Sustainable Energy for Panama within the Framework of the Kyoto Protocol: A Stochastic Analysis of Different Options

By

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ABSTRACT

In this paper, a stochastic model is applied to forecast the financial returns of small scale renewable energy projects under the Clean Development Mechanism (CDM) of the Kyoto Protocol taking into account the trading of Certified Emission Reductions (CERs) in the primary market. In parallel, the use of Net Metering, Feed in Tariffs and rebates are considered for residential projects in order to identify the best mechanisms to support renewable energy technologies. The proposed model encompasses the uncertainties associated with the renewable energy generation, retail prices, spot prices, household energy consumption, system component prices and CERs trading. The results obtained by using the Monte Carlo simulation have shown that the projects generating less than 1600 CERs per year would find difficulties to cover the transaction costs with the revenue from the sale of CERs. In the case of homeowner projects, the simulation results revealed that Net Metering may improve the financial returns of the investment when the energy output is lower or matches the household consumption. Nevertheless, these projects are still depending on the governmental support particularly PV systems. It seems to be that the use of feed in tariffs as supporting mechanism is more profitable that Net Metering as the energy output increases. In spite of some hurdles, the trading of the carbon credits are still very important tool to reach greenhouse gases emission targets, address global warming problems and support renewable energy development. In the near future, it is expected that they will play a significant role in the electric sector. The paper concludes that it is critical to capture the environmental and other non-traditional benefits associated with renewable energy generation in order to guarantee cost effective investments.

1 INTRODUCTION

The interest in renewable energy technologies have recently intensified because of the need to implement climate change mitigation policies as the Kyoto protocol, reduction of fossil fuels dependence, concerns on energy security and the restructuring of the electricity markets.

The Kyoto Protocol has set up three flexible mechanisms to enable Annex-1 countries to reach their greenhouse gases reduction targets at the lowest possible cost. Firstly, an international emissions trading and secondly two based project mechanisms: Joint Implementation (JI) and the Clean Development Mechanism (CDM). The CDM involves non-annex-1 countries encouraging the establishment of renewable energy projects as well as other activities for greenhouse gas (GHG) mitigation in developing countries. Moreover, the article 12 of the Kyoto Protocol envisages two objectives for the CDM: cost efficient abatement of GHG emissions and contribution to sustainability of the host countries.

Furthermore, the implementation of carbon credit markets such as NordPool European Union Emissions Trading Scheme (EU ETS), Chicago Climate Exchange (CCX) and New South Wales greenhouse gas abatement scheme among others will facilitate the integration of renewable energy technologies into the restructured electricity industry. At the same time, it will provide the mechanism for these technologies to be economically compensated for the environmental benefits that they generate in comparison with conventional power production (Morthorst, 1999). These emerging markets are an important response to global warming issues. Nevertheless, they have to prove their ability to be a reliable and cost-effective tool for climate change mitigation.

In 2006, the carbon market grew in value to an estimated US$30 billion, three times greater than the previous year. This market was dominated by the sale and re-sale of European Union Allowances (EUAs) at a value of nearly $25 billion under the EU ETS. Project-based activities through the CDM and JI grew sharply to a value of about US$5 billion according to the World Bank, State and Trends of the Carbon Market 2007 (Capoor, 2007).

After ratification of the Kyoto protocol by the government of Panama in 1999 the amount of renewable energy projects to be implemented as well as the international interest to invest on GHG mitigation projects considerable increased. Netherlands was the first country to sign an agreement with Panama to transfer the CO_2 ton avoided emissions. These attempts have been followed by Finland, Canada, Spain and Italy. Moreover, the European community has provided a financial fund to install solar systems for rural electrification. In order to attract new investment in renewable projects the Government of Panama passed Law No. 45 of August 4, 2004 to supply a number of incentives for the construction and development of new hydroelectric plants and other renewable energy projects.

An ample range of eligible CDM projects can lead to creditable reductions of GHG emissions. However, this research concentrates on renewable energy CDM (RE-CDM) projects These projects besides contribute to GHG mitigation, their employment provide multiple benefits to the host countries such as enhanced energy security, energy availability for remote areas, increase in the level of technology and sustainability. Despite these advantages, several hurdles prevent the profitable realization of these projects (Del Río, 2005). Therefore, it is necessary to assess the economic competitiveness of the renewable energy resources available in Panama as well as how the trade of the Certified Emission

Reductions[1] (CERs) will influence the profitability of RE-CDM projects

This paper examines the economical options for off-grid and grid-connected renewable projects taking into account the environmental benefits associated to the sale of CERs. These options reflect a broad range of possible examples. Furthermore, the paper compares small scale projects (wind, hydro and solar) to demonstrate the different financial returns that could be earned under different scenarios.

2 THE CDM PROJECTS IN PANAMA

Latin America was a pioneer and precursor of the CDM projects in the carbon finance business. When the CDM became operational in 2003, six of the nine first project methodologies approved by the CDM Executive Board were from Latin American projects. Nowadays, China dominated the CDM market on the supply side, followed by India. Nonetheless, Latin America continues to be significant player in the carbon market (Polland, 2005).

The CDM portfolio of Panama contains 108 projects of which 94 projects are renewable energy projects. The majority of these projects are associated to hydroelectricity. It is also the leading form of renewable energy existing in Panama up to now. Thirty two of the renewable energy CDM projects have obtained the letter of approval by ANAM[2]. The implementation of these RE-CDM projects will avoid 3.8 million CO_2 ton per annum. According to the UNEP/RISOE project pipeline database, Panama has five CDM projects registered by the CDM executive board, one more project requested registration and two more that are in the stage of validation by the Designated Operational Entity (DOE). All of them are hydroelectric projects. The credit buyer of three registered projects is Unión Fenosa (Spain) which is also the owner of the two Panamanian distribution companies.

In the case of wind energy, there are technological and economical barriers that affect the implementation of the wind power projects in Panama. The wind regime that prevails in the city areas is low. Nevertheless, near to the Caribbean cost and the central mountain chain there are several regions where wind power projects can be developed. In 2002, a research sponsored by Global Environment Fund identified sites with average wind speed of 12 m/s. They estimated a potential wind capacity between to 100 MW and 300 MW that can be integrated to the national electric grid. As consequences, few projects arose among them the Cerro Tute wind farm which will have an installed capacity of 81 MW. The DNA had approved two of the wind power projects though these projects have not been submitted to the CDM Executive Board yet.

In Panama, the solar projects that have been implemented are off-grid as well as installed in remote areas. So far, there are not any solar energy projects submitted for evaluation to the DNA. The biggest application for solar energy is for rural electrification. The most important of these projects that is in

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[1] 1 CER = 1 ton of CO_2 reduced under the Clean Development Mechanism. CER is also known as carbon credit.

[2] ANAM is the Designated National Authority (DNA)

process consist in the installation of 450 PV (photovoltaic) systems to supply electricity to 350 school and 100 health clinics located in a rural area. This project is supported by the European community. The micro scale solar projects contribute to the sustainable development, however the volume of CERs that can be obtained are small and the transaction costs of CDM projects are high avoiding a profitable revenue from the sale of the CERs. Nowadays, the CDM rules allow the bundling of projects to reduce transaction costs and submit as one project activity. These rules may help to make more competitive and attractive for investor the employment of small scale RE-CDM (Bosi, 2001).

3 THE BASELINE METHODOLOGY

The Clean Development Mechanism (CDM) allows project developers to earn carbon credits for projects that reduce the GHG emissions and contribute to the sustainability of the host countries. The quantity of the CERs is determined by comparing the project emissions to the emission baseline. The emission baseline is the best estimate of what would have happened in the absence of the project activities. The level at which the emission baseline is set as well as the value of CERs critically affect the revenue of the CDM projects. Therefore, it is essential to formulate effective methodologies for quantifying the emissions reductions by electricity projects. Three calculation methodologies are being discussed as benchmark for avoided GHG emissions (Hanson, 2004):

- *System average* is based on the average emissions rate of all electricity generators in the wholesale market where the renewable facility is located.
- *Operating margin* reflects the emissions rate of the conventional power plants that are 'backed down' when a renewable facility comes on line. This approach considers the effect of a renewable project on the present operation of the electric grid.
- *Build margin* is based on the emissions rate of the fossil-fuelled power plants that the construction of the renewable project cancelled or postponed.

No a single baseline methodology can fit the ample range of the CDM projects in the electric power sector. Moreover, the calculation of the baseline depend on different factors such as the scale of the project, the electricity market where the project will be implemented, the technologies and fuels employ in the host country as well as grid-connected or off-grid projects (Kartha, 2004).

In this work, we estimated the emission factor for the Panamanian wholesale electricity market. Due to the existent differences between typical sources of supply for off-grid and grid-connected electricity was necessary to calculate different baseline for each.

3.1 The Grid-connected Projects

Several studies have recommended the use of the combined margin approach for the RE-CDM projects. Since most of the renewable energy projects will have some influences on the operating margin in the short term and the build margin in the long term. Thus, the method that combines both effects will provide a more accurate baseline.

$$E_{combined-margin} = \frac{E_{operating-margin} + E_{Build-margin}}{2} \qquad (1)$$

In this work, the operating margin was calculated by:

$$E_{GENCO} = \frac{\sum\left(E_{tech} * X_u\right)}{X_t} \qquad (2)$$

$$X_{co_2} = \sum\left(E_{GENCO} * X_{GENCO}\right) \qquad (3)$$

$$E_{operating-margin} = \frac{X_{CO_2}}{X_{thermal}} \qquad (4)$$

where, E_{GENCO} is the generating company emission factor, E_{tech} is the emission factor by generating technology, X_u is the generating unit capacity, X_t is the total installed capacity of the generating company, X_{co_2} is the annual CO_2 ton emissions from electric generation, X_{GENCO} is the annual energy output of the generating company, $X_{thermal}$ is the total thermal generation in the wholesale market where the renewable project is located. In 2006, the operating margin of the Panamanian wholesale electricity market was found to be equal to 0.78 CO_2 ton/MWh. The obtained operating margin is the weighted average emissions of all generating sources serving the electric grid, excluding the hydroelectric generation.

The build margin was estimated using the recent capacity additions to the electric grid from 2002 to 2005. The majority of the installed capacity came from hydroelectric projects as it is depicted on Fig. 1. During this period were installed 146 MW from hydroelectric projects and 58 MW from thermal projects. In addition, one thermal plant was shut down at the end of 2003 and other thermal plant changed the owner. The build margin was found to be 0.49 CO_2 ton/MWh. Consequently, the combined margin calculated was equal to 0.64 CO_2 ton/MWh. The estimated reduction in CO_2 achieved by the employment of a renewable energy project is calculated by multiply the annual generation of the RE-CDM project by the combined margin.

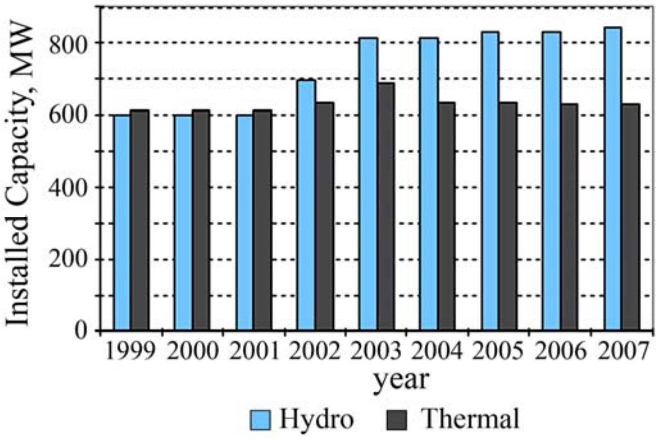

Fig. 1. The Installed Capacity 1999-2007.

The Annual CO_2 ton emissions of the Panamanian electricity market from 1982 to 2006 are shown on Fig. 2. In Panama the hydro generation is the dominant source for the electricity generation. The thermal generation grew in 2001 and 2003 (see Fig. 2). These changes were product of long drought caused by the “el niño” phenomenon that disrupts weather in the pacific coast of Panama.

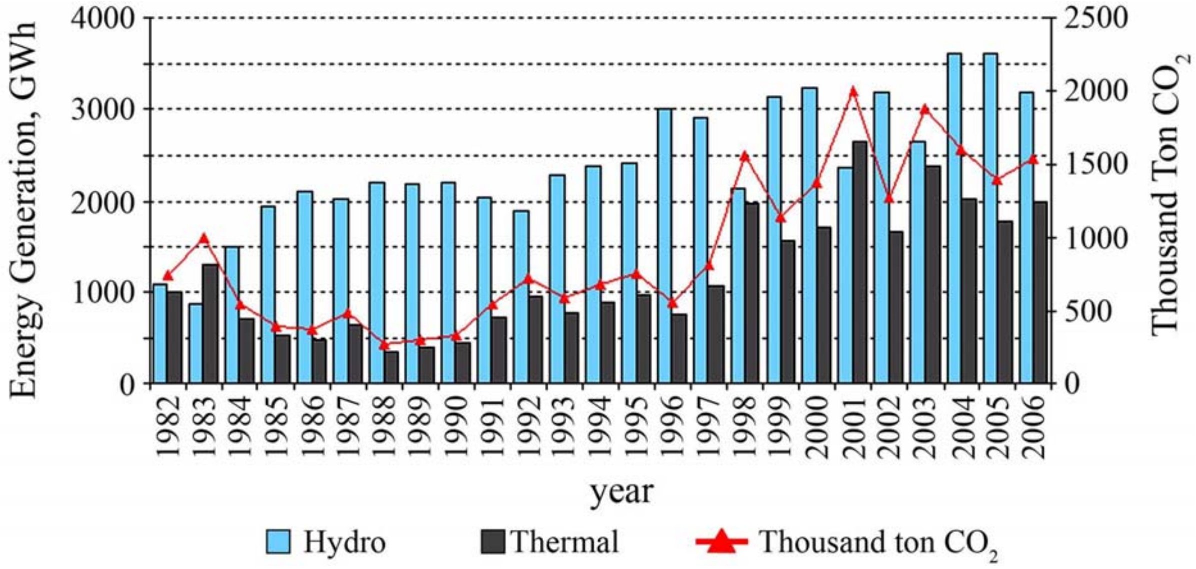

Fig. 2. The CO_2 Emissions from Electric Generation, the Hydro Generation and the Thermal Generation 1982-2006

3.2 The Off-grid Projects

Off-grid energy generation is mainly used to deliver electricity services to remote areas. These projects will displaced the employment of diesel generators or a combination of non-electric resources, such as kerosene and candle for lighting, battery recharging, etc. Although sites conditions could vary, diesel generators can easily be said to be the prevailing off-grid generation technology in most developing countries (Kaufman, 1999; Martens, 2001). Therefore, it is recommended that off-grid small CDM power projects generally be assessed against a diesel-based baseline. The carbon intensity of a small diesel generator can be considered equal to 0.88 CO_2 ton/MWh.

4 THE MODEL

We formulated a stochastic net present value (NPV) model to analyze the financial return of small scale RE-CDM projects. The proposed model relies on the probability distributions and statistical techniques. There are several factors that influence the revenue from RE-CDM project such as the energy output, retail prices, CERs trading, spot prices and cost of the installed system. Therefore, it is difficult to reflect these uncertainties in the NPV calculation using conventional deterministic techniques.

The NPV calculation depends on the initial investment, the total accumulated cash-flow and the discount rate. The cash-flows are the costs and the benefits associated to the project. In our model, the costs, benefits as well as the variables used in their calculation were represented as probabilistic distributions. The costs were defined as the initial investment, the transaction cost associated to the CDM process, the operation and maintenance costs. The following benefits were taking into account: the value of energy output, the governmental grants and the environmental benefits regarding to the avoidance of CO_2 emitted to the atmosphere.

$$NPV = \sum_{t=1}^{t=m} \frac{X_t}{(1+I)^t} - X_i \tag{5}$$

where X_i is the initial investment, X_t is the cash flow at year t, m is the end of the project, I is the discount rate. The simulations were performed using Monte Carlo techniques. To ensure the appropriated accuracy of the simulation results 10,000 trials were running.

This study consists of two parts. Firstly, we investigated the economic options of renewable projects carry out by independent power producer and finally, we evaluated the residential projects.

4.1 The Renewable Projects by Independent Power Producer

We evaluated small scale wind energy and hydroelectric projects up to 10 MW. In the case of solar energy, we calculated the NPV of the several solar system off-grid bundled and presented as one project. At present, the Panamanian government is implementing the project SOLEDUSA for rural electrification. However, this project has not been considered as CDM project.

Three scenarios were considered to investigate the benefits that the sale of CERs can bring to the projects.

- *The Base Case* scenario does not take into account the sale of CERs or Governmental grant. In this scenario the only benefit is the value of the energy output.
- *The CERs scenario* is related to the monetary value of the environmental benefits that renewable technologies generate compared to conventional energy production in these cases associated to the sale of the CERs.
- *The governmental grant* scenario is based on the Law No. 45 of august 4, 2004 of Panama which establishes a regime of incentives for the promotion of renewable energy systems. According to this law, there is an incentive up to 25 % of the direct investment cost based upon the reduction of the carbon dioxide emissions. However, the revenue obtained by the selling of CERs can be deducted of the 25% incentive.

The value of energy output for these projects relies on the contract market price and the system marginal cost.

4.2 The Residential Projects

In the new restructured electricity industry homeowners have many choices. They can choose their electricity provider and supply electricity to the electric grid. Besides, the impacts of the global warming on new energy policies will also involve consumers, although these strategies are still unclear. The financial returns of the grid-connected wind power and PV system were computed using Monte Carlo Simulation.

In these cases, the value of the energy output relies on the value of the electricity consumed by the household (retail prices) and the value of the energy that is supplied to the electric grid.

At present most renewable energy technologies cannot compete on their own against conventional technologies. Thus, additional instruments have been created to support their development and secure their participation in the new restructured electricity industry.

- *Feed in Tariffs (FiT),* this term refers to the regulatory, minimum guaranteed price per kWh that an electricity utility has to pay to a private or independent producer of renewable power fed into the grid. Feed in Tariff has been successful in the countries that have been applied, all of them developed countries. The economical and political barriers will make difficult to apply this support mechanism in developing countries where governments try to get cheaper tariffs. In the present investigation, we evaluated the profitability of the feed in tariffs for residential projects as comparative example. We fixed this price to US $ 0.5/kWh. Moreover, feed in tariff cannot be applied for renewable power producer in Panama except for a change to the article 68 of the Law No. 6 which states that any privilege offer to one generating company it must be given to all the generating companies in existence at that moment.
- *Net Metering,* it means that when the renewable system is supplying all of the power that the homeowner needs, the electricity meter stops spinning. However, if there is more generation than current needs, the meter will turn backwards and the kWh read decreases. When the renewable system isn't operating, the electric utility provides power to the household and the meter spins forward. Thus, the read increases again. In effect, the utility becomes a kWh “bank” for the excess generation. Since renewable customer/generators will receive a kWh credit rather than a dollar credit for any excess power, they are guaranteed the same rate for excess generation as that which they are billed. Nonetheless, the credit in kWh may be carried forward for up to one year after that the credits expire and the process begins again.
- Governmental Subsidies, We applied a governmental grant (GG) of 25% of the direct investment cost.

5 THE INPUT DATA

The input variables were represented as probabilistic distributions. It is important to note that both the distribution and the parameter values critically affect the results of the simulation. Therefore, the input distributions were carefully selected based upon available data.

5.1 *The Household Energy Consumption*

The consumption pattern used for the analyses was provided by EDEMET (Panamanian Distribution Company). The data covered the period from January 2004 to March 2006. The household monthly average load ranges were from 428 kWh in November to 557 kWh in March. The annual average household electricity use was about 6000 kWh. Each month of electricity usage was denoted by the beta distribution.

5.2 *The Cost of the PV Systems*

The cost of the system C, in $ US dollars per watt, is calculated by

$$C = P_{\mathrm{mod}} + P_{BOS} + P_{inst} + \frac{A_{BOS}}{1000n} \tag{6}$$

where P_{mod} is the module cost, P_{BOS} is the price related to the balance of system (BOS), P_{inst} is the installation cost, A_{BOS} is the area related to BOS cost, and n is the nominal module efficiency which was defined by the uniform distribution (minimum 10%, maximum 15%). For this simulation, the model calculates the system cost using triangular distributions for the costs of system components using the following parameters:

Table 1 The Parameters for the Triangular Distributions of System Component Costs

	Minimum	Likeliest	Maximum
Module Cost (US$/Wp)	4.0	4.5	5.0
Power BOS (US$/Wp)	0.5	0.75	1.0
Installation (US$/Wp)	1.0	1.5	2.0
Area Bos (US$/m^2)	75	125	150

5.3 *The Cost of the Wind System*

The cost of the wind turbine (US$/W) was represented by the uniform distribution, minimum 2 US$/W, maximum 3 US$/W. The electric infrastructure was fixed to 9 %, civil work 11 %, grid integration 7 %, installation 2 % of the cost of the wind turbine. The inverter was defined with the Weibull distribution (US $ per continuous watt).

5.4 *The Cost of the Hydroelectric Projects*

The goodness of fit test revealed that the gamma distribution was the best fit to represent the initial investment of the hydro projects (US$/W) from our data. The parameters are location 0.94, scale 0.27 and shape 3.87.

5.5 *The Operation and Maintenance Costs*

We used the triangular distribution to define the annual operation and maintenance costs. The distribution parameters were fixed as follow: the minimum 0 %, the likeliest 1 % and the maximum 2 % of the initial investment.

5.6 *The Wind Regime and the Energy Output*

The wind regime was analyzed using the Weibull distribution, for this purpose the shape (k) and scale (c) parameters were found through the equations given below:

$$\left(\frac{\sigma_v}{V_m}\right)^2 = \frac{\Gamma\left(1+\frac{2}{k}\right)}{\Gamma^2\left(1+\frac{1}{k}\right)} - 1 \tag{7}$$

$$c = \frac{V_m}{\Gamma\left(1+\frac{1}{k}\right)} \tag{8}$$

where σ_v is the standard deviation, Γ is the gamma function and V_m is the mean wind speed. The scale and shape parameters were calculated for each month. The annual average wind speed was 5 m/s in the case of residential projects (wind regime that prevails in city areas) and 10 m/s for independent power producer. For residential projects, the variation in power response with respect to the wind speed was calculated using the power curve of different types of small wind turbines that are available in the market from a range of 850 W to 6 kW.

5.7 *The Sunshine Hours, the Solar Radiation and the Energy Output*

The sunshine duration data employed in this study were provided by the Hydrometeorology Management of the Transmission Company of Panama (ETESA). The data covered the period from 2000 to 2006. For Panama City (latitude 09^{o}03’N, longitude 79^{o}22’W) during the period under consideration the average sunshine hours was 5.5 hours per day. The daily Solar Radiation data came from the Panama Canal Authority with an average potential radiation of 3.93 kWh/m^2 per day.

After applying the goodness of fit test to our data, the beta distribution was the best fit to represent our sunshine data. We calculated a probability distribution for each month.

The beta distribution of the daily sunshine hours together with DC to AC derate factors was used to assess the energy output of 1 kW, 2.5 kW, 3 kW, 4 kW and 6 kW rooftop PV systems for homeowner. The DC to AC derate factor was designated by the triangular distribution (Minimum 0.75, Maximum 0.85 and most probable 0.80).

5.8 *The Retail Electricity Price*

The sources of the retail prices (1982-2005) were the Independent Regulatory Entity (ERSP) of Panama. The electricity tariffs were assumed to rise at escalation rate of 1.5 % per annum. The normal distribution was used to define the annual retail prices.

5.9 *The System Marginal Cost*

In Panama, the energy trading occurs in the contract market and the spot market which is balancing market and cost-based market. The spot price is given by the system marginal cost on a short-term basis. Besides, this price is calculated by system operator through an economical dispatch.

The Panamanian competitive wholesale market began working in 1998. In 2005 and 2006, the system marginal cost showed a large variance (See Fig. 3) due to the distribution companies decided to buy more energy in the spot market than in the contract market as result the spot prices immediately increased as well as higher fuel prices. The percentage of energy that is traded in the spot market was defined by the uniform distribution (Minimum 0%, Maximum 70%). The table 2 shows the statistical description of the system marginal cost.

Table 2 The Statistical Description of the System Marginal Cost (US$/MWh)

Year	Mean	Standard deviation	Minimum	Maximum
1998	56.56	5.23	41.40	64.48
1999	43.19	11.60	0	97.93
2000	50.98	13.52	0	111.29
2001	49.99	8.62	33.29	126.07
2002	43.15	10.92	3.89	227.14
2003	53.96	9.40	35.82	159.04
2004	55.95	10.67	18.57	155.76
2005	90.80	24.33	4.01	96.38
2006	125.03	18.10	8.75	213.92

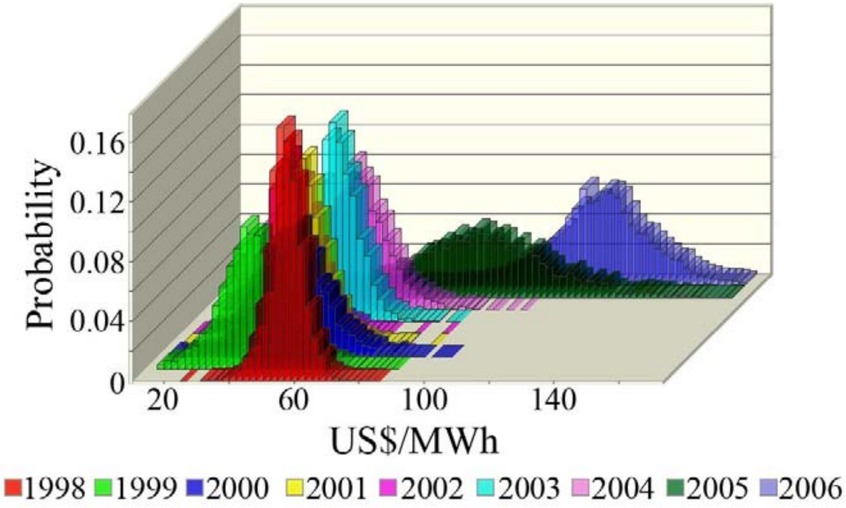

Fig. 3. The System Marginal Cost 1998-2006

5.10 *The Contract Market*

There is scarce public or available information about the contract market prices. The contracts are bilateral agreements on supply and receipt of energy/power or both between the generating companies and distribution companies. Nevertheless, they can not alter the economic dispatch. The contract market price was represented by the triangular distribution, minimum US$ 40/MWh likeliest US$ 70/MWh Maximum US$ 100/MWh. The percentage of energy that is traded in the contract market was defined by the uniform distribution (Minimum 30%, Maximum 100%).

5.11 *The Discount Rate*

The triangular distribution was used to describe the discount rate possible values. The distribution parameters are: the minimum 7 %, the most probable 8 % and the maximum 10 %.

5.12 *The Crediting Period*

Under the terms of the Marrakesh Accords, the CDM project participant can choose between a period of 10 years without renewal and a period 7 years that may be renewed twice (maximum of 21 years). This decision will depend on the project lifespan, the expected performance and the changes that can occur in the baseline. We assumed a crediting period of 21 years based on the expected generation and the baseline. We forecast that the combined margin may decrease a bit due to the recently increment of hydroelectric projects and other renewables affecting the baseline. However, twenty one years crediting period is more profitable than ten years according to the performance of these projects.

5.13 *The Transaction Cost*

The transaction costs are associated to the following costs:

A. Pre-implementation Costs
- Elaboration of the Project Ideas Note (PIN)
- Elaboration of the Project Design Document (PDD)
- Approval
- Validation of the PDD
- Registration

B. Implementation Costs
- Monitoring
- Verification
- Enforcement and supervision
- Adaptation fees (2% of CERs)

These costs are variable and depend on several factors such as project type, project cost, etc. De Gouvello & Coto (2003) estimated the transaction costs of the small scale CDM project reporting annually over a Crediting period 3*7 years. They found the transaction costs around US$ 23,000/US$ 80,000, the minimum/maximum value reflects the use of local consultant and international consultant respectively. Besides, Ahonen (2005) calculated the transaction costs under the Finish CDM/JI pilot program. She determined the average unit transaction costs of CDM projects between a range of 0.37 € - 1.89 € per ton of CO_2e. The transaction costs for the Panamanian RE-CDM projects that have been registered by the CDM executive board are in the range of US$ 75,000 to US$ 125,000. Thus, we represented the transaction costs with the uniform distribution minimum US$ 75,000 and maximum US$ 125,000.

5.14 The CER Price

In 2006, the average price for CER in the primary market[3] was about US$ 10.90, representing a 52% increase over 2005 levels. The lowest price paid for a CER in 2006 was US$ 6.80 and the maximum price was about US$ 24.75 (World Bank, 2007). The triangular distribution was used to describe the CER prices using the minimum, maximum and average prices that occurred in 2006.

6 SIMULATION RESULTS AND DISCUSSION

The NPV of the possible CDM projects are examined below, as well as the factors that affect their revenue level. Then, the influence of the CERs in the financial returns is studied under different scenarios. Besides, the use of the support mechanism such as Net Metering, Feed in Tariff and governmental grants are explored in the case of residential wind power and PV systems.

6.1 The Renewable Projects by Independent Power Producer

The simulation results demonstrated that the profits obtained using the CERs scenario are bigger than the ones using governmental supports as the energy generation increases (See Fig. 4), since the avoided CO_2 emissions from the renewable energy projects are related to the energy output. Conversely, the governmental grant depends exclusively on the initial investment of the project.

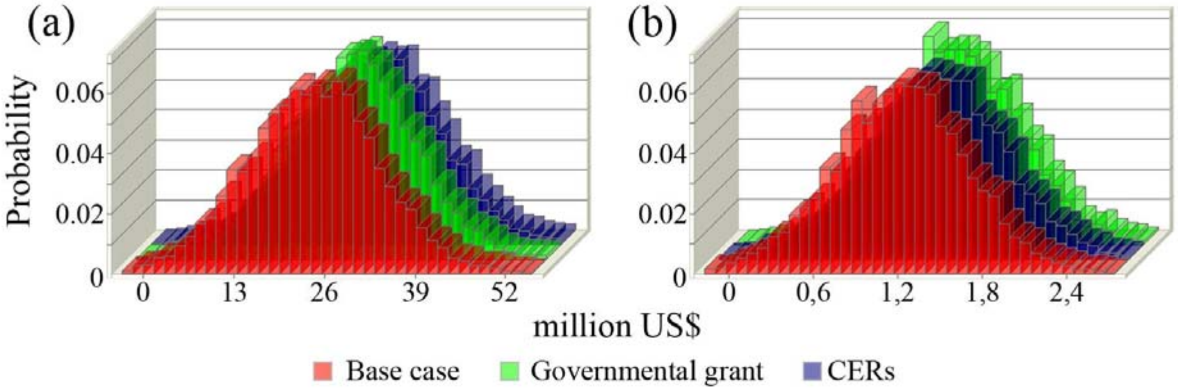

Fig. 4. The NPV Forecast of the Hydroelectric Projects.
(a) Installed capacity 10 MW (b) Installed capacity 500 kW

For the hydro and wind systems studied here, the parameter that most contribute to the variability of the project's NPV is the initial investment, followed by the amount of the energy trade in the contract and spot market with their respective prices. Additionally, the CER prices and their transaction costs affect the profitability of the projects as shown on Fig.5. The profits obtained from the sale of the CERs can represent up to 18% of the project's NPV[4]. The governmental grant also influences the variability of the project's NPV and this support become more relevant for very small renewable projects.

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[3] Transactions between the original owner (or issuer) of the carbon asset and a buyer.
[4] Our calculations are based on the mean of the probability distribution.

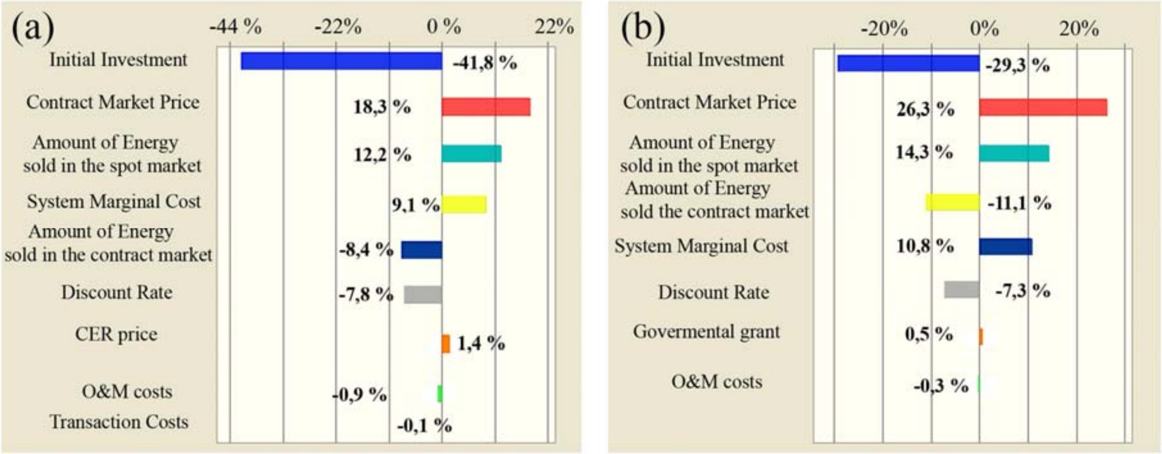

Fig. 5. The Contribution to the Variance of the NPV Forecast for 10 MW Hydro Project.
(a) The CERs scenario (b) The governmental grant scenario

In the case of solar generation, we estimated the income from the sale of the carbon credits hypothetically bundling 610 off-grid solar system projects, 30 projects of 500 W, 350 projects of 600 W, 106 project of 800 W, 24 projects of 1.5 kW and 100 projects of 1.7 kW. The total installed capacity of the bundled projects is 515.8 kW. Then, we compared these results with 500 kW wind system and hydroelectric projects as it is shown on Fig. 6.

Despite the higher baseline to calculate the CO_2 avoided emissions (0.88 tCO_2e/MWh) for off-grid projects, the volume of CERs from the bundled solar systems is smaller than the hydro and wind systems. Besides, the profit from the sale of the CERs has low certainty to reach a value over US$ 0 about 55 %. The certainty levels to cover the transaction costs for 500 kW hydro and wind system are 99% and 88% respectively. The volume of CERs obtained from the wind generation exhibits high variability due to the wind regime and its stochastic behavior (see Fig.6). For all studied cases, the incomes from the sale of carbon credits are bigger for hydroelectric projects as well as these projects are more profitable.

Although the small scale CDM projects are often associated with considerable sustainable development benefits, they are hampered by several barriers such as: transaction costs (see Table 3), low potential volume of CERs and their market price making them less attractive investments to the project developers.

Table 3 The Transaction Costs as Percentage of the CERs NPV

Installed Capacity	Hydro	Wind	Solar
10 MW	2.3%	2.8%	
5 MW	4.7%	5.6%	
1 MW	27.3%	28.1%	
500 kW	47.1%	56.2%	87.5%

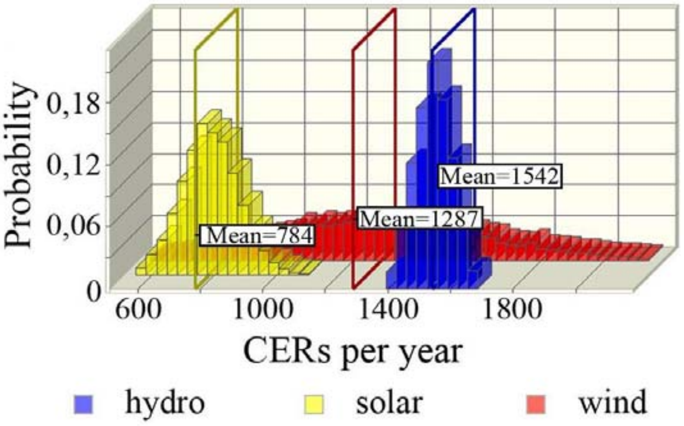

Fig. 6. The Volume of CERs per year (Installed Capacity 500 kW).

The transaction costs associated to the CDM process could be a barrier to implement small RE-CDM projects. Lower transaction costs are very important to encourage investment in micro RE-CDM projects. However the decision to invest in a small RE-CDM project will mainly depend on the overall CER revenues that can be expected from the sale of CERs. The Table 4 illustrates the impact of the sale of CERs on the internal rate of return (IRR).

Table 4 The Impact of the Sale of CERs on the Internal Rate of Return

Installed Capacity	Increase in IRR	
	Hydro	Wind
10 MW	10.0%	10.8%
5 MW	9.4%	10.2%
1 MW	4.5%	5%
500 kW	0%	0%

Based on the trade of the CERs in the primary market, the projects generating less than 1600 CERs per year would find difficulties to cover the transaction costs with the revenue from the sale of CERs as it is depicted on Fig.7.

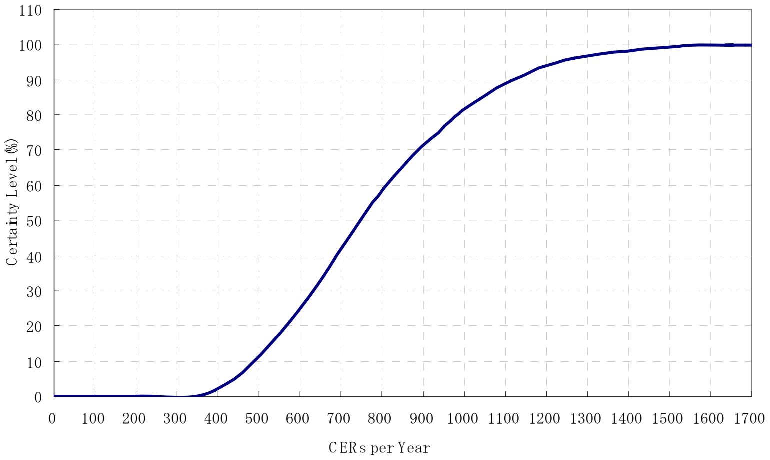

Fig.7. The Certainty Level of the CERs NPV Forecast (Minimum US$ 0).

6.2 The Residential Projects

In the case of residential PV system, the results obtained from Monte Carlo simulations have shown that the net metering might improve the financial returns of the investment when the energy output is lower or matches the household consumption. Nevertheless, the projects are still depending on the governmental subsidies to reach some profitable level as it shown on Fig. 8.

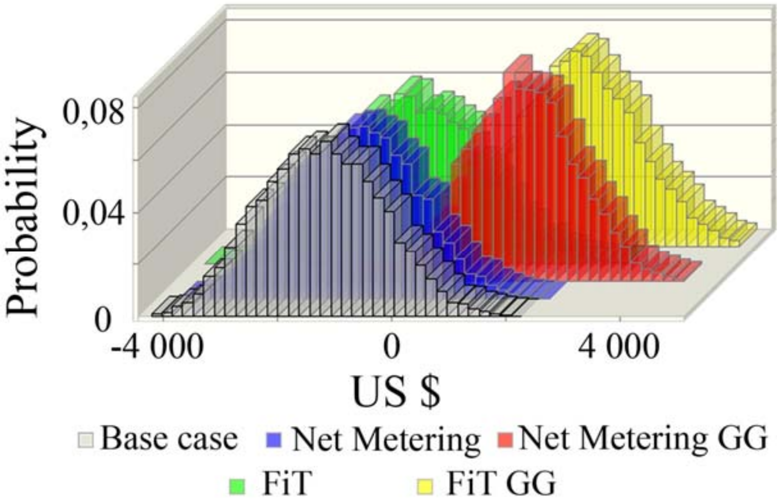

Fig. 8. The NPV Forecast of the 2 kW Wind System Applying Different Support Mechanism.

The simulation results demonstrated that feed in tariffs enhance the NPV of the projects as the energy output got bigger than household consumption as depicted on Fig. 9. Nonetheless, these results are only given for indicative purpose. In practice, the use of feed in tariffs in developing countries will be extremely difficult due to economical constrains, political issues and technological barriers.

For the household consumption pattern studied here, a 3 kWp PV system would reduce the household's electricity bill during its lifespan in 80% applying net metering and 84 % for feed in tariffs.

The Tables 5 and 6 show the certainty level of the NPV forecast for PV and wind systems. These results confirmed the wind energy technology is more cost-effective than solar PV energy.

Table 5 Certainty level (%) of the NPV forecast for PV System (Minimum US$ 0)

Support Instrument	PV System Installed Capacity				
	1 kW	2.5 kW	3 kW	4 kW	6 kW
Net Metering	0	0	0	0	0
Net Metering GG	14	14	12	0	0
FiT	0	1	5	21	55
FiT GG	14	31	48	74	89

Table 6 Certainty level (%) of the NPV forecast for Wind System (Minimum US$ 0)

Support Instrument	Wind System Installed Capacity				
	850 W	1 kW[5]	2 kW	2.5kw	6 kW
Net Metering	0	34	38	43	0
Net Metering GG	1	100	96	100	7
FiT	0	25	32	80	100
FiT GG	1	100	99	100	100

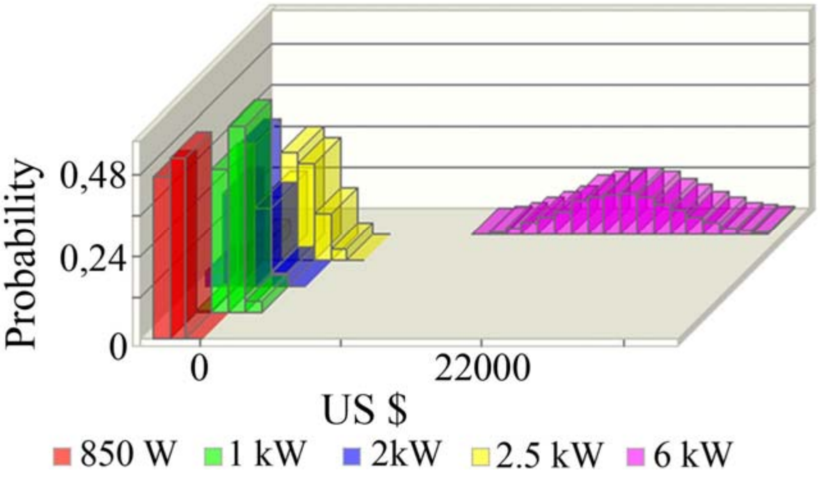

Fig. 9. The NPV Forecasts of the Feed in Tariffs (FiT) for the Wind Turbine Capacities of 850 W to 6 kW.

7 CONCLUSION

The small scale RE-CDM projects can assist to meet the growing electricity demand in a sustainable manner while directly mitigating the emissions of the greenhouse gases. Nevertheless, these projects face several barriers that make them less attractive for the investors. For instance, the volume of emission reductions from RE-CDM projects is much smaller than other type of potential CDM projects, high initial investment and transaction cost. The CER is essentially a market value. The investors will tend to purchase CERs at a minimum cost. Therefore, Renewable energy projects are at a comparative disadvantage to other CDM projects.

The transaction cost for the Panamanian RE-CDM projects that have been registered by the CDM executive board is in the range of US$ 75,000 to 125,000. However, it is important to note that the SGS (DOE) have opened a branch office in Panama which may make lower the transaction costs. The simulation results have showed that projects generating less than 1600 CERs per year will not be able to cover the transaction cost associated to CDM process.

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[5] The 1 kW wind turbine has better interaction with the existent wind regime than the others. Besides, the capacity factor of this wind turbine is bigger than the others

Comparing the simulation results of the different scenarios applied in this investigation, we can conclude that the trading of CERs plays a more important role than governmental grant as the energy output increase. It was found that the profits obtained from the sale of the CERs can represent up to 18% of the project's NPV. In contrast, the governmental grants are essential for very small scale renewable projects which cannot absorb the transaction costs. These costs are prohibitively high compared to the volume of the CERs expected to be generated by the projects.

In order to encourage the implementation of RE-CDM projects as well as achievement sustainable development, several alternatives should be considered such as payment of a premium for CERs from renewable energy projects, additional support mechanism like Feed in Tariffs (FiT), choosing the appropriate baseline methodology as well as less transaction costs. Otherwise, the clean development mechanism is likely to produce a limited effect on the support of renewable energy technologies.

In the case of homeowner projects using net metering, the simulation results confirmed the importance of choosing the appropriated PV system or wind turbine capacity that matches the household energy consumption, bigger capacities are worthless. Feed in tariffs as support mechanism can provide the best returns for the PV and wind system homeowner projects.

In spite of some hurdles, the trading of the carbon credits are still very important tool to reach greenhouse gases emission targets, address global warming problems and support renewable energy development. In the near future, it is expected that they will play a significant role in the electric sector.

ACKNOWLEDGMENT

Ms. Falconett would like to thank MONBUKAGAKUSHO (Japanese government scholarship program). The authors express their gratitude to the Dirección de Hidrometeorología de la Empresa de Transmisión Eléctrica (ETESA). We are also very grateful to the Dirección de Cambio Climático de la Autoridad Nacional del Ambiente (ANAM) as well as the Oficina de Electrificación Rural (FIS).

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