

Decision support system for exploiting local renewable energy sources: A case study of the Chigu area of southwestern Taiwan

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Abstract

The topic of climate and energy policy has drawn new attention since the Kyoto Protocol has now come into force. It is hoped that strengthened use of renewable energy sources can meet new international environmental requirements and provide self-sufficient domestic energy supplies. The decision support system established in this study integrates potential evaluations, cost analyses, legal incentives, and analysis of returns on investments with the aid of a geographic information system (GIS). This system can provide insights for policymakers into where and the extent of the potentials, for lawmakers into whether the current legal incentives are sufficient to encourage private investment, and for investors into whether investments in exploiting local renewable energy sources are economically feasible. Under the current incentive framework in Taiwan, the amortization periods of investment on renewable energy are generally longer than the period over which the investment is to be recovered. This presents an unfavorable condition for attracting investments to and for developing renewable energy. An increase in remuneration through legal revisions is needed before domestic investment in renewable energy will actively expand.

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1. Introduction

The topic of climate and energy policy has drawn new attention in the international community after the Kyoto Protocol came into force. Developing countries with high growth rates of greenhouse gas emissions have begun to deliberate on how to respond to the new climate regime which is expected to profoundly influence the rules of world trade and the economies of all countries. Renewable energy technologies are becoming a significant option in countries such as Taiwan. It is hoped that the strengthened use of these clean energy sources can meet new international environmental requirements, and provide a self-sufficient domestic energy supply.

Renewable energy sources are characterized by their decentralized energy production (Beatley, 2000). Their exploitation has to take into account factors such as technical potential, environmental restrictions, and incen-

tives for investment (BMU, 1999; Boyle, 1996; ECDGE, 1998; Voivontas et al., 1998). Building a decision support system based on these factors would facilitate the evaluation of investment for exploiting renewable energy sources. This study attempted to investigate the Chigu area of southwestern Taiwan as an example, and to establish a decision support system for evaluating the feasibility of exploiting local renewable energy sources.

In the Chigu area, there are abundant wind resources, insolation, and farmland available for exploiting energy from the wind, PV systems, and biomass.¹ The “ordinary agricultural area” is the most-extensive land-use pattern in this area (Fig. 1), and has mostly been exploited as fish farms for many decades, although many have fallen into disuse. Overexploitation of groundwater for fish farming has long led to land subsidence. The “special agricultural area” is cropland of good quality, and is used for food production. The agricultural area is increasingly being subjected to pressures for conversion into non-agricultural

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¹For geographic location and distribution of mean annual wind speed of the Chigu region please refer to Yue et al., 2005.

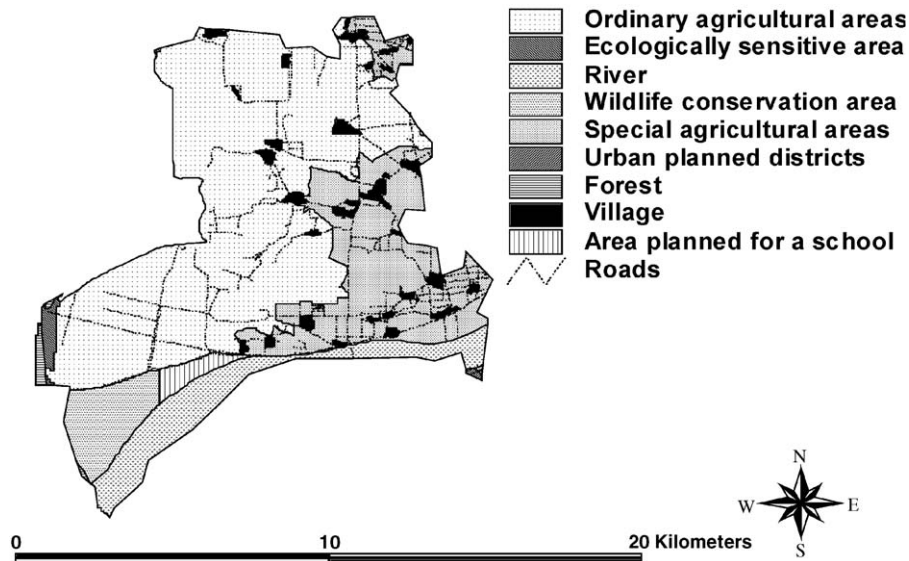


Fig. 1. Land-use zoning at Chigu.

land due to the drop in agricultural output value in Taiwan after accession to the WTO in 2002. The effective use of land resources in favor of the local economy while taking ecological imperatives into account has become a significant issue for development in the Chigu area.

Faced with global trends of cutting greenhouse gas emissions, Taiwan's government has set a target that 10% of the total installed capacity of power generation in Taiwan should be from renewable energy sources by 2010 (Lee, 2005). To achieve this goal, governmental status and utilities have to successively provide incentives for investment in the use of renewable energy sources, e.g., guaranteed remuneration prices. Information for decision-making, such as whether the provided incentives are sufficient or under what conditions an investment for using renewable technology is profitable, is not available. This precludes lawmakers and investors from effectively grasping the investment conditions. A decision support system is therefore needed to close this gap so that decision-making procedures for exploiting local renewable energy sources can be facilitated. In this context, the aims of this study are as follows:

- to establish a decision support system with the aid of a geographical information system (GIS) to facilitate evaluations of the feasibility of investments for exploiting local renewable energy sources,
- to evaluate the economic feasibility of investments for exploiting local renewable energy sources in the Chigu area, and
- to propose recommendations for the government and for legislation to revise the incentive frameworks.

The decision support system established in this study integrates evaluations of the potential, cost analyses, and

legal incentives, and can serve as a tool for investors to evaluate the economic feasibility of investments in exploiting local renewable energy sources. This information can provide the government with insights into whether legal incentives are sufficient to attract investments.

2. Methodology

This study attempted to establish a decision support system to facilitate the evaluation of investments for private investors, policymakers, and lawmakers. The framework of this decision support system is illustrated in Fig. 2. The construction of the decision support system is comprised of two components:

- evaluation of the potential for exploiting renewable energy sources from wind, rooftop PV systems, energy crop production, including ethanol and biodiesel production from sugarcane and rapeseed, respectively, in suitable areas with the aid of a GIS (Yue et al., 2005), and
- analysis of the returns on investment based on a cash flow analysis and GIS according to the expected energy outputs, energy costs, and legal incentives.

The financial analysis of investments was conducted in this study with a cash flow analysis based on the following parameters.

2.1. Wind energy

- A period of 20 years over which the investment is to be recovered,
- capital cost of US\$1094/kW,
- running costs of 3% of the total capital cost per year,

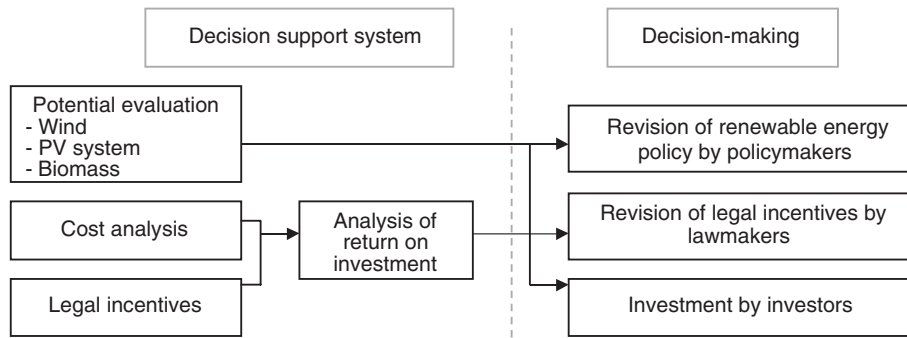


Fig. 2. Framework of the decision support system for evaluating the feasibility of investments in exploiting local renewable energy sources.

- interest rate of 4%; amount of credit at 60% of the capital cost; a period of credit of 7 years,²
- remuneration at US\$0.063/kWh,³ and
- increases of running cost and remuneration of 1.2% per year.⁴

2.2. Photovoltaics (PV)

- A period of 30 years over which the investment is to be recovered,
- capital cost of US\$6563/kW,
- running cost of US\$38/kW per year,
- capital grants from the government at 50% of capital cost,⁵
- average annual electricity consumption per household in Taiwan of 3564 kWh,⁶
- annual energy output of a PV system of 1200 kWh/kW,⁷
- average share of consumed electricity within the daytime of 1/3 of the total consumed electricity per household and day in Taiwan,⁸
- interest rate of 4%; amount of credit at 60% of capital cost; a period of credit of 7 years,
- remuneration of US\$0.063/kWh,⁹
- electricity price of US\$ 0.0738/kWh,¹⁰ and

²According to the “Ordinance of Premium Credit of Purchasing Installation of Energy Savings”, the interest rate of credit should be not more than interest rate of 2-year-period time deposit of postal savings (currently at 1.55%) plus annual interest rate of 2.45%. Amount of credit should be not more than 80% of total capital costs of the projects. The period of credit should not be longer than 7 years.

³According to the “Ordinance of the Taiwan Power Company for Remunerating the Power generated from Renewable Energy Sources”.

⁴The annual increase rate of 1.2% is based on average fluctuation of the price index from 1995 to 2004.

⁵According to the “Regulation of Subsidizing the Installation of Demonstration Plant for Electricity Generation from Photovoltaics”.

⁶According to the estimate of the Taiwan Power Company.

⁷The Chigu area is located in region with the highest irradiation in Taiwan (Chen and Hsieh, 2002).

⁸Based on analysis of temporal relationship between electricity generation by PV system and domestic electricity consumption load.

⁹According to the “Ordinance of the Taiwan Power Company for Remunerating the Power generated from Renewable Energy Sources”.

¹⁰Average price of the year 2003 in Taiwan.

- increase of running costs, remuneration, and electricity price of 1.2%.

2.3. Biomass

- A period of 15 years over which the investment is to be recovered,
- capital cost of US\$531/(l/day) for ethanol from sugarcane growing, and US\$625/(l/day) for biodiesel from rapeseed growing,
- running cost of 23% of the capital cost per year,
- interest rate of 4%; amount of credit at 60% of the capital cost; a period of credit of 7 years,
- remuneration of US\$0.50/LOE for ethanol, and US\$0.44/LOE for biodiesel,¹¹ and
- increase of running cost and remuneration of 1.2%.

3. Results of the analysis of the return on investment

3.1. Wind energy

Governmental investment subsidies for the installation of wind turbines in Taiwan were terminated after the term of validity for application for capital grants due at the end of 2004 according to the “Regulation of subsidizing the installation of demonstration plant for electricity generation from wind power”. Based on this legal condition, the return on investment can be estimated using a cash flow analysis, as exemplified in Table 1. The energy cost can then be calculated as shown in Table 2.

The net present value and the amortization period of investment on installing a single wind turbine in areas with various mean wind speeds can then be calculated, as shown in Fig. 3. The distribution of the net present value and of the amortization period for the investment on installing a single wind turbine can be illustrated with a GIS, as depicted in Fig. 4.¹² Both graphs indicate that the investment will have to be sited in areas with wind speed

¹¹According to the remuneration proposed in evaluation of the Energy Commission of the Republic of China. LOE: liter oil equivalent; 1 LOE = 3.7674×10^7 J.

¹²The land uses of the unsuitable areas are to be referred to in Fig. 1.

Table 1

Cash flow analysis of investment for installing a single wind turbine in an area with a mean wind speed of 5.4 m/s at Chigu with remuneration of US\$0.063/kWh at current levels and without capital grants from the government (all costs in thousands of 2005 US\$)

Year	1	2	3	4	5	6	7	8	9	10
Self-raised capital cost	875.0	0	0	0	0	0	0	0	0	0
Running costs	65.6	66.4	67.2	68.0	68.8	69.7	70.5	71.3	72.2	73.1
Debt payments	218.7	218.7	218.7	218.7	218.7	218.7	218.7	0	0	0
Total annual costs	1159.3	285.1	285.9	286.7	287.5	288.3	289.2	71.3	72.2	73.1
Present value of costs	1114.7	263.6	254.2	245.1	236.3	227.9	219.7	52.1	50.7	49.4
Annual output (GWh)	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Present value of annual output (GWh)	3.4	3.3	3.2	3.1	2.9	2.8	2.7	2.6	2.5	2.4
Annual revenue	224.9	227.6	230.3	233.0	235.8	238.7	241.5	244.4	247.4	250.3
Present value of annual revenue	216.2	210.4	204.7	199.2	193.8	188.6	183.5	178.6	173.8	169.1
Annual net benefit	−934.4	−57.5	−55.6	−53.6	−51.7	−49.7	−47.6	173.1	175.2	177.3
Present value of annual net benefit	−898.5	−53.2	−49.4	−45.9	−42.5	−39.2	−36.2	126.5	123.1	119.8
Cumulative present value of net benefit	−898.5	−951.7	−1001.1	−1047.0	−1089.5	−1128.7	−1164.9	−1038.4	−915.4	−795.6
Year	11	12	13	14	15	16	17	18	19	20
Self-raised capital cost	0	0	0	0	0	0	0	0	0	0
Running costs	73.9	74.8	75.7	76.6	77.6	78.5	79.4	80.4	81.3	82.3
Debt payments	0	0	0	0	0	0	0	0	0	0
Total annual costs	73.9	74.8	75.7	76.6	77.6	78.5	79.4	80.4	81.3	82.3
Present value of costs	48.0	46.7	45.5	44.3	43.1	41.9	40.8	39.7	38.6	37.6
Annual output (GWh)	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Present value of annual output (GWh)	2.3	2.2	2.1	2.1	2.0	1.9	1.8	1.8	1.7	1.6
Annual revenue	253.3	256.4	259.5	262.6	265.7	268.9	272.1	275.4	278.7	282.1
Present value of annual revenue	164.6	160.1	155.8	151.6	147.5	143.6	139.7	135.9	132.3	128.7
Annual net benefit	179.4	181.6	183.7	185.9	188.2	190.4	192.7	195.0	197.4	199.7
Present value of annual net benefit	116.5	113.4	110.3	107.4	104.5	101.7	98.9	96.3	93.7	91.2
Cumulative present value of net benefit	−679.1	−565.7	−455.3	−347.9	−243.5	−141.8	−42.9	53.4	147.1	238.2

Table 2
Cost analysis based on cash flow analysis

NPV of net benefit	US\$238.2 thousand
Discount rate	4.0%
Costs	Total to year 20 NPV to year 20
	US\$3.9 million US\$3.1 million
Output	Total to year 20 NPV to year 20
	71.4 GWh 48.5 GWh
Cost of electricity	US\$0.065/kWh

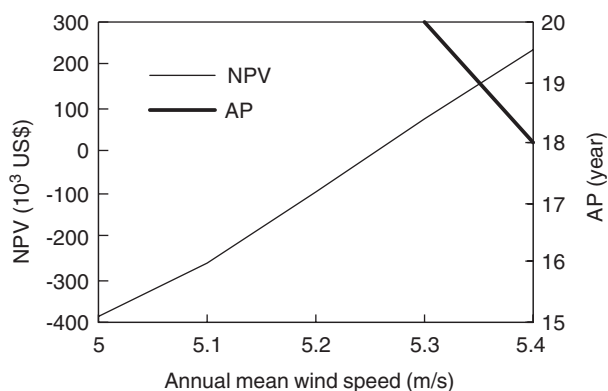


Fig. 3. The net present value (NPV) and amortization period (AP) of investment in installing a single wind turbine in areas with various annual mean wind speeds at Chigu with remuneration of US\$0.063/kWh at the current level and without capital grants from the government.

of at least 5.3 m/s if the project were to be amortized within the life span of a turbine of 20 years and with a net present value higher than US\$0.

3.2. Photovoltaics

The cash flow analysis indicated that the net present value of investment on a rooftop PV system would be less than US\$0, with an amortization period of more than 30 years over which the investment is to be recovered, regardless of whether 1, 2, or 3 kW of capacity is installed for a single household. The distribution of the net present value and amortization period of investment on rooftop PV systems in urban planned districts and villages at Chigu are depicted in Fig. 5.

There is currently no incentive to install PV systems in Taiwan due to their relatively high capital cost (US\$0.43/kWh) on the one hand, and to the low remuneration price of US\$0.063/kWh on the other. This leads to an unfavorable investment condition in which the greater the capacity of a PV system that is installed, the lower the net present value of the investment. A further drop in the investment cost would be needed through cost reductions induced by technological advances and/or enhanced remuneration provided by a legal framework for the widespread application of this clean energy.

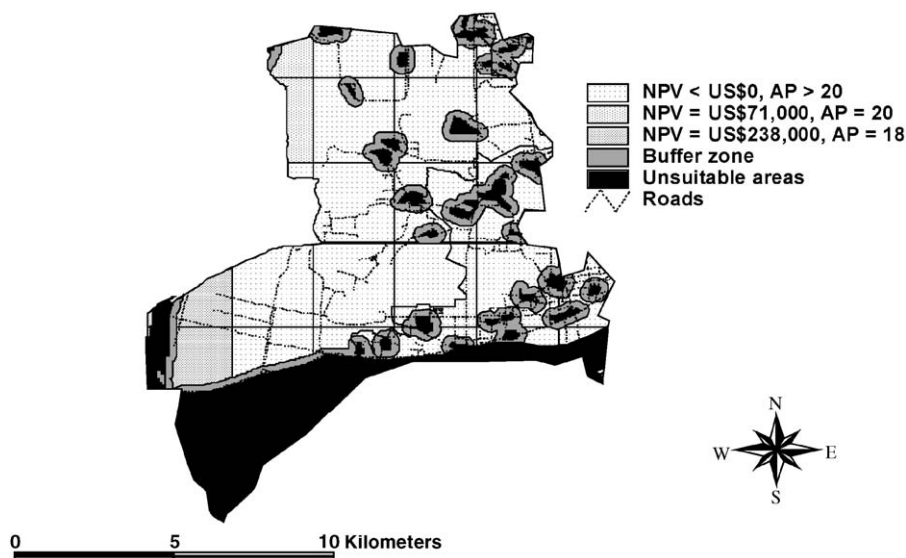


Fig. 4. Distribution of the net present value (NPV) and the amortization period (AP in years) for investment in installing a single wind turbine at Chigu with remuneration of US\$0.063/kWh at the current level and without governmental capital grants.

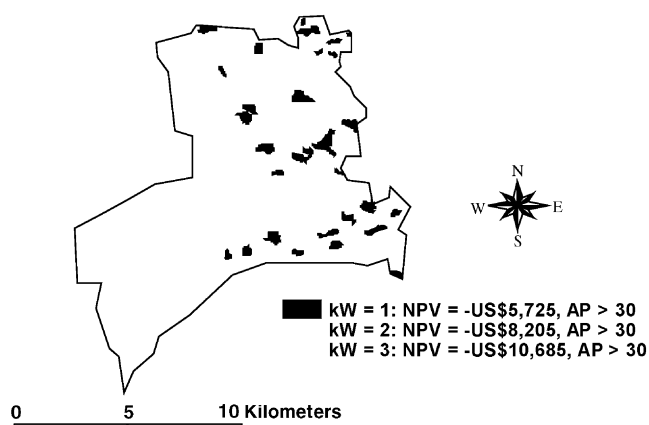


Fig. 5. Distribution of the net present value (NPV) and the amortization period (AP in years) of investment in rooftop PV systems in urban planned districts and villages at Chigu with remuneration of US\$0.063/kWh at current levels and governmental capital grants at 50% of capital cost.

3.3. Biomass

With the remuneration price considered by the ECROC at US\$0.50/LOE for ethanol and US\$0.44/LOE for biodiesel, the net present value of the investment on 1000 L of ethanol production through sugarcane growing is calculated to be –US\$9400, and biodiesel production through rapeseed growing would be –US\$598,000. The amortization period of both are more than 15 years over which the investment is to be recovered. Accordingly, investment on ethanol and biodiesel appears to be economically unattractive. The lower net present value of investment in biodiesel production compared to that in ethanol production is due to the higher production costs and lower remuneration prices for biodiesel. The areas available for growing sugarcane and rapeseed at Chigu are illustrated with a GIS in Fig. 6.

4. Sensitivity analysis

Whether or not the exploitation of renewable energy sources is profitable plays a decisive role in private investment in using local renewable energy sources. Determining how to make this investment economically attractive has therefore become a significant task for policy-making and legislation. Incentives for investing in the exploitation of renewable energy sources essentially hinge on factors such as the levels of remuneration and of capital grants from the government. The net present value and amortization period of investments in installing a single wind turbine in areas with different annual mean wind speeds at Chigu at various remuneration price levels is illustrated in Figs. 7 and 8.

With remuneration at the current level at US\$0.063/kWh without capital grants from the government, the investment in installing a single wind turbine in areas with annual mean wind speeds of 5.3 and 5.4 m/s would provide a net present value higher than US\$0. In this case, the attractiveness of wind resources for exploitation would account for 15.3% of the total wind potential exploitable in the Chigu area with an annual mean wind speed exceeding 4 m/s, as shown in Table 3. If the remuneration were enhanced to US\$0.10/kWh, the investment in installing a single wind turbine in areas with annual mean wind speeds of ≥ 4.5 m/s would provide a net present value higher than US\$0. In this circumstance, the attractiveness of exploiting wind resources would account for 97.8% of the total wind potential exploitable in areas with annual mean wind speeds exceeding 4 m/s. This means that an increase in the feed-in tariff from US\$0.063 to 0.10/kWh would greatly enhance the use of exploitable wind resources.

With a capital grant of 50% of capital costs from the government, a remuneration of at least US\$0.30 and 0.50/kWh would be needed for installation of PV systems of 3

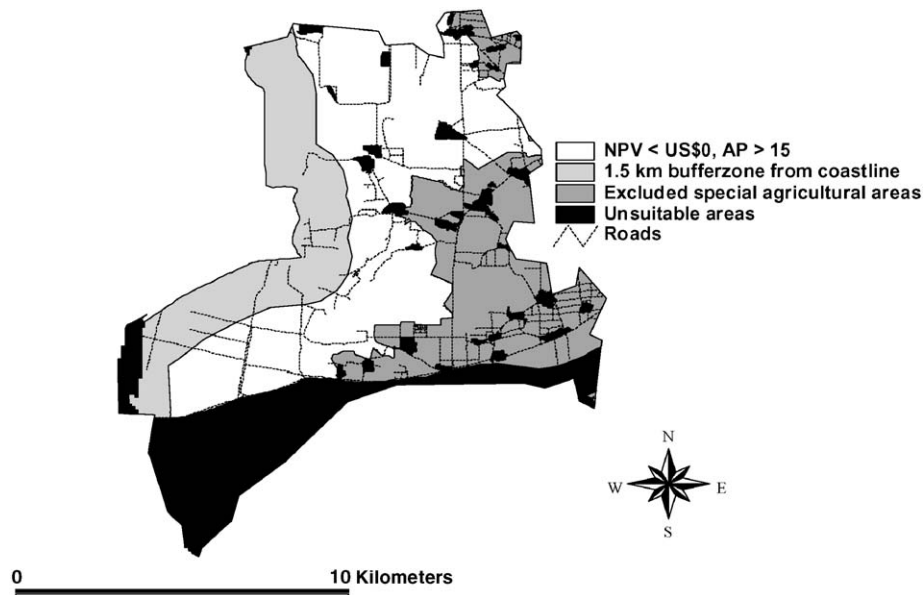


Fig. 6. Distribution of the net present value (NPV) and of the amortization period (AP in years) for investment in 1000 L of ethanol production from sugarcane and biodiesel production from rapeseed at Chigu with remuneration of US\$0.50/LOE for ethanol and US\$0.44/LOE for biodiesel, but without governmental capital grants.

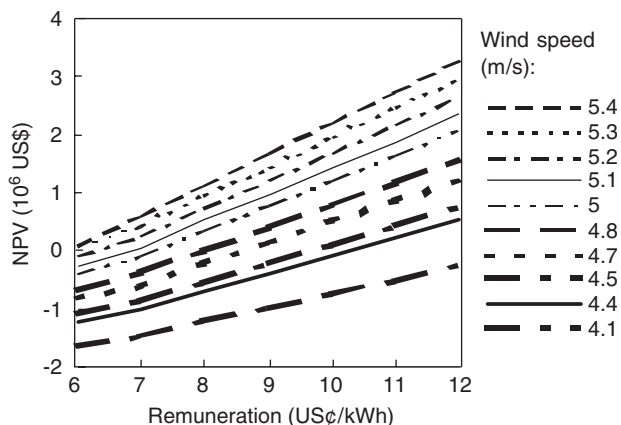


Fig. 7. Net present value (NPV) of investment in installing a single wind turbine in areas with different annual mean wind speeds at Chigu at various remuneration price levels.

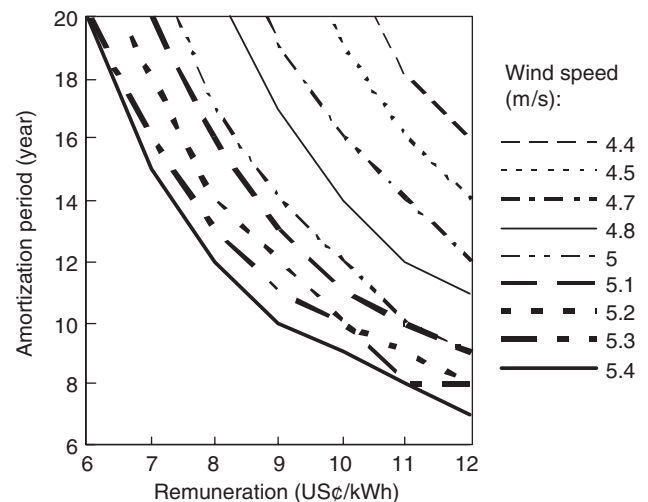


Fig. 8. Amortization period for investment in installing a single wind turbine in areas with different annual mean wind speeds at Chigu at various remuneration price levels.

and 2 kW, respectively, in order to provide a net present value higher than US\$0 (Fig. 9). Considering that an installation capacity of 2 kW for a single household would be more feasible than of 3 kW in Taiwan with a high population density, a remuneration of US\$0.50 would be needed to encourage investment in a 2-kW installation.

The net present value and the amortization period of investment in 1000 L of ethanol production from sugarcane growing at Chigu with various remuneration price levels are illustrated in Fig. 10. A remuneration of US\$0.51/LOE would provide a net present value of higher than US\$0. The amortization period of 15 years being equal to the period over which the investment is to be recovered makes the investment unattractive in this case. An enhanced remuneration of US\$0.55/LOE would provide investment

in 1000 L of ethanol production a net present value of US\$189,000 with an amortization period of 11 years. This remuneration price level appears more attractive for investment in production of this biofuel.

Fig. 11 illustrates the net present value and the amortization period of investment in 1000 L of biodiesel production from rapeseed growing at Chigu with various remuneration price levels. A remuneration of US\$0.60/LOE would provide a net present value of higher than US\$0 with an amortization period of 15 years. The long amortization period in this case seems unattractive for investment. An enhanced remuneration of US\$0.65/LOE would provide an investment in 1000 L of biodiesel

Table 3
Technical potential of wind energy at Chigu

Mean annual wind speed (m/s)	Annual energy output per wind turbine (MWh)	Total no. of wind turbines allowed to be installed	Total energy output annually (MWh)	Share (%)
4.1	1586	32	50,760	1.6
4.4	2027	9	18,242	0.6
4.5	2159	212	457,723	14.1
4.7	2423	16	38,775	1.2
4.8	2600	332	863,101	26.5
5.0	2908	131	380,966	11.7
5.1	3040	150	456,049	14.0
5.2	3217	152	488,920	15.0
5.3	3393	77	261,248	8.0
5.4	3569	67	239,128	7.3
Total		1178	3,254,913	100.0

Source: Yue et al., 2005.

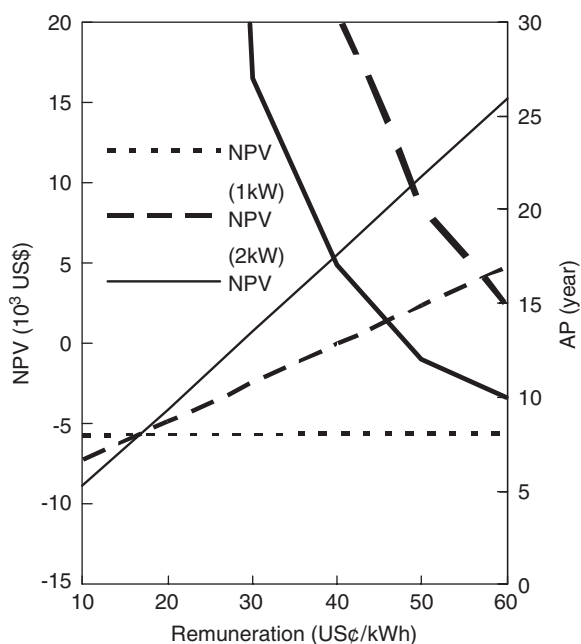


Fig. 9. Net present value (NPV) and amortization period (AP) of investment in rooftop PV systems at Chigu with various remuneration price levels.

production a net present value of US\$233,000 with an amortization period of 11 years. For the development of the biomass industry in its infancy, these enhanced levels of remuneration price would be justifiable in order to create a market for ethanol and biodiesel as substitutes for gasoline and diesel, respectively.

5. Implications for decision-making

5.1. Energy and environmental policy

Taiwan is now the country with the highest energy consumption per unit area in the world. Imported energy represented 98% of the total domestic energy supply in 2003, including fossil fuels at 90% and nuclear energy at

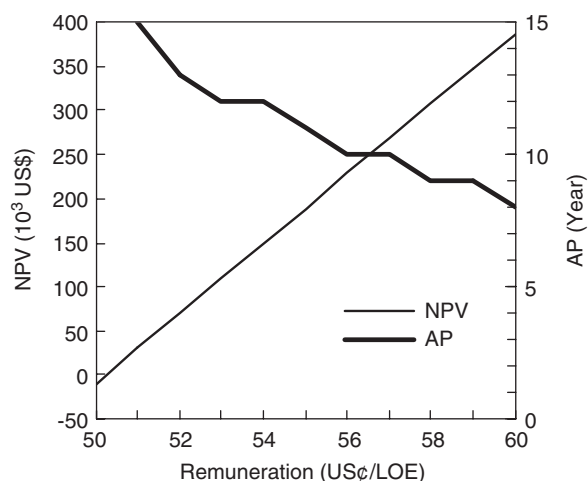


Fig. 10. Net present value (NPV) and the amortization period (AP) of investment in ethanol production from sugarcane growing at Chigu with various remuneration price levels.

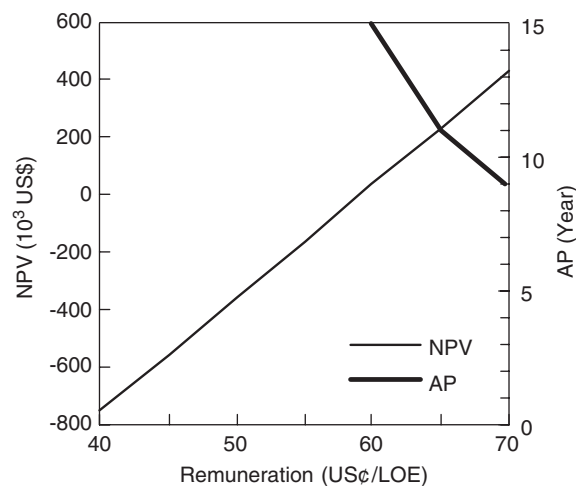


Fig. 11. Net present value (NPV) and the amortization period (AP) of investment in biodiesel production from rapeseed growing at Chigu with various remuneration price levels.

8% (ECROC, 2004). The exclusion of Taiwan from the Climate Convention has led to a passive and wait-and-see attitude by the government toward the reduction of domestic greenhouse gas emissions since the signing of the Convention in 1992 (Lin and Yo, 2005; Yue and Sun, 2003). The intended investment in massive coal-burning power plants, a petrochemical plant, and steel-making plant, that will vastly increase CO₂ emissions which has thus been stringently criticized by environmental NGOs, is a case in point (Lue, 2005). The expansion of these carbon-intensive industrial sectors also runs counter to the appeals and efforts made by the international community to cut global carbon emissions (Brown, 2003; Hill et al., 1995; Houghton, 1997; IPCC, 2001; Owen et al., 1998; Scheer, 2002).

The effectiveness of the Kyoto Protocol in February 2005 is expected to spur Taiwan's government to take more proactive steps for cutting CO₂ emissions. The government has announced its intension of enhancing the share of renewable energy in the national energy supply in response to the Kyoto Protocol coming into effect (Tsai et al., 2005). In view of self-sufficiency of the energy supply and mitigation of global warming, renewable energy sources are becoming an inevitable option in the domestic energy portfolio.

Current incentives for investment in renewable energy seem insufficient for effectively promoting the production of clean energy. This can be illustrated by the conditions for attracting investment into the Chigu area where excellent wind, insolation, and land-use conditions are available for developing wind energy, PV systems, and energy crop growing (Chen and Hsieh, 2002; ECROC, 1999). For wind energy, only the investment in Chigu areas with annual mean wind speeds of at least 5.3 m/s would be economically attractive, and this would account for only 15.3% of the total wind potential exploitable in the area with annual mean wind speeds exceeding 4 m/s. An increased feed-in tariff would be needed for an expanded use of wind resources in areas with wind speeds of less than 5.3 m/s. Investment in rooftop PV systems with capacities of 1, 2, and 3 kW would not be amortized under current incentive conditions, unless the feed-in tariffs were to be increased. Similarly, ethanol and biodiesel production at the remuneration price level considered by the ECROC would provide insufficient incentives for investment. Legislation providing enhanced remuneration prices is needed in order to legitimize the incentives.

5.2. *Legal framework for promoting renewable energy*

Policy and legislation have the leverage to drive private investment in renewable energy sources by means of setting a favorable incentive framework. This is particularly significant for a society like Taiwan where concerns of profit dominate investment considerations of businesses and the general public.

Experiences in the EU, Japan, and India indicate that legislatively stipulated remuneration prices have proven to be the most effective way to help renewable energy sources penetrate markets. The remuneration price in Taiwan is currently available for electricity generated from wind and PV systems according to the “Ordinance of the Taiwan Power Company for Remunerating the Power Generated from Renewable Energy Sources”. The inclusion of biomass in the remuneration system is needed to encourage investment in growing energy crops.

Except for the availability of legislated feed-in tariffs, the level of the premium prices is a factor profoundly affecting the willingness of entities to invest. Investment incentives for exploiting renewable energy sources in Taiwan are shown in Table 4. As a whole, the amortization periods are longer than the periods over which the investments can be recovered, which presents an unfavorable condition for attracting investment in and for the development of renewable energy.

An increase of the feed-in tariff for electricity generated from renewable energy sources is currently in the legislative process.¹³ Accordingly, the feed-in tariff of electricity generated by renewable energy sources will be increased from US\$0.063 to 0.069/kWh with a 20-year guarantee for remuneration. This would make investment in wind power capable of being amortized in areas with wind speeds of at least 5.1 m/s. In the case of the Chigu area, over 55% of the wind potential with wind speeds higher than 4 m/s would not be attractive for exploitation. Considering the relatively low generation cost of wind energy compared to other forms of renewable energy sources, an increase of feed-in tariff to US\$0.10/kWh seems reasonable in order to actively explore wind energy.

For the electricity generated by PV systems, an increase of the feed-in tariff to US\$0.50/kWh, instead of the recommended US\$0.10/kWh for electricity generated from wind energy, would be needed to help eliminate barriers to investment due to its current high capital cost. Similarly, the remuneration prices for ethanol and biodiesel have to increase to US\$0.55 and 0.65/LOE, respectively, in order to attract investment. Due to soaring oil prices recently in the international market, the suggested remuneration price for ethanol and biodiesel at US\$0.55 and 0.65/LOE is already lower than the market price of gasoline and diesel at US\$0.92 and 0.66/LOE. This indicates that the investment in biofuel is currently already profitable for energy companies with the suggested remuneration price. The probable further increases in oil prices in the future, prompted by factors such as the gradual exhaustion of oil reserves and the uncertainty of energy supplies in the future international energy market due to political instability, would make the investment even more profitable.

¹³The drafted “Developmental Ordinance of Renewable Energy Sources” has been passed by the Executive Yuan in June 2005, and is to be passed by the legislative.

Table 4
Investment incentives for exploiting renewable energy sources in Taiwan

Source	Costs (US\$)	Current		Suggested		Period over which the investment is to be recovered (years)	
		Remuneration (US\$)	Subsidy of the total investment costs (%)	NPV (10 ³ US\$)	AP ^a (years)	Subsidy of the total investment costs (%)	NPV (10 ³ US\$)
Wind	0.079/kWh ^b	0.063/kWh	0	−387.3 ^b	>20 ^b	0	1229.2 ^b
PV ^c	0.429/kWh	0.063/kWh	50	−8.2	>30	50	2.4
Ethanol	0.542/LOE	0.50/LOE ^d	0	−9.4 ^e	>15	0	188.5 ^e
Biodiesel	0.638/LOE	0.44/LOE ^d	0	−598.0 ^e	>15	0	233.5 ^e

^aAmortization period.

^bInvestment in areas with annual mean wind speeds of 5 m/s.

^cInvestment for an installation capacity of 2 kW.

^dRemuneration considered by the ECROC.

^eFor production of 1000 L.

The current legal framework providing a single remuneration price for electricity generated by various renewable energy sources in Taiwan does not appear to be adequate; different kinds of renewable energy sources require different levels of financial support according to individual energy and environmental benefits and energy costs. In comparison, the higher production costs of biodiesel require higher remuneration prices relative to ethanol. However, biodiesel presents a wide application scope as a substitute fuel for transportation and power generation. Its promotion is therefore important.

In addition to legislatively stipulated remuneration prices as an economic tool, institutional regulations may be effective and complementary for introducing new alternatives into the energy market. In the fuel market for transportation in Taiwan which has long been monopolized by gasoline and diesel, an obligation to have a certain percentage of ethanol and biodiesel in the transportation fuel to sell could effectively overcome structural and non-cost factors of barriers to introducing new technologies.

5.3. Private investment in renewable energy

The willingness of private entities to invest in renewable energy hinges strongly on incentives provided by legislation and governmental promotion programs, since these incentives directly affect the revenues of the investment. With the current remuneration price of US\$0.063/kWh, the investment in wind power would be profitable only in areas with mean wind speeds of at least 5.3 m/s with a net present value higher than US\$0, and amortization periods shorter than 20 years. If the remuneration were enhanced to US\$0.10/kWh, the investment in installing a single wind turbine in areas with annual mean wind speeds of ≥ 4.5 m/s would provide a net present value exceeding US\$0 with an amortization period shorter than 19 years.

Investment in PV systems would not be amortized with the current remuneration price of US\$0.063/kWh. Remuneration of at least US\$0.30 and 0.50/kWh would be needed for installation of PV systems of 3 and 2 kW, respectively, in order to provide a net present value higher than US\$0. With this enhanced remuneration price, the amortization period of 20 years for a 2-kW installation is notably shorter than the 30 years over which the investment is to be recovered. Even though its net present value of US\$2370 might not be attractive from a lucrative point of view, PV systems present a particular energy security of a decentralized power supply in addition to its environmental benefits.

The production of ethanol from sugarcane and of biodiesel from rapeseed would not be profitable with the considered remuneration prices of US\$0.50/LOE for ethanol and US\$0.44/LOE for biodiesel. If the remuneration prices for ethanol and biodiesel increased to US\$0.55 and 0.65/LOE, the profitability of the investment could be notably enhanced with an amortization period of 11 years

relative to the 15 years over which the investment is to be recovered.

5.4. Financing of subsidies

Subsidies to utilities are meant to balance the lower energy prices compared to the remuneration price, and those for investment costs can be covered in the short term in Taiwan through the following sources:

- the annual budget of US\$91 million arranged from the budget and dictated by the draft of “The Special Action Plan for a Non-Nuclear Country” passed in September 2003 for promoting energy savings and renewable energy sources, and
- revenue from fees for preventing air pollution levied on gas consumption since 1995.

The long-term funding is suggested to be combined with distortion-correcting taxes by means of the following measures:

- expansion of “The Fees for Preventing and Remedying Air Pollution”, levied since 1995 for SO_x and NO_x pollutants, to include carbon as a pollutant in proportion to carbon contents of various energy sources,
- taxation of carbon in proportion to the carbon content of various energy sources, or
- fees levied on utilities and energy companies based on electricity sold per kilowatt hour or fuel generated from fossil fuels in proportion to the carbon content.

The carbon tax could particularly play a reasonable role in the financing of subsidies. The economic analysis currently adopted in framing energy and industrial policies cannot handle the costs of pollution and the depletion of common property resources because common property cannot be privatized and thus is outside the market place (Hill et al., 1995; Tietenberg, 2000; Wenz, 2001). Under this market distortion, green taxes, the levying of which is currently being considered by Taiwan’s Council for Economic Planning and Development, are regarded as an effective tool for internalizing environmental and social costs of using carbon-containing energy sources (Barrow, 1999; Brown, 2001; Goulder, 2000; Smith, 2000; Weizsäcker et al., 2001; Woodward et al., 2000), and thus could play a corrective role through providing revenues for the financing of subsidies. The so-called “feebate mechanism” is particularly significant under the current limited financial capability of the government in Taiwan.

5.5. Decision support system as a tool of evaluating political incentives for attracting private investment

The analysis of the return on investment in Chapter 3 indicates whether the current return on investment is

attractive enough for private investment under conditions of the current costs and legal incentives. Following this line, the sensitivity analysis in Chapter 4 elucidates what intensities of remuneration would provide certain levels of incentive for investment. A decision support system involving these analyses can be used to help policy makers choose adequate and sufficient remuneration intensities in order to attract private investment in renewables.

5.6. Transferability of the decision support tool to other geographical contexts and different forms of renewable energy

The decision support system established in this study integrates potential evaluations, cost analyses, legal incentives, and analyses of returns on investments. This evaluation model is transferable to localities in other countries where an energy supply system from renewables is to be established. In this study, the discussion focused on three of the most promising renewable sources: wind, PV, and bioenergy. The methodologies and procedures of evaluation applied with this tool are also applicable to other forms of renewable energy sources, such as solar thermal, with emphasis on different technical and environmental considerations.

6. Conclusions

This study which attempted to establish a decision support system for exploiting local renewable energy sources reached the following conclusions:

- The decision support system established in this study integrates evaluation of the potential, cost analysis, legal incentives, and analysis of the return on investments with the aid of a GIS. This system can provide insights for the government into where and how much potential is available and whether the provided legal incentives are sufficient for attracting private investment, and can serve as tool for private investors to evaluate the economic feasibility of investments in exploiting local renewable energy sources.
- Under the current incentive framework in Taiwan, the amortization periods for investments in renewable energy are generally longer than the period over which the investment is to be recovered, which presents unfavorable conditions for attracting investment. Enhancement of the remuneration price is needed to actively develop renewable energy.
- By increasing the feed-in tariff from US\$0.063 to 0.10/kWh, the annual mean wind speed of areas attractive for investment would decrease from 5.3 to 4.5 m/s, and the share of wind resources attractive for exploitation of the total wind potential exploitable in the Chigu area with annual mean wind speeds exceeding 4 m/s would increase from 15.3% to 97.8%.

- With current capital grants from the government at 50% of capital costs, a remuneration price of US\$0.50/kWh is needed for a household installation of a rooftop PV system of 2 kW in order to provide an amortization period of 20 years relative to 30 years over which the investment is to be recovered.
- Remuneration prices of US\$0.55 and 0.65/LOE are needed for ethanol and biodiesel production, respectively, in order to provide an amortization period of 11 years relative to the 15 years over which the investment is to be recovered. These prices are already lower than the market price of gasoline and diesel at US\$0.92 and 0.66/LOE, respectively, and present a profit potential for investors. The probable further increases in oil prices in the future would make the investment even more profitable.
- The current legal framework providing a single remuneration price for electricity generated by various renewable energy sources in Taiwan does not appear to be adequate, for different kinds of renewable energy sources require different levels of financial support according to individual energy and environmental benefits and energy costs.
- In addition to legislatively stipulated remuneration prices as an economic tool, institutional regulation would be effective and complementary for introducing new alternatives to the energy market to overcome structural and non-cost factors of the barriers to introducing new technologies.
- A decision support system involving an analysis of current investment incentives and sensitivity analyses can help policymakers choose adequate and sufficient remuneration intensities in order to attract private investment in renewables.
- The decision support tool integrating potential evaluations, cost analyses, legal incentives, and analyses of returns on investments is applicable to other forms of renewable energy sources, and also transferable to localities in other countries where an energy supply system from renewables is to be established.

The decision support system established in this study with the aid of a GIS can facilitate the evaluation of investing in local renewable energy sources. The information produced may provide insights for investors, policymakers, and lawmakers to exploit more sustainable energy systems based on locally available natural resources. This appears particularly significant for countries such as Taiwan who are tackling the thorny problems of surging domestic energy demand and greenhouse gas emissions in a time when international climate policy has begun to seriously mitigate greenhouse gas emissions in the post-Kyoto era.

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