Feasibility Study of the CDM/JI Project in FY 2008
Summary of the Report

Title of the survey

Survey of the Biomass Electric Generation System by the Phosphoric Acid Fuel Cells in Phi Phi Don Island in Thailand

Title of the enforcement company

KRI Inc.

1. General description of the project

(1). Location of the project

Phi Phi Don Island enforcing the project belongs to the Krabi province in kingdom of Thailand. The site is located in between the large island of Phuket and the western Andaman Sea coast of the mainland.in Kingdom of Thailand. The project site is located in mid north part of Phi Phi Don Island as shown in the Figure 1.

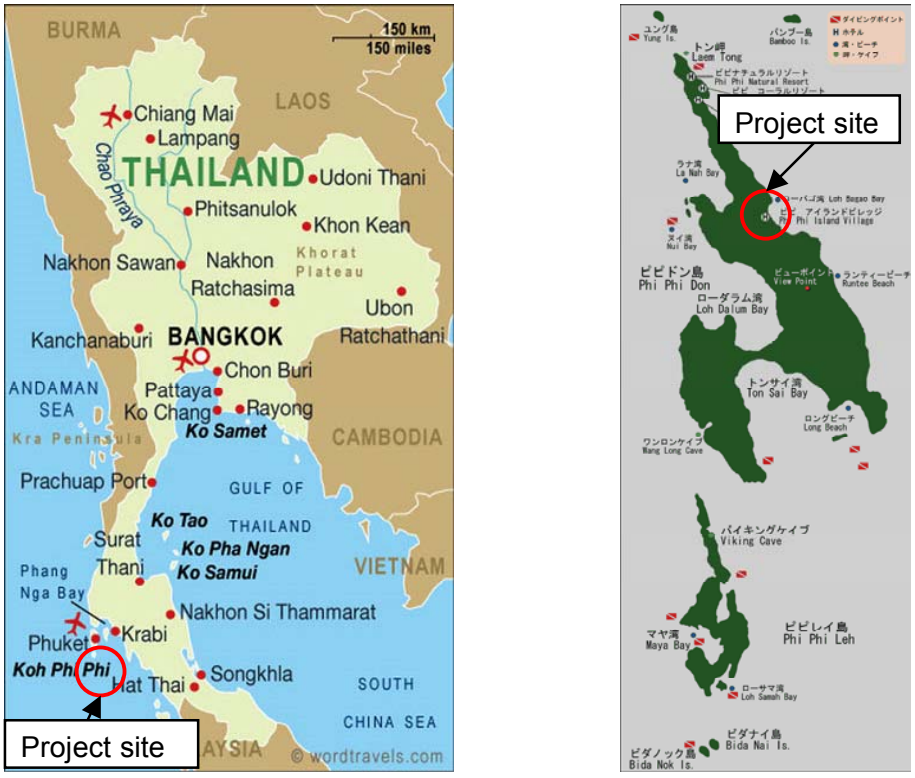

Figure 1. Location of the project site.

(2). Description of the project

In FY 2007, KRI enforced the survey of the biomass electric generation system by the phosphoric acid fuel cells (PAFC) in Phi Phi Don Island in Thailand. This feasibility study aims at the evaluation of feasibility of an electricity generation project from unused biomass, which plans to produce bio-gas (60% of methane gas) through the CH4 fermentation from kitchen wastes (garbage and wastewater) and human wastes from these resort hotels. The produced bio-gas will be input to 100 kW PAFC which is already home produced and commercialized in Japan, and electricity will be generated to meet the hotel's demand. As a result, from only 0.9 t/d of garbage, the system can be produced CH4 gas to electricity

generation by PAFC. Therefore, the reduction of fossil fuel use for diesel engine generators will be achieved (reduced 216 kL/y of fossil fuel and 2,500-6,000 t-CO2/y.

In FY 2008, KRI enforced the survey again deeply as engineering point of view. As the result, from 6.6 t/d of garbage will be reduced the 10,898 t-CO2 of GHG in the 1st. year

The project effects will be spread to remote island-type resorts in Southeast and South Asia and Micronesia regions, since it will provide a solution against the energy supply problem those resorts would face to.

2. Contents of the survey

(1). Subjects of the survey

a. Study of garbage composition and way of collection

As the results of FY 2007, Phi Phi island village made a 0.9 t/d of garbage from Kichen. In this survey, to secure amount of the garbage that is necessary for the system concerned, we examined the optimum method for collection of garbage while cooperating with other resorts. Furthermore, we analyze a composition of the garbage by official method of analysis, through estimate a volume of biogas, merit of the system concerned is made clear.

b. Study of initial cost and economical analysis

Local engineering company estimates cost of the system in Thailand with logistic factor. The cost is used for an estimation of economical analysis.

(2). Organization of the survey

a. Domestic party

I. KRI Inc.

KRI is entrusted by GEC and operate all company for the survey.

II. Fuji Electric Advanced Technology Co., Ltd.

FAT submit the newest information of PAFC, making a rough plan of appurtenant facilities, condition of oversea transportation for PAFC.

III. Yu Environment System Research Institute Co., Ltd.

Yu estimate the cost of the system with all facilities in Thailand.

b. Oversea party

I. Thailand Institute of Science and Technological Research, TISTR

TISTR gather the information from Ministry of Energy (MOEN), Department of Alternative Energy Development and Efficiency (DEDE), analyze the garbage and wastewater from the resorts.

II. PAE Thailand Public Co., Ltd., Ecopros Co., Ltd. (Local engineering companies)

PAE and Ecopros cooperate with Yu, and an estimate the cost of the system in Thailand.

III. Phi Phi Island Village, Holiday Inn Resort Phi Phi Island, P. P. Erawan palms Resort and Phi Phi natural Resort

These resorts submit the information of heat and electricity demand, amount of garbage and system for wastewater.

(3). Contents of the survey

We survey the Phi Phi Island deeply 3 times in Oct., Dec. 2008 and Jan. 2009.

a. The 1st. survey

I. Requesting cooperation to Holiday Inn Resort Phi Phi Island

We present our system to Mr. Brendan Corcoran as General Manager, Mr. Suriya Jittaratsenee as Front Office Manager, Mr. Phuritt Phantawong as Director of Engineer. The resort, 2 new diesel engine generators are purchased so that electric demand increases by construction of a new 50 cottages adding 80 current cottages. Therefore, the resort was interested in our system

II. Study for selection of the project site

Basically, KRI and others suppose Phi Phi Island Village as project site. However, Holiday Inn Resort Phi Phi Island and old /broken incinerator in Ton-sai area were investigated as possible project site.

Phi Phi Island Village has a back yard for wastes behind the resort, the areas suitable for induction of the system by unused area and logistics from shore that informed by Mr. Olaf Clamer as Engineer Consultant.

Holiday Inn Resort also has a back yard for electric generation behind the resort, the areas suitable for induction of the system by unused area (19 m long by 40 m width) and logistics from shore that informed by Mr. Phuritt Phantawong as Director of Engineer.

The inside of broken incinerator in the Ton-sai area, this facility has a area for induction of the system. Mr. Wichet Kwankhao as Chief Administrator of Aonang SAO and Mr. Suchart Kittithorakul as Deputy Mayor of Aonang Administration agreed use of this area. However, narrow width of road from shore to the area and a lot wire for electricity across the road in low position are there, It's serious logistics problems.

Candidate site		AoTon Sai	Ao Lo Bakao	Leam Tong
Mail target hotel		**Phi Phi Hotel Group**	**Phi Phi Island Village**	**Holiday Inn**
Candidate installation site		Incinerator plant vacant lot	Backyard	Backyard
Area	m	17×25	Enough	14～19×40
Logistics		Narrow streets, steps, wires	No problem	Slope but no problem
Distance of electricity demand site		Close	Close	Close
Distance of heat demand site		Close	Close	Close
Amout of hotels		Many	2	4
Amout of garbage	Low season	10	1	4
t/d	High season	20	1	4
Treatment site		Krabi	Phuket	Phuket
Treatment method		Landfill	Landfill	Landfill
Treatment Cost				
THB/t		1,333	1,800	Under survey

Table 1. Condition of possible project site

b. The 2nd. survey

l. The 1st. cost estimation with PAE Co., Ltd. and Ecopros Co,.Ltd.

Both company estimate the 1st. cost estimation together based on the specification

for the system from KRI and FAT.

Table 2. The 1st. cost estimation

Item		Cost	
		M THB	M JPY
Induction	Labor cost, etc.	67.7	223.3
Piping		5.1	16.8
Electric		3.1	10.2
Civil work		1.8	5.9
		77.7	256.3

1 THB=3.3 JPY

c. The 3rd. survey

I. The 2nd. cost estimation with PAE Co., Ltd. and Ecopros Co,.Ltd.

Both company estimate again the 2nd. cost estimation together based on the specification for the system from KRI and FAT. The precise cost increased up to about 100 M THB added by transportation, travel expenses and wastewater treatment system.

Table 3. The 2nd. Cost estimation

Description		Amount	
		M THB	M JPY
Equipment and installation	Equipment and labor cost	62.3	205.7
Piping system	Pyping and labor cost	5.1	16.7
Electrical system	Mail power system, etc.	3.1	10.1
Civil work	Building, foundation, etc.	1.7	5.7
Site admin		0.9	3.0
Traeatment plant and foundation pad		10.3	34.1
Subtotal		83.4	275.4
Overhead	15%	12.5	41.3
Sub total		98.8	326.2
Travel expenses		0.4	1.2
Logistic		2.8	9.3
Total		102.0	336.6

1 THB=3.3 JPY

II. Survey in 3 resorts in north part of the Island.

KRI and others investigate deeply to Phi Phi Natural Resort, Zeabola and P. P. Erawan Palms Resort as way of operation for wastes, especially, garbage and wastewater. Every resort separates garbage to organic and inorganic basically. However, sometimes, these components mixed in a same bucket as less than 10%. Also, Every resort transport garbage by ordered boat to SWDS in Krabi province. 。

Figure 2. Locations of 3 resorts in the north part of the Island.

Table 4. Way of garbage operation in each resorts

			Phi Phi Island Village	Holiday Inn	Zeabola	Erawan	Natural Resort
Amount of garbage	Garbage	t/d	1	0.45	0.4 t/w	0.6	0.5
	Inorganic	t/d	0.2	0.05	0.07	0.2	0.5
Transportation garbage	Frecency		Private boat	Private boat	Private boat	Private boat	Private boat
	Times	times/w	4	2	2	1	8-10 times/m
	Amount	t/trip	2	1.6	0.2	1	1
Boat	Fuel consumption	L/trip	160	2,000 THB/trip	6,000 THB/trip	200	180
		km/L	0.5	-	-	0.4	0.44
Cost of garbage		THB/m	-	16,000-20,000	48,000	29,000-32,000	-

III. Report of the results to cooperated resorts

KRI and others report the result from the survey to cooperated resorts and discuss about it freely. As for the project site, all resorts agree the project site by common that is Phi Phi Island Village. Comments from these resorts are ad below.

- The resort in Phi Phi Island must be keeps environment, therefore, we interested in the system.
- Almost visitor in the resort are western people that quite sensitivity for smell and environments in the resort. As for the gathering a garbage, how to hide it?,
- Gathering 6.6 t/d of garbage, it's out of business of the resort.
- We separate garbage at present basically, however, it's not perfect. If you can be induct the equipment for separation of garbage, every resorts agree it.
- You must be present the maintenance and driving cost.
- If all problems makes clear, we will prepare the budget for induction of the system.

3. Commercialization of the project

(1). Project boundary and baseline

Current state of the island resort in Thailand: There are not a waste/wastewater treatment/incinerator facilities and a public power plant/grid. Therefore, each resort handle it by themselves using own expense.

About the wastes from resort: The wastewater flows into sea without water treatment enough in individual resort. Because, Phi Phi island has not public wastewater treatment system. The garbage at resort is brought out and dumped at SWDS.

About electric power supply: The electric power supply in the island is generated from diesel engine generators on site by individual resorts in general. The capacity of these energy generators by the users is below several MW.

Gas engine generators using biogas: Gas engine generator is popular technology for small power generation using natural gas and/or city gas. Efficiency of the generator from fuel to electricity is low so as to be small scale. Moreover, using biogas, the efficiency drop down below 25% rapidly. Because, biogas has low contents of energy (60% of CH4) . Maintenance cost of the generator, it's about above 0.06 USD/kWh. The users in here does not consider having generators using biogas

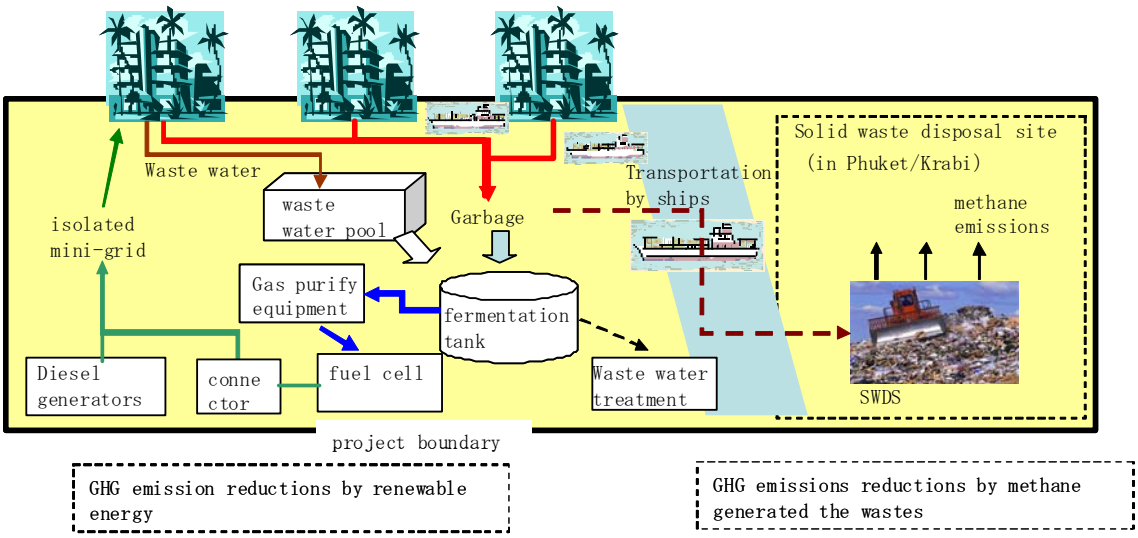

Figure 3. Project boundary.

(2). Plan of monitoring

Reduction of GHG emission is calculated by official equation based on data of monitoring.

$$ER_{y\ ex\ post} = \min((BE_{y\ ex\ post} - PE_{y\ ex\ post} - LE_{y\ ex\ post}), (MD_y - PE_{y\ power\ ex\ post} - PE_{y\ transp\ ex\ post} - PE_{y\ res\ waste\ ex\ post} - LE_{y\ post}))$$

$$MD_y = BG_{burnt,y} \times W_{CH4,y} \times D_{CH4} \times FE \times GWP\_CH4$$

Table 5. Item of GHG emission

Item	Unit	Others
$ER_{y,ex\ post}$	t-CO2e/y	Reductionof GHG emission in the y year
$BE_{y,ex\ post}$	↑	Baseline GHG emission
$PE_{y,ex\ post}$	↑	Project GHG emission
$LE_{y,ex\ post}$	↑	Leakage GHG emission
MD_y	↑	Amount of CH4 in the y year in the project
$PE_{y,transp,ex\ post}$	↑	Increase GHG emission by transportation in the y year
$PE_{y,power,ex\ post}$	↑	GHG emission by driving power in the y year
$PE_{y,res\ waste,ex\ post}$	↑	GHG emmision by sludge in the y year
$BG_{burnt,y}$	m3	Amount of flared bioges in the y year
$w_{CH4,y}$	-	CH4 contents in the biogasi in the y year
D_{CH4}	t/m3	CH4 contents under temparature/pressure in the biogas in the y year
FE	-	Ratio of flare of the biogas in the y year

All monitoring facilities will be installed and regularly calibrated for quality control by a reliable constructor (PAE Thailand) with the appropriate industry standards. Execution will be carried out by PAE Thailand, record and store relevant data. Such data will be made available to the DOE for verification in a transparent manner.

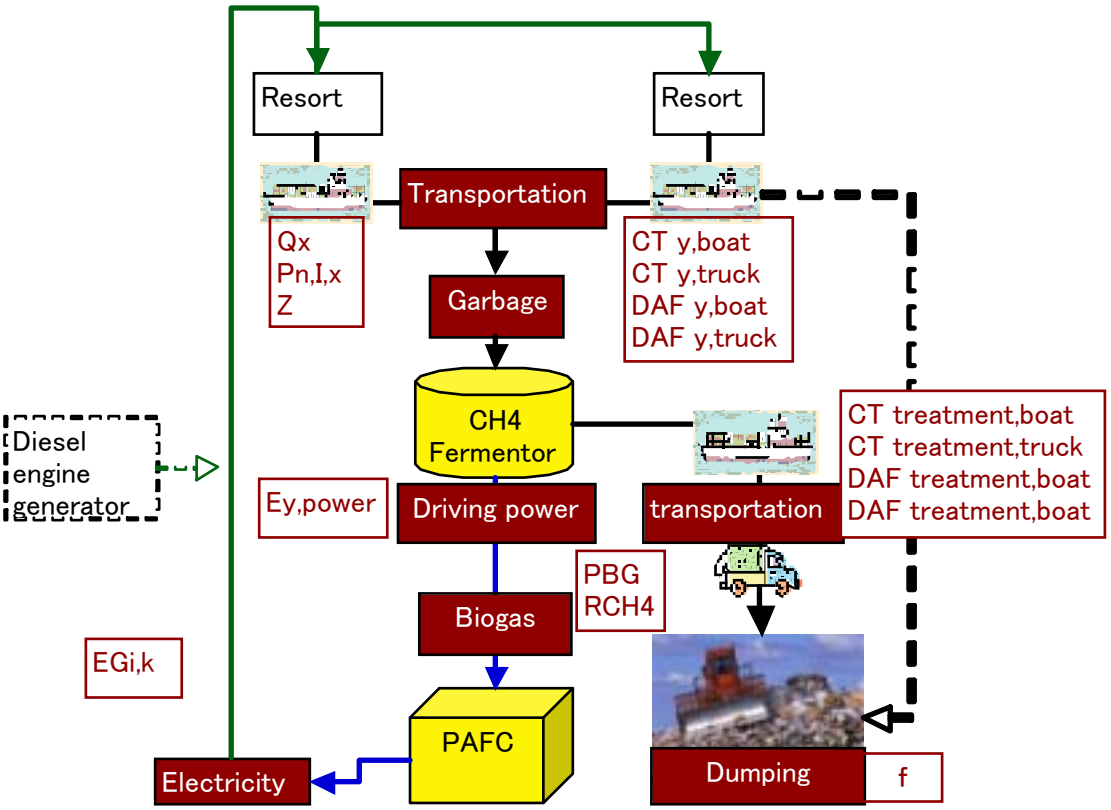

Figure 4. Outline of the planned monitoring.

Table 6. Item of the monitoring

Item	Frequency	Others
f	1 time/y	Ratio of flared CH4 in SWDS
GWP_CH4	1 time/y	GPW value of CH4
Qx	Continiously	Amount of garbage without dumping
Pn,j,x	4 time/y	Ratio of garbage i in the sample of N
z	Continiously	Sample number of the year
Condition	1 time/y	Confirmation of operation
EG i,k	Continiously	Electricity by PAFC from biogas
P BG	1 time/y	Amount of baiogas from 1 kg of garbage
R CH4	Continiously	Contents of CH4 in the biogas
CT y,boat	1 time/y	Avarage capacity of boat for garbage transportation
CT y,truck	1 time/y	Avarage capacity of truck for garbage transportation
DAF w,boat	1 time/y	Increase of average distance for garbage tranportation by boat
DAF w,truck	1 time/y	Increase of average distance for garbage tranportation by truck
Q y,treatment,i	1 time/y	Amount of sludge
CT treatment,boat	1 time/y	Avarage capacity of boat for sludge transportation
DAF	1 time/y	Increase of average distance for sludge tranportation by boat
CT	1 time/y	Avarage capacity of truck for sludge transportation
DAF	1 time/y	Increase of average distance for sludge tranportation by truck
E y,power	Cumulatively	Poer for operation

(3). Reduction of GHG emission

Reduction of GHG emission equal to baseline GHG emission minus project GHG emission. In the project, reduction of GHG emission in the 1st year is 10,898 t-CO2e, in 10 years later is 31,183 t-CO2e

$$ER_y = BE_y - PE_y$$

Table 7. Reduction of GHG emission by the project

Project period	Reduction of GHG emission (t-CO2e)		
	BE_y	PE_y	ER_y
1st	17,053	6,156	10,898
2nd	27,115	9,342	17,773
3rd	33,860	11,478	22,382
4th	38,381	12,909	25,471
5th	41,411	13,869	27,542
6th	43,443	14,512	28,930
7th	44,804	14,944	29,861
8th	45,717	15,233	30,484
9th	46,329	15,426	30,903
10th	46,739	15,556	31,183

(4). Project period and CER gained period

15 years of project period is decided by the official duration of the generator in Japan. Contrary, 10 years of CER gained period is decided by situation of after 1st period of Kyoto protocol beyond imagination.

(5). Influence of environment

In Phi Phi Island, there are some serious problems by surroundings of remote Island. Lots of people visit the island, they drop and produce any kind of waste during visiting the island. Also, they require comfortable accommodation, light, fresh water and air-conditioner that driven by much electricity. In Phi Phi, there is not a wastes treatment facility and public power plant. All of fuel for generator and living and foods has to be transported from Phuket and Krabi, contrary, all of wastes have to be transported back to Phuket and Krabi. In this project, wastes in resort hotels can be used as fuel for electric generators. Amount of garbage that has to be transported out of island will be less than existing condition. In Krabi and Phuket province, there are lots of islands like Phi Phi Island and this system is applicable to there. Totally, the project can be reduce CO2, NOx and SOx by reduction of amount dumping, fosil fuel for generation/transportation.

(6). Comments from stakeholders

a. Comments from governor of Krabi province

・As for a reduction of the cost for garbage transportation from Phi Phi island, Krabi province agree for the system and project. If possible, KRI spread the system to other remote island in Krabi and Thailand.

b. Comments from owner of resorts

・The resort in Phi Phi Island must be keeps environment, therefore, we interested in the system.
・Almost visitor in the resort are western people that quite sensitivity for smell and environments in the resort. As for the gathering a garbage, how to hide it?
・Gathering 6.6 t/d of garbage, it’s out of business of the resort.
・We separate garbage at present basically, however, it’s not perfect. If you can be induct the equipment for separation of garbage, every resorts agree it.
・You must be present the maintenance and driving cost.

・If all problems makes clear, we will prepare the budget for induction of the system.

(7). Organization of commercialization

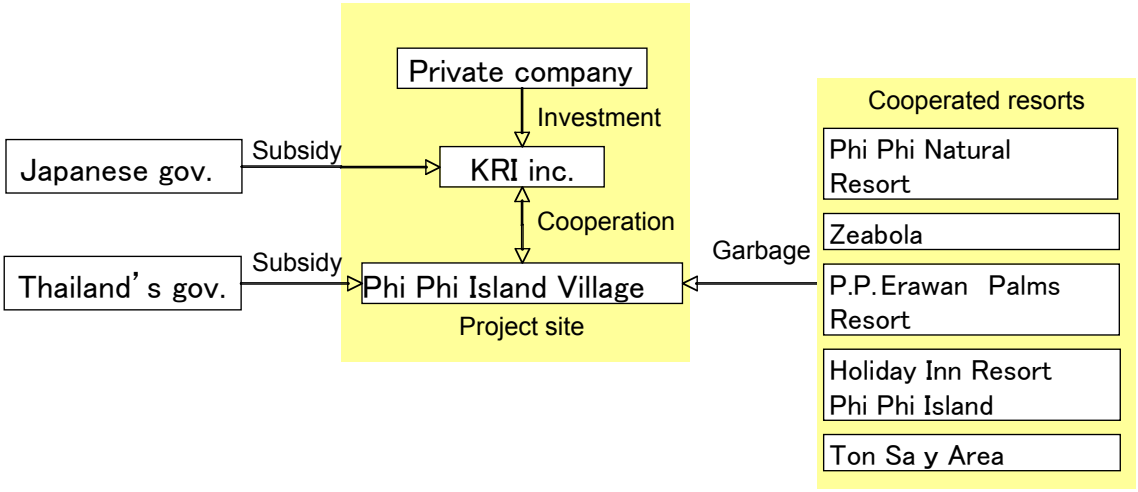

Figure 5. Organization of the project for commercialization.

(8). Plan of financial

Both governments had a suitable subsidy for the project. In Thailand, EPPO support a biogas utilization for small-to-medium-sized enterprises (80%). In Japan, NEDO support an International energy saving project (100%), also MOEJ support international model project (50%).

(9). Economic analysis for the project

In economic analysis for the project, we decide on the assumption that more that 25% of IRR in 10 years and go into the total black until 5 years. Initial cost of the project was 102 M THB, income was 10.7 M THB/y+CER (depend of price and project period), expenses was 4 M THB + 12 M THB/7.5y (cost of overhaul + interest (depend on government support). Then we trial calculate an economic analysis using price of CER: 0, 8, 16.5, 25 EUR/t-CO2, subsidy from government: 0, 50%. As for the results, the project will realize under price of CER is 16.5, 25 EUR/t-CO2, 50% of initial cost as subsidy from government.

Table 8. Economic analysis for the project

		Support from government (%)			
		0%		50%	
		IRR	SPY	IRR	SPY
Price of CER (EUR/t-CO2)	0	–	–	–	–
	8	–	–	13%	8
	16.5	7%	–	28%	5
	25	15%	8	40%	4

Simple Payback Year

(10). Verify of additionality

At a resort island in Thailand, there are few public infrastructures for sewage treatment and poor electrical power grid. The wastes as garbage are dumped at SWDS and an organic wastewater flowed through river to sea without wastewater treatment enough. In that area, the electric power supply is generated by diesel engine generators on site in general. The increase of visitors causes the increase of wastes and environment disruption in that area.

Electricity generated by PAFC using biogas is supplied through private grid to any facilities in the resort hotel. In this project using the renewable energy will reduce fuel consumption of generator by diesel engines. Avoiding dumping the wastes at SWDS reduces methane emissions from SWDS in Phuket and Krabi. The system that consists of methane fermentation and PAFC as generator using biogas make easy to the operations and maintenance by engineers without high education. Moreover, the maintenance cost of the PAFC is lower than a generator by gas engine.

(11). Progress of commercialization

As for the results, the project will realize under price of CER is 16.5, 25 EUR/t-CO2, 50% of initial cost as subsidy from government. However, under worldwide depression in business, It's difficult for a private company to bear 1/2 of the initial cost (150 M JPY). For early commercialization of the project, economic recovery is a necessary condition.

As for the gathering garbage without being noticed by anyone, separation of garbage and/or depression of odor are problems. After avoid this problem, owner of the resort decide induction of the system rapidly.

Execution of the project will acquire a building up a zero emission type resort facilities in such a remote island in the world. Also, a zero emission type resort invites an executive person from the world. Because, a lot of countries has a remote island for plan of a resort, a resort is hardly required the environmental friendly.

4. (Pre) Validation

(1). Summary of (Pre) validation

None

(2). Progress with DOE

None

5. Realization of co-benefit in host country

(1). Evaluation of environmental disruption in Thailand

In Phi Phi Island, there are some serious problems by surroundings of remote Island. Lots of people visit the island, they drop and produce any kind of waste during visiting the island. Also, they require comfortable accommodation, light, fresh water and air-conditioner that driven by much electricity. In Phi Phi, there is not a wastes treatment facility and public power plant. All of fuel for generator and living and foods has to be transported from Phuket and Krabi, contrary, all of wastes have to be transported back to Phuket and Krabi. In this project, wastes in resort hotels can be used as fuel for electric generators. Amount of garbage that has to be transported out of island will be less than existing condition. In Krabi and Phuket province, there are lots of islands like Phi Phi Island and this system is applicable to there. Totally, the project can be reduce CO2, NOx and SOx by reduction of amount dumping, fosil fuel for generation/transportation.

(2). Proposal for indicator of co-benefit

None