從永續發展觀點探究台灣太陽能光電產業之關鍵因素
Exploring the Key Factors of Taiwan's Solar Photovoltaic Industry from A Perspective of Sustainable Development

李正文*
Cheng-Wen Lee*

摘要

本研究主要是以「永續性」觀點來評估台灣太陽能光電企業之現況及未來市場發展性，而永續管理決策是屬於多元性議題，因此運用分析網路程序法來評估各階層不同決策因素之重要優先順序，其主要決策因素包括政府政策、進入模式、市場需求及商品化能力。結果發現，政府支持及顧客環保意識可創造極大的市場商機，薄弱的企業商品化能力是目前台灣太陽能光電企業擴展市場所面臨的主要障礙。

關鍵詞：永續性，太陽能光電企業，分析網路程序法

Abstract

This paper assesses the present and future market for solar photovoltaic industy in Taiwan, especially from the "sustainability" perspective. Within the scope of this paper, sustainable management is considered as a multi-criteria decision problem. An analytic model aiming the usage of analytic network process in sustainable management is developed owing to the evaluation of the relations between four main criteria – governmental policy, entry mode, market demand, and commerical capacity – in a feedback systematic. The results suggest that governmental support and customer's eco-recognition create greater opppotunities and however, the firms' weaker commercial capacity might establish the barriers for the infant solar photovoltaic market and industry in Taiwan.

Keywords: sustainability, solar photovoltaic industry, analytic network process method

I. INTRODUCTION

The world-wide solar photovoltaic (PV) industry has seen dramatic growth rate of 27% in the recent years, even reaching 32% in 2003, when 742 MWp^2 of cells are sold, taking the cumulative world production to 3145 MW [1]. The global solar industry has grown to USD7 billion per annum, largely on the back of government incentive programs, together with lower prices secured through volume purchases. The industry has experienced an annual growth rate in excess of 18% in over the past decade [2].

Taiwan's green energy manufacturers set to boom after new law enacted. According to Bureau of Energy, Ministry of Economic Affairs (MOEA), Taiwan's green energy industry is poised to boom after a statute aimed at promoting renewable energy development cleared the legislative floor in June, 2009 [3]. A passage of the Renewable Energy Development Act has formally ushered Taiwan into the era of alternative energy development and related applications. It means that in the future, the development and application of renewable, pollution-free sources of energy that produce low amounts of carbon-dioxide emissions will be given priority in terms of low-carbon energy development in the country. Additionally, the benefits of exploiting renewable energy sources (RES) would be enormous. [4] indicates: (1) by relying completely on indigenous resources, renewable energy will reduce reliance on imported fuels and enhance the country's energy security; (2) the envionmental impact of renewable technologies is far less than that of nuclear and fossil fuel power plants. These are no emissions of greenhouse gases of toxic wastes; (3) the cost of electricity from some RES is already competitive with many conventional technologies and is dropping rapidly; renewable technologies have no fuel costs and are virtually inexhaustible.

The statute stipulates that the development of solar photovoltaic energy, solar thermal energy, wind power generation, biomass energy and nuclear power generation will be given priority in terms of energy development.

中原大學國際貿易學系
*Corresponding author. E-mail: chengwen@cycu.edu.tw
Department of International Trade, Chung Yuan Christian University, Chung Li, Taiwan, R.O.C.
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Among the alternative clean energy resouces in Taiwan, the most important one is the solar energy. Taiwan has a larger chance than the other countries in terms of solar energy potential due to its geographical situation. Of these sectors, the solar energy sector will hopefully become the country's next USD35 billion industrial sector and result in Taiwan becoming a leading manufacturer of solar photovoltaic energy equipment in the world. Meanwhile, the Solar Photovoltaic Energy Development Committee under the non-profit Semiconductor Equipment and Materials International (SEMI) Taiwan forecasts that the enactment of the statute will spark investment of USD1 billion in Taiwan's renewable energy sector within one year. In addition, the investment can create up to 10,000 jobs and generate USD3.5 billion in revenues within one to two years [5]. The Taiwan PV Advisory Committee and SEMI PV Group commend the Taiwan Government on its swift passage of the Renewable Energy Act to increase the adoption of solar power in Taiwan. With the goal of making Taiwan the world's third-largest producer of solar cells by 2015, SEMI Taiwan and its members have strongly pushed for a greater role for PV in the region's renewable energy plan to boost development of the island's green energy industries [6]. The traditional meaning of sustainability in terms of sustained yield is radically expanded [7]. However, sustainable management is now defined as "stewardship and use of resources in a way, and at a rate, that maintains their biodiversity, productivity, generation capacity, vitality, and their potential to fulfil now and in the future, relevant ecological, economic, and social functions at local, national, and global levels" [8].

II. LITERATURE

1. Governmental policy

Observing the successful experiences of those who have developed PV industry, the appropriate government policies are needed essentially. For example, the 2002 Australian market for PV systems grow by 27% and sales for grid-connected solar PV systems grow by 95%. According to the Australian Business Council for Sustainable Energy (BCSE), part of this success can be attributed to government incentives to promote sustainable PV systems, such as households wanting to install a solar PV system can receive a federal government grant of up to USD2,300. Looking at the level of firm or industry, tax incentives may reduce a firm's production cost, and further make products more competitive. PV manufacturers in Taiwan expect the governmental help for promoting the industry by offering a range of tax incentives on imported parts and materials and funding support. As more solar systems are installed, their costs continue to fall. BCSE [9] reports that production costs decline 18-20% with every doubling of global installed capacity. If current growth rates are maintained, then unit costs can be expected to halve every seven years or so.

Under the Renewable Energy Act, Taiwan government will provide incentives such as equipment purchase subsidies and low-interest loans to increase renewable energy generating capacity between 6.5 million kilowatts and 10 million kilowatts. Since these policies can give the industry a boost, companies have stronger willingness to increase their investment, enlarge domestic market demand and allow for greater expansion globally, which in turn, create more jobs in the process [6]. On the other hand, setting a training program also can improve the quality of technician in order to improve the R&D ability of Taiwan's solar PV industry. In terms of governmental policy, the five dimensions – tax incentives, supported program, subsidy, carbon levy, and location setting – need to be taken into account in this paper.

2. Entry Mode

Companies commercialize new ideas and technologies through their business mode of entering a new market. A mediocre technology pursued within a great business model may be more valuable than a great technology exploited via a mediocre business model [10]. That is, the economic value of a technology remains latent until it is commercialized in some way via a business model. The same technology commercialized in two different ways may yield two different returns.

Most of time, cooperating with foreign firms can improve the processing technology and fix up some shortcomings. Firms have adopted a number of different modes to enter a market. In resource- and technology-intensive industries, firms use shared control modes to access related resources or technologies [11]. This paper focuses on four modes of entering into a new technology-based market – greenfield, acquisition, joint venture, and strategic alliance, which the former three modes involve equity investments, and the latter one is unnecessarily related to equity investment. This onus is on the entrant to provide all the requisite resources and capabilities for the investment to overcome industry structural barriers, as well as risks due to liabilities of renewable technology. Among the four modes, acquisitions are used when "time" is an important issue in the investment decision, as it can be done much faster than a greenfield or joint venture entry [12]. Accordingly, we use greenfield, acquisition, joint venture, and strategic alliance as sub-criteria of the "entry mode" indicator involved in sustainable management.

A joint venture is the pooling of assets and (or) knowledge by two or more firms who share joint ownership and control over the results of the pooling [13]. Note, that this definition includes both joint ventures and strategic alliances as defined in the traditional sense. Acquisition refers to the purchase of stock in an already existing company in an amount sufficient to exercise control. Greenfield investment is a start up investment in new facilities in the extant or new market. The characteristics of the decision maker will influence the choice of the decision strategy employed [14]. In other words, a manager's knowledge, ability, and motivation will affect the amount of information processing upon the decision of entry modes.

3. Market demand

Raising the consumers' consciousness of environmental protection can stimulate the demand of domestic PV market. The incremental speed of market growth is expected due to the cost-down of PV products. The demand of PV products is, however, relatively inelastic at present because of the attribute of niche market. In the near future, the demand is expected to become more elastic since the larger size market for photovoltaics become viable. When prices fall below a particular price at annual output greater than a particular quantity/volume the efect of lower costs on increasing market size will accelerate. As the prices of PV products become lower, the larger markets for PV products will become viable and the price elasticity of demand for PV products will become much higher [15].

The network effect is extremely important for the co-evolution of demand and supply. The strength of the network effect for three different forms: through market share, a positional good, and conformity [16]. The network effect operating through market share is a most common formalization in the literature. It assumes that preferences change depending on the number of individuals within the social network who actually purchase a particular product. As one alternative, we introduce the network effect through a positional good. In this case, a consumer tends to buy a good that satisfies or exceeds the threshold level for product performance in his social network. As another alternative, we consider the conformity effect. In this case, consumers attain a higher utility the smaller the distance from product quality to the level aspired by an individual. The latter is defined as a quality adopted by the majority of consumers within his social network. A slightly worse product may be preferred over an item that is much better, if the distance to the desired performance is smaller.

Green power products may be seen as a means of fostering RES because they create and channel consumer demand for environmentally sound power generation. Clean, domestic and renewable energy is commonly accepted as the key for future life, not only for Taiwan but also for the world. The renewable energy contribution in the total primary energy production is insignificant. The alternative and renewable energy systems have been neglected so far in Taiwan, but they must be included in the new energy programs. On June 12 in 2009, the Renewable Energy Act is successfully passed, ushering Taiwan into a new era of alternative energy development and related applications. In the context, Renewable Energy Act is enacted in 2009 in order to encourage renewable-based generation in competitive market conditions. Supporting mechanisms such feed-in tariffs and purchase obligation are defined in the act/law, in conformity with EU legislation and practice. These mechanisms are envisaged to facilitate the development of the power plants based on RES.

A good reputation or brand helps a firm increase its sales and has better negotiation ability when facing from upstream and downstream firms. The lifespan of a solar system is about 20-30 years [17]**.** Thus, creating a good after-sales service is important for a firm to keep the reputation when competing with other firms. In general sense, conformity behaviour can be seen as an attempt to gain security in a social network. People are highly motivated to feel that they belong, and having strong social connections is associated with better psychological health, whereas rejection and isolation are associated with enhanced psychological well-being such as "high social connectedness appears to serve as a protective factor with regard to a range of symptoms of psychological distress" [18]. The conformity scale assesses the degree to which individuals have "a characteristic willingness to identify with others and emulate them, to give in to others so as to avoid negative interactions and generally, to be a follower rather than a leader in terms of ideas, values, and behaviour" [19]. The expression formalizes the need for conformity, as consumer's tendency to purchase the same product as members of his social network. The component denotes the distance between the product quality the desired performance. The closer a product quality is to the aspiration level, the higher the value of the expression [16]. As a result, market price, consumer's eco-recognition, market access, brand reputation, and conformity behaviour exert influence on the volume of market demand. Accordingly, we use market price, consumer's eco-recognition, market access, brand reputation, and conformity behaviour as sub-criteria of the "market demand" indicator of sustainable management.

4. Commercial capacity

The prices for PV modules prevailing in the international markets are determined by the dynamics of demand and supply, launch of subsidy programs in different countries and the production volumes and efficiencies of relatively large manufacturers. The general observation is that producers have been progressively ramping up production capacities to meet projected prices and no single producer might be in a position to exercise substantial market power, even in what, at fist sight, appears to be an oligopolistic setting [20]. This may be attributed to the nature of the industry and its current level of maturity, given that demand is largely driven by subsidy programs and other government and donor initiatives and procurement is generally managed or supervised by industry experts.

Renewable energy, state-of-the-art technologies often have a strong tacit dimension derived from internal firm-specific learning processes [21]. Because the creation of new knowledge (including technology, know-how and organizational capability) depends on existing capabilities, the knowledge of the firm evolves in a path-dependent way, through the replication of recombination of existing knowledge [22].

To develop the solar PV industry, we have to consider the following segments: supply, maintenance, training, and financing. One key for solar cells to enter the major market in electricity is if they can convert up-front costs into recurrent costs [23]. Also, the strategy implemented by a firm with competitive advantage provides the opportunity for a reduction in costs [24]. Therefore, we considered that

the cost is a crucial factor which influences the development of PV Industry.

Constructing a complete industrial chain can build up a whole production line, improve the production efficiency, reduce extra costs, and achieve the economics of scale in order to compete with foreign firms. SEMI pledges to continue bridging the gap between the government and industry, by relaying industry perspectives to the government. SEMI Taiwan has been a longtime advocate of the proliferation of PV technologies, and through its PV Group initiative is deeply involved in supporting its members across the PV supply chain through the development of PV-industry standards, Environmental, Health and Safety (EHS) initiatives, market statistics, and global expositions.

The PV Group is a SEMI special interest group that serves the photovoltaic supply chain. Participating companies provide manufacturing equipment, materials, cells, modules, sub-systems, and components to the solar energy industry worldwide. The PV Group mission is to advance continuous manufacturing cost reductions, industry growth, and sustainable business practices through international standards development, events, public policy advocacy, EHS support, market intelligence, and other services. In conclusion, this paper defines "commercial capacity" as six main activities: innovation, technology learning, cost supply chain, industrial cluster, and R&D dependence as sub-criteria of the "commercial capacity" indicator of sustainable management.

III. METHODOLOGY

1. Analytic network process

The analytic network process (ANP) technique, developed by [25], is not nearly as prominent in the literature as the analytic hiearchy process (AHP) technique. ANP is a multi-criteria decision tool which allows for the consideration of the interdependencies among and between levels of attributes and laternatives. ANP does involve hierarchical structure as does not require a strict hierarchical structure as does AHP. The ANP technique allows for more complex interrelationships among the decision levels and attributes. ANP models problems involving systems in which the relationships between the levels are not distinct (i.e., easily represented as higher or lower, controlling or subordinate). These sytems are known as "systems with feedback" and refer to systems where a level may both dominate and be doninated, directly or iderectly, by other decision attributes and levels [26].

Sustainable management of PV industry is not solely an environmental issue; there are diverse ecological, economic, and socio-economic aspects, which increase problem complexity and analysis of sustainable management of PV industry. At a local level, sustainable management of PV industry is embedded in a network of external and internal relationships. Due to the intrinsically complex nature of assessing sustainablility, it is difficult to develop a framework that has universal applicability [27]. Desirable characteristics of a well-defined framework can be described as holistic and systematic. The analysis of all system-wide elements should be comprehensive and interactive [28]. The problems of sustainable management of PV industry can hardly be solved or even addressed, when a network-analysis approach to indicators is taken. With a fragmented approach, indicators should refer to the context of practical PV management, measure the quantity and quality of actions taken in strategic management, and the response of the PV system to these actions [29]. A systematic framework implies a structured process, employing the principles of dynamic systems analysis [30]. These principles are incorporated in ANP. The process of building an ANP model can be used as a better understanding of the holistic approach that substainable strategic management of PV addresses. The individual indicator priorities from the ANP supermatrix lead to what we call a key-indicator concept from a systemic and cross-topical one.

2. An analytic model of sustainable management

The demand to evaluate sustaible management regimes and alternatives in regard to their specific benefits and to sustainablitiy in general has led to the use of criteria and indicator (C&I) [31, 32]. An additional strenghth of a C&I approach is that it can be used to collect and report information within a system (e.g., solar PV system), which is usually characterized by a lack of knowledge, uncertainties, and missing information about impacts, dependentcies, and feedbacks [33, 34].

Fig. 1 illustrates an analytic model of sustainable management in Taiwan's solar PV industy. The sustainable management network model's control hierarchy according to the determined criteria is given in Fig. 1. In the follow-up process according to the literature mentioned above, four cirteria for sustainable management in solar PV industy of Taiwan are defined.

The ANP structure is formed according to the characters of Taiwan PV industry. It was composed by the goal, four criteria, and twenty sub-criteria. Both criteria and sub-criteria are based on some relevant leterature and industrial reports. Criteria are classified into four catagories – governmental policy, entry mode, market demand, and commercial capacity. The conceptualized criteria are shown in Fig. 1.

In this study, the super-matrix has five comparative matrices, W_{21}, W_{22}, W_{32}, W_{33}, W_{43}. They all locate in an approprate position and group the super-matrix. W_{21} represents the related importance of the goal in criteria; W_{32} demonstrates the related importance of the criteria on the sub-criteria; and W_{43} shows the related importance of the sub-criteria on the alternatives. W_{22} and W_{33} are matrices with inner dependence; W_{22} illustrates the inner dependence of the criteria; and W_{33} explains the inner dependence of the sub-criteria. The super-matrix is caculated by Equation (1).

$$W=\begin{bmatrix} 0 & 0 & 0 & 0 \\ W_{21} & W_{22} & 0 & 0 \\ 0 & W_{32} & W_{33} & \vdots \\ 0 & 0 & W_{43} & 1 \end{bmatrix} \quad (1)$$

3. Data Collection

As a qualitative research, the data sources must be meticulous. Only feasible data can present precise results and meaningful conclusion for the research. This research adopts Expert Depth Interview method by choosing 18 experts related to Taiwan's solar PV industry. Although the sample may be quite few, the important positions they serve in their company or institute are enough to represent the whole viewpoint of Taiwan's solar PV industry. The data collection period is during January-March 2010.

IV. RESULT

After the questionnaires are collected, the software of Super Decision is applied to analyze the data. Table 1 shows the comparisons of each criterion respect to the goal (W_{21}), the eigenvector represents the importance of each criterion. Among these factors, "commercial capacity" ranks the highest (0.40), the second is "entry mode" (0.30), the third is "governmental policy" (0.20), and the lowest is "market demand" (0.10).

Table 1 Comparison matrix of criteria with respect to goal (W_{21})

	Governmental policy	Entry mode	Market demand	Commercial capacity	Eigen-vectors
Governmental policy	1	0.67	2.00	0.50	0.20
Entry Mode	1.50	1	3.00	0.75	0.30
Market demand	0.50	0.33	1	0.25	0.10
Commercial capacity	2.00	1.33	4.00	1	0.40

On the other hand, observing from Equation (2), "governmental policy" gets the largest weighting (0.30), the second largest is "market demand" (0.26), "entry mode" (0.25) is the following one, and "commercial capacity" obtains the lowest weighting (0.19). The reasons of these different results are that the each comparison matrix is calculated together with another one within the limit-matrix. In other words, each comparison matrix may be influenced by other comparison matrices.

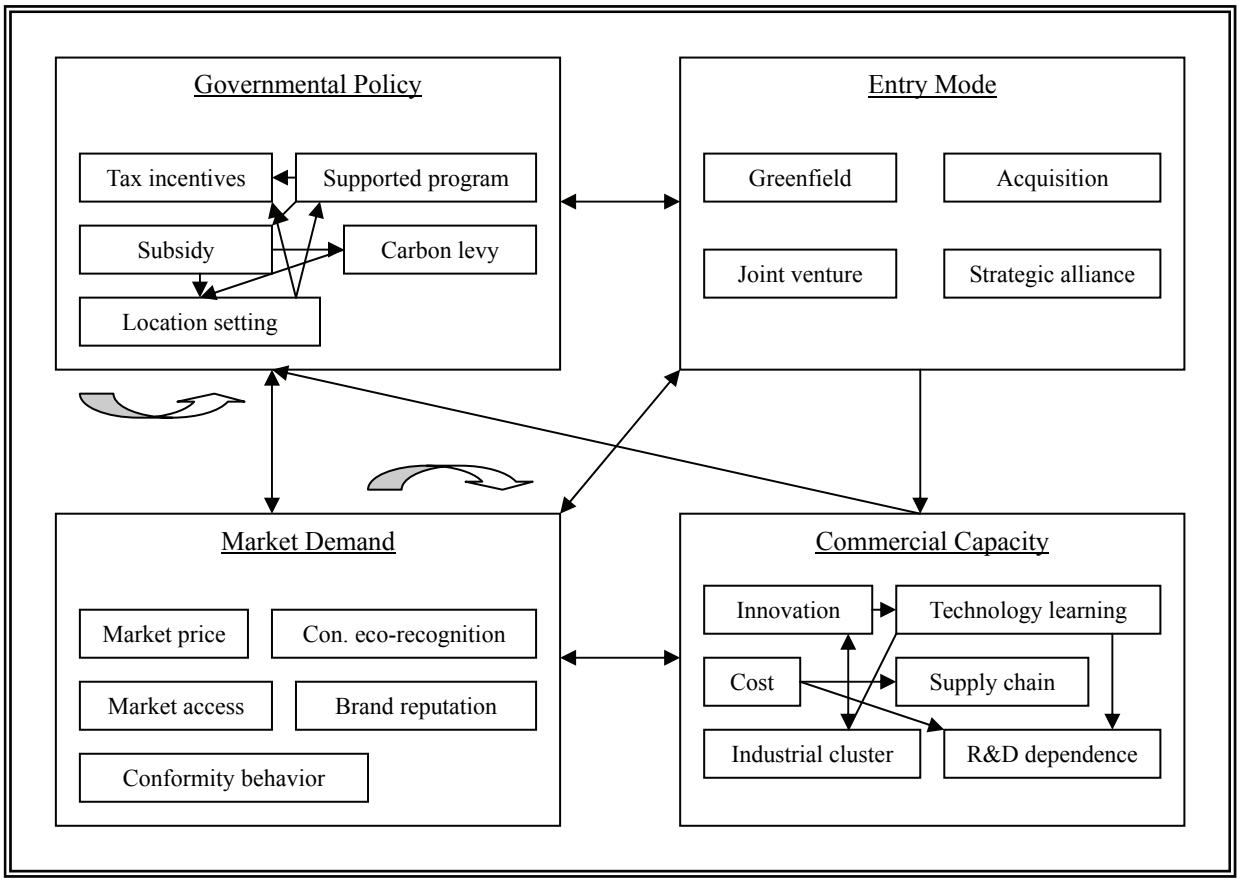

Fig. 1 An analytic model for sustainable management

Table 2 Comparison matrix of inner dependence of sub-criteria (W_{33})

	G1	G2	G3	G4	G5	E1	E2	E3	E4	M1	M2	M3	M4	M5	C1	C2	C3	C4	C5	C6	G1
G1	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.10	0.15	0.11	0	5
G2	0.22	0.44	0	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.19	0.12	0.13	0	6
G3	0	0	0	0.67	0.30	0.20	0	0.33	0	0	0	0	0	0	0	0.23	0.24	0.22	0.09	0	8
G4	0	0	0	0.33	0.40	0.40	0	0	0	0	0	0	0	0	0	0.24	0.29	0.25	0.15	0.40	8
G5	0.13	0.56	0	0	0.10	0	0	0	0	0	0	0	0	0	0	0.15	0.14	0.15	0.07	0	7
E1	0	0	0	0	0	0.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
E2	0.31	0	0	0	0	0	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	2
E3	0.26	0	0	0	0	0	0	0.17	0	0	0	0	0	0	0	0	0	0	0	0	2
E4	0	0	0	0	0	0	0	0	0.67	0	0	0	0	0	0	0	0	0	0	0	1
M1	0	0	0	0	0.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
M2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M3	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0	0	0	0	0.18	0	2
M4	0	0	0	0	0	0	0.67	0.50	0	0	0	0	0.33	0	0	0	0	0	0.17	0	4
M5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C1	0	0	0	0	0	0	0	0	0.33	0	0	0	0	0	0.67	0.04	0	0	0.04	0	4
C2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0	0	0.06	0.25	3
C3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0.07	0	0.25	3
C4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0	0	1
C5	0	0	0	0	0	0.30	0	0	0	0	0	0.67	0.67	0	0.33	0	0	0	0.02	0	5
C6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.10	1

Note: G1 (tax incentives), G2 (supported program), G3 (subsidy), G4 (carbon levy), G5 (location setting); E1 (greenfield), E2 (acquisition), E3 (joint venture), E4 (strategic alliance); M1 (market price), M2 (consumer eco-recognition), M3 (market access), M4 (brand reputation), M5 (conformity behaviour); C1 (innovation), C2 (technology learning), C3 (cost), C4 (supply chain), C5 (industrial cluster), C6 (R&D dependence)

$$\begin{pmatrix} \text{Governmental policy} = 0.30 \\ \text{Entry mode} = 0.25 \\ \text{Market demand} = 0.26 \\ \text{Commercial capacity} = 0.19 \end{pmatrix} \quad (2)$$

Furthermore, Table 2 illustrates this analysis result. In Table 2, the column of right end represents the summation of times of each sub-criterion with figures presented in each row. It means how many times the sub-criterion has been considered. In other words, this is the inner dependence among the sub-criteria. The inner dependence influences each sub-criterion, so that the figures occur in the matrix and meanwhile, strongly influence the other comparison matrices. In the overall hits, "governmental policy" obtains 34 hits and on the contrary, commercial capacity just acquires 17 hits. Sequentially, this is how the priorities of criteria are altered.

We can further describe from the comparison matrices of sub-criteria with respect to each criterion. From Table 3 (a), "subsidy" (G3) and "carbon levy" (G4) have larger weightings. The reason of firms considering them as the important factors may be that the governmental policies regarding solar PV industry of Taiwan is still behind United States, Japan, and European countries. It means that firms cannot directly influence the generation cost and performance ratio, so that the PV manufacturers are eager for Taiwan government's support. On the other hand, the consequence which "location setting" (G5) stands the third, while "tax incentives" (G1) and "supported program" (G2) rank the fourth and the last one.

Consulting Table 3 (b), "joint venture" (E3) is the most important one among criteria within entry modes. Because producing machines are mostly imported, it constraints the development of Taiwan's solar PV industry and also form some barriers against the entry modes. Therefore, Taiwan's solar PV firms really want to increase the innovation of entry modes in order to diverse the solar PV products and further strengthen the competitiveness of solar PV industry. On the other hand, "greenfield" (E1) and "acquisition" (E2) stand in the approximate status, which means the two sub-criteria are recognized the same importance. Taiwan's solar PV firms should find out some ways to maintain the supply of materials and continue to develop the solar PV technology in the future.

Table 3 (c) shows the weightings of "market demand" and "brand reputation" (M4) get the highest and the second highest. Both of the two sub-criteria are related to the trade conditions among countries. In terms of firm's view, the relationship of countries cannot be changed by them; therefore it needs the subsistent consumer. Table 3 (d) presents that "industrial cluster" (C5) and "supply chain" (C4) have the largest and second largest weightings. That is, improving technologies or cooperating with other firms are crucial. Therefore, firms need to take much more effort in the field. As a result, all the comparison matrices are combined in order to form the super-matrices. Three super-

Table 3 Comparison matrices of sub-criteria with respect to each criterion (W_{32})

(a) Comparison matrix of sub-criteria with respect to "governmental policy"

Code	G1	G2	G3	G4	G5	Eigenvectors
G1	1	1.26	0.37	0.34	0.53	0.11
G2	0.79	1	0.29	0.27	0.42	0.09
G3	2.71	3.42	1	0.93	1.44	0.29
G4	2.92	3.68	1.08	1	1.55	0.31
G5	1.89	2.38	0.70	0.65	1	0.20

(b) Comparison matrix of sub-criteria with respect to "business model"

Code	E1	E2	E3	E4	Eigenvectors
E1	1	1.14	0.65	2.62	0.26
E2	0.87	1	0.57	2.29	0.23
E3	1.53	1.75	1	4.00	0.40
E4	0.38	0.44	0.25	1	0.10

(c) Comparison matrix of sub-criteria with respect to "market demand"

Code	M1	M2	M3	M4	M5	Eigenvectors
M1	1	0.66	0.43	0.46	1.99	0.13
M2	1.50	1	0.65	0.70	2.99	0.20
M3	2.32	1.55	1	1.08	4.61	0.31
M4	2.16	1.44	0.93	1	4.28	0.29
M5	0.50	0.34	0.22	0.23	1	0.07

(d) Comparison matrix of sub-criteria with respect to "commercial capacity"

Code	C1	C2	C3	C4	C5	C6	Eigenvectors
C1	1	0.34	0.25	0.19	0.18	0.51	0.05
C2	2.98	1	0.75	0.57	0.53	1.51	0.14
C3	3.96	1.33	1	0.75	0.71	2.00	0.19
C4	5.27	1.77	1.33	1	0.94	2.66	0.25
C5	5.60	1.88	1.42	1.06	1	2.83	0.27
C6	1.98	0.66	0.50	0.38	0.35	1	0.10

matrices in total are formed based on different calculation methods. They are the unweighted-matrix (shown in Appendix I), the weighted-matrix (shown in Appendix II), and the limit-matrix (shown in Appendix III). The limit-matrix is often applied as the result to illustrate the priorities of each factor.

V. DISCUSSION

However, due to lack of efficient technologies and sufficient funds, Taiwan's solar PV industry hasn't been developed effectively. This paper aims to analyze the competitiveness of Taiwan's solar PV industry using an improved dynamic network model. The analysis also educes applicable recommendations to impetus Taiwan's solar PV industry.

High generation costs and high power prices are two main features of solar PV industry in Taiwan, which present the main obstacles to its widespread commercialization. From an economic perspective, the price of solar PV system (or product) is further increased due to the burden of tax costs and loan repayment. Before we leave this overview of recent PV installation developments, there is one issue which we cannot let go unremarked. Industry observers are also issuing warnings concerning the lack of sufficient information sharing among the renewable energy community, including PV. Because so many of the interested parties – government departments, international finance institutions, private companies and NGOs – are involved in the planning and installation of renewable energy systems, it is no wonder that sharing of experience falls short of the ideal. These observers say that it is not so surprising that these parties cannot or will not perceive all the benefits to be possessed from sharing and offering feedback from their projects on a wider basis than they presently do. As a result, quite a lot of the follow-up work that can inform policy-makers about choices for energy policy using renewable energy has been weak and unfocused. It is time to stop repeating the mistakes already made by others.

Going down this route can have a dramatic effect not only on the aesthetics and structural integrity of the project, but more importantly on the overall economics of the project. This is because only the incremental costs of PV – over and above the costs of alternative cladding – need to be factored into the cost equation. Consumers will be aware that purpose-designed products are now coming onto the market. For example, PV roof titles are already commercially available. Notably, while Building-integrated photovoltaic (BIPV) technology is widely used in Europe, it is only just beginning to be applied in North America. Most US architects, engineering firms, building owners and builders know very little about BIPV, and so here is another relatively untapped market opportunity. Both the government and donor agencies have been vital to solar PV market development because they have created one of the world's largest markets for the technology [35].

The implications of sustainable management are the most frequently cited barriers for firms of all sizes. However, this may be a resource issue, with international businesses having more resources to devote to sustainability. It remains the result that Taiwan's solar PV manufactures possess significance through governmental policy-making and support whatever grant-in-aid or abatement of tax and through the stronger role of potential green consumers if they are to become more involved in renewable resources.

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Appendix I Unweighted supermatrix of sustainable management selection by using ANP

	Goal	G	B	M	C	G1	G2	G3	G4	G5	E1	E2	E3	E4	M1	M2	M3	M4	M5	C1	C2	C3	C4	C5	C6
Goal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G	0.20	0.10	0.50	0.37	0.26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	0.30	0.37	0.17	0.20	0.23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M	0.10	0.23	0.33	0.10	0.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	0.40	0.29	0	0.33	0.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G1	0	0.11	0	0	0	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.10	0.15	0.11	0
G2	0	0.09	0	0	0	0.22	0.44	0	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.19	0.12	0.13	0
G3	0	0.29	0	0	0	0	0	0	0.67	0.30	0.20	0	0.33	0	0	0	0	0	0	0	0.23	0.24	0.22	0.09	0
G4	0	0.31	0	0	0	0	0	0	0.33	0.40	0	0	0	0	0	0	0	0	0	0	0.24	0.29	0.25	0.15	0.40
G5	0	0.20	0	0	0	0.13	0.56	0	0	0.10	0	0	0	0	0	0	0	0	0	0	0.15	0.14	0.15	0.07	0
E1	0	0	0.26	0	0	0	0	0	0	0	0.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E2	0	0	0.23	0	0	0.31	0	0	0	0	0	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0
E3	0	0	0.40	0	0	0.26	0	0	0	0	0	0	0.17	0	0	0	0	0	0	0	0	0	0	0	0
E4	0	0	0.10	0	0	0	0	0	0	0	0	0	0	0.67	0	0	0	0	0	0	0	0	0	0	0
M1	0	0	0	0.13	0	0	0	0	0	0.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M2	0	0	0	0.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M3	0	0	0	0.31	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0	0	0	0	0.18	0
M4	0	0	0	0.29	0	0	0	0	0	0	0	0.67	0.50	0	0	0	0	0.33	0	0	0	0	0	0.17	0
M5	0	0	0	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C1	0	0	0	0	0.05	0	0	0	0	0	0	0	0	0.33	0	0	0	0	0	0.67	0.04	0	0	0.04	0
C2	0	0	0	0	0.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0	0	0.06	0.25
C3	0	0	0	0	0.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0.07	0	0.25
C4	0	0	0	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0	0
C5	0	0	0	0	0.27	0	0	0	0	0	0.30	0	0	0	0	0	0.67	0.67	0	0.33	0	0	0	0.02	0
C6	0	0	0	0	0.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.10
Dis	0	0	0	0	0	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.10	0.10	0.10	0.10	0.10	0.09	0.10	0.10	0.10	0.09	0.10	0.10
All	0	0	0	0	0	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.28	0.29	0.30	0.29	0.30	0.29	0.28	0.30	0.30	0.30	0.22	0.30	0.30
VC	0	0	0	0	0	0.22	0.20	0.20	0.20	0.20	0.20	0.20	0.16	0.18	0.23	0.18	0.20	0.18	0.16	0.23	0.20	0.23	0.18	0.20	0.20
Div	0	0	0	0	0	0.38	0.40	0.40	0.40	0.40	0.40	0.40	0.46	0.43	0.39	0.43	0.40	0.43	0.46	0.37	0.40	0.37	0.51	0.40	0.40

Note: G1 (tax incentives), G2 (supported program), G3 (subsidy), G4 (carbon levy), G5 (location setting); E1 (greenfield), E2 (acquisition), E3 (joint venture), E4 (strategic alliance); M1 (market price), M2 (consumer eco-recognition), M3 (market access), M4 (brand reputation), M5 (conformity behaviour); C1 (innovation), C2 (technology learning), C3 (cost), C4 (supply chain), C5 (industrial cluster), C6 (R&D dependence)

Appendix II Weighted supermatrix of business model selection by using ANP

	Goal	G	B	M	C	G1	G2	G3	G4	G5	E1	E2	E3	E4	M1	M2	M3	M4	M5	C1	C2	C3	C4	C5	C6
Goal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G	0.20	0.05	0.25	0.18	0.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	0.30	0.19	0.08	0.10	0.12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M	0.10	0.12	0.17	0.05	0.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	0.40	0.15	0	0.16	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G1	0	0.05	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.06	0.05	0.08	0.05	0
G2	0	0.04	0	0	0	0.11	0.22	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0.10	0.06	0.06	0
G3	0	0.15	0	0	0	0	0	0	0.33	0.15	0.10	0	0.17	0	0	0	0	0	0	0	0.11	0.12	0.11	0.05	0
G4	0	0.16	0	0	0	0	0	0	0.17	0.20	0	0	0	0	0	0	0	0	0	0	0.12	0.14	0.13	0.07	0.20
G5	0	0.10	0	0	0	0.07	0.28	0	0	0.05	0	0	0	0	0	0	0	0	0	0	0.08	0.07	0.08	0.04	0
E1	0	0	0.13	0	0	0	0	0	0	0	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E2	0	0	0.12	0	0	0.16	0	0	0	0	0	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0
E3	0	0	0.20	0	0	0.13	0	0	0	0	0	0	0.08	0	0	0	0	0	0	0	0	0	0	0	0
E4	0	0	0.05	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0	0	0	0	0	0	0	0	0

(Continued)

M1	0	0	0	0.07	0	0	0	0	0	0.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M2	0	0	0	0.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M3	0	0	0	0.16	0	0	0	0	0	0	0	0	0	0	0	0.17	0	0	0	0	0	0	0.09	0
M4	0	0	0	0.14	0	0	0	0	0	0	0	0.33	0.25	0	0	0	0	0.17	0	0	0	0	0.09	0
M5	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C1	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0.17	0	0	0	0	0	0.33	0.02	0	0.02	0
C2	0	0	0	0	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0	0.03	0.12
C3	0	0	0	0	0.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.04	0	0.13
C4	0	0	0	0	0.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0
C5	0	0	0	0	0.13	0	0	0	0	0	0.15	0	0	0	0	0	0.33	0.33	0	0.17	0	0	0	0.01	0
C6	0	0	0	0	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05
Dis	0	0	0	0	0	0.05	0.05	0.10	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.10	0.05	0.10	0.05	0.09	0.05	0.05	0.05	0.05	0.05
All	0	0	0	0	0	0.15	0.15	0.30	0.15	0.15	0.15	0.15	0.14	0.15	0.30	0.29	0.15	0.15	0.28	0.15	0.15	0.15	0.11	0.15	0.15
VC	0	0	0	0	0	0.11	0.10	0.20	0.10	0.10	0.10	0.10	0.08	0.09	0.23	0.18	0.10	0.09	0.16	0.11	0.10	0.11	0.09	0.10	0.10
Div	0	0	0	0	0	0.19	0.20	0.40	0.20	0.20	0.20	0.20	0.23	0.22	0.37	0.43	0.20	0.22	0.46	0.18	0.20	0.18	0.25	0.20	0.20

Note: G1 (tax incentives), G2 (supported program), G3 (subsidy), G4 (carbon levy), G5 (location setting); E1 (greenfield), E2 (acquisition), E3 (joint venture), E4 (strategic alliance); M1 (market price), M2 (consumer eco-recognition), M3 (market access), M4 (brand reputation), M5 (conformity behaviour); C1 (innovation), C2 (technology learning), C3 (cost), C4 (supply chain), C5 (industrial cluster), C6 (R&D dependence)

Appendix III Limited supermatrix of business model selection by using ANP

	Goal	G	B	M	C	G1	G2	G3	G4	G5	E1	E2	E3	E4	M1	M2	M3	M4	M5	C1	C2	C3	C4	C5	C6
Goal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G	0.02	0.02	0.02	0.02	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	0.02	0.02	0.02	0.02	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M	0.02	0.02	0.02	0.02	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	0.02	0.02	0.02	0.02	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G1	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0.01	0.01	0.01	0.01	0	0	0.01	0.01	0	0.01	0.01	0.01	0.01	0.01	0.01
G2	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0	0	0	0.03	0.03	0.03	0.03	0	0	0.03	0.03	0	0.03	0.03	0.03	0.03	0.03	0.03
G3	0.07	0.07	0.07	0.07	0.07	0.07	0.11	0	0.11	0.11	0.07	0.07	0.07	0.07	0	0	0.07	0.07	0	0.07	0.07	0.07	0.07	0.07	0.07
G4	0.05	0.05	0.05	0.05	0.05	0.06	0.07	0	0.06	0.06	0.06	0.06	0.06	0.06	0	0	0.06	0.06	0	0.06	0.06	0.06	0.06	0.06	0.06
G5	0.03	0.03	0.03	0.03	0.03	0.04	0.19	0	0	0	0.04	0.04	0.04	0.04	0	0	0.04	0.04	0	0.04	0.04	0.04	0.04	0.04	0.04
E1	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E2	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0.01	0.01	0.01	0.01	0	0	0.01	0.01	0	0.01	0.01	0.01	0.01	0.01	0.01
E3	0.01	0.01	0.01	0.01	0.01	0..01	0	0	0	0	0.01	0.01	0.01	0.01	0	0	0.01	0.01	0	0.01	0.01	0.01	0.01	0.01	0.01
E4	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0.01	0.01	0.01	0.01	0	0	0.01	0.01	0	0.01	0.01	0.01	0.01	0.01	0.01
M1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M3	0.03	0.03	0.03	0.03	0.03	0.03	0	0	0	0	0.03	0.03	0.03	0.03	0	0	0.03	0.03	0	0.03	0.03	0.03	0.03	0.03	0.03
M4	0.05	0.05	0.05	0.05	0.05	0.04	0	0	0	0	0.04	0.04	0.04	0.04	0	0	0.04	0.04	0	0.04	0.04	0.04	0.04	0.04	0.04
M5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C1	0.02	0.02	0.02	0.02	0.02	0.02	0	0	0	0	0.02	0.02	0.02	0.02	0	0	0.02	0.02	0	0.02	0.02	0.02	0.02	0.02	0.02
C2	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0.01	0.01	0.01	0.01	0	0	0.01	0.01	0	0.01	0.01	0.01	0.01	0.01	0.01
C3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C5	0.06	0.06	0.06	0.06	0.06	0.07	0	0	0	0	0.07	0.07	0.07	0.07	0	0	0.07	0.07	0	0.07	0.07	0.07	0.07	0.07	0.07
C6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dis	0.05	0.05	0.05	0.05	0.05	0.06	0.08	0	0.08	0.08	0.06	0.06	0.06	0.06	0	0	0.06	0.06	0	0.06	0.06	0.06	0.06	0.06	0.06
All	0.15	0.15	0.15	0.15	0.15	0.18	0.23	0	0.25	0.25	0.18	0.18	0.18	0.18	0	0	0.18	0.18	0	0.18	0.18	0.18	0.18	0.18	0.18
VC	0.10	0.10	0.10	0.10	0.10	0.12	0.16	0	0.17	0.17	0.12	0.12	0.12	0.12	0	0	0.12	0.12	0	0.12	0.12	0.12	0.12	0.12	0.12
Div	0.20	0.20	0.20	0.20	0.20	0.24	0.31	0	0.33	0.33	0.24	0.24	0.24	0.22	0	0	0.24	0.24	0	0.24	0.24	0.24	0.24	0.24	0.24

Note: G1 (tax incentives), G2 (supported program), G3 (subsidy), G4 (carbon levy), G5 (location setting); E1 (greenfield), E2 (acquisition), E3 (joint venture), E4 (strategic alliance); M1 (market price), M2 (consumer eco-recognition), M3 (market access), M4 (brand reputation), M5 (conformity behaviour); C1 (innovation), C2 (technology learning), C3 (cost), C4 (supply chain), C5 (industrial cluster), C6 (R&D dependence)