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Which CDM methodology is the best option? A case study of CDM business on S-Water treatment plant

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Abstract. Clean development mechanism (CDM) validity study was conducted to suggest better and more adaptable CDM scenario on water treatment plant (WTP). Potential four scenarios for CDM project; improvement of intake pumping efficiency, hydro power plant construction, solar panel construction and system optimization of mechanical mixing process were evaluated on S-WTP in Korea. Net present value (NPV) of each scenario was estimated based on sensitivity analysis with the variable factors to investigate the CDM validity percentile. Hydro power plant construction was the best option for CDM business with 97.76% validity and $1,127,069 mean profit by 9,813 tonsCO_2e/yr reduction. CDM validity on improvement of intake pumping efficiency was 90.2% with $124,305 mean profit by huge amount of CO_2 mitigation (10,347 tonsCO_2e/yr). System optimization of mechanical mixing process reduced 15% of energy consumption (3,184 tonsCO_2e/yr) and its CDM validity and mean profit was 77.25% and $23,942, respectively. Solar panel construction could make the effect of 14,094 tonsCO_2 mitigation annually and its CDM validity and mean profit was 64.68% and $228,487, respectively.

Keywords: water treatment plant; CO_2 emission and mitigation; CDM business; sensitivity analysis

1. Introduction

Global warming is a world-wide hot issue and a vigorous efforts to cut down the Greenhouse gases (GHGs emission usually converted as CO_2 equivalent emission) are being implemented everywhere (Olabisi *et al*. 2009). As a solution for reducing GHGs emission, Clean Development Mechanism (CDM), one of the Kyoto-mechanism have received spotlight (Schneider *et al*. 2008). The concept of CDM includes that developed countries (Annex I group: investor) those who are under the regulation of CO_2 mitigation on duty can invest at GHG reduction business on developing countries (Annex II group: host) to meet the CO_2 reduction goal economically with host's sustainable development (UNFCCC 2006). Recently, unilateral CDM methodology that Annex II countries can invest their own capital to reduce CO_2 emission on one's home or other Annex II countries is also possible.

Investors can select project baseline (e.g., high CO_2 emission sources such as refining system,

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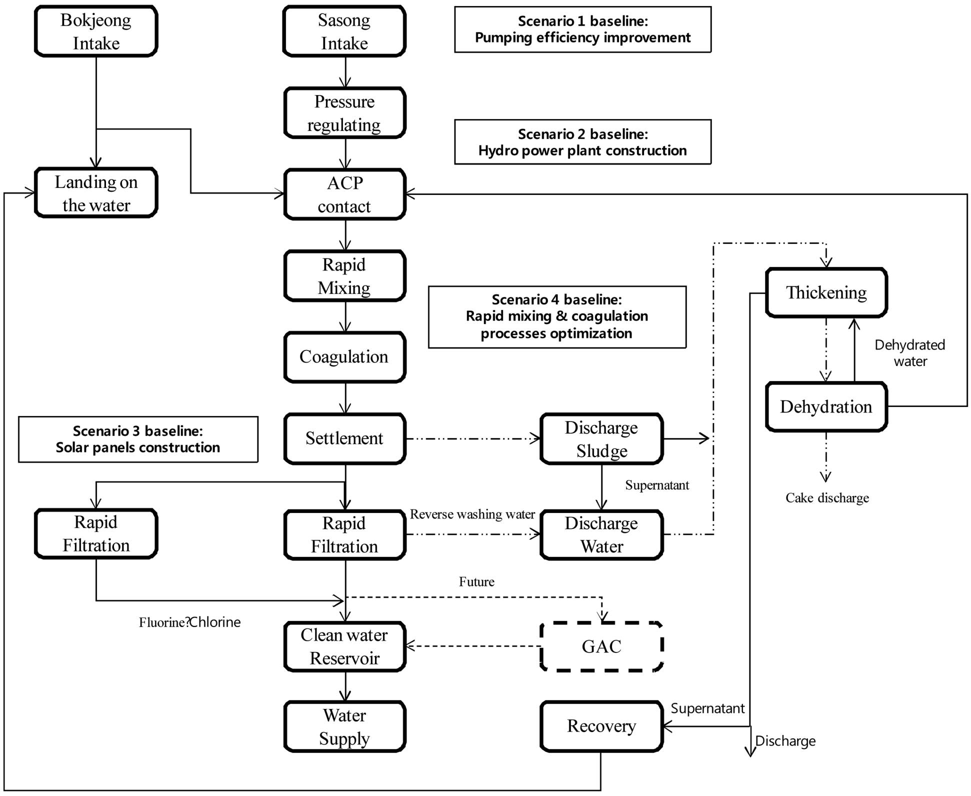

Fig. 1 Scheme of project baseline on S-WTS

manufacturing factory, power plant etc.) on host countries to reduce the CO_2 emission with eco-friendly technologies. Water Treatment Plant (WTP) is also a larger minor source of CO_2 emission as well as important infra-structure to supply water for human activity (Reiling *et al*. 2009). Many developing countries need to construct water treatments plant as fundamental infra structure and the demand increases continuously. Therefore, CDM projects on WTPs are timely and valuable and it can contribute to make future benefit with Certified Emission Reduction (CERs) issued from CDM executive boards when investors achieve the reduction goal. However, there has been little interest in CDM business investment on WTP until now even though WTP has much room for improvement to reduce CO_2 emission.

The objective of this study is to propose available CDM projects on WTP and investigate the validity of assumed scenarios for CDM business and its effects. This paper is case study type of research; we selected Sungnam Water Treatment Plant (S-WTP) as a project baseline which is located in near Seoul city, South Korea. Four possible scenarios chosen for CDM projects on S-WTP are demonstrated in Fig. 1; improvement of intake pumping efficiency, hydro power plant construction, solar panel construction and optimization of mechanical mixing processes (rapid mixing and coagulation process). Intake pumping system takes first place as top CO_2 emission source on WTP, which emits more than 90% of total CO_2 emission by huge amount of electricity consumption (Ramos and Ramos 2009, Moreno *et al*. 2007). Renewable energy facilities are limited to small hydro power plant and solar panel construction because they have better possibility to adapt on WTP compared to other renewable energy sources such as wind, ground water and etc. Optimization of rapid mixing and coagulation process was selected as one of option for CDM business because these unit processes also can produce considerable amounts of CO_2 during water purification with high energy dissipation. On project boundary for each scenario, baseline CO_2 emission and predicting amount of CO_2 mitigation was calculated and as of this results, available carbon credits (CERs) are estimated. In case of hydro power plant and solar panel construction projects, available electricity generation and its effect was considered additionally. Moreover, Net Present Value (NPV) with CERs (or electricity sales together) was calculated to evaluate the CDM validity on WTP and suggest better option. Monte Carlo analysis was also implemented to understand the effect of changeable factors (e.g., CERs prices, capital loan interest, exchange rate, etc.) on CDM validity.

This paper suggests the right direction of CDM methodology on WTP and evaluates its validity and value. Ultimately, this result can contribute to solve global warming problem with CO_2 mitigation on WTP and affect to make advisable environmental and economical policy.

2. Methodology

This analysis incorporates an important distinction among four different scenarios for CDM business on S-WTP. Four primary stages are required to evaluate the CDM validity and the steps are illustrated in Fig. 2. Life time of project (25 years), yearly natural resource source tax (2%), business tax (first period: 0%, second period: 7.5%, third period: 15% and forth period: 15%) and O&M cost (2% of total investment) were set up as same for all of the scenarios. Based on scenario characteristic, project information, investment costs, capital sources and interest rate were installed differently. For the accurate NPV calculation, distribution of investment in construction period, payment and depreciation information were also considered. Conversion factor of 0.424 $kgCO_2/kWh$ was used to calculate CO_2 reduction quantity in this study (KEEI 2005).

2.1 Project baseline 1

There are eight intake pumps of 3000 kW capacity to pull up 150 m^3/min of water from reservoir to S-WTP (94 m height). Each pump needs 2003.6 kW for pulling water but the efficiency of pumps are only 80% so that each pump spends 500 kW electricity more. For the 1 year operation of pumps, 140,412 MWh is needed for water supplying and this pumping system emits 79,734 tons CO_2 annually. Scenario 1 is improvement of intake pumping efficiency from 80% to 95% by changing impeller types, rotation velocity and pump capacity. This scenario assumes changed 95% pumping efficiency maintain during 5 years and reduce 0.5% per year from 6th operation year to the end of project lifetime with 2% transmission loss. For equipment change and fundamental construction, 3 years construction period is required. Total investment, $705,942 are composed of 30% equity capital and 70% domestic loaned capital with 10% interest rate. Distribution of total investment during 3 years construction period assumed as follows; first year 50%, second year 30% and third year 20%; equity investment capital distributed 60%, 30% and 10% and domestic loaned capital was 30%, 40% and 10%. For the payment and depreciation, grace year, repayment period and depreciation period of equipment were set up as 2, 10 and 20 years respectively.

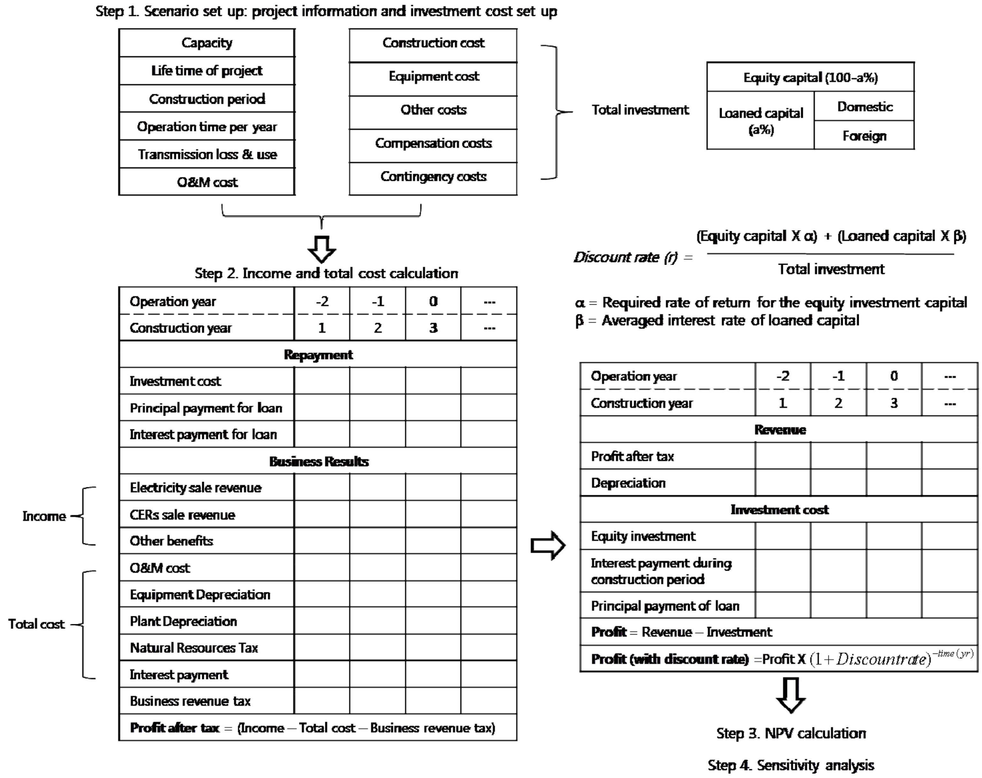

Fig. 2 Procedure of methodology for CDM validity evaluation

2.2 Project baseline 2

One of renewable energy option for CDM project on S-WTP is small hydro power plant construction in front of water inflow gate (Thorburn and Leijon 2005). 30.2 m elevation difference between intake tower and gate of S-WTP can generate electricity. Total capacity of water turbine generator is 3.6 MW (two generator of 1.8 MW capacity) and operation time per year is 4800 h/yr, so 17280 MWh electricity can be produced annually with 2% transmission loss and owner use. This scenario assumed that total investment is $4,152,550 including construction cost, equipment cost, contingency cost and other cost. Equity capital takes 30% of total investment and domestic loaned capital takes 70% with 11.5% interest rate. For the construction of power generator, 3 years construction time is required. Distribution of total investment during 3 years construction period assumed as follows; first year 28.2%, second year 24.6% and third year 47.2%; equity investment capital distributed 40%, 20% and 40% and domestic loaned capital was 33.2%, 23.5% and 43.3%. For the payment and depreciation, grace year, repayment period and depreciation period of plant and equipment were set up as 2, 10 and 15 years respectively.

2.3 Project baseline 3

The other renewable energy scenario for CDM project on S-WTP is solar panel construction above the settlement unit process (Zakharchenko and Licea 2004, Steven and Joshep 2002). Area of settlement unit process is 1,324 m^2 and 10MW capacity of solar panel generator can be constructed. This scenario assumed that annual operating time of solar panel is 2482 h/yr (i.e., 85% sunny day and 8 hour operating time on a daily basis) so 24,820 MWh electricity can be generated annually with 3% transmission loss. Assumed total investment was $5,861,265 in this scenario including construction cost, equipment cost, contingency cost and other cost. And it was composed of 20% of equity capital and 80% of loaned capital. Loaned capital consists of 70% domestic loaned capital with 12% interest rate and 30% foreign loaned capital with 14% interest rate. For solar panel construction, 4 years construction period is needed. Distribution of total investment during 4 years construction period assumed as follows; first year 15.4%, second year 26.2%, third year 32.5% and fourth year 25.9%; equity investment capital distributed 20%, 30%, 30% and 20%. Domestic loaned capital and foreign loaned capital distribution were set up as 12.3%, 22.4%, 30.2%, 35.1% and 14.7%, 18.2% 34.3%, 32.8% respectively. For the payment and depreciation, grace year, repayment period and depreciation period of plant and equipment were set up as 2, 10 and 15 years respectively.

2.4 Project baseline 4

System optimization of rapid mixing and coagulation processes was considered as CDM project scenario 4 in this research. Previous studies revealed that rapid mixing and coagulation processes are main CO_2 emission source on water treatment process (Rossini *et al.* 1999, Wang *et al.* 2007, Mhaisalkar *et al.* 1991). Based on results of baseline CO_2 emission on S-WTP, rapid mixing process ranked as a top CO_2 emission unit process (15,223 tons CO_2e/yr) and coagulation took the second place (6,001 tons CO_2e/yr) except the intake pumping system. Our previous work showed that 15% of CO_2 mitigation (3,184 tons CO_2e/yr) is possible by automatic controlling of impeller rotation speed and mixing time (Kyung and Lee 2011). We assumed that total investment cost, $412,229 includes only equipment cost and contingency cost for system change and retrofitting. Equity capital takes 30% of total investment and domestic loaned capital with 11.5% interest rate covers remaining total cost. For automatic regulation of system, 2 years equipment change period is required to install inverter. Distribution of total investment during 2 years construction period assumed as follows; first year 60%, second year 40%; equity investment capital distributed 50% and 50% and domestic loaned capital was 42% and 58%. For the payment and depreciation, grace year, repayment period and depreciation period of equipment were set up as 2, 10 and 15 years respectively.

2.5 Income and total cost calculation

CDM business incomes are categorized as electricity sale revenue, CERs sale revenue and other revenues by external effects. 3.69 Cent/kWh of electricity charge was adapted on scenario 2 and 3 (electricity generation by renewable energy) to estimate the electricity sale revenue. All of scenarios applied CERs sale revenue with mitigation of CO_2 emission on project baseline with $12/tons of CO_2 CERs price. In this research, other revenues by external effects were excluded in all of scenarios to focus on realistic value with accuracy (i.e., external effects are difficult to convert as economic values). Costs can be subdivided into Operating and Maintenance cost (O&M cost), insurance cost, fuel cost and other costs. Moreover, depreciation of plant and equipment and principal payment for loaned capital were also considered. This research only calculated O&M cost and it was set up as 2% of total investment on all of scenarios. Depreciation of equipment and plant were calculated by division equipment and construction costs into depreciation period respectively. Principal payment for loaned capital was computed with dividing loaned capitals as repayment period.

2.6 NPV calculation

NPV indicates business investment validity in present situation. Positive NPV suggests that business is profitable while negative NPV means that investment makes the loss during the project period (Lin 2009). Total revenue and investment cost were calculated for all of scenarios to compute net profit on every year (during project lifetime including construction period). Total revenue includes benefit after tax and depreciation and total investment cost contains equity investment, interest payment during construction period and principal payment of domestic and foreign loan. Net profit equals total revenue minus total investment cost. During project life time, net profit of each year should be changed as present value with discount rate. In this study, discount rate were calculated by dividing total investment into sum of equity and loaned investment with each interest rate at each scenario and CDM business validity was evaluated with NPV value estimated by the following equation. Where, CI and CO are total cost income and cost outcome. PLT and r mean project lifetime and discount rate respectively.

$$NPV = \sum_{t=0}^{PLT}\left\{\frac{CI_t}{(1+r)^t} - \frac{CO_t}{(1+r)^t}\right\}$$

2.7 Sensitivity analysis

A sensitivity analysis was conducted to evaluate the contribution of specific input parameters on CDM business validity. The input parameter ranges and distributions were bounded by assumptions based on economies of scale and parameter characteristics (Chester and Martin 2009). The parameters considered were selected as fluctuating factors which cannot be sustained steadily during the project life time and include the following:

1. Project operation time per year of each scenario follows triangular distribution and mean operation time is used as likeliest (min. is -10% of mean and max. is +10% of mean value).
2. O&M cost is varied between 1% and 3% influencing total cost with uniform distribution.
3. Mean interest of domestic loaned capital is set up as assumed rate at each scenario and it follows normal distribution with standard deviation of 1.2.
4. Mean interest of foreign loaned capital is set up as assumed rate at each scenario and it follows normal distribution with standard deviation of 1.4; only the scenario which borrowed capital from foreign considered this factor.
5. In 2009, Korea average exchange rate is 1164.4 KRW/$ and it can varied between ±10% as uniform distribution.
6. In 2009, USA average electricity charge is 4.20 cent/kWh and it may vary between ±10% as uniform distribution; only the scenario which generate electricity considered this factor.
7. In 2009, USA average CER price is \$15/tCO_2 and it may vary between ±10% as uniform distribution.

3. Results

The CO_2 mitigations at each scenario and profit by CERs and electricity sales are described in Table 1. For the verification of CDM business on each scenario, NPV values both with and without CERs are estimated and compared (Table 2). CDM project adequacy of each scenario was predicted based on statistical NPV probability taken by Monte Carlo analysis and the effects of variable factors on project validity was evaluated.

3.1 Improvement of intake pump efficiency

Based on assumed scenario, pumping efficiency improvement from 80% to 95% saved 18,221 MWh of electricity and this result could guarantee 10,347 tons CO_2 mitigation annually. At first 5 years $152,098 of business income was taken place by CERs sales, however, revenue decreased 0.5% per year with pumping efficiency deterioration during the rest of project lifetime. Equipment and construction depreciation were $34,352 and $12,710 respectively during 15 years and sum of these is counted as net revenue with CERs benefit after tax. For 3 years construction period, investment cost (equity investment and interest payment) exceeded net revenues but after operation of improved pumps, there was net profit. In this scenario, NPV with CERs and without CERs were $124,750 and $-849,278 respectively with 10.6% of discount rate. Sensitivity analysis showed that this scenario has 90.2% probability of making profit with $124,305 mean benefit value in variable factor range (Fig. 3). CERs price affected mostly to CDM business profit as 27.3% then exchange rate and operation time followed as 24.2% and 12.8%. Interest of domestic loan and O&M cost increase showed negative effects on CDM business with the value of -28.8% and -6.8% respectively. Interest rate of foreign loaned capital and electricity charge was independent to the result (Fig. 4).

Table 1 Comparison of CO_2 mitigation at each scenario and profit

Project baseline	CO_2 mitigation (tons CO_2/yr)	CERs sales profit (USD/yr)	Electricity sales profit (USD/yr)
Project baseline 1	10,347	152,098	0
Project baseline 2	9,813	144,246	711,245
Project baseline 3	14,094	205,072	1,011,167
Project baseline 4	3,184	46,800	0

Table 2 Comparison of CDM business validity

Project baseline	NPV without CERs (USD)	NPV with CERs (USD)	CDM validity percentile	Mean profit (USD)
Project baseline 1	-849,278	124,750	90.2%	124,305
Project baseline 2	-156,700	682,993	97.76%	1,127,069
Project baseline 3	-771,010	222,781	64.68%	228,487
Project baseline 4	-285,313	24,994	77.25%	23,942

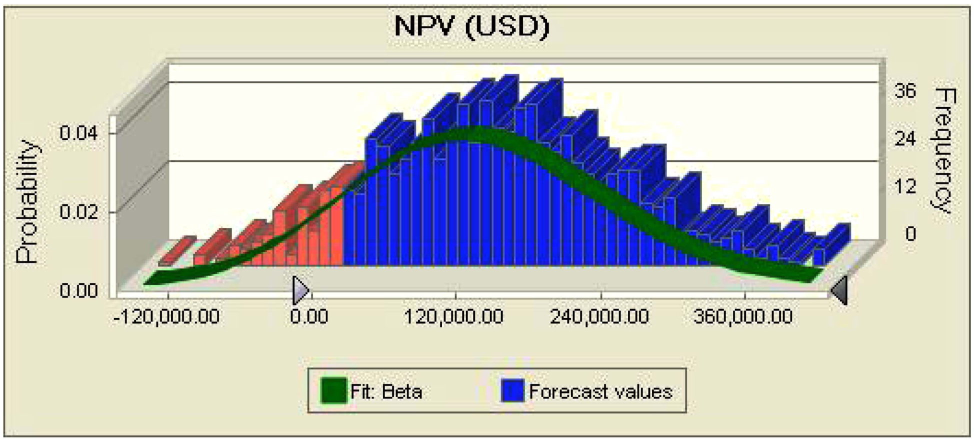

Fig. 3 Distribution of NPV with CERs (Scenario 1)

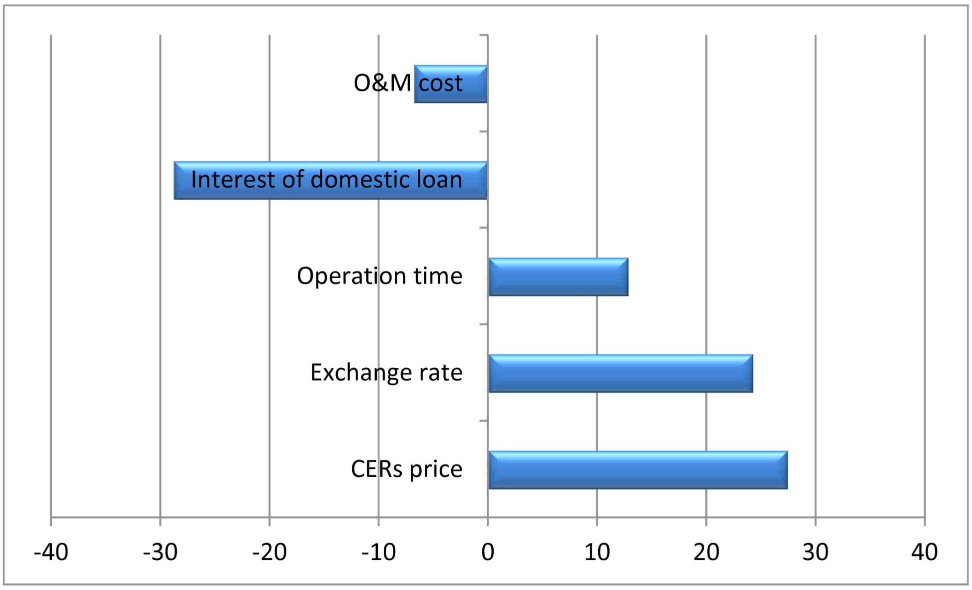

Fig. 4 Effects of variables on CDM business (Scenario 1)

3.2 Hydro power plant construction

3.6 MW capacity hydro power plant can generate 17,280 MWh of electricity annually based on assumed scenario and it is same with 9,812.6 tons of CO_2 reduction effect on project baseline. Electricity and CERs sales made \$711,245 and \$144,246 of profit respectively every year during the whole project lifetime. Equipment and plant depreciation were \$83,170 and \$152,930 each during 15 years and sum of these was counted as net revenue with electricity and CERs sales benefit after tax. Until the 4th year (i.e., first operation period after 3 year construction), investment cost was

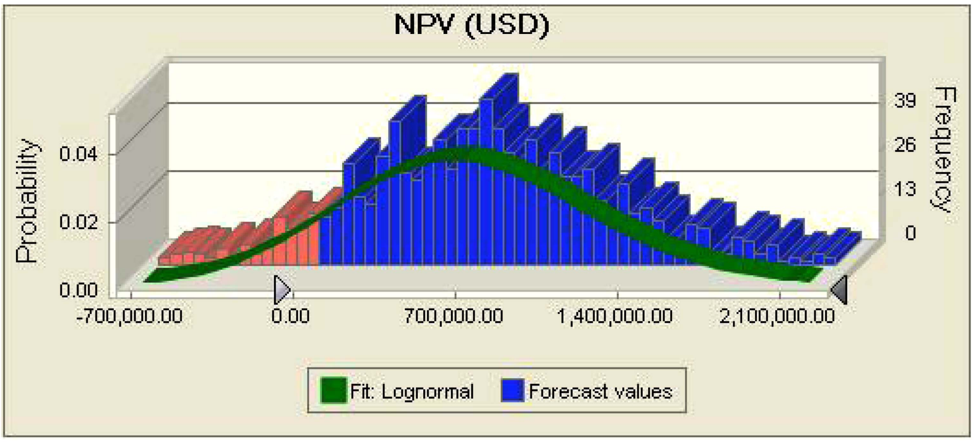

Fig. 5 Distribution of NPV with CERs (Scenario 2)

higher than net revenues. However, total profit was maintained as positive value since 2nd operation year. In this scenario, NPV with CERs and without CERs were \$682,993 and \$-156,700 respectively with 11.65% of discount rate. Sensitivity analysis demonstrated that this scenario has 97.76% probability of bringing profit with \$1,127,069 mean benefit value in changeable factor range (Fig. 5). Interest rate of domestic loan gave negative effect to CDM business profit as highly as -39.4% and the exchange rate, electricity charge and operation time influenced on CDM business profit positively as 23.0%, 19.0% and 13.8% each. O&M cost and CERs price showed a slight effect on CDM business profit (Fig. 6).

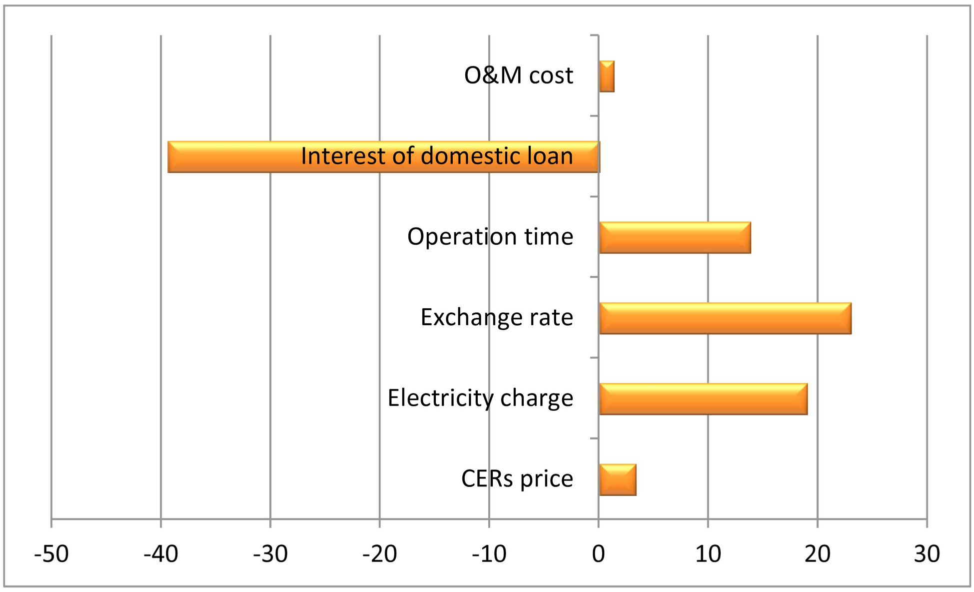

Fig. 6 Effects of variables on CDM business (Scenario 2)

3.3 Solar panel construction

10 MW capacity solar panels can generate 24,820 MWh of electricity and mitigate 14,094 tons of CO_2 annually on project baseline. Electricity sales made considerable income with $1,011,167 and CERs sales revenue was $205,072 for 25 years project lifetime, except 4-years construction period. Equipment and plant depreciation were $231,320 and $128,669 respectively during 15 years and they were included as net revenue with electricity and CERs sales benefit after tax. At the first 4 years for construction, there was net loss for CDM business due to interest payment and initial investment. NPV with CERs and without CERs were $222,781 and $-771,010 respectively with 12.48% of discount rate. Sensitivity analysis verified that this scenario has 64.68% probability for succeeding CDM business with $228,487 mean benefit in variable condition (Fig. 7). Exchange rate and electricity charge contribute highly on NPV value as 27.6% and 20.8% separately. Interest rate of domestic and foreign loan showed -18.2% and -7.3% effect on CDM business validity. Because of the character of this project, operating time was very significant factor with a value of 14.8%. CERs price slightly influenced on NPV because the profit from CERs sale was very small compared to electricity sales (Fig. 8).

3.4 Optimization of mechanical mixing process

Optimization of rapid mixing and coagulation process with satisfactory removal efficiency and 15% energy save can reduce 5,606.4 MWh of electricity utilization on project baseline. This is relevant with 3183.6 tons of CO_2 mitigation and it can provide $46,800 profit by CERs sales annually until the project is over. Equipment and construction depreciation were $13,740 and $9,160 respectively and these value added altogether with CERs sales benefit after tax to get net revenue. There was net loss for CDM business with interest payment and initial investment at first 2 years period for the substitution of the equipment and system. In this scenario, NPV with CERs and without CERs were $24,994 and $-285,313 respectively with 11.65% of discount rate. Sensitivity analysis results proved that this scenario has 77.25% probability to make profit on CDM business with $23,942 mean benefit value in fluctuating condition (Fig. 9). Most significant variable on

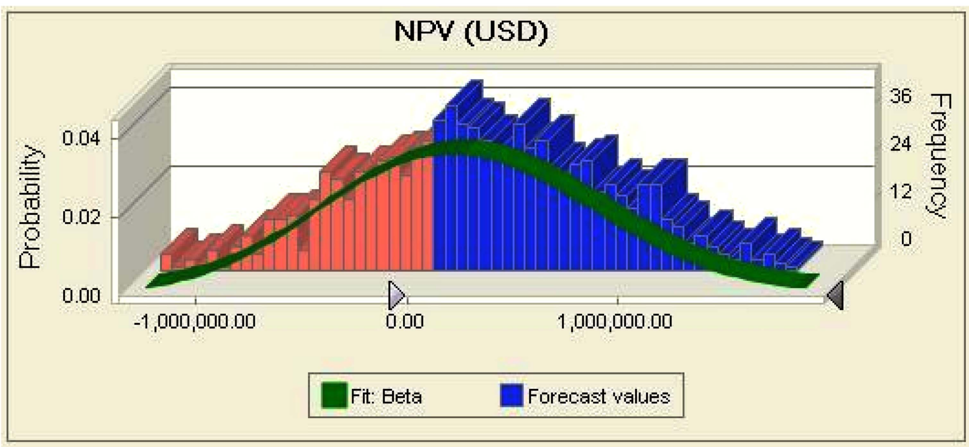

Fig. 7 Distribution of NPV with CERs (Scenario 3)

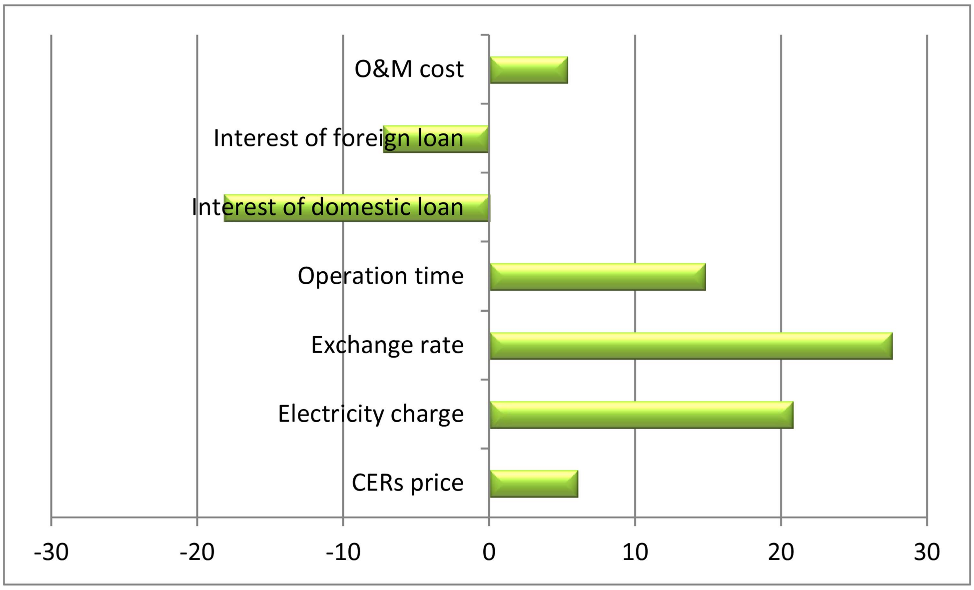

Fig. 8 Effects of variables on CDM business (Scenario 3)

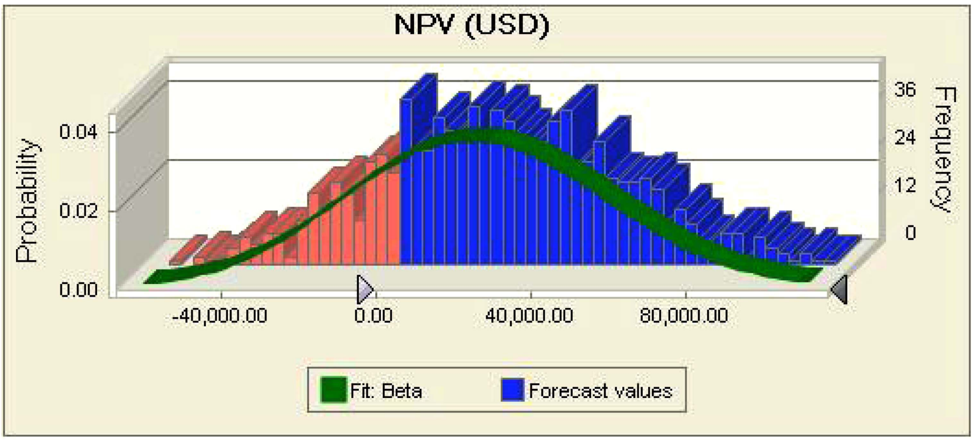

Fig. 9 Distribution of NPV with CERs (Scenario 4)

CDM business was CERs price with 36.6% impact and exchange rate (27.7%) and operation time (15.3%) followed in order. O&M cost was only negative factor on this project as -20.4%. Different with other projects, effect of interest rate of domestic loan was negligible because this scenario had the smallest initial investment capital among assumed four scenarios and construction period was also short as 2 years compared to others (Fig. 10).

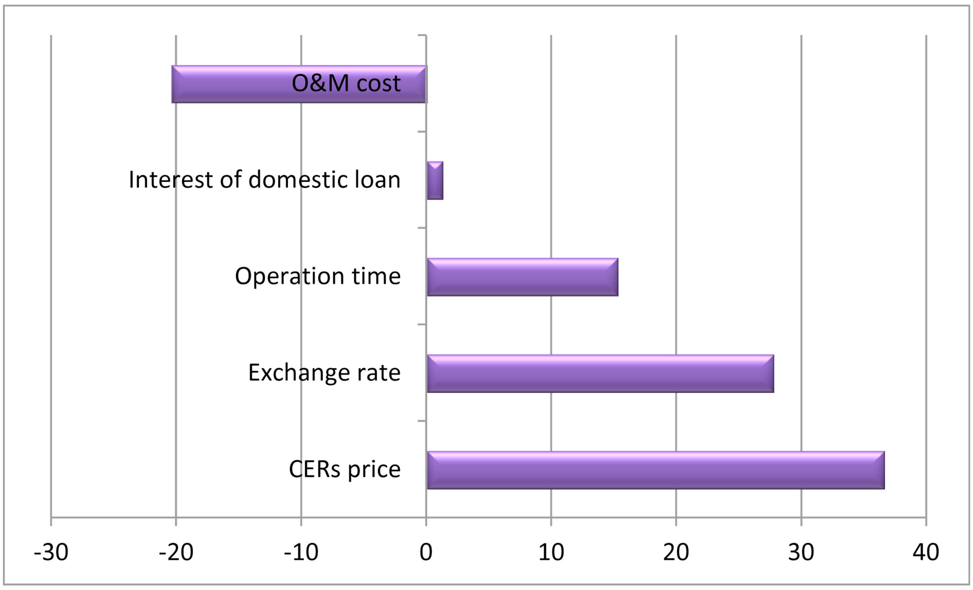

Fig. 10 Effects of variables on CDM business (Scenario 4)

4. Conclusions

Results in NPV without CERs proved that all of scenarios in this study can have CDM additionality because without CERs they all had minus NPV. That means that these projects are not common activity in ordinary condition and planned projects induce additional profits socially, technically and economically. Moreover, all of assumed scenarios have validity for investment of CDM business on S-WTP because their NPV probability for CDM business with CERs exceeded more than 50% statistically.

Considering ensured profit with high probability, hydro power plant construction takes priority than other projects for the investment. This project highly guarantees the largest profit with adequate CO_2 reduction. Project for improving the intake pump efficiency also has proper probability for succeeding CDM business and this project could overcome the limitation of less economical profit with initial investment reduction and achievement of better performance pumping system than assumed scenario. Although solar panel construction scenario has the lowest CDM validity probability, it can mitigate the most CO_2 emission due to electricity generation with non-carbon emission source. Saving of initial investment cost through the confirmation of self technology could enhance the CDM business validity of solar panel project and it will contribute to make huge benefit on WTP. Optimization of mechanical mixing process can be also good choice for CDM business because it can meet the appropriate NPV probability with low initial investment. However, in this scenario, potential CO_2 reduction and CERs sale profit is posterior to other projects because baseline CO_2 emission is much less than others so there is not much room for cut down of CO_2 emission. Bundle type of CDM business with other WTPs is possible to reduce the CO_2 emission altogether from the each mechanical mixing process and if so the chance to attract investors with better profits and satisfy the host with more reduction will increase.

CDM businesses on S-WTP can contribute to mitigate CO_2 emission and make profit with CERs sales and electricity sales in case of renewable energy induction. Considering other profits from external effects which excluded in this study, CDM business on WTP seems more timely and desirable. This research emphasizes that it is possible to treat global warming problem economically using CDM businesses. Furthermore, this methodology could be adapted on other areas to lead positive reaction and the results would suggest the right direction for solving global warming problem with environmental and economical policy.

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Supporting Information

1. Basic common assumption for all of scenarios

<Conversion factors>

Baseline CO_2eq emissions factor	gCO_2/kWh	424
Total number years of crediting period	Year	21
Exchange rate	KRW/USD	1164.40
Electricity price	Cent/kWh	3.69
CER price	USD/tCO_2	9.1

<Tax information>

Yearly natural resource tax	%/year	2.00 %

<Payment and depreciation>

Business tax	From year	Value (%)	To year
First period	1	0.00%	4
Second period	5	7.50%	11
Third period	12	15.00%	13
Fourth period	14	15.00%	25

<Project information in detail>

Items	Unit	Amount
Grace period	Years	2
Repayment period	Years	10
Plant depreciation period	Years	15
Depreciation period of equipment	Years	15

2. Project information in detail

2-1 Improvement of intake pump efficiency

Items	Unit	Amount
Capacity	MW	2.6
Life time of project	year	25
Starting year	-	2010
Construction period	year	3
Reservoir area	m^2	1,200
Operation time per year	h/year	7,008
Transmission loss & Owner use	%	2.00
O&M Cost	%	2.00

Items	KRW	USD
Construction cost	221,999,683	190,655.86
Equipment cost	600,000,000	515,286.84
Other costs	0	0
Compensation costs	0	0
Contingency costs	0	0
Total investment	821,999,683	705,942.70

Items	%	USD	Interest rate (%)
Equity capital	30.00	211,782.81	-
Loaned capital	70.00	494,159.89	-
Domestic loaned capital	100.00	494,159.89	10.00%
Foreign loaned capital	0.00	0.00	12.00%
Other loaned capital	0.00	0.00	0.00%

Items	Year 1	Year 2	Year 3	Year 4
Total investment capital	50.00%	30.00%	20.00%	0.00%
Equity investment capital	60.00%	30.00%	10.00%	0.00%
Domestic investment capital	50.00%	30.00%	20.00%	0.00%
Foreign investment capital	0.00%	0.00%	0.00%	0.00%
Special investment capital	0.00%	0.00%	0.00%	0.00%

Weighted – average financial discounted rate for capital sources		
Equity investment	USD	211,782.81
Capital	%	12.00 %
Loaned investment	USD	494,159.89
Interest rate	%	10.00 %
Total investment	USD	705,942.70
Discount rate	%	10.60 %

2-2 Hydro power plant construction

Items	Unit	Amount
Capacity	MW	3.6
Life time of project	year	25
Starting year	-	2010
Construction period	Year	3
Reservoir area	m^2	2,310
Operation time per year	h/year	4,800
Transmission loss & Owner use	%	2.00
O&M Cost	%	2.00

Items	KRW	USD
Construction cost	2,671,068,150	2,293,943.79
Equipment cost	1,452,642,318	1,247,545.79
Other costs	327,189,899	280,994.42
Compensation costs	0	0
Contingency costs	384,328,392	330,065.61
Total investment	4,835,228,759	4,152,549.60

Items	%	USD	Interest rate (%)
Equity capital	30.00	1,245,764.88	-
Loaned capital	70.00	2,906,784.72	-
Domestic loaned capital	100.00	2,906,784.72	11.50%
Foreign loaned capital	0.00	0.00	12.00%
Other loaned capital	0.00	0.00	0.00%

Items	Year 1	Year 2	Year 3	Year 4
Total investment capital	28.20%	24.60%	47.20%	0.00%
Equity investment capital	40.00%	20.00%	40.00%	0.00%
Domestic investment capital	33.20%	23.50%	43.30%	0.00 %
Foreign investment capital	0.00%	0.00%	0.00%	0.00%
Special investment capital	0.00%	0.00%	0.00%	0.00%

Weighted – average financial discounted rate for capital sources		
Equity investment	USD	1,245,764.88
Capital	%	12.00%
Loaned investment	USD	2,906,784.72
Interest rate	%	11.50%
Total investment	USD	4,152,549.60
Discount rate	%	11.65%

2-3 Solar panel construction

Items	Unit	Amount
Capacity	MW	10
Life time of project	year	25
Starting year	-	2010
Construction period	Year	4
Reservoir area	m^2	1,324
Operation time per year	h/year	2,482
Transmission loss & Owner use	%	3.00
O&M Cost	%	2.00

Items	KRW	USD
Construction cost	2,247,340,047	1,930,041.26
Equipment cost	4,040,243,712	3,469,807.38
Other costs	247,150,370	212,255.56
Compensation costs	0	0
Contingency costs	290,123,457	249,161.33
Total investment	6,824,857,586	5,861,265.53

Items	%	USD	Interest rate (%)
Equity capital	20.00	1,172,253.11	-
Loaned capital	80.00	4,689,012.43	-
Domestic loaned capital	70.00	3,282,308.70	12.00 %
Foreign loaned capital	30.00	1,406,703.73	14.00 %
Other loaned capital	0.00	0.00	0.00 %

Items	Year 1	Year 2	Year 3	Year 4
Total investment capital	15.40%	26.20%	32.50%	25.90%
Equity investment capital	20.00%	30.00%	30.00%	20.00%
Domestic investment capital	12.30%	22.40%	30.20%	35.10%
Foreign investment capital	14.70%	18.20%	34.30%	32.80%
Special investment capital	0.00%	0.00%	0.00%	0.00%

Weighted – average financial discounted rate for capital sources		
Equity investment	USD	1,172,253.11
Capital	%	12.00%
Loaned investment	USD	4,689,012.43
Interest rate	%	12.60%
Total investment	USD	5,681,265.53
Discount rate	%	12.48%

2-4 Optimization of mechanical mixing process

Items	Unit	Amount
Capacity	MW	0.8
Life time of project	year	25
Starting year	-	2010
Construction period	Year	2
Reservoir area	m^2	1,132
Operation time per year	h/year	7,008
Transmission loss & Owner use	%	2.00
O&M Cost	%	2.00

Items	KRW	USD
Construction cost	160,000,000	137,409.82
Equipment cost	240,000,000	206,114.74
Other costs	80,000,000	68,704.91
Compensation costs	0	0
Contingency costs	0	0
Total investment	480,000,000	412,229.47

Items	%	USD	Interest rate (%)
Equity capital	30.00	123,668.84	-
Loaned capital	70.00	288,560.63	-
Domestic loaned capital	100.00	288,560.63	11.50%
Foreign loaned capital	0.00	0.00	12.00%
Other loaned capital	0.00	0.00	0.00%

Items	Year 1	Year 2	Year 3	Year 4
Total investment capital	60.00%	40.00%	0.00%	0.00%
Equity investment capital	50.00%	50.00%	00.00%	0.00%
Domestic investment capital	42.00%	58.00%	0.00%	0.00%
Foreign investment capital	0.00%	0.00%	0.00%	0.00%
Special investment capital	0.00%	0.00%	0.00%	0.00%

Weighted – average financial discounted rate for capital sources		
Equity investment	USD	123,668.84
Capital	%	12.00%
Loaned investment	USD	288,560.63
Interest rate	%	11.50%
Total investment	USD	412,229.47
Discount rate	%	11.65%