

Article

A Two-Tier Scenario Planning Model of Environmental Sustainability Policy in Taiwan

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Abstract: This study proposes a two-tier scenario planning model, consisting of scenario development and policy portfolio planning, to demonstrate the environmental sustainability policy planning process. Scenario development embodies future scenarios that incorporate the uncertainties regarding the decision values and technological alternatives. Policy portfolio planning is used to assess the selected policy alternatives under each scenario and to develop a robust and responsive plan. We organized first- and second-tier committees of 10–12 experts from diverse professional fields to undertake environmental sustainability policy planning in Taiwan. The first-tier committee generated three scenarios: “live at the mercy of the elements”, “industry convergence”, and “technology pilot”. The second-tier committee ensured that, from cradle-to-cradle (C2C), green supply chain management (GSCM), and industry symbiosis (IS), life-cycle type policies enhance green willingness and capabilities in the businesses. This is the first study to consider the first-tier process with scenario development and the second-tier process with policy portfolio planning for environmental sustainability, and contributes by considering intuitive logics approach-based scenarios and robust policies for extant portfolio plans, providing life-cycle- type policy profiles in environmental sustainability.

Keywords: scenario planning; green supply chain management; scenario development; policy portfolio planning; environmental sustainability policy

1. Introduction

A scenario is an outline description of various aspects of a situation in the future. Scenario development proposes plausible future events and describes their driving forces and induced effects [1]. Scenario planning stimulates strategic thinking and helps address and resolve possible issues by creating certain plausible futures [2]. We conducted two-tier scenario planning with a stepwise, logical, and systematic procedure composed of scenario development and policy portfolio planning to highlight the environmental sustainability policy planning in Taiwan. Scenario development is considered a valuable tool that helps Taiwan’s government prepare for future uncertainty, innovation, and change, and render them more reasonable and controllable [3]. Policy portfolio planning is defined as a type of strategic planning, which Taiwan’s government can employ to develop long-term environmental sustainability policies based on scenario development outcomes [4]. Thus, scenario planning is an important tool for government departments and industrial departments when implementing science and technology policy management, and two-tier scenario planning is an innovative approach.

Taiwan’s environmental load factor is deteriorating. The country is located on a small island with a large population. In 2015, the population density in Taiwan was 0.67 (million person/103 km²), which was higher than that in the United States (0.04), Germany (0.23), the UK (0.27), France (0.12), the

Netherlands (0.50), and other Western European countries. It was also higher than that in Japan (0.35) and South Korea (0.52). The estimated number of motor vehicles per area in Taiwan was 0.58 (million vehicle/103 km²), which was significantly higher than in the above-mentioned countries (0.03–0.35). In Taiwan, the energy consumption per area in Taiwan was 3.08 (106 oil equivalent/103 km²), far higher than the world's major countries (0.25–2.83). These statistics (Table 1) [5] indicate an urgent need for Taiwan to promote environmental sustainability policy [6].

Table 1. Summary of environmental load factors.

Country	Population	GDP	Area	Motor Vehicle	Energy Consumption
Taiwan	24	523	36	21	111
USA	321	17,947	9147	256	2281
Japan	127	4123	365	88	449
Germany	81	3358	349	54	321
UK	65	2849	242	36	191
Netherlands	17	738	34	12	82
France	64	2422	548	41	239
South Korea	51	1377	98	22	277

Country	GDP/Person	Population/Area	Motor Vehicle/Area	Energy Consumption/Area
Taiwan	21.8	0.67	0.58	3.08
USA	55.9	0.04	0.03	0.25
Japan	32.5	0.35	0.24	1.23
Germany	41.5	0.23	0.15	0.92
UK	43.8	0.27	0.15	0.79
Netherlands	43.4	0.50	0.35	2.41
France	37.8	0.12	0.08	0.44
South Korea	27.0	0.52	0.22	2.83

Unit: Population (Million); Gross Domestic Product (GDP, Billion); Area (103 Sq KM); Motor vehicle (Million); Energy consumption (106 Oil equivalent) and data year is in 2015. Source: Environmental Protection Administration, Executive Yuan, Taiwan.

The Earth's climate is now changing faster than at any point in the history of modern civilization. Global climate change has resulted in a wide range of impacts across every region of the global, and many sectors of the economy are expected to grow in the coming decades. The role of the government is now more vital as the issue of climate change has become one of the greatest threats that people are facing. Taiwan, as an emerging Asian country, is no exception. However, government agencies are often considered undecided and inefficient. Effective and efficient planning of environmental sustainability policy is worthwhile and needs to be explored in-depth by researchers, which was the motivation behind this study.

At this time, traditional quantitative analysis and planning methods cannot provide effective solutions because the future is not a continuation of the past, and chaos is inherent in the complex natural order [7]. Thus, scenario development is a powerful approach in addressing the uncertainty of the future [8]. Scenario planning can be applied to issues related to environmental sustainability policies. Climate change, fossil fuel depletion, and cleaner production are three urgent environmental problems in contemporary society [9]. Useful approaches to these issues are the creation of a strategic plan for environmental sustainability policies, the use of non-carbon dioxide emissions, and to recycle renewable resources, such as solar thermal, wind, marine, and geothermal energy [10]. These approaches are the responsibility of citizens of the world because they affect the overall quality of life [11]. Another measure involves building a systematic bottom-up approach for estimating urban CO₂ emissions and offering a consistency check with current top-down estimates in Taiwan [6]. As many environmental sustainability policy alternatives exist and the resources for economic growth are

restricted, the Taiwanese government must consider an effective strategy for the reasonable allocation of scarce resources.

In summary, we employed a systematic scenario planning procedure that integrated scenario analysis and policy portfolio planning. The Taiwanese government has attempted to promote several policies; however, they have rarely been implemented. This results in the misuse of precious resources and delays in implementation. For this study, we compiled a list of the seven major green energy policies created to protect the environment. The Taiwanese government should focus on implementing these limited policies to best use the scarce resources. These policies can effectively resolve issues related to maintaining a sustainable environment and can reduce energy waste [12]. Based on the analysis of the literature review, knowledge gaps in scenario analysis and policy portfolio planning were identified. The first-tier Scenario Development Committee, consisting of 10 experts from diverse fields, conducted a qualitative scenario analysis to obtain a broad description of the physical environment in the future, covering various contexts as well as non-quantitative factors. The second-tier Policy Portfolio Planning Committee, which consisted of 12 senior experts, planned a policy portfolio to develop a concrete and sustainable policy and formulate a list of prioritized policies to match the needs of the Taiwanese government. Another contribution of this study is the finding that Taiwan's sustainable industry policy must emphasize life-cycle type policies (cradle-to-cradle, C2C; green supply chain management, GSCM; and industry symbiosis, IS) rather than incentive-type policies (functional sales, FS; energy saving company, ESC; and design, build, finance, and operate, DBFO). This result is useful for developing countries as their resources are rather limited and they must focus on a specific policy in order to effectively develop sustainable industry policies [6].

2. Literature Review

Both quantitative and qualitative approaches are available to explore environmental sustainability policy. An example of the quantitative approach is time series and/or econometrics model; the qualitative approach is used in scenario planning. The time series and/or econometrics model can be used to combine traditional forecasting techniques to conduct trend impact analysis with the quantitative factors [13,14]. It can be modified with trend extrapolation to investigate how unprecedented events affect future events. This approach can identify some of the impacting factors combined with evaluating the probability of occurrence to reinforce the impact effects [15]. This approach limits the assessment of a quantitative key decision or predictive variable, which predicts the future through historical data. However, the future is not necessarily a continuation of the past. When reliable historical time series data are not available, the estimation process is bound to be limited [2,16].

The scenario approach is not as accurate as predictive models, like the econometrics model; the specific predictive results cannot be represented by a clear magnitude [17]. However, the scenario approach can portray the greater likelihood of future alternatives to include the uncertainty of the future. It can extensively describe the background environment, including the driving factors and environmental impact factors at all levels [18]. Thus, it can present the arguments to recognize a number of significant structural differences in the future [2]. The conclusion of a scenario analysis has highly decision-oriented management implications.

It is difficult for the general public to understand and respond to the sophisticated issues of sustainable environmental policy based on the global warming trend. The foresighted policy and view were hard to investigate through general surveys, using large-scale questionnaires, or empirical studies [2,16]. As no statistical databank is available for this issue, a quantitative model of econometric measurement would be difficult to conduct. Therefore, we suggest that the scenario approach, which relies on expert opinion, can provide an in-depth understanding of environmental sustainability policy. The pros and cons between the scenario approach and empirical studies are listed in Table 2.

Table 2. Pros and cons of the scenario approach and empirical studies.

Item	Scenario Approach	Empirical Studies (Time Series and/or Econometrics Model)
Pros	Scenario approach can portray several likelihood future alternatives to include the uncertainty of the future.	Empirical approach combines more traditional forecasting techniques to conduct trend impact analysis with the quantitative qualitative factors.
	Can describe the background environment extensively including the driving factors and environmental impact factors at all levels. Thus, it can present the arguments to recognize a number of significant structural differences for the future.	Can be modified with trend extrapolation to consider perceptions that investigate how unprecedented events affect the future events.
	The conclusion of scenario analysis has highly decision oriented and management implications.	Some impacting factors can be identified, combined with evaluating the probability of occurrence to reinforce the impact effects.
Cons	Unable to present the high accuracy of the predictive model like the econometrics model; that is, the specific predictive results cannot be represented by a clear magnitude.	Only limits the assessment of a quantitative key decision or predictive variable, which predicts the future through historical data. However, the future is not necessarily a continuation of the past.
	Unable to predict the future based on a set of natural laws that can be used to quantify human behavior.	Does not consider possible impacts of the causal relationship between each event.
	The process of scenario building is time-consuming, requiring one or more days of activity. This requires participants to have enough time.	When reliable historical time series data are not available, the estimation process is limited.

Scenario analysis is conducted to posit plausible future events and highlight their driving forces and consequent effects [19]. Although scenario analysis does not produce predictions or forecasts, as this type of investigation could be used to emphasize possibilities in the future, it is considered a device for “disturbing the future” [9]. Mietzne and Reger proposed two types of scenarios: Exploratory and normative scenario. An exploratory scenario is based on past and present trends to lead to a realizable future, and a normative scenario involves building a scenario based on different visions of the future [20]. Berkhout and Hertin argued three kinds of scenarios: Issue, mission, and action scenario. The issue scenario highlights the essence of the problem and demand requirements in the future, and the mission scenario is developed based on a specific intent or direction. The action scenario sets forth objectives and is directed toward the strategic actions [21]. Global and technology scenarios have also been applied. The global scenario offers a guide to many distinctive future environments, where each has different implications for long-term investment and operating decisions. The technology scenario provides an understanding of the opportunities, risks, and choices to prepare for better technological decisions [22].

In detail, there are three major approaches to scenario development in the literature: (1) Intuitive logic, (2) probabilistic modified trends (PMT), and (3) the French La Prospective approach. In scenario development, the intuitive logic approach is qualitative, PMT methodology is a quantization method, and the French approach is a hybrid method [2]. Amongst these approaches, the intuitive logic approach is the most popular and dominant.

The advantage of an intuitive logic approach is in considering the close relationship between experts, creative atmosphere, and cooperation consciousness, and to integrate communication skills to develop the scenarios. An intuitive logic approach generates new ideas and can help identify the bottom layer of environment context. Thus, it is connected to the experts who work on the scenario;

however, the disadvantage of an intuitive logic approach is that it struggles consider the precise values of external environmental forces and checking the validity of the intuitive logics approach adopted from a scientific point of view is hard [9].

The probabilistic modified trends approach is a type of trend impact analysis, which involves statistical extrapolations with probabilities with the benefits of being highly formalized [23,24]. The French approach is also a highly formalized method. These two methods can only be used when a detailed and reliable time series of data is available and the participating experts are controlled to those with a background in the field of statistical probability [20]. Thus, the selectivity of experts is severely restricted, and the creativity of expert opinions is highly suppressed.

Moss et al. [8] adopted four climate scenarios to explore environmental uncertainty and climate change variability to examine the projections of potential future ranges from dry and cold to wet and warm. In the study, three scenarios were derived from eight scenarios on three uncertainty axes instead of the full four scenarios from two uncertainty axes. The most intensive discussions among the experts were highlighted, and three scenarios were selected from the eight scenario options. Consistency and common opinion principles were applied to choose the final three scenarios [25]. A plausible scenario in the uncertainty axes was chosen rather than directly selecting the most desirable or the most likely option.

Stewart et al. [26] applied multiple criteria decision analysis (MCDA) to a scenario analysis of agricultural crops in a developing country. Amer, Daim, and Jetter [27] used a scenario analysis in a fuzzy MCDA approach to investigate the wind energy sector in developing countries. However, several non-quantitative factors such as political culture and the ethics of science and technology cannot be included in a quantitative analysis using MCDA or fuzzy MCDA. In our study, the structural and stepwise procedures in expert discussions were analyzed using the Delphi method and the nominal group technique rather than an MCDA or fuzzy MCDA approach. Thus, this study provides high-level descriptions of the contextual environment based on the input of experts from diverse fields [7].

Since the late 1980s, the scenario analysis procedure has been frequently used by Stars Lab (San Jose, CA, USA) and Stanford Research Institute (SRI) International (Menlo park, CA, USA), and has been confirmed as a powerful tool in government agencies and business organizations in the USA (e.g., Pacific Gas and Electric Company), Western Europe (e.g., governments in Norway and Sweden), Japan (e.g., Mitsubishi Electric Corporation), and South Korea (e.g., Samsung Group).

Regarding scenario planning, the SRI has expanded several planning programs that include scenario analysis, technology portfolio planning, and technology roadmaps [1,25,28]. Sharma and Yang [4] discussed three types of scenario analysis: The prospective approach, the firecracker method, and the shell approach, and proposed the use of a scenario approach in the field of digital media with three policy construction parameters: Ownership, innovation, and distribution. Parallel studies were conducted by Mitchell et al. [29] who employed both social ecological systems and scenario analyses to investigate the interactions between humans and biodiversity outcomes. Ramírez and Selsky [12] also used a social ecology approach in scenario analysis to examine the unpredictability and uncertainty that characterizes turbulent environments. They employed a transition principle, a heterogeneity principle, and a subjectivity principle to demonstrate how scenario planning could help instantiate each principle.

In practice, the United Nations Environment Group implemented a scenario analysis in 2018 to present the impact of climate change on global financial activities to evaluate the need for the banking industry to conduct actual assessments of the climate change challenges. The United Nations Environmental Finance Initiative (UNEP-FI), in conjunction with 16 leading banks around the world, used a scenario analysis approach to launch an innovative project and completed a report in April 2018 that enabled the banking industry to predict its strategy and plan its portfolio [30].

Regarding to the methodology of the scenario planning models that have appeared in the literature for the last five years, Morandi [31] developed an adaptation of the system thinking and scenario planning method to realize the key factors that impact the pricing of commodities and implemented it

in the iron industry. The system thinking helps to catch the understanding of the driving forces of the price; while in the scenario planning, action research was adopted, which is characterized by the principles of collaborative and continuous learning for the proposal of future prices in some scenarios. Yao et al. [32] proposed a scenario planning model in the power sector, which was combined with scenario analysis and scenario-based comprehensive expansion planning framework. Bowman [33] investigated the practice of scenario planning to focus on inter- and intra-organizational strategy. Amongst, scenario planning was deemed as a practice of simplex that combined with the complexity of thought and simplicity of action. Thus, Bowman [33] employed an in-depth, longitudinal case study to demonstrate the importance and interaction of sense-making, storytelling, and meaning creation at the inter- and intra-organizational levels. Derbyshire and Wright [34] applied the intuitive logics scenario planning method to conduct a comprehensive analysis of uncertainty from a step-by-step procedure. They employed a broader consideration of causes; that is, incorporating Aristotle's nuanced analysis of causation, to conduct the scenario development. Loßner [35] assessed the economic performance of virtual power plants by the scenario-based and model-supported analysis. Loßner depicted the future energy market conditions from employing the scenario methodology. Finally, Oliver and Parrett [36] evaluated the role of scenario planning and provided empirical evidence on how the scenario planning tool was adopted and selected from the strategist's toolbox. However, all of the above studies [12,29–36] employed the one-tier scenario planning model. Lacking comprehensive consideration has been the major drawback for the one-tier model, because a single committee has to complete two challenging tasks: Scenario development and policy planning. Besides, the capability of the one-tier committee might be relatively limited. This study, thus, proposed a two-tier scenario model to explore and establish the corresponding environmental sustainability policy in Taiwan by extending and updating the traditional scenario planning model. The first-tier committee is in charge of generating potential scenarios at first. Based on the scenarios resulted in, the second-tier committee then developed viable policies in the hope to enhance the green willingness and capabilities for businesses. The proposal of the two-tier scenario model is the primary academic contribution of this study.

To explore environmental sustainability policy-making, an exploratory scenario, an issue scenario, and a global scenario are required, rather than a normative scenario, a mission scenario, or a technical scenario [2,20]. The future is not a continuation of the past, and the dynamics are not human choice and action that can be measured. Nothing is impossible in the future; uncertainty produces a number of future scenarios for a possible space. Thus, we employed a scenario approach with the intuitive logic approach to conduct scenario planning.

Our research expands sustainable policy into two-tier scenario planning. Within the two-tier policy portfolio planning, we included objective criteria in the four evaluation criterion of the suggested policies, which further refine the scenario planning. Thus, the scenario content is derived from a megatrend in the external environment rather than from a prediction of the future based on statistical confidence intervals [2].

3. Scenario Planning Procedure

The purpose of a scenario planning procedure is to pair and coordinate scenarios with applicable policies. In our study, the scenario planning procedure included the seven steps shown in Figure 1: (1) Identify the decision values and priorities, (2) confirm the interests of the stakeholders and the driving forces of the main megatrends, (3) identify the axes of uncertainty, (4) select and revise scenarios, (5) develop policy alternatives, (6) evaluate the policy alternatives under each scenario, and (7) develop a robust policy portfolio plan. Steps 1–4 are conducted by the first-tier Scenario Analysis Committee, and Steps 5–7 are conducted by the second-tier Scenario Planning Committee.

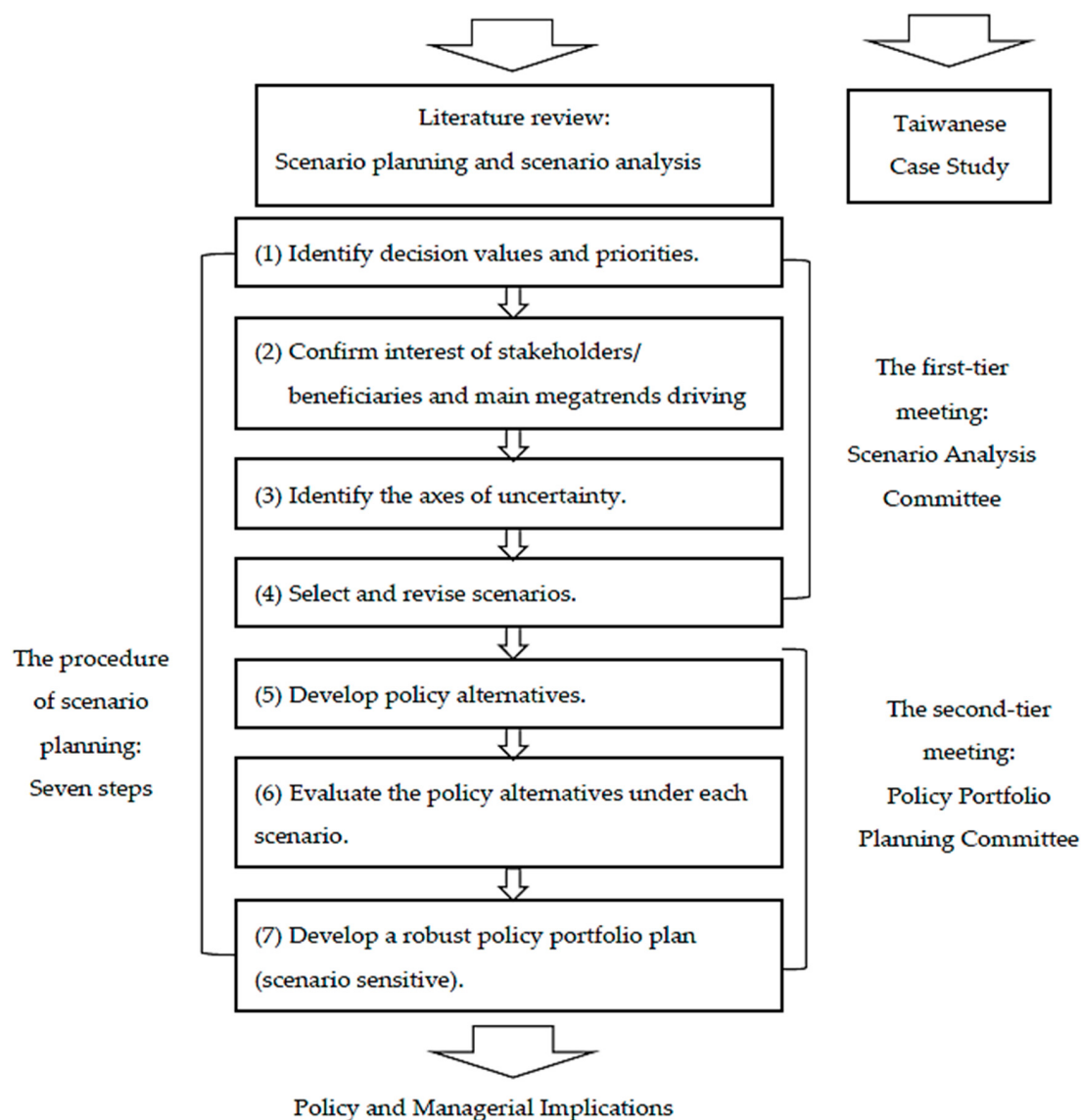


Figure 1. The two-tier scenario planning process.

In this study, first, the four policy selection criteria were discussed. Second, the criteria used to select the seven policies were quantitatively assessed. Third, a scenario robustness analysis was conducted to provide conclusions about concrete and sustainable policy development. Finally, the priorities of the various policies were determined. Therefore, this study is different from similar scenario planning studies that have discussed the framework of the policy selection criteria only using a nominal group technique. The above four steps provided major contributions to the methodology.

In Step 1, decision values and priorities were identified to reveal management problems. The first-tier Scenario Analysis Committee included policy managers, economists, engineers, legal experts, and researchers. These committee members discuss several issues, such as goals and the basic concerns with the scenario analysis. Two operational issues were suggested for discussion: (1) Proposing the policy strategy, time range, and target market for the policy creation process; and (2) identifying the policy attributes, including risk and return [25,37].

In Step 2, the interests of the stakeholders/beneficiaries and the driving factors of the megatrends were confirmed. The interests of the stakeholders/beneficiaries include the government, private sectors, and non-profit organizations [37]. The driving factors behind the megatrends cause governance problems that are affected by the policy priorities. The Scenario Analysis Committee examined the

cause-and-effect relationship between the interests of stakeholders, the focus of the scenarios, and the driving forces behind the megatrends assist the committee members in systematically clarifying the issues. The driving forces of the megatrends are regarded as the prerequisites and elements of the scenario context because they drive the development of the scenario [2,37]. In preparation, the proposed driving forces of the megatrends include supply-side factors, demand-side factors, and regulatory factors.

In Step 3, the axes of uncertainty were identified. The axes of uncertainty predict the results of the driving forces of the megatrends and identify their antecedents. The Scenario Analysis Committee builds an impact–uncertainty matrix (Wilson matrix) to reorganize the suggested driving forces of the megatrends and selecting the high (middle) uncertainty level and high (middle) impact level to condense the uncertainty axes [2,38]. This Wilson matrix is particularly suitable for the policy-oriented properties of energy and environmental policies. As the importance of the dimensions can be attributed to key decision factors, the committee then developed the three uncertainty axes into eight targeted scenario logics as the basis of the scenario framework ($2^3 = 8$).

In Step 4, the scenarios were selected and revised. The Scenario Analysis Committee used the axes of uncertainty to expand the selected scenarios that result from the axes [39]. The committee adopted the scenario validation process and employed plausibility and the consistency and common opinion principle to select the final scenarios, as these are the common rules that most governments use [2]. A scenario was selected out of the possible combinations of the uncertainty axes rather than by directly selecting the most desirable or the most likely [19]. Two to four scenarios were selected and reported. To formulate an image of the future, the committee revised the scenarios according to their four main components: Purpose, orientation, framework, and justification/supporting materials [28].

In Step 5, the policy alternatives were developed. The first-tier Scenario Analysis Committee finally highlighted the opportunities and threats under three scenarios and determined the needs of the government, then generated seven policy alternatives. The policy alternatives are presented as the solutions or decisional implications of the environmental sustainability policies of the selected scenarios [28]. Generating government needs and policy alternatives are the core of Step 5.

In Step 6, the policy alternatives under each scenario were evaluated and a two-tier Policy Portfolio Planning Committee consisting of senior experts was organized. The two-tier committee then uses the policy assessment tool to evaluate the suitability of the seven policy alternatives, the policies themselves, and the portfolio plan under each scenario [12]. To help visualize this analysis, the committee employed four evaluating indices to assess opportunities and threats in addition to the policy planning: Strategic importance, market value, market timing, technology status, and committed resources [25].

In Step 7, a robust policy portfolio plan was developed. The robust policies portfolio plan was tested and the results of Step 6 were developed. The two-tier Policy Portfolio Planning Committee then created another robust policy portfolio plan by aggregating the results of the three scenarios [36].

4. Taiwanese Case Study

4.1. Stage 1: The First-Tier Committee: Scenario Analysis Committee

First, the decision values of the environmental sustainability policy were obtained based on the results of a survey of 65 social opinion leaders [40], such as academic professors, industrial experts, business chief executive officers (CEOs), professional artists, social leaders, and government officials. The resulting values were weighted as follows: A 50% weight on economic growth, such as increased per capita gross domestic product (GDP); 25% on social equity, such as reductions in the income gap between the rich and the poor and increased care for the elderly and disabled; and 25% on quality of life, including environment protection policies and a balance between work and leisure. These values provided references for assessing the strategic importance of the environment management alternatives.

The first-tier Scenario Analysis Committee consisted of 10 experts from diverse backgrounds such as law, history, technology, economics, public affairs, finance, administrative management, international business, and other academic and professional fields. One-third of the experts had experience in working for the government (Table 3). We identified and selected suitable experts and scholars from the expert consultants list of governmental sectors. The Public Construction Commission (PCC) of Taiwan Executive Yuan, complying with the Government Procurement Law, built and maintained an expert list containing the database of scholars in several fields. The candidates were randomly selected within the list from four categories: Environmental sustainability, industrial development, public administration, and financial accounting. Based on the inventory list of expert consultants, we drew lots to determine their order, and then separately asked about their willingness to participate, and placed a priority order to the member of the steering committee. The results showed that most of the selected experts were consultants/members of the Environmental Protection Agency, Energy Agency, and Executive Yuan, university professors, and members of the well-known major think-tanks in Taiwan. They convened in Taiwan in June 2017 to conduct a scenario analysis of future development based on decision values and environmental policies. Through frequent communication about the list of discussion topics shown in Table 4, the committee members developed the driving forces of megatrends in future scenarios of environmental policies. Based on an uncertainty–impact matrix and axes of uncertainty, the committee developed three scenarios of sustainable environmental development in Taiwan.

Table 3. Backgrounds of the two-tier committee members.

Committee Attribute	Scenario Analysis Committee	Policy Portfolio Planning Committee
Job Position		
president/vice president	2	1
CEO/Dean/Director	3	4
division leader	3	4
expert/professor	2	3
Expertise Field		
Commerce		
finance	1	1
business administration	1	1
international business	1	1
Law and Public Affair		
law	1	1
real estate	1	1
economics	1	0
public administration	0	1
Humanities		
linguistics	1	0
history	1	2
philosophy	1	1
Engineering		
engineering	1	1
natural resource	0	2
Number of Members	10	12
Three more years' experiences in the government sector	3	4

Table 4. Discussion topics for the Scenario Analysis Committee Members.

No	Topic
1	What fields of sustainable environment have a good chance of being developed in Taiwan over the next five years?
2	The Environmental Protection Agency is in charge of sustainable environmental development. What are the stakeholder interests that the decision makers should be concerned with while planning the development strategy for a sustainable environment?
3	What are the main driving forces that influence the Environmental Protection Agency in making decisions?
4	What other issues should be considered in our study?

We first defined the issues of interest, including timeframe, scope, and major stakeholders (roles, interests, and power positions). The timeframe was 2018 to 2022, and the geographical scope was the public sector in Taiwan. The research question was “What is the future development of the culture, settlement, and public goods in Taiwan during the next five years?” After extensive discussions by the Scenario Analysis Committee, the driving forces of 21 major megatrends in Taiwan were proposed and divided into three groups: Natural environment and technology, political and economic development, and social and cultural environment.

Furthermore, 10 main driving forces of the external business environment were identified to have high-to-medium uncertainty and impact levels and were grouped as follows. (1) Climate and environment forces: Extreme climate increases global warming and environment protection needs to be uplifted; (2) technology development forces: New energy and environment related technology breakthroughs, renewable energy technology development, the gap between technology development and sustainable environment development, and the construction of law norms with new technology development; and (3) industry development forces: The status of the green supply chain industry, cycle economy, and green finance, and the incoherence of long-term political and economic policies.

The Scenario Analysis Committee built an impact–uncertainty matrix (Wilson matrix) to organize the suggested driving forces of the megatrends [2,38]. Each expert was asked to answer a questionnaire and was asked about the comments on megatrends in Taiwan. Each megatrend consisted of two questions: (1) Do you agree that the impact of this megatrend is very high? (2) Do you agree that the uncertainty of this megatrend is very high? The answer option for each question was a five-scale Likert scale including five options that ranged from ‘mostly disagree’, ‘disagree’, ‘ordinary’, ‘agree’, to ‘mostly agree’. There were 42 questions in the questionnaire. When the statistical calculation was completed, it was classified into the established impact–uncertainty matrix. To condense into the uncertainty axes, “high impact and high uncertainty”, “high impact and middle uncertainty”, and “medium impact and high uncertainty” in the matrix were chosen to organize critical uncertainties.

These critical uncertainties were placed into three axes of uncertainty: (1) Degree of severity of global warming, (2) degree of maturity of renewable energy technology, and (3) degree of integration of green energy industry. The degree of maturity of renewable energy technology refers to environmental science, environmental monitoring, clean energy, and green chemistry to conserve the natural resources and environment in order to attain a high degree of reliability. The spectrum of the degree of maturity ranged from the well-established to the less mature [35]. For example, Huang, et al. [41] compared the difference in the results with and without market diffusion curves through scenario analysis, and proved the necessity of incorporating the diffusion curve setting of emerging technology market into the linear programming model.

This spectrum is similar to the degree of integration of the green energy industry. Solar photovoltaics and wind power industries are two examples of the green energy industry. For example, in Taiwan, the Hsinchu green industry alliance assists in industrial research and development (R&D) and the transition to technology integration. It provides a shared platform to facilitate resource recycling and fish-cuisine industry symbiosis [42]. The degree of integration is critical for the effectiveness of

green industry development. The degree of integration is the extent to which diverse green energy industries are incorporated into a market, policy, and technical field in order to build, monitor, and maintain green energy infrastructures at domestic and global levels [43].

The selected scenarios were generated from three uncertainty axes based on impact–uncertainty matrices. In turn, eight scenarios were generated from three uncertainty axes. We selected scenarios based on the principle of consistency; we omitted the uncertainty axis where the strength and direction were obviously inconsistent [19]. Following the principle of commonality, three to four scenarios were selected for most of the decision-making. To build consensus and enhance mutual understanding among the expert participants, the candidate scenarios were discussed simultaneously [19,28]. At this stage, the potential scenarios, which were mutually exclusive, were selected. To demonstrate the rich connotations of the uncertainty envelope curves, this approach encompasses the variability of multiple levels and opportunities.

Eight scenarios were established by combining each extreme of the three axes of uncertainty ($2^3 = 8$; from scenarios A to H) as shown in Table 5. We omitted eight combinations that were not internally consistent or intrinsically similar. We then selected three structurally different and plausible scenarios—D, F, and G—to supply a possible combination that incorporated the main uncertainties in the future external environment. Each scenario was given a title. The details are provided in the following sections. The first-tier Scenario Analysis Committee highlighted the opportunities and threats under the three scenarios and derived the needs of the government, then generated seven policy alternatives (Table 6), including seven policies in two major considerations of environmental sustainability. First, the incentive type policies included FS, ESCO, and DBFO. Second, the life-cycle typed policies included GSCM, TBM, C2C, and IS [44]. Although this case study was conducted in Taiwan, the methodology used in the scenario planning could be applicable, comprehensive, and stepwise in other contexts, and the results could be applied to developing countries.

Table 5. Scenario shortlist procedure.

Scenarios	Impact of Global Warming	Degree of Maturity of Renewable Energy Technology	Degree of Integration of Green Energy Industry	First Round Selection ¹	Second Round Selection ²	Final Scenarios ³	Scenario Nominate
A	Moderate	Mature	Integrated	X			Utopian
B	Moderate	Mature	Fragmented		0		Busy oneself with helping other people
C	Moderate	Early-stage	Integrated		2		Original equipment manufacturer
D	Moderate	Early-stage	Fragmented		5	O	Live at the mercy of the elements
E	Serious	Mature	Integrated		3		Big harvest
F	Serious	Early-stage	Integrated		8	O	Industry convergence
G	Serious	Mature	Fragmented		6	O	Technology pilot
H	Serious	Early-stage	Fragmented		3		Turn upside down

Notes: ¹ “X” is the scenario being excluded because it did not exist. ² The number in the second-round selection is the voting result. There were 10 members, each member could vote at most for three scenarios; thus, the total voting number was 27, which was less than the maximal number (30). ³ O is the final chosen scenario.

Table 6. Scenario deriving government needs.

Scenarios	D. Live at the Mercy of the Elements	F. Industry Convergence	G. Technology Pilot
Opportunity	1. The business opportunities of green energy products are unlimited 2. Green electric goods and green building goods have great potential (such as ocean temperature difference, geothermal)	1. Green industry supply chain has development opportunities 2. Establish an inter-enterprise green energy cooperation platform	1. Electric car booming 2. Enterprises promote recycling from cradle-to-cradle
Threat	1. Lack of energy-saving technology and industry chain	1. Enterprises face high electricity prices 2. Political interference interferes with business opportunities for green energy industry development	1. Green energy industry supply chain is subject to other countries 2. Excessive use of energy-consuming products causes energy waste
Government Needs	1. Promote the rental system to increase the sales function 2. Establish a design and construction financial operation system 3. Build and operation an energy-saving management system in the enterprise institution	1. Design and operate the mechanism of supply chain management with environmental benefits 2. Establish an industrial integration system or symbiosis platform	1. Architecture systems with a long green life-cycle in production and sales system 2. Establish a retrieval management system
Policy Alternatives	1. Functional sales 2. Design, build, finance, and operate 3. Energy-saving company	1. Green supply chain management 2. Industrial symbiosis	1. From cradle to cradle 2. Take-back management

The seven environmental sustainability policies were based on a case study in Taiwan and the relevant literature. Four of the seven environmental sustainability policies have been adopted by the Taiwanese government (i.e., Environmental Protection Administration (EPA), Executive Yuan; Industrial Bureau and Bureau of Energy, and the Ministry of Economic Affairs). The other three policies have recently been launched in Taiwan although they had been executed in the European Union for several years [45].

TBM, FS, ESCO, and GSCM are well-developed policies that have been implemented in Taiwan. The short-term goals of the five policies have almost been completed. Among these policies, the TBM policy was implemented by the Environmental Protection Administration (EPA) several years ago for the collection, regeneration, and recycling of energy, resources, waste, and wastewater discharged from industrial processes. The Four-in-One Resource Recycling Program was fully implemented using recovery funds in conjunction with the community, local cleaning teams, and recyclers to establish a sound recovery system. To increase the effectiveness of the recovery fund, the EPA maintained the fund and compensated victims for suffering from serious environmental pollution. Regarding FS, the Industrial Bureau have revised the industrial innovation regulations several times to promote a circular economy and implement tax relief subsidies to encourage the exports of related industries [46]. ESCO is a mature project that has been supported by Taiwan's Central Government (Bureau of Energy) and local governments (Economic Development Board) for many years. They also established an ESCO energy landing platform and a founding corporation to promote the Taiwan Green Productivity Foundation. Yang et al. [47] explored an energy management service for energy service company (ESCO) with transaction cost theory, which affects energy demand willingness and links the energy service company internal/external scenario through a formal control mechanism. The Industrial Development Bureau has promoted the Industrial Green Technology Upgrading Program to assist industries in importing advanced technologies and concepts to build a GSCM. Through diversified counseling, the Industrial

Development Bureau assists the industry in introducing advanced environmental technologies and in building a complete industry supply chain and a pollution prevention and control system to enhance the overall business performance of enterprises. These programs include the following: Industry green supply chain enhancement counseling, dynamic analysis and response to relevant laws and regulations related to the establishment of green supply chain, and examination and examination of relevant environmental issues.

Second, IS, C2C, and DBFO have already been implemented in the European Union for many years. They are beginning to be implemented in Taiwan as the result of emerging policies. Among them, the IS policy specifies a recycling economy called “your waste, my resources”. The Industrial Bureau promotes the proper use of industrial waste, such as the slag produced by Taiwan’s steel industry, the sludge produced by its textile industry, the calcium chloride sludge and waste solvents produced by its electronics industry, and the waste produced by the petrochemical industry, which can be transferred to the cement industry as a catalyst. The sulfuric acid and solvents in the electronics industry, steam in the steel industry, and hydrogen in the petrochemical industry can be diverted to the chemical materials industry. Industrial grade sulfuric acid in the chemical materials industry and steam in the steel industry are diverted to the metal manufacturing industry. In 2017, more than 90 types of industrial waste were used, the reuse rate of industrial waste reached 80%, and the output value of the resource recycling industry generated a profit of USD \$2.6 billion [48]. Regarding C2C, the EPA has helped the private sector to establish a C2C information exchange platform in Taiwan. The EPA has links with the C2C community to promote relevant knowledge and practices and assist private enterprises to establish strategic alliances in this community. Finally, DBFO offers options for financing renewable green (wind and solar) energy power plants in Taiwan, which are already covered by the Industrial Property Ordinance in Tax Concessions Relief.

4.1.1. Scenario D: Live at the Mercy of the Elements

Scenario D represents a passive stance toward renewable energy technology breakthrough and green energy industry development in Taiwan. In this scenario, the timing is wrong for developing a green industry. Furthermore, the pressures of climate change and the global warming crisis are decreased, and the degree of concern of worldwide environment issue is reduced. Moreover, renewable energy technology does not have an obvious breakthrough, which is partly due to the reduction in funding to promote and develop renewable energy technology. The Taiwanese government has not reinforced the development of green industry because it has not been pressured to do so by forces overseas. Green finance and the recycle economy are still marginalized, and related legislation procedures have been laid aside. In summary, scenario D presents a weak incentive for developing green industry and renewable energy technology.

4.1.2. Scenario F: Industry Convergence Scenario

In the industry-convergence scenario, global temperatures continue to rise, and an extreme climate is experienced in Taiwan. To relieve the pressure of further climate change, carbon dioxide emissions could be further controlled over the next five years. In addition, the green energy industry has progressed remarkably, and the government has supported policies that have enhanced the integration of green industry. However, the green renewable energy technology process has become stagnant because of governmental disability and an unclear renewable energy technology policy. The development of renewable energy technology in Taiwan is slow even though the Taiwanese government has aggressively supported the green industry.

4.1.3. Scenario G: Technology Pilot Scenario

In the technology pilot scenario, global warming and extreme climate change are worsening. The global community urges the reinforcement of environmental conservation to regain the environmental balance, which induces the apparent growth of renewable energy technology. The green cross-industry

supply chain platform has been well established. The regulation of carbon dioxide emissions drives the progress of the renewable energy technology. However, there is a lack of obvious industrial integration. As a result, green industry and renewable energy industry are dependent on foreign imports that are not locally available. There is a huge need to develop resource take-back management, industrial symbiosis management, energy saving, and reusing operations. Thus, green finance and the recycle economy have not flourished, and related legislation procedures have repressed them. Social enterprises and shared economies have not been well established.

4.2. Second-Round Meeting: Policy Portfolio Planning Committee

The second-tier Policy Portfolio Planning Committee met in Taiwan in October 2017. This committee consisted of 12 senior academic, technology, and policy experts who first confirmed the above seven policy alternatives, then assessed the seven environment policies, and constructed an environment treatment technology portfolio plan (Table 3). The 12 committee members mainly focused on the energy, environment, industry, and public administration fields. We also identified and randomly selected suitable experts and scholars from the expert consultants list of the PCC. The Policy Portfolio Planning Committee employed a policy portfolio analysis method to evaluate the seven candidate policies.

In the present study, four evaluating indices, consisting of strategic importance, business market value, commercial opportunity, and technology status/committed resources, were used to examine the seven policies to assess opportunities, threats, and policy planning.

The strategic importance of a policy alternative was evaluated by two indicators: The consistency in governmental industrial policy and the consistency in overall governmental policy. The business market value was assessed by the market value or revenue capability in 2022 and by the percentage deduction in energy costs (cost competitiveness) from 2018 to 2022. The opportunity of the policy in Taiwan was evaluated by the following indicators: Lead time to commercialization and market entry barriers. Technology status and committed resources were measured according to technology position and manufacturing capability and accessibility. Strategic importance and business market value were combined and renamed “importance”, which is shown in the ‘Imp’ column in the policy assessment table (Table 6). Similarly, the commercial timing and/or risk, technology status, and committed resources were combined and renamed “opportunity”, which is shown in the ‘Opp’ column in the policy assessment table (Table 7). Table 7 shows the results of the evaluation of the importance and opportunities in the seven policies. Table 7 provides the empirical results in the policy assessment table of the three scenarios. These indicators were fitted to the Taiwan case study and were established by 12 academic and technology professionals in the second-tier Policy Portfolio Planning Committee. The indicators could be applied to other nations albeit with certain adjustments.

4.2.1. Scenario D: Live at the Mercy of the Elements

In scenario D, the importance–opportunities evaluation showed that since the threat of climate change had decreased, technical innovation failed, and green industry development weakened; only the traditional GSCM, which had been developed since 1980, was of high importance and high opportunity. GSCM is universally recognized as achieving long-term sustainability in the face of increasing climate, ecological, and environmental complexity [49]. Supply chain partnering, waste management, and closed-loop supply chain management are the factors important for attaining a sustainable environment [50].

Table 7. Policy Assessment Results.

Policy	Item											
	Scenario D			Scenario F			Scenario G			Robustness (Total)		
	Imp ²	Opp ²	Sub-Total ³	Imp ²	Opp ²	Sub-Total ³	Imp ²	Opp ²	Sub-Total ³	Imp ²	Opp ²	Sub-Total ^{3,4}
A ¹	23	16	39	25	21	46	18	22	40	66	59	125 (3)
B ¹	24	22	46	14	17	31	19	20	39	57	59	116
C ¹	29	26	55	29	38	67	33	31	64	91	95	186 (1)
D ¹	22	20	42	40	24	64	26	26	52	88	70	158 (2)
E ¹	14	17	31	20	19	39	10	13	23	44	49	93
F ¹	17	27	44	12	17	29	30	20	50	59	64	123
G ¹	15	16	31	4	8	12	8	12	20	27	36	63
Total ⁵	144	144	288	144	144	288	144	144	288	432	432	864

Notes:

- 1 Regarding the seven policies, 'A' is C2C, 'B' is TBM, 'C' is GSCM, 'D' is IS, 'E' is DBFO, 'F' is ESCO, and 'G' is FS. Meanwhile;
- 2 "Imp" is the abbreviation of strategic importance, and "Opp" is the abbreviation of policy opportunity;
- 3 In the subtotal, the bottom line in bold letters represents the policy;
- 4 (1), (2), (3) are the top three priorities of seven policies;
- 5 Each expert assessed and selected the top three rankings in the seven policies as follows: The first-order gives 3 points; the second-order gives 2 points; and the third-order gives 1 point. Thus, each expert can give a total of 6 points (=3 + 2 + 1). There were 12 experts, so the total scores can be up to 72 points (=6 × 12). Because we combined the total strategic importance/value and business/market value, the total score of strategic importance is 144 points (=72 + 72). Policy opportunity scores were obtained in the same way. Finally, we added the scores of three scenarios to those obtained in the robustness analysis, where the final score of strategic importance or policy opportunity is 432 points (= 144 × 3). The final subtotal score is then 864 points (=432 + 432).

However, even with increased opportunities, IS and ESCO still merit government investments to improve their importance. Similarly, the C2C and TBM are sound technologies in which the government should support. Other technologies are not attractive because they rely on economic developments in the USA and Europe, or those that compete with low oil prices in importance and opportunity. Such technologies could be continued to be monitored as their future progress increased importance.

4.2.2. Scenario F: Industry Convergence

In scenario F, the importance–opportunities evaluations indicate that both GSCM and IS have high importance and high opportunity, and are good targets for public government investment. In this scenario, because the green energy industry has been fully integrated, it provides an ideal environment for developing GSCM and IS [50,51]. As industry convergence functions, IS supplies raw material and a closed-loop energy platform in the implementation of technological and organizational design networks in industrial and urban environments to deal with the complex challenges [52].

C2C, DBFO, and TBM showed medium opportunity or medium importance. They could benefit from governmental investment to increase their opportunity and their importance. The remaining policies are not attractive to Taiwan either because of the low energy returns on input (EROI) in ESCO and FS [53], or because of low level development opportunities, such as the limitations of the sharing economy and the rigid regulations in Taiwan. Thus, constant supervision is needed in the event of the potential enhancement of importance and opportunity.

4.2.3. Scenario G: Technology Pilot

In scenario G, the results of the importance–opportunity evaluation indicate that technical challenges have weakened the progress of sustainable environment technology. The findings showed that the effective policies of GSCM and IS had high importance and high opportunity, and thus are positioned for investment by the government and the private sector. GSCM and IS could be developed and operated if a technology pilot were conducted [54,55].

The findings showed that technology emerging from ESCO, C2C, and TBM are worth government investment to increase their opportunity and enhance their importance.

Scenario G showed the increased demand for equilibrium between economic development and environmental protection. This demand improved the opportunity of FS which produces in a more sustainable way, while others, such as the food, beverage, and alcohol industries, tend to encourage overconsumption. High technical threshold enhanced the opportunities of the remaining alternatives.

4.3. Robustness Analysis

Finally, the contexts of the three scenarios were examined using a stepwise analytical and discussion procedure. The Policy Portfolio Planning Committee found that GSCM, IS, and C2C were the three robust policies that should be developed first, regardless of which scenario was simulated [56]. The empirical results of the robustness tests of the three scenarios are shown in Table 7.

The sustainable policy encouraged enterprises to develop two types of ecological sustainability: The incentive model from the individual side and the life cycle model from the system side [44]. The incentive model refers to providing material incentives to induce the enterprises to operate toward the direction of green enterprise set by the government, which includes FS, ESCO, and DMFO. The life-cycle model directly or indirectly enables enterprises to effectively develop green enterprises and establish the life-cycle-system and includes GSCM, IS, C2C, and TBM [55,56]. Thus, life-cycle-type sustainable environmental policies are recommended based on scenario planning, since the establishment of a sound and sustainable environmental system through the Taiwanese government will be more effective in promoting small- and medium-sized enterprises (SMEs) to implement environmental sustainability, given that Taiwan is dominated by SMEs [45].

The Taiwanese government has developed several policies that have usually been implemented in vain. Seven major environmental sustainability policies designed to develop a sustainable environment were examined over the course of this study. In reality, at least four of these policies would not be effective in Taiwan, wasting precious resources and delaying implementation [42,48]. The results of this study illustrate that GSCM, IS, and C2C are the top three environmental sustainability policies that are life-cycle-type policies, which are worth concentrated promotion in Taiwan. The significance of this result is the contribution of our study.

Regarding the GSCM policy, a single-product, single-period, and multi-echelon closed-loop supply chain (CLSC) was proposed, which channels manufacturers, wholesalers, retailers, and first customers in the forward chain and channels repair/service centers, collectors, remanufacturers, recyclers, resellers, and second customers in the reverse chain [57]. Consequently, a product can be manufactured that integrates both forward and reverse logistics in the supply chain, enabling both cost-efficient and quick responses to the consumers' needs [55]. For example, in the fast-fashion industry, fashion retailers develop inexpensive designs that move quickly from the runway to stores to meet current trend demands [57]. Thus, companies focus on sustainability and ensure the quality and standards of production conditions in their supply chains based on green design. They can use green materials and green production process.

5. Conclusions

The main uncertainties regarding Taiwan's future sustainable environmental development are the degree of severity of global warming, the degree of maturity of renewable energy technology, and the extent to which green energy industries are integrated. To examine these uncertainties, a passive scenario (living at the mercy of the elements) and two active scenarios (industry convergence and technology pilot) were proposed. These three scenarios include a chaotic and unpredictable environment within Taiwan in the future.

The practical contribution of this study was the development of three future scenarios, and then suggesting three sustainable environmental policies that should be formulated and implemented immediately through the cooperation of government and industry. The policies include industrial

symbiosis, from cradle-to-cradle, and green supply chain management that the Taiwanese government needs to promote in a timely manner. This result is useful for developing countries as their resources are rather limited and they must focus on a specific policy in order to effectively develop sustainable industry policies.

The theoretical contribution of this study was the proposal of the two-tier scenario planning method, through the two-stage scenario analysis and policy planning process, which has a more refined current scenario planning procedure. Referring to methodology of the scenario planning model in the last five years, most studies [12,29–36] employed the one-tier model. However, lacking comprehensive consideration has been the major drawback for the one-tier model, because a single committee has to complete two challenging tasks: Scenario development and policy planning. Besides, the capability of the one-tier committee might be relatively limited. This study, thus, proposed a two-tier scenario model to explore and establish the corresponding environmental sustainability policy in Taiwan by extending and updating the traditional scenario planning model. The first-tier committee is in charge of generating potential scenarios at first. Based on the scenarios resulted in, the second-tier committee then developed viable policies in the hope to enhance the green willingness and capabilities for businesses.

Life-cycle-type sustainable environmental policies were recommended based on scenario planning and four insights are highlighted. First, in all scenarios, the findings showed that Taiwan must enrich the private sector and increase government investment in GSCM and industry symbiosis policies. GSCM could motivate businesses to cooperate with green raw material suppliers as key partners in reinforcing green resources and green activities, which would require critical policy instruments that have been adapted for the proposed innovative green business model [44]. IS and GSCM policies could help businesses increase their raw material purchases and production operation systems for upstream suppliers, midstream manufacturers, and downstream enterprises [27,50]. Under these circumstances, inter-organizational cooperation and intra-organizational improvement in green projects would become technically and economically feasible. Second, Taiwan should use C2C design and increase government and private sector investment to generate international cooperation between energy-saving companies to progress future sustainable environmental development. The C2C policy could enhance green willingness and capabilities in the daily operations of businesses. These innovations could be combined with green business model innovations that involve switching to greener inputs, recycling, or reusing resources [37]. Third, Taiwan should continue to supervise other environmental sustainability policies related to accessible technological innovations and their potentially increased importance based on the variations in public and private sector environments that are influenced by climate changes and/or global oil prices [6]. Fourth, the results of the policy portfolio could be applied in the development of a combination of policies that balances analyses, conducts action plans, and allocates limited resources [43].

This study also described the advantages and limitations of the proposed method compared to existing methods [58,59]; the megatrends of the external environment were first discussed to derive the scenario content from three uncertainty axes instead of predicting the future based on an existing quantitative analysis (e.g., a regression model, a time series model, or an MCDA model) [6]. The reliability lower bound (LB) and the reliability upper bound (UB) measurements of the model were unavailable; however, this approach provides a rich description of the contextual environment, including various levels of non-quantitative factors, such as political culture and the ethics of science and technology, that an existing quantitative analysis would not investigate. The findings of the experts on four policy selection criteria were analyzed, an assessment of the selection criteria of seven policies was conducted, and a scenario robustness analysis was performed, the results of which were used to draw conclusions regarding policy development and to formulate the priorities for the implementation of the seven environmental sustainability policies [26].

The research method employed in this study has four limitations. First, the members of the Scenario Analysis Committee and the Policy Portfolio Planning Committee were different. Thus,

the varying perceptions of the two committees' members could cause inconsistencies in the results. However, such two-tier Committees may encourage independent and diversified viewpoints, which could improve the effectiveness and variety of the findings. Second, within this study, the scenarios were influenced by variations in the development of industry and sustainable environments [60]. Renewable energy technology and green industry have experienced dramatic changes [8]. In addition, other uncertainty factors may have significant effects upon sustainable development. In January 2017, for example, the global oil price was USD \$31 per barrel, and increased to over USD \$56 per barrel by October 2017. This case study could be comprehensively improved by incorporating further uncertainty factors into the scenario planning procedure. Third, we provided a quantitative analysis to help the committee experts to scientifically select the final scenarios. A correlation matrix formed by the eight combinations of the uncertainty axes was computed and analyzed by software [38]. However, the correlation matrix method poses an issue because uncertainty axes are unstable, timely, and expensive to create. Besides, we omitted the focused investigation that could provide a theoretical foundation for the effects on the development-specific technological developments due to time and budget constraints. These limitations provide potential avenues for future research. Future research should be conducted to develop uncertainty axes, thus providing a theoretical foundation for specific technological developments [3]. A focused investigation could be performed to select the most suitable megatrends driving factors. Therefore, we suggest that future research include a focus study using the correlation matrix method. Fourth, in this case study, the scenarios, indicators, and outcomes are specific to Taiwan. The historical background and related circumstances in Taiwan differ from those of other countries. Therefore, the analytical results of similar studies performed in other countries could also differ, which might affect the generalizability of the research findings [40,44,45].

In terms of environmental sustainability policies, although we focused on Taiwan, it contains general economic and managerial implications. The scenario planning methodology employed in this study could be extended to research in other nations and areas that have the same issues with natural resources and environmental sustainability. The scenarios, indicators, and outcomes could be applied to other nations if the natural resource endowment, economic development status, and government's operational effectiveness are similar [2]. Thus, the results of the study in the case of Taiwan are meaningful for other nations/regions and we can share Taiwan's experience with other nations/regions. Overall, despite its limitations, the research findings are significant and can be applied to other emerging nations. The stepwise procedure of scenario analysis and policy portfolio planning is an effective methodology for examining environmental sustainability [46].

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