks regarding the development of renewable energy. Overall, survey process planning of this study has the following steps.

Step 1: The questionnaire was designed by all four authors, and we compared with Lederer et al.'s [31] and Pegels et al.'s [32] previous related research, to identify some main risk for this questionnaire design. According to the identification of risk, the top 10 main risks are listed. Step 2: Some of surveyed respondents were asked to formally document for the questionnaire. Step 3: While offshore wind operators are more concerned about political risk, solar photovoltaic operators motioned administrative efficiency as the highest risk.

4. Result Analysis

The respondents of the questionnaire were bank, insurance, and renewable energy developers, and related financial, legal, and technical advisors, all of whom were registered in Taiwan. The collection methods included a list of relevant public association member companies. We sent a total of 93 questionnaires and collected 93 valid questionnaires, 88 of which were from the green energy industry, and five of which were from financial institutions; the total non-response rate was about 30%. Questionnaire recovery, data construction, and statistical analysis were completed by the end of December 2020.

4.1. Basic Information of Respondents

The results of the questionnaire showed that the majority (almost 60%) of the green institutions were private enterprises. Of the other companies who participated, 26% were publicly listed enterprises, and 17% were foreign-funded enterprises. Most of the companies surveyed operated in multiple green energy sectors, such as solar photovoltaics, and were involved in both energy conservation and energy storage. The main business of the surveyed companies' component is as following, in Table 3.

Table 3. The main business of the surveyed companies.

1. Solar Photovoltaics Industry	58
2. Offshore wind power industry	12
3. Energy storage industry	4
4. Finance industry	4
5. Land-based wind power industry	3
6. Other	12
Total	93

Overall, 62% of the green operators were in the solar photovoltaics industry, 13% were in the offshore wind power industry, 4% mainly operated in the energy storage industry, 4% mainly operated in the finance industry, and 3% mainly operated in the land-based wind power industry. The sample descriptive statistics are shown below in Table 4.

Table 4. The sample descriptive statistics.

		Total Number/Proportion
Total send questionnaires		93
The number of valid questionnaires		93
The types of surveyed companies	1. Private enterprises	57%
	2. Publicly listed enterprises	26%
	3. Foreign-funded enterprises	17%
	Subtotal	100%
The main business of the surveyed companies	1. Solar photovoltaics industry	62%
	2. Offshore wind power industry	13%
	3. Energy storage industry	4%
	4. Finance industry	4%
	5. Land-based wind power industry	3%
	6. Other	14%
Subtotal		100%

4.2. Key Risks Recognized by the Regulated Green Energy Industry

This questionnaire was disseminated to the participants via the internet and in face-to-face interviews. The following reflect the most commonly recognized key risks that affect the green energy industry: political risks (64%); administrative procedures and efficiency (61%); and a lack of sound regulations (50%). A summary of the key risks is shown in Table 4.

According to the respondents, other issues include the following: green energy investment projects have a long timeframe; Taiwan's electricity industry is not liberalized enough; electricity prices are so low that green energy producers have no choice but to develop using electricity rather than renewable energy; and green energy businesses have to rely on feed-in tariff (FIT) subsidies. The policy risks (green energy policy sustainability, and the effect of uncertainty on policy intensity) that pose the greatest risk to the development of the green energy industry are shown in Table 5.

Table 5. The 10 most commonly recognized key risks for green energy businesses.

All Regulated Green Operators		
Ranking	Perceived Critical Risks	Proportion
1	Political risks	64%
2	Administrative efficiency	61%
3	Imperfect regulations	50%
4	Green electricity price system	39%
5	Public protests	38%
6	Natural disasters	33%
7	Price bidding	30%
8	Investment incentives	26%
9	Environmental assessment system	25%
10	Climate change	24%

Source: Self-tabulation of this report

Some of the green energy manufacturers stated that progress has been made in the areas of green energy regulations, administrative department integration, and efficiency in recent years, but there are still significant shortfalls in terms of industry development risks.

4.3. Key Risks Recognized through the AHP Technique

The solar photovoltaic industry companies surveyed felt that administrative procedures and efficiency are the most commonly recognized risks to their development. Incomplete regulations, public protests, and the green electricity pricing system are also relatively commonly cited risks.

For the offshore wind power operator industry, developers reported that political risks are the most common. In addition, they also reported imperfect laws and regulations, inadequate administrative processes and efficiency, insufficient infrastructure, public protests, power purchase contracts, and talent supply and demand as common risks. The 10 most commonly recognized key risks are shown in Table 5 below.

Each individual value in any priority vector will range between 0.0 and 1.0. The values in any priority vector will sum to 1 (subject to rounding errors). The priority vector for the criteria is shown in Table 6. The CR for this study was also calculated, and a score of 0.0 was obtained; therefore, this paper indicates a high level of consistency.

For the solar photovoltaic industries surveyed, natural disasters and the soundness of laws and regulations are considered in risk assessments and in the planning of projects. For the offshore wind power operator industry developers surveyed, project financing,

natural disasters, and the soundness of regulations are considered in risk assessments and planning.

Table 6. The 10 most commonly recognized key risks for SPV and OWP businesses from AHP.

Solar Photovoltaic (SPV) Operators			Offshore Wind Power (OWP) Operators		
Perceived Critical Risks	W	R	Perceived Critical Risks	W	R
Administrative efficiency	0.165	1	Political risks	0.182	1
Political risks	0.157	2	Imperfect regulations	0.102	2
Imperfect regulations	0.116	3	Administrative efficiency	0.102	2
Public protests	0.102	4	Infrastructure construction	0.102	2
Natural disasters	0.099	4	Public protests	0.091	5
Green electricity price system	0.092	6	Power purchase contract (PPA)	0.091	5
Price bidding	0.082	7	Talent supply and demand	0.091	5
Environmental assessment system	0.065	8	Green electricity price system	0.08	8
Climate change	0.061	9	Natural disasters	0.08	8
Investment incentives	0.061	10	Inadequate project financing concept	0.08	8

Source: Self-tabulation of this report. Footnote: W = weight, R = ranking.

From the above AHP analysis, the empirical results provide three main areas of importance for the green energy development industry:

1. Risk items that have led to money being lost in the past year.

For the solar photovoltaic industry members surveyed, the top 10 key operating risks recognized by the respondents included imperfect regulations and the soundness of these laws and regulations. For the offshore wind power operator industry developers, the risks that caused losses also included imperfect regulations.

2. Key risks that are likely to be faced over the next three years.

For all industries surveyed, there was no clear consensus regarding risk perception. However, “political risks” have the highest level of awareness according to the AHP. In this regard, the solar photovoltaic industry members surveyed pointed out that the government must create land planning policies to release land as soon as possible so that solar photovoltaic power equipment can be installed.

3. Overview of company operations and cash flow of the surveyed industry.

Of the surveyed companies, 72% were in the commercial operation stage, and 21% were in the preparatory stage. Of the surveyed companies, 82% raised funds via the private sector, such as from bank loans or short-term financing bills, accounts receivable, letters of credit, etc. Around 80% of the surveyed companies raised funds in the public capital market, which included those listed on the stock market, counters, and those that relied upon public offerings to raise funds.

Overall, the surveyed companies believe that the green energy investment project has a long timeframe and that the liberalization of Taiwan’s electrical industry is insufficient, meaning that green energy manufacturers can only rely on the FIT system. Therefore, policy risks (e.g., the continuity of green energy policy and the uncertainty of policy intensity) are some of the biggest development risks for the green energy industry.

No other study has considered the effects of the top 10 key operating risks recognized by specific green energy companies; however, it is vitally important that green energy companies assess the risks they face. The AHP technique applied in this study also includes some methods that can be used to determine operational risks.

However, it is found in the survey of Taiwan that the overall risk awareness is gradually awakening, but the risk management and prevention are insufficient. Faced with the

strong trend of financial technology, the current progress in the risk control and mitigation of Internet risks in Taiwan is far from enough. Natural disasters are a permanent and unpredictable risk in Taiwan (especially earthquakes). At present, apart from rigorous risk control, appropriate insurance arrangements will be the last line of defense to protect the safety of investment.

This study is aimed at the future development of these policy industries to do a more objective risk analysis. It is hoped that the above views can provide and strengthen the risk management concept of these industries and promote the healthy development of these industries in a safe environment.

5. Conclusions and Limitations

The results of this paper show that political risks (reported by 64% of respondents) and administrative procedures and efficiency (reported by 61% of respondents) are the two most widely recognized risks for the renewable energy industry. The third most prevalent risk is the fact that laws and regulations are not sound (as reported by 50% of respondents). According to the respondents, green energy investment projects have long timeframes, Taiwan's electricity industry is not liberalized enough, and electricity prices are so low that green energy producers have no choice but to develop using electricity rather than renewable energy. As a result, green energy businesses have to rely on FIT. Therefore, policy risks (e.g., green energy policy sustainability and the uncertainty of policy intensity) have become some of the biggest development risks for the green energy industry.

According to the AHP technique, for the solar photovoltaic industry members surveyed, administrative procedures and efficiency are the most common risks. In addition, incomplete regulations, public protests, and the green electricity price system are also relatively common risks. For the offshore wind power operator industry developers surveyed, political risks are the most common kinds of risks. Additional risks are also posed by imperfect laws and regulations, the fact that the administrative process and efficiency need to be improved, the insufficient infrastructure, public protests, power purchase contracts, and talent supply and demand. In terms of regulatory barriers, respondents reported that the government review unit is too harsh on the interpretation of the law, and the government's green energy policy-related regulations are not obvious and clearly disclosed, so enterprises have to collect and judge their correctness via the Internet.

In order to relieve the pressure of balancing the fiscal structure of Taiwan, and the outbreak of the epidemic, the contradiction between fiscal revenue and expenditure has intensified, increasing the pressure of promoting green finance through the government departments. In this paper, it is expected that, while promoting green finance, public private cooperation and green investment and financing mechanism innovation will relieve the pressure of fiscal expenditure, so as to achieve the purpose of promoting green finance, and finally achieve the goal of promoting the development of renewable energy and achieving the goal of carbon reduction.

The limitations of our study are as follows: When the surveyed companies filled out the questionnaire, they may have been confused about some uncertain attributes or incomplete information, meaning that it is difficult to make comparisons between surveys. There may also be inconsistencies between the options provided; therefore, this research only faithfully presents the results of the risk survey, as a consistency analysis of the comparison results cannot be performed. The evaluation result is the average of the weights, but distribution information for each weight was not available. As this study applied the AHP technique, the questionnaire could be designed with more complete information or simpler options within the AHP technique, which is an area for further study.

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Appendix A

Table A1. The Questionnaire.

A Questionnaire on Key Risks Perceived by the Green Energy Industry	
1.	Is your company a public or private enterprise?
2.	What kind of green energy is your company engaged in?
3.	What is your business operation and cash flow profile? Whether the product is “available and partially sold” or “fully sold”, or in the preparatory stage?
4.	How your company will raise funds?
5.	What are the top ten risks that your company faces in renewable energy business?
6.	Has your company suffered losses in the past year from risk projects?
7.	Does your company have any risk assessment or planning in place?

Table A2. The hierarchical framework of risk factors.

The Main Criteria	The Second Criteria	Describe
Politics & law	Regulation	Such changes in regulations can make significant changes in the framework of an industry.
	Politics	an investment’s returns could suffer as a result of political changes or instability in a country.
	Lack of contractor experience	Contractors of all sizes can run into issues with workload, cash flow, or business practices. But with fewer staff and resources available, smaller contractors can quickly end up in a situation that gets out of their control.
External environment	Geological risk	encompass all kind of natural hazards caused by geological conditions.
	Climate change	Climate change is a long-term change in the average weather patterns that have come to define Earth’s local, regional, and global climates.
	Natural Disasters	A natural disaster is a major adverse event resulting from natural processes of the Earth.
Accounting & Technology	risk of insufficient financial instruments	Lack of appropriate financial instruments to reduce the risk of renewable energy development.
	inadequate infrastructure	Weakness of public works. Unavailable public facilities. Nature: In some countries basic infrastructure is lacking.
	interface risk	Interface risk in construction. Interfaces are points of interaction between two or more aspects of a project.
	decommissioning risk	If the demobilization policy and relevant legal framework are not clear or constantly changing, it will lead to great uncertainty of demobilization plan and related costs.

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