A GIS-based decision support system for facilitating the investment on exploiting local wind energy sources

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Abstract

The increasingly evident dangers of global warming and limited availability of fossil fuels are forcing the international community to actively exploit clean energy sources. 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 the location and 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. This tool may help facilitate the decision making process for exploiting renewable energy sources.
Keywords: *wind energy, decision support system, geographic information system.*

1 Introduction

The development of renewable energy is an important strategy in the fight against global warming. The IPCC (International Panel on Climate Change) and many authors have called for increased use of clean energy sources in order to reduce global CO_2 emissions [1–5], and provide a self-sufficient domestic energy supply [6].

WIT Transactions on Ecology and the Environment, Vol 105, © 2007 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/ESUS070401

The exploitation of renewable energy has to take into account factors such as technical potential, environmental restrictions, and incentives for investment [7–9]. Building a decision support system based on these factors would facilitate the evaluation of investment for exploiting renewable energy sources. This study investigated the Chigu area of southwestern Taiwan as an example (Figure 1), and to establish a decision support system for evaluating the feasibility of exploiting wind energy sources due to the abundant wind resources and farmland available in this area (Figure 2, 3).

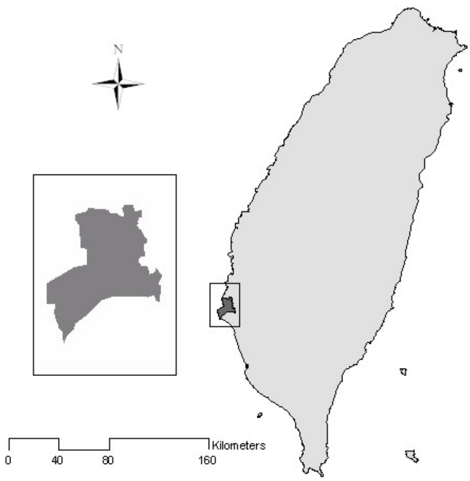

Figure 1: Geographic location of the Chigu region in southwestern Taiwan.

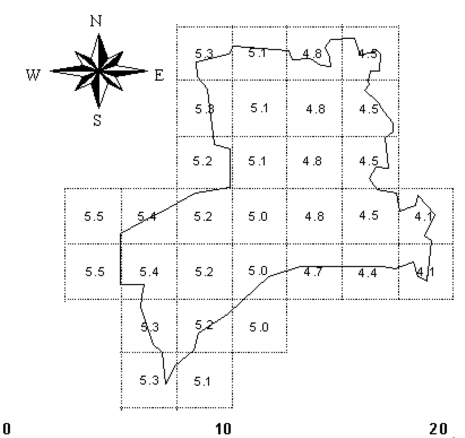

Figure 2: Distribution of mean annual wind speed in Chigu in m/s (source: ITRI [10]).

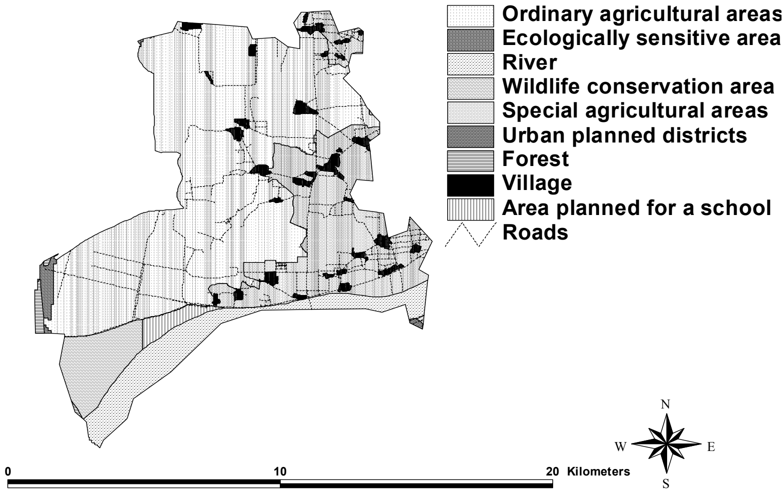

Figure 3: Land use zoning at Chigu.

In line with global trends towards 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 [11]. To achieve this goal, governmental statutes 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 to the government 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 investment.

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 Figure 4.

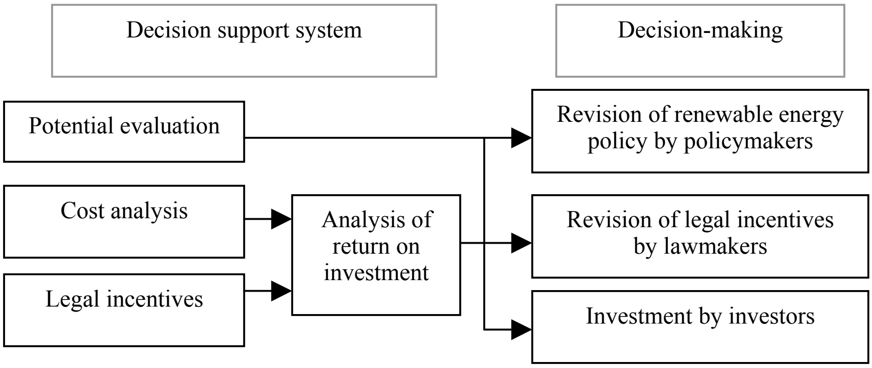

Figure 4: Framework for the decision support system for evaluating the feasibility of investments in exploiting local wind energy sources.

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

- 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;
- Interest rate of 4%; amount of credit at 60% of the capital cost; a period of credit of 7 years (according to the "Ordinance of Premium Credit of Purchasing Installation of Energy Savings", the interest rate of credit should be no more than the interest rate of a 2-year-period time deposit of postal savings (currently at 1.55%) plus an annual interest rate of 2.45%. The amount of credit should be no more than 80% of total capital costs of the projects. The period of credit should not be longer than 7 years);
- Remuneration at US$0.063/kWh (according to the "Ordinance of the Taiwan Power Company for Remunerating the Power generated from Renewable Energy Sources"); and
- Increases of running cost and remuneration of 1.2% per year. (The annual increase rate of 1.2% is based on the average fluctuation of the price index from 1995 to 2004.)

3 Results of the analysis of the return on investment

Based on current legal conditions, the return on investment is estimated using a cash flow analysis, as exemplified in Table 1. The energy cost can then be calculated, as shown in Table 2.

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	1,159.3	285.1	285.9	286.7	287.5	288.3	289.2	71.3	72.2	73.1
Present value of costs	1,114.7	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	-1,001.1	-1,047.0	-1,089.5	-1,128.7	-1,164.9	-1,038.4	-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

The distribution of the net present value for the investment on installing a single wind turbine is depicted in Figure 5. It indicates that the investment will have to be sited in areas with a wind speed 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.

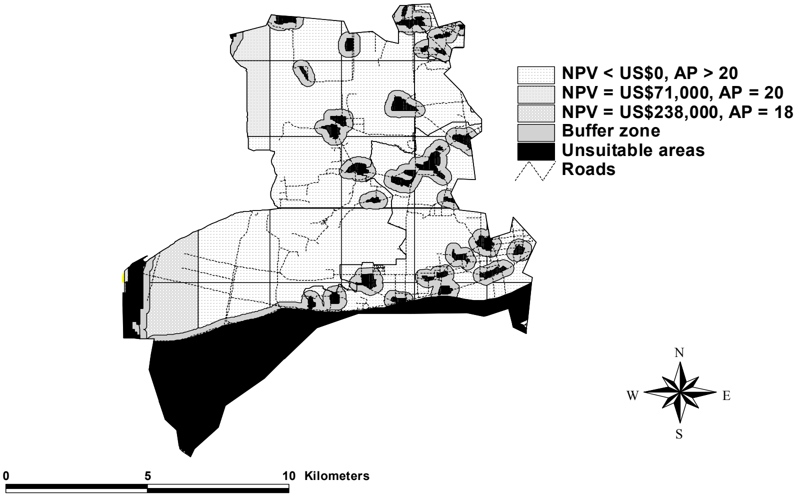

Figure 5: Distribution of the net present value (NPV) and the amortization period (AP in years) for investment in installing a single wind turbine at Chigu with remuneration of US$0.063/kWh at the current level and without governmental capital grants.

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	US$3.9 million
	NPV to year 20	US$3.1 million
Output	Total to year 20	71.4 GWh
	NPV to year 20	48.5 GWh
Cost of electricity		US$0.065/kWh

4 Sensitivity analysis

Incentives for investing in the exploitation of renewable energy sources essentially hinge on factors such as the levels of remuneration and capital grants from the government. The net present value 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 Figure 6.

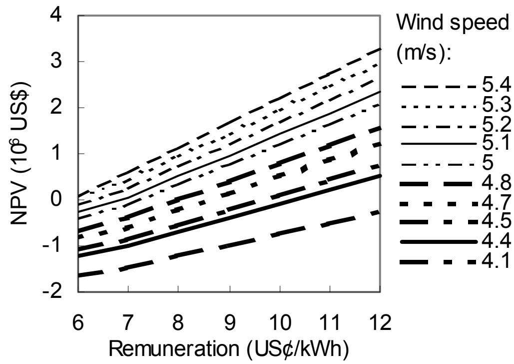

Figure 6: Net present value (NPV) of investment in installing a single wind turbine in areas with different annual mean wind speeds at Chigu at various remuneration price levels.

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. 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 of from US$0.063 to 0.10/kWh would greatly enhance the use of exploitable wind resources.

5 Implications for decision-making

5.1 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 about 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 [12]. In addition to the availability of legislated feed-in tariffs, the level of the premium prices is also a factor profoundly affecting the willingness of entities to invest. Under the current incentive framework, the investment would have to be sited in areas with wind speed 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. If a wind resource of less than 5.3 m/s were to be exploited, an increase of the feed-in tariff for electricity from wind power would be necessary.

5.2 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.

5.3 Financing of subsidies

Subsidies to utilities are meant to compensate for low energy prices (compared to remuneration prices), and investment costs. Goulder [13] and Smith [14] pointed out that the subsidies for renewable energy should be financed by the revenues from distortion-correcting taxes. Along this line, the following economic instruments should be taken into account:

- 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.

6 Conclusions

This study 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 legal incentives provided are sufficient to attract private investment, and can serve as a tool for private investors to evaluate the economic feasibility of investments in exploiting local renewable energy sources.
- Under the current incentive framework, the investment in wind energy will have to be sited in areas with a wind speed of at least 5.3 m/s if the project is to be amortized within the life span of a turbine of 20 years and with a net present value higher than US$0.
- 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%.

- A decision support system involving an analysis of current investment incentives and sensitivity analyses can help policy-makers choose adequate and sufficient remuneration intensities in order to attract private investment in renewable energy sources.
- 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 renewable energy sources 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 at a time when international climate policy has begun to seriously mitigate greenhouse gas emissions in the post-Kyoto era.

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