FY2018 Project for Ministry of the Environment Japan

FY2018 City to City Collaboration Program for the Realization of Low-Carbon Society

(Promotion of low-carbon society in transportation, green production field and so on based on the action plan for the climate change strategy in Phnom Penh Capital City 〔Kitakyushu City- Phnom Penh Capital City Collaboration Project〕)

Report

February 2019

Nikken Sekkei Civil Engineering Ltd.

Kitakyushu Asian Center for Low Carbon Society

FY2018 City to City Collaboration Program for the Realization of Low-Carbon Society (Promotion of low-carbon society in transportation, green production field and so on based on the action plan for the climate change strategy in Phnom Penh Capital City 〔Kitakyushu City- Phnom Penh Capital City Collaboration Project〕)

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Chapter 1 Purpose and overview

1.1 Purpose of work

At the 21 Conference of the Parties to United Nations Framework Convention on Climate Change (COP21) held in December 2015 in the suburb of Paris, France and the Paris Agreement - legal framework on equitable and effective countermeasures on climate change after 2020 - was adopted with the approval of 196 participating countries and regions.

The Paris Agreement aims to keep the global temperature rise well below 2 degrees centigrade and to pursue efforts to limit the temperature increase even further to 1.5 degrees centigradecompared with pre-industrial levels and requires all parties to put forward their efforts toward decarbonization.In addition, recognizing activities of non-state entities, including cities, welcoming the efforts of all the non-state organizations (cities, other local governments, etc.) and asking for scale-up of their efforts was decided at COP21.

Cities are places with socio-economic development supporting activities where many people live. Although urban areas account for less than 2% of the world's land area, more than 50% of the world's population lives in urban areas and that is expected to increase to 70% by 2050. At the time of 2006, it was estimated that over 70% of the world's CO2 emissions were emitted from urban areas. Urban areas have major roles to mitigate climate change.The stable step-by-step implementation of climate change countermeasures to reduce greenhouse gas emissions in surrounding urban areas is very important to achieve goals of the Paris Agreement.

In this project, we carried out the survey for the development of a JCM project focusing on the transport field, the glean production field and the environmental conservation field in Phnom Penh capital city with Kitakyushu city, which has experience and know-how about the development of a low carbon society in order to implement measures stated in the Phnom Penh City Climate Change Action Plan developed by Kitakyushu City and Phnom Penh City in 2016.

1.2 Overview of work

1.2.1 Overview of work

(1) Investigation contents

Conduct feasibility study of JCM subsidized projects in <Transportation field>, <Green production field> and < Environmental conservation Field > as follows.

- Transportation Field：Taxi business by electric tricycles
- Green production field：Agricultural biomass power plant project
- Environmental conservation Field：Organic wastewater treatment project

(2) Investigation area

Phnom Penh and surrounding areas

1.2.2 Implementing methods of work

(1) Feasibility study of JCM subsidized projects

Specific investigation contents in "Transportation field", "Green production field" and "Environment conservation field" are as follows. Field survey was conducted 4 times.

【Transportation Field：Taxi business by electric tricycles】

1) Consideration of applied techniques

Considered the technology to be applied (electric tricycle, charging station), efficiency of CO2 reduction, cost-effectiveness of JCM subsidy, economic viability of the project and method of monitoring. In considering technology to be applied, examined how to reduce initial costs and ensure economic efficiency. In addition, conducted surveys of necessary administrative procedures for project implementation, such as vehicle inspection and taxi business permission.

2) Assessment onproject implementation mechanism

Conducted survey to select a representative company, a partner participant and cooperative companies (manufacturer, etc.) and considered a business structure.

3) Conduct surveyon of capital mobilization method

Conducted survey on financial arrangements to implement the project such as self-financing, external loans, leasing equipment, etc.

4) Conduct surveyon project implementation schedule

Coordinated with the representative company, the partner participant and cooperative companies to consider a schedule of JCM project.

【Green production field：Agricultural biomass power plant project】

1) Assessment of applied techniques

Considered the technical content to be applied, efficiency of CO2 reduction, cost-effectiveness of JCM subsidy, economic viability of the project and method of monitoring. In considering technology to be applied, examined how to reduce initial costs and ensure economic efficiency. In addition, investigated the necessity of acquisition of permission and the procedures in the case of the selling electricity project.

2) Assessment of project implementation mechanism

Conducted survey to select a representative company, a partner participant and cooperative companies (EPC company, O&M company, etc.) and considered a business structure.

3) Assessment of capital mobilization methods

Conducted survey on financial arrangements to implement the project such as self-financing, external loans, leasing equipment, etc.

4) Conduct survey on project implementation schedule

Coordinated with the representative company, the partner participant and cooperative companies to consider a schedule of JCM project.

【Environmental conservation Field: Organic wastewater treatment project】

1) Assessment of applied techniques

After studying the current situation and demand for organic wastewater treatment in livestock facilities, food processing factories, etc. Considered the technology to be applied, efficiency of CO2 reduction, cost-effectiveness of JCM subsidy, economic viability of the project and method of monitoring. In considering technology to be applied, examined how to reduce initial costs and ensure economic efficiency.

2) Assessment of project implementation mechanism

Conducted survey to select a representative company, a partner participant and cooperative companies ((EPC company, O&M company, etc.) and considered a business structure.

3) Conduct survey ocapital mobilization methods

Conducted survey on financial arrangements to implement the project such as self-financing, external loans, leasing equipment, etc.

4) Conduct survey on project implementation schedule

Coordinated with the representative company, the partner participant and cooperative companies to consider a schedule of JCM project.

(2) The others

1) Monthly report (by e-mail)

Reported monthly survey progress.

2) Progress reporting to Ministry of the Environment

Had meetings in Tokyo 4 times/year (May, August, November, and February)

3) Local workshop

Hold 3 progress report meetings (workshops) in Phnom Penh Capital City.

4) Presentation on initiatives on inter-city collaboration in Japan

Once a year (in Tokyo)

5) Give a presentation at conferences designated by Ministry of the Environment and Adjust corresponding (Not include workshop 2), 3), 4) like mentioned above)

1.2.3 Implementation time

From 16th April, 2018 to 28th Feburary, 2019

1.2.4 Survey organization

The survey organization of this survey is as in the following table.

Table 1.2.1 Survey organization

Names	Role of each organization
Kitakyushu city	- Application for interviews with administrative organizations such as Phnom Penh Capital City and Ministry of the Environment, Cambodia and local companies (issued letter) - Discuss with administrative organizations such as Phnom Penh Capital and Ministry of the Environment, Cambodia and local companies - Hosting the workshop
Nikken Sekkei Civil	- Survey for the development of a JCM subsidized project(include field survey) - The others (Monthly report, Progress reporting to Ministry of Environment, organize workshop) - Summary of this work

1.3 Background of work

1.3.1 Outline of Phnom Penh Capital City

Phnom Penh is the capital of the Kingdom of Cambodia as well as the cultural, economic and administrative center, with beautiful streetsof the French colonial called "Paris of the East". As of 2016, the population is about 1.9 million people[1], about three times higher than when the civil war has not finished about 30 years ago in 1986.

The political situation becomes unstable※ in the period from 2017-2018, but the real GDP growth rate in 2018 is expected to reach 7.0%; GDP per capita will be 1.485 USD (according to IMF estimates)[2]. In economic terms, stability and high growth ratestill maintain (see Fig. 1.3.1).

It is said that Phnom Penh city has about 12% of Cambodia's population and is creating about 60% of GDP[1]. In the capital, the construction of hotels, commercial facilities, high buildings, office buildings, etc. is performed in a positive way.

However, in Phnom Penh, while the population is increasing and the economy grows, there are still many issues to be addressed such as stable power supply to meet the rising electricity demand and measures to prevent environmental pollution including air pollution, public water pollution and increase of waste generated in the capital city.

※The leader of Cambodia rescue party, one of the largest opposite parties, has been arrested on charges of treason and the Party was dismissed in 2017. The House of Representatives general election was held without a major opposite party, Prime Minister Hun Sen got all seats in the Cambodia People's Party but was condemned by the international community in 2018,.

■ Power supply

・The Electrification rate in Cambodia is stable. The rural electrification rate in 2017 is 81.85% and the household electrification rate is 68.64%. The government is implementing the target of 100% in the rural electrification rate by 2020 and 70% in the household electrification rate in 2030[3].

・Regarding time and numbers of power outages: power outages due to insufficient power generation has been resolved in 2014, so it has been greatly improved. The System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) for each household were improved to approximately 9,500 minutes, equivalent to 90 times. In 2006, it improved to 1,370 minutes and equivalent to 18.7 times. However, this data is higher than Japan and neighboring countries. For reference, in Japan (2019) SAIDI: 14 minutes, SAIFI: 0.13 times; in Thailand MEA (2015), SAIDI: 36 minutes, SAIFI: 1.37 times. In Vietnam (2015), SAIDI: 2,110 minutes, SAIFI: 12.85 times[3].

・In addition, ensuring voltage stability and reducing electricity costs is also an issue as this may cause difficulties for production activities. Electric cost, as shown in Table 1.3.1, is more expensive than surrounding countries, which is a major constraint to production activities. Therefore, the demand for renewable energy and energy saving is very high。

■Air pollution / noise

・While the number of cars and motorbikes has increased and road conditions were bad because the maintenance of road is delayed, the remarkable traffic congestion has become normal. Therefore, air and noise pollution is becoming a serious problem but it is impossible to know real status well because there is no adequate observation/ sampling.

■Water pollution

・In the capital city, excreta from households is usually treated in septic tanks. However, most of it is not treated and discharged directly into public water sources and drainage paths.
Due to this reason, waterways in the city and lakes along the downstream of the river become black and smelly. Moreover, wastewater is discharged from wetlands in the South and the North of the capital city and the amount of wastewater is increasing rapidly due to the rapid population growth and urbanization. Therefore, the waste quantity dischaging into rivers and streams exceeds the natural ability of weltand to clean up; polluted water on lakes and rivers in the city is increasing (Please see Photo 1.3.1, Picture 1.3.2)

・In Phnom Penh Industrial Zone (PPSEZ), after being treated initially at the factories , wastewater is treated with a simple aeration system to meet the national waste water standards. Large scale factories not in PPSEZ are limited, but it is estimated that wastewater treatment is not performed properly because regular inspection by the administration is not done at the factory. (Refer to Photo 1.3.3)

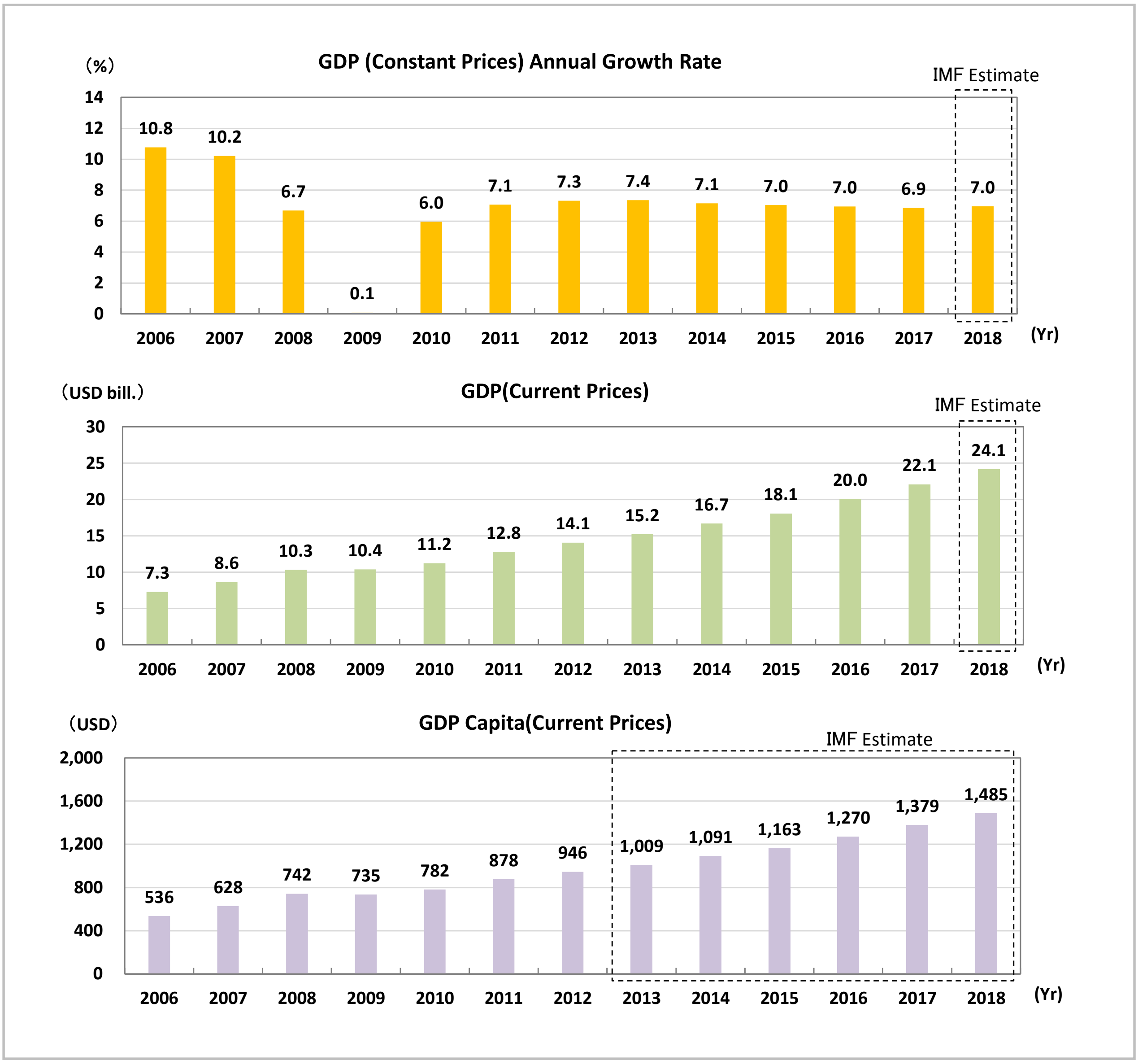

Fig.1.3.1 Nominal GDP growth rate in Cambodia, Nominal GDP and GDP per capita[2]

Table 1.3.1 Comparison of electricity prices between Cambodia and neighboring countries in 2017[4]

Item	Capital	Cambodia	Thailand	Myanma―	Laos
For business	Monthly basic fee(USD)	―	9.7	―	―
	Cost for 1kWh(USD)	0.17	0.08～0.16	0.05～0.11	0.08～0.09
For general use	Monthly basic fee(USD)	―	1.18	―	―
	Cost for 1kWh(USD)	0.15～0.19	0.10～0.14	0.03～0.04	0.05～0.13

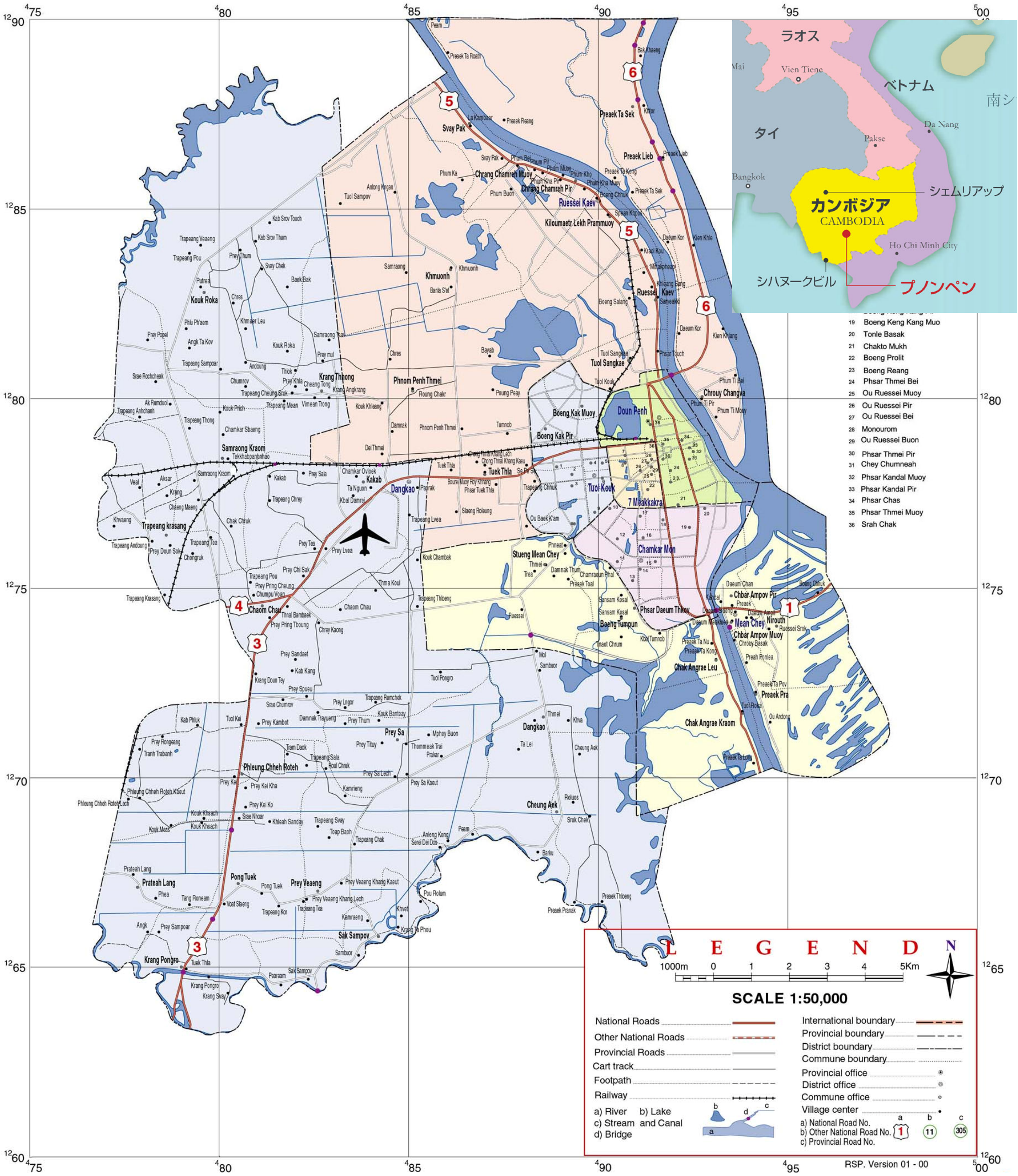

Fig.1.3.2 Phnom Penh City Location[1]・Overall view of Phnom Penh[5]


Photo 1.3.1 Large amount detergent foam generated near the inner city drainage


Photo 1.3.2 Urban waterways which is adjacent to nearby slums, are polluted by scattering waste,

Photo 1.3.3 Drainage from breweries in the capital city
(Colored waste water, detergent foam)

Photo 1.3.4 Hospitals wastewater treatment facilityin urban area
(Liquidmedical wastewater directly discharges into the environment without treatment)

1.3.2 Cooperative relationship between Kitakyushu City and Phnom Penh Capital City

Kitakyushu City has implemented technical cooperation regarding water supply with Phnom Penh Capital City since 1996. As a result, leakage/stealing rate has been greatly improved and water supply became drinkable in 2005. The contribution of Kitakyushu city is called "miracle of Phnom Penh" and after that Kitakyushu city continues its technical support by sending dispatching experts of water supply field to Phnom Penh Capital City.

As Prime Minister Hun Sen proposed "Sister cites agreement with Phnom Penh Capital City" when he visited Kitakyushu City in July 2015, Kitakyushu City signed the sister city agreement with Phnom Penh on March 29, 2016 based on the trust relationship established by technical cooperation so far.

In 2016, Kitakyushu City formulated "The action plan for the climate change strategy in Phnom Penh Capital city" (Action Plan) which contributes to the low carbonization and sustainable development of the city as a whole under this sister city agreement. This work is the feasibility study for formulating other projects based on this action plan. The details are described in the next section.

In FY 2017, Kitakyushu City supported the capital city toward low carbonization and appropriate waste management through "City Collaboration Program for the Realization of Low-Carbon Society" and JICA's technical cooperation project.

In this way, cooperation between the two cities has continued and expanded since the water technology cooperation in 1996, and a strong relationship of trust has been established.

Photo 1.3.4 Sister cites agreement with Phnom Penh Capital City (March, 2016)[6]

1.3.3 Position of this project in "The action plan for the climate change strategy in Phnom Penh Capital city

In this project, "Phnom Penh City Climate Change Strategic Action Plan" (Action Plan) was formulated in "FY2016 Feasibility Study of Joint Crediting Mechanism Project by City to City Collaboration based on the superior plans (national plan) such as"Royal Government of Cambodia Rectangular Strategy","Cambodia Climate Change Strategic Plan 2014-2023"and"Cambodia's Second National Communications submitted to the UNFCCC and related superior plan of Phnom Penh city.

The action plan was created utilizing the "Kitakyushu Model" technology and expertise system which organized Kitakyushu city's from overcoming the pollution to the environmental city.

Action plan reviewed and provided the basic policy of the overall plan, as well as each sector in six areas: waste, energy, transportation, waterworks/sewerage, environmental conservation and green production. The action plan has studied and proposed priority pilot projects that need to be implemented first and specific policies for each field

In this survey, in order to realize these projects stipulated in action plan, feasibility study of these projects that were supposed to apply the scheme of JCM was conducted as follows while focusing on <Transportation field>, <Green production field> and <Environmental conservation field> as shown in Fig. 1.3.3.

<Feasibility study for JCM project>

- Transportation field：Taxi business by electric tricycles
- Green production field：Agricultural biomass power plant project
- Environmental conservation Field：Organic wastewater treatment project

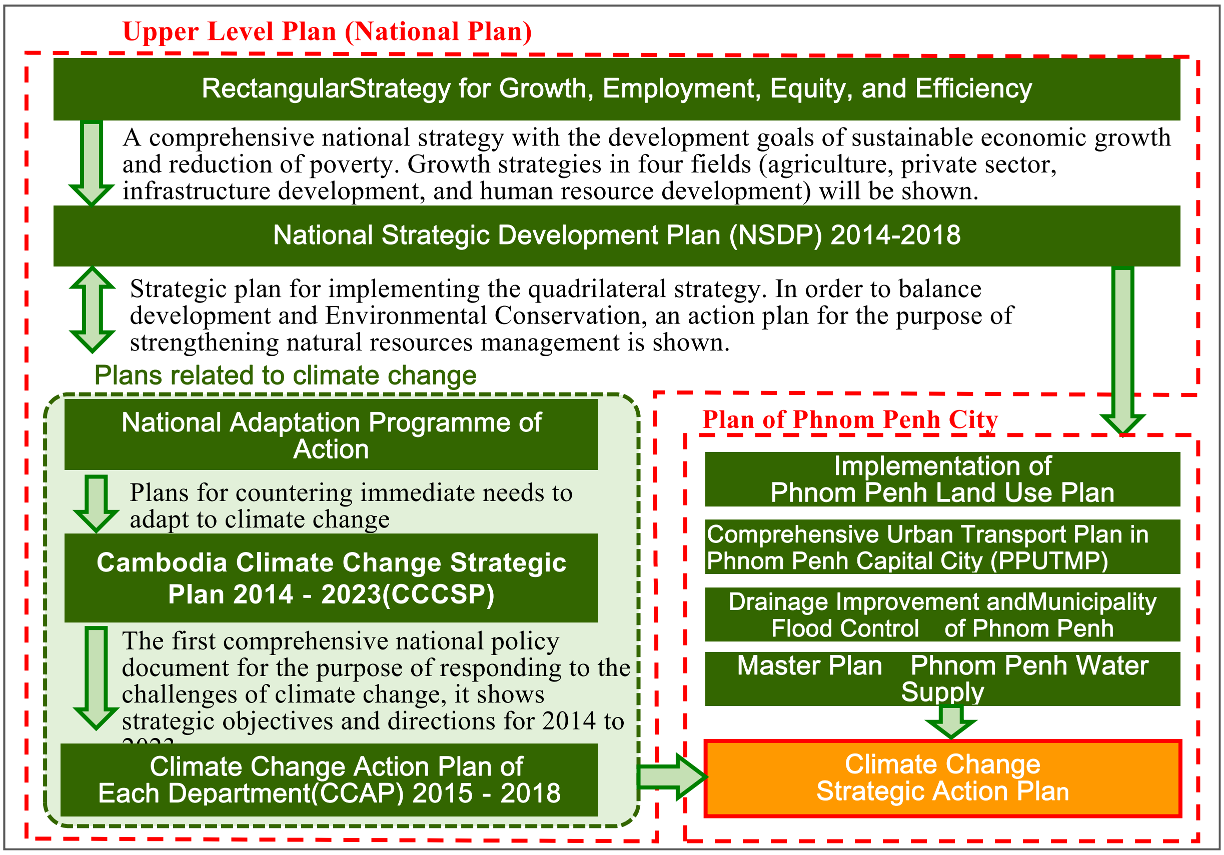

Fig.1.3.3　Phnom Penh City Climate Change Strategic Action Plan

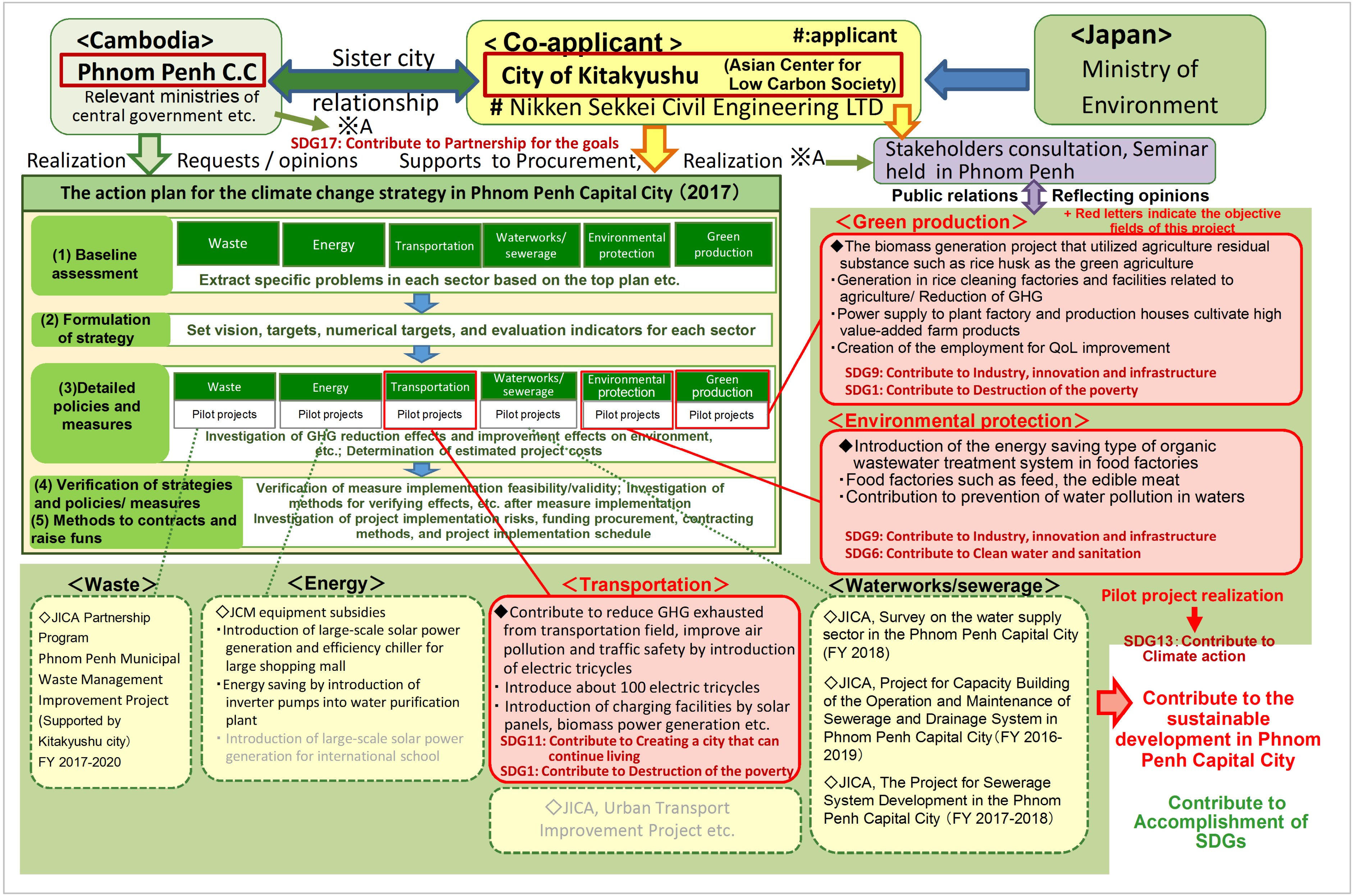

Fig.1.3.4 Position of this work in "The action plan for the climate change strategy of Phnom Penh Capital city (Action Plan)

1.3.4 Cambodia's second national Communications

The Cambodian government has made and proposed to the UNFCCC Cambodia's Second National Communications (MoE, Nov.2015) with contents such as its global warming policy, greenhouse gas emissions forecasts, climate change effects and appropriate response measures.

Table 1.3.2 shows the national emission reduction targets mentioned in the report. In the field of energy, reduce CO2 by the use of electricity generation rice husk (reduction target of 2035 ※: 463 Gg CO2 - eq, total volume decreased by 12.4%); in the field of transportatin, reduce CO2 emissions by electric motorbikes and cars (reduction target of 2035 ※: 95 Gg CO 2 - eq, total volume decreased by 2.5%). This survey aims to contribute to achive the reduction target of this business.

* 2035 is the target year of the action plan.

Table 1.3.2 Cambodia's Second National Communications(MoE, Nov.2015)
Maximum reduction of CO2compared to baseline emissions[7]

［GgCO2-eq］

Year	2010	2015	2020	2025	2030	2035	2040	2045
Total Baseline Emissions	5,533	5,987	7,551	9,601	11,599	14,043	17,075	20,848
Energy Industries								
Grid Connection REEs	3	12	30	51	80	106	140	172
Grid Connection Auto Producers	18	152	269	268	309	354	430	492
Grid Connection Battery Charging Stations		5	12	16	16	14	12	10
Solar Power Plant	0	0	1	2	5	9	18	36
Solar Home Systems	0	6	16	22	22	19	16	12
Mini and Micro Hydro		2	3	4	4	4	4	4
Rice Husks for Electricity Generation	27	67	167	417	445	463	481	498
Energy efficiency end users	22	55	138	344	592	797	1,002	1,264
Energy efficient buildings	50	85	193	285	354	443	557	702
Sub Total Savings	**120**	**384**	**829**	**1,409**	**1,826**	**2,210**	**2,659**	**3,191**
% savings compared to Baseline	2%	6%	11%	15%	16%	16%	16%	15%
Manufacturing Industries								
Rice milling ,Garment, Rice Mills, Brick Works	326	373	429	497	580	681	803	953
Biofuel	13	32	79	147	147	147	147	147
Sub Total Savings	**339**	**405**	**508**	**644**	**727**	**828**	**950**	**1,100**
% savings compared to Baseline	6.1%	6.8%	7%	7%	6%	6%	6%	5%
Transport Sector								
Hybrid Cars			2	6	15	37	92	229
Motor Vehicle Inspection	62	154	192	238	297	369	461	574
Electric scooters and Bicycles	4	9	22	54	78	95	116	141
Sub Total Savings	**66**	**163**	**216**	**298**	**390**	**501**	**668**	**944**
% savings compared to Baseline	1.2%	2.7%	3%	3%	3%	4%	4%	5%
Other Sectors								
Efficient Cookstoves, Biodigesters, Water Filters	3	7	17	39	96	136	160	170
Solar Lanterns	0.6	6.2	31	56	50	44	44	44
Wind Water Pumping	0.0	0.4	3	5	9	11	14	16
Sub Total Savings	**4**	**14**	**51**	**100**	**155**	**191**	**218**	**230**
% savings compared to Baseline	0.1%	0.2%	0.7%	1.0%	1.3%	1.4%	1.3%	1.1%
Total Savings	**528**	**966**	**1,603**	**2,452**	**3,098**	**3,730**	**4,495**	**5,465**
% savings compared to Baseline	9.5%	16.1%	21%	26%	27%	27%	26%	26%

Citations and Reference

1 JETRO, Phnom Penh style, March 2017
2 International Monetary Fund, World Economic Outlook Database, October 2018
3 JICA expert, Hirose Koichi, Present situation of electricity in Cambodia, 30th March 2018
4 JETRO, Cambodia latest power situation, The existing electricity status in Cambodia, Japan's movement to solve the problem https://www.jetro.go.jp/biz/areareports/2018/3ef8f6062023c66e.html
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7 Ministry of Environment、Cambodia's Second National Communications、Nov.2015

Chapter 2 Feasibility study for JCM project (Transportation Field：Taxi business by electric tricycles)

This project aims to mitigate atmospheric pollution via reducing CO2 emissions by replacing tuk-tuk, which is a fossil-fuel-run vehicle currently used as local taxi, with electric tricycle. This kind of electric tricycle is expected to be solar-powered or biomass-powered vehicle.

2.1 Current situation

According to "the comprehensive urban transport plan in Phnom Penh capital city (PPUTMP)"[1], tuk-tuk is considered to be likely used as a feeder system for bus and train system in the suburbs. Based on this direction, in this chapter, we firstly conducted a study on the current situation of public bus system in Phnom Penh. Then, we will show the current situation of tuk-tuk and the results from examination on administrative procedures for starting taxi business in the capital city.

2.1.1 Transportation situation

(1) Public bus system

Public bus system came into use from 2014. It has increased from 57 buses up to 235 buses, and the bus routes have been expanded from 3 lines to 13 lines, thanks to non-refundable aid from Japan, and China. Since then, the system has improved its convenience (refer to Fig. 2.1.1 and 2.2.2).

The bus fares are the same at 1,500 Riel (around 0.4 USD), and free of charge for students, monks, disabled people, the elderly, and workers (for maximum period of 2 years) (which means 60% are free passengers).

Due to the expansion of routes and preferential measures for bus fares as mentioned above, the number of public bus passengers has increased rapidly from 6,000 people/day (nearly 200,000 people/month) to 25,000 people/day (about 700,000 people/month), but transport share of public bus is currently only at 1% (25,000 passengers/day) (Fig. 2.1.3). The reason is because of worsening situation of traffic congestion caused by increasing number of private cars, which makes buses unable to run on time as scheduled (Fig. 2.1.4).

At present, JICA is implementing "The Project for Improvement of Public Bus Operation in Phnom Penh (1/2017~12/2017)". This project consists of 5 activities: 1) operation improvement of route buses, 2) improvement of bus inspection & maintenance, 3) bus crew training, 4) improvement of business administration, 5) suggestion of priority policies for public transportation. Regarding the activity 5), priority bus lanes will be built, and the introduction of public transport priority system & bus location system is being advanced. As for the bus location system, JICA has been conducting discussions with some application development companies for taxi dispatch (including tuk-tuk) in order to mutual use of bus and tuk-tuk in the near future.

Taxi business by electric tricycles, after being conducted, is regarded as a feeder connecting with public bus routes (ultilizing bus location system). This project is expected to play an important role in increasing the number of people using public buses, and to become a solution to areas with inconvenient transportation such as suburban areas, where there are no public buses.

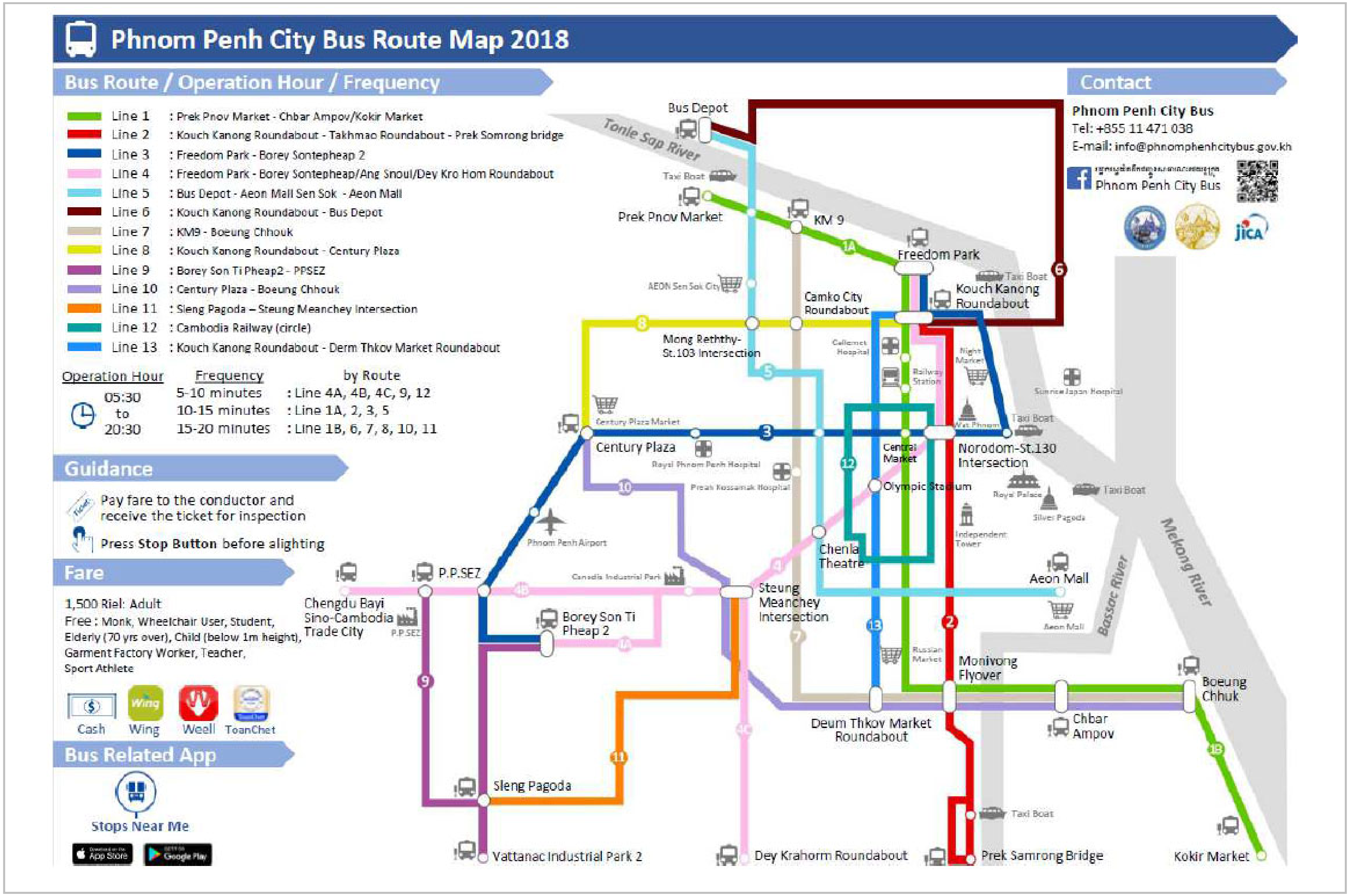

Fig 2.1.1 Map of public bus routes [2]

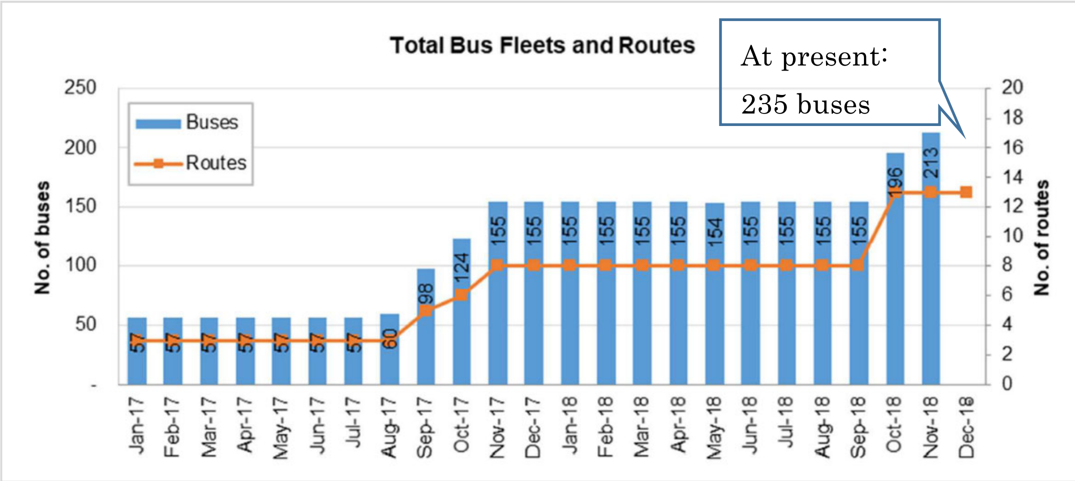

Fig. 2.1.2 Number of public bus fleets and routes [2]

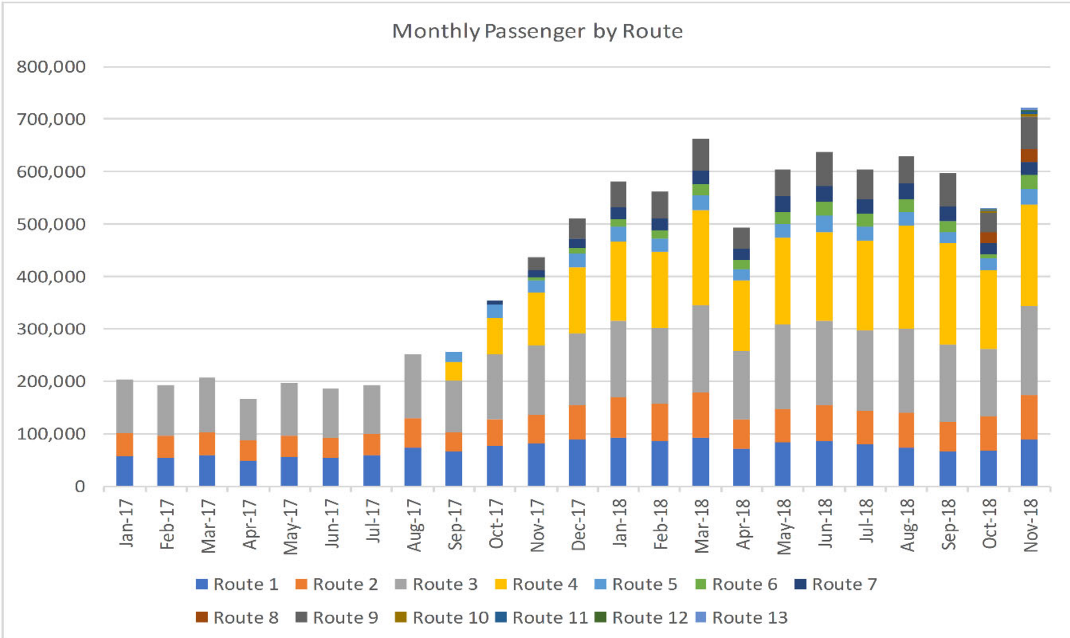

Fig. 2.1.3 Number of monthly public bus passenger by route [2]

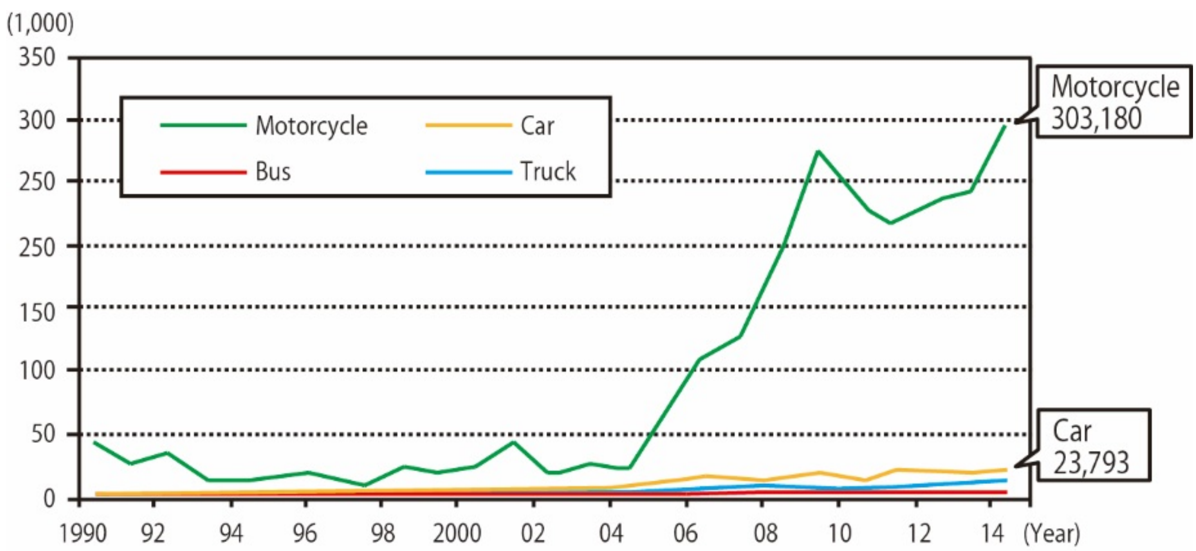

Fig. 2.1.4 Number of vehicle registration in Cambodia [3]

Photo 2.1.1 Pubic bus (left: bus from Japan, right: bus from China)

Photo 2.1.2 The fully equipped bus stop

(2) Tuk-tuk

■ From Remorque to LPG-run tricycles

People without cars and tourists use tuk-tuk quite a lot, and in some recent years, there have been major changes in this tuk-tuk business.

From previous years until around 2016, when tuk-tuk was mentioned, people often thought of remorque (Photo 2.1.3), which is a kind of gasoline-powered motorbike with a cabin for passengers in the back, and it has been considered as a typical passenger-carrying vehicle in Cambodia. However, in some recent years, this kind of vehicle has been gradually replaced by LPG tricycles imported from abroad such as India, etc. (Photo 2.1.4).

The main reason why LPG tricycle has become so popular is not only because of its reasonable fuel consumption & operation capacity, but also because of its high usability thanks to its conectivity with smartphone apps for booking the vehicle (such as PassApp), so passenger can book a LPG tricycle with clearly shown fares on the app, which is near their location (the fare is 1,000 Riel/km, 1,000Riel≒28 Yen)*distance (PassApp). Passengers no longer need to negotiate the fares before getting on the vehicle, like they have to do so with remorque. Also, tourists & foreign residents are not worried about being overcharged.

Photo 2.1.3 Typical tuk-tuk of Cambodia (Remorque)

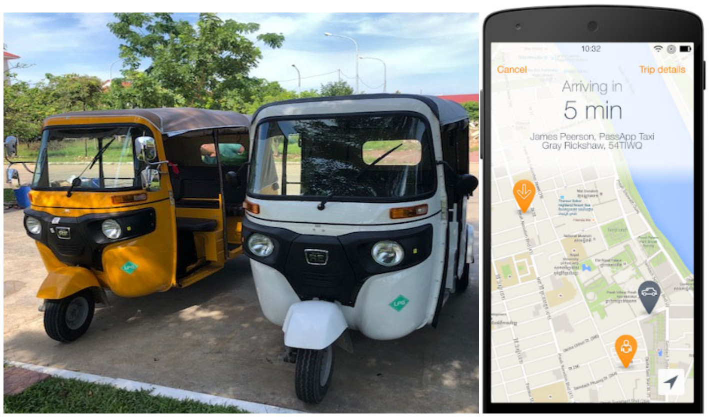

Photo 2.1.4 LPG tricycle & Application of taxi dispatch

We interviewed the remorque association(CAID) which about 3,100 remorque drivers(self-employed) join as members, and they told that even now when the association occupies major stops at important airports & markets, LPG tricycles have still completely taken taxi market (Table 2.1.1)

Table 2.1.1 Results from the hearing with remorque association

Item	Content
Association name	・CAID (Cambodian Association for Informal Economy Development)
Activities	・Supports related to training in safe-driving & market exploitation for drivers (self-employed). ・Remorque rental for drivers who are short of funds . ・Thanks to the license granted by Phnom Penh city, the association occupies stops at important airports & markets, and the CAID members are allowed to provide their services at those stops. ・Agreement signing with airports on the basis of permission from Phnom Penh city. Based on that, members will pay parking fees for the airport, and pick up passengers. The agreement is effective for 3 years and has been renewed 4 times.
Membership	・Around 3,100 people
Issues	・Traditional remorque of CAID members cannot compete with LPG tricycles imported from India with better fuel consumption capacity. ・Due to PassApp (application for booking taxi), LPG tricycles can receive bookings, and get to the airport to pick up passengers normally (even when remorque of CAID is available and waiting for passengers at the airport, passengers still refuse to take it). ・Fare is about 1,000 Riel/km (from airport ~ inner city: around 10km →about 3USD). Whereas, CAID are offering fare from airport to inner city at 7~9 USD.

On the other hand, because of the popularity of LPG tricycles, there are more and more makers manufacture LPG tricycles. We have conducted a survey on dealers selling LPG tricycles in the city, and aggregated the results of specifications & prices for popular kinds of tricycles as shown in Table 2.1.3.

Price for a LPG tricycle is around 3,500~3,900 USD (tax included), which is quite high compared to a remorque (1,000~1,800 USD (tax included)), but there are companies which lease those tricycles with fee of 3.5 USD/day, so there are more and more LPG tricycles drivers (Table 2.1.2)

From above situation, in case of starting a taxi business with electric tricycles as a JCM project, referenced vehicle should be LPG tricycles.

Table 2.1.2　Results from the hearing with a LPG tricycle service company and rental company

Item	Content
Company name	・Cam Go
Business field	・LPG tricycle distribution service (smartphone app business) ・Rental service for drivers (self-employed individuals) (3.5USD/day)
Company scale	・100 LPG tricycles (TVS) ・There are about 4 companies with similar services in the city, of which Cam Go's scale ranks the 1st or 2nd
Related company	【Three Wheel Motor Company (TWM, with same director)】 ・Import & sell LPG tricycles, and lease tricycles to CG company ・Repair garage with 3 engineers (salary of 250～300USD/month)
Inspection & repair	・Tricycles need to be inspected every 10 days at TWM. ・Inspection is carried out based on TWM's specific standards ・Inspection process is free of charge, but if any replacement of vehicle parts is made, driver has to bear this cost.
Others	・The business operations are going very smoothly (except for cars being repaired, 100% of the company's cars are in use) ・The company is also covering accident insurance costs for both drivers and passengers (6USD/month)

Table 2.1.3 Specifications and prices for most popular LPG tricycles in Phnom Penh city

Name of LPG tricycle	TVS	ATUL GEMINI CARGO	APE PIAGGIO	BAJAYJ RE
Maker name (country of origin)	Ccs (India)	Atul Cambodia (India)	Piaggio Group (Italy)	BAJAJ Cambodia (India)
Design (photos)				
Size (L×W×H)	L 2.65m×W 1.3m×H 1.75m	L 2.72m×W 1.2m×H 1.7m	L 2.49m×W 1.26m×H 1.55m	L 2.6m×W 1.3m×H 1.7m
Capacity	3 people (passengers) + 1 person (driver)	3 people (passengers) + 1 person (driver)	3 people (passengers) + 1 person (driver)	3 people (passengers) + 1 person (driver)
Maximum speed (km/hour)	80km/hour	80km/hour	65km/hour	70km/hour
Cruising distance (km) (when fuel tank is full)	480km (LPG 16L, Gasoline 4L)	600km (LPG 20L, Gasoline 3L)	450km (LPG 15L, Gasoline 3L)	378km (LPG 14L, Gasoline 3L)
Fuel consumption (km/L)	LPG 30km/L	LPG 30km/L	LPG 30km/L	LPG 27km/L
Characteristics (Strength or weakness)	Price is lower than other kinds, good quality, quite large size, light weight	Safe ignition device, 200cc cylinder, bigger than BAJAJ RE, not good design at the back, quite high driver's seat, not very good quality	Best design, loud engine sound, high price, low speed	Fuel consumption capacity is not as good as the one from other companies
Exhaust emission, number of cylinders	200cc 1 cylinder	200cc 1 cylinder	200cc 1 cylinder	100cc×2＝200cc 2 cylinders
Price (Tax included)	3,380$ (VAT included)	3,500$ (during promotion period) 3,700$ (VAT included)	3,850$ (VAT included)	3,550$ (VAT included)
Evaluation	New model, good condition, in popularity	From April 2018 till now, 300 units were sold	In popularity	In popularity and imported from 2014 till now.

2.1.2 Administrative procedures for starting taxi business

We interviewed the Department of Public Works and Transport Phnom Penh to learn about administrative procedures for starting taxi business. When a Cambodian legal entity (including entity with capital from Japan) wants to do taxi business, it will need to go through following procedures ”vehicle inspection & examination”, “Vehicle Registration”, “Applying for transport service license”. In addition, if the entity wants to operate at bus interchange stations at public facilities such as airports and markets, it is required to obtain permission from Phnom Penh. Besides, it is also necessary to carry out business registration procedures (in charge: Ministry of commerce), and tax registration (in charge: General Department of Taxation) as usual if the entity is a new-established company.

According to information gained from the hearing with Department of Public Works and Transport Phnom Penh, current taxi business by LPG tricycles is mainly run by self-employed individuals. And most of them operate without registering for the vehicle, or applying for transport service license. Also based on results from the hearing, traffic accidents caused by LPG tricycles in Phnom Penh happen quite a lot. The main reason for it is because drivers come from countryside areas and are not familiar with driving this kind of vehicle, and they have to drive on urban streets with heavy traffic.

(1) Vehicle inspection and examination

- When inspected, drivers need to show import license of the electric tricycle and its sales contract.
- Vehicle inspection is carried out by the Department of Public Works and Transport Phnom Penh.
- Vehicle inspection cost is 40,000 Riel (around 10USD)/vehicle).
- Inspection time often takes half day for one vehicle. But the time necessary for inspection of around 100 vehicles is not clear.

(2) Vehicle registration

- After inspection & examination, the vehicle registration will be conducted. Normally, vehicle number plate will be issued on the same day, and after that, the vehicle will be allowed to run on public streets.
- Vehicle registration is carried out at People’s committee at district level in the city from the beginning to the end (one-stop service). The fee is 27,000 Riel (around 6.8USD) for one vehicle.

(3) Applying for transport service license

- Along with applying for the transport service license by the Ministry of Public Works and Transport, it is also required to obtain vehicle registration.

(4) Applying for license to provide taxi business at stops/stations at airports & markets, etc.

- In order to provide taxi service at stops at airports & markets, it is required to get the license from the city.
- As for stops at airports, after being licensed by the city, it is still required to sign an agreement with airports. The official letter needs to be submitted to the General affairs departmen of the capital city for guidance on implementation.

2.2 Examination of introduction technology

2.2.1 Contents of introduction technology

(1) Electric tricycle

The subjects for consideration are 2 models from Terra Motors Corporation. Terra Motors Corporation is a Japanese enterprise, which is currently expanding its sales of electric tricycles (lead-acid storage batteries) in such countries as Bangladesh and India, thanks to its cheap price, good functionality, and suitability for demands in these countries.

According to results of the hearing in local areas, and from the viewpoint of design & functionality (especially speed), lithium-ion-battery-run Auto models are more highly appreciated than lead-acid-storage-battery-run Y4A models. Therefore, even Auto model series are still under development stage, we still think that it will possess higher applicability and popularity. In this section, CO2 emissions reduction & profitability consideration for Auto series have been taken into account. In addition, regarding service scale based on consideration on makers' production capacity, it is assumed that the number of tricycles under operation will be 100 units.

Table 2.2.1 Specifications of electric tricycles (Terra motors)

Name	Y4A	Auto※
Design		
Dimension	L:2790×W:990×H:1735 mm	L:2635×W:1300×H:1710
Capacity	4＋1 (driver)	3＋1 (driver)
Battery	Lead-acid storage battery (Lifespan: 500 charging times／1.5 years)(Voltage: 60V, capacity: 140Ah)	Lithium-ion battery (Lifespan: 1500 charging times／2 years)(Voltage 48V, capacity: 78Ah)
Maximum speed	25km/h	40km/h
Distance	90km	80km
Charging time	8－12h	4h
Price (tax excluded)	1,900USD (Battery: 800USD)	4,500USD (Battery: 1,600USD)
Evaluation from local areas	Many opinions show dissatisfaction on both design and maximum speed ✕	○

※Because it is still under development stage, the specifications may change.

Aside from the fact that Auto tricycles have higher prices than LPG tricycles, their batteries also need to be replaced every 2 years, so regarding the costs, Auto Tricycles definitely cannot compete with LPG ones.

In addition to appealing its technological advancement, environmental friendliness, noticeability, innovative car body design, safe and secure driving, high-quality customer service with Japanese style are required.

(2) Charging station

Charging station is expected to use solar power or biomass power. As for biomass power, it has been considered specifically in Chapter 3, so in this section, solar powered charging station will be considered.

It is planned to build 5 charging stations in the city, and each station can charge battery sets for 20 electric tricycles. The battery is removable, so each vehicle will be prepared with another replacement battery. When the tricycle is about to run out of battery, it can go to the station for a replacement with a fully charged battery. By this way, it helps to assure daily travel distance.

Each charging station will need the solar power generation with rated capacity of 40 kW and need to cover the cost for 20 spare battery sets, so each station has initial costs of around 162,000 USD.

Table 2.2.2 Costs for putting charging station into operation(one station)

Item	Specifications & quantities, etc.	Estimated costs
Replacement battery	・Lithium-ion battery ・Voltage 48V, capacity 78Ah ・20 sets for 20 tricycles	・32,000USD (＝1,600USD×20 sets)
Solar power generation	・Norm-based capacity: 40kW ・Installation area: ~300 ㎡	・130,000USD (land rental fee excluded)
Total estimated costs		・162,000USD

2.2.2 Efficiency of CO2 reduction

(1) Reference emissions

Reference emissions is calculated based on the following formula, referring to anamnestic methodology (AMS-III.C) and anamnestic research report[4]. The set value is shown in Table 2.2.3

$$RE_y = \sum_i((DD_y/SFC_{RE}) \times IR^y \times NCV_{LPG} \times EF_{LPG} \times N_y)$$

$$= 11{,}999/30 \times 0.99^1 \times 23.4 \times 0.0616 \times 10^{-3} \times 100$$

$$= 57 tCO2/y$$

In which,

RE_y : Reference emissions (tCO2/y)

DD_y : Average running distance of electric tricycle used in the project in y year (km)

SFC_{RE} ：Fuel consumption capacity of referenced vehicle model (km/L)

IR^y ：Coefficient of improvement in fuel consumption capacity of referenced vehicle model (LPG tricycle) in y year (－)

NCV_{LPG} ：Net calorific value of LPG (MJ/L)

EF_{LPG} ：CO2 emissions coefficient of LPG (tCO2/MJ)

N_y ：Number of vehicles used in the project (electric tricycles) in y year (unit)

Table 2.2.3 Set values of referenced exhaust emissions and other parameters

Parameter	Value	Basis for set values & parameters
DD_y	11,999(km) (40km/day×300day)	・Survey results of anamnestic report[4] エラー! ブックマークが定義されていません。 ・Although it was said at hearings of the Phnom Penh Remorque association that the average driving distance 50 to 75 km/day[5], the figures in the above report were used from a conservative viewpoint.
SFC_{RE}	30(Km/L)	・See Table 2.1.3
IR^y	0.99	・Set value of anamnestic report[4]
NCV_{LPG}	23.4 (MJ/L)	・Calculated result[6、7] from NCV : 44.8MJ/kg and fuel density : 522.2kg/m^3
EF_{LPG}	0.0616×10^{-3} (tCO2/MJ)	・Set value of anamnestic report[6]
N_y	100 (unit)	・Number of vehicles used in the project

(2) Project emissions

Electric tricycles are charged at charging stations using solar power or biomass power, so exhaust emission of this project is 0.

$PE_y = 0$

In which

PE_y ：is the exhaust emission amount of the project (tCO2/year)

(3) Emissions reduction

The emissions reduction is calculated based on the difference between reference emissions and the project emissions. The project period is set to be 3 years based on “Ministerial Ordinance Concerning the Useful Life of Depreciable Assets”, in which shows the statutory useful life of “Vehicles used in transportation business, car for rent”, “Automobile (including 2-wheel and 3-wheel vehicles, except for omnibus), “Small-sized vehicles (vehicle with emissions 2L or less)” is 3 years.

1) Annual emissions reduction ER_y

$$ER_y = RE_y - PE_y$$

$$= 57(\text{tCO2/y}) - 0$$

$$= 57\ (\text{tCO2/y})$$

2) Emissions reduction during project period ER_p

As shown in Table 2.2.4, total amount of emission reduction during the project period (statutory useful life; 3years) is 168tCO_2. The project emissions are fixed. On the other hands, the reference emissions may be less but according to the improvement on fuel consumption of referenced vehicles (LPG tricycle), which leads to lesser emissions reduction.

Table 2.2.4 Emissions reduction during the project period

Year	1	2	3	Total
Reference emissions (tCO2)	57	56	55	168
Project emissions (tCO2)	0	0	0	0
Emission reduction (tCO2)	57	56	55	168

2.2.3 JCM equipment subsidy・Cost effectiveness

The JCM equipment subsidy, based on the following formula, will be 672,000 Yen, which is the product of the cost-effectiveness (4,000 Yen/tCO2), the minimum level required to be achieved to be chosen in JCM subsidized project, and CO2 emissions reduction during project period.

【JCM equipment subsidy】

=【Cost-effectiveness (4,000 Yen/tCO2)】×【Emissions reduction during project period (168tCO2)】

= 672,000 Yen ≒ 6,000USD（it is assumed that 1USD=111Yen）

2.2.4 Business profitability

(1) Initial costs

Regarding initial costs, we assume 2 cases: Case1 (taxi business operator bears costs of introducing charging stations) and Case 2 (taxi business operator does not bear costs of introducing charging stations).

<u>Case1: Taxi business operator bears costs of building charging station</u>

Initial investment cost in this case will cover additional costs of construction & equipment for charging stations.

Table 2.2.5 Initial costs (charging station included)

Item	Unit cost (USD)	Quantity	Total (USD)
Electric tricycle	4,500	100 vehicles	450,000
Replacement battery	1,600	100 sets	160,000
Charging station(solar power)	130,000	5 stations	650,000
JCM supported device	—	—	-6,000
Total initial costs			1,254,000

※It is assumed that taxi business operator rented land for charging stations.

※It is assumed that tricycles and replacement batteries are not subject to tariffs thanks to the agreement with

Phnom Penh capital.

Case2: Taxi business operator does not have to bear costs of building charging stations

In this case, it is assumed that a company in renewable energy field (solar power or biomass power) will act as a business operator of electric tricycles. By then, initial costs will not include costs of building charging stations.

Table 2.2.6 Initial costs (charging stations excluded)

Item	Unit cost (USD)	Quantity	Total (USD)
Electric tricycle	4,500	100 vehicles	450,000
Replacement battery	1,600	100 sets	160,000
JCM supported device	—	—	-6,000
Total initial costs			604,000

※It is assumed that both tricycles and replacement batteries are not subject to tarrifs thanks to the agreement with Phnom Penh capital.

(2) Costs

Costs for one year are shown in the table below.

Table 2.2.7 Cost details in one year

Item	Unit cost (USD)	Quantity	Total (USD)	Remarks
Charging	0	0	0	
Maintenance	1,200	100 vehicles	120,000	Annual
Replacement of batteries	1,600	200 sets	320,000	Every 2 years
Personnel expenses	—	—	220,000	Annual
Land rental	72,000	5 places	360,000	Only applicable to Case 1

(3) Income

Income from transport fares in one year is divided into cases as follows. Travel distance in 1 year is calculated based on the existing report[4], and the number of transport times in 1 year calculated based on the assumption of 10 times for 1 day (4km/ each time of transport x 10 times).

Annual income A: in case of fares are equal to fares of LPG tricycles (currently)

Annual income B: in case of increasing Case A's fares from 0.25 USD/km up to 0.5 USD/km

Annual income C: in case of increasing Case A's fares from 0.25 USD/km up to 1.0USD/km

Annual income from fares in case A: fares are equal to fares of current LPG tricycles

In this case, annual income gained when doing business with fares level equal to fares of current LPG tricycles

Table 2.2.8 Annual income A (fares equal to fares of current LPG tricycles)

Item	Quantity	Fare	Income	Remarks
Annual Number of transport	3,000 times/vehicle	0.75USD/each time	2,250USD/vehicle	10times/day×300 days
Annual Travel distance	11,999 km/vehicle	0.25USD/km	2,999USD/vehicle	40km/day×300 days
Income gained from transport fares (per vehicle)			5,249USD/vehicle	
Income from transport fares (100 vehicles)			524,900 USD	

Annual income from fares in case B: fares/km increase up to 0.5USD/km

In this case, annual income gained when flag drop/starting fare is still equal to fares of current LPG tricycle, and fares for next kilometers increase from 0.25 USD/km up to 0.5 USD/km.

Table 2.2.9 Annual income B (when fares/km increase to 0.5 USD/km)

Item	Quantity	Fare	Income	Remarks
Annual Number of transport	3,000 times/vehicle	0.75USD/each time	2,250 USD/vehicle	10 times/day×300 days
Annual Travel distance	11,999 km/vehicle	0.5USD/km	5,999 USD/vehicle	40km/day×300 days
Income gained from transport fares (per vehicle)			8,249 USD/vehicle	
Income from transport fares (100 vehicles)			824,900 USD	

Annual income from fares in case C: fares/km increase up to 1.0USD/km

In this case, annual income gained when flag drop/starting fare is still equal to fares of current LPG tricycle, and fares for next kilometers increase from 0.25 USD/km up to 1.0 USD/km.

Table 2.2.10 Annual income C (when fares/km increase to 0.5 USD/km)

Item	Quantity	Fare	Income	Remarks
Annual Number of transport	3,000 times/vehicle	0.75USD/each time	2,250 USD/vehicle	10 times/day×300 days
Annual Travel distance	11,999 km/ vehicle	1.0USD/km	11,999 USD/vehicle	40 km/day×300 days
Income gained from transport fares (per vehicle)			14,249 USD/vehicle	
Income from transport fares (100 vehicles)			1,424,900 USD	

(4) Business profitability

Based on figures of initial costs, operation costs and income as shown above, we made cash-flow calculations and evaluated the profitability of each case: Case 1 (taxi business operator bears costs of building charging station), and Case 2 (taxi business operator does not bear costs of building charging station). The results are as follows:

- If model of annual income A is applied, both Case 1 and Case 2 are not feasible (Table 2.2.11、Table 2.2.12).
- As for case 1, if model of annual income C (fares increase to 1.0 USD/km) is applied, it will be profitable. Specifically, IRR (internal rate of return) is 48.5% in 6 years, and recovery period of initial cost is 2 years (Table 2.2.13).
- As for Case2, it may be profitable if model of annual income B (fares increase to 0.5 USD/km) is applied. Specifically, IRR (internal rate of return) is 65.7% in 6 years and recovery period of initial cost is 1.3 years. (Table 2.2.14)

Table 2.2.11 Cash-flow worksheet (Case1: taxi business operator bears costs of charging stations + model of annual income A (fares are equal to fares of current LPG tricycles))

Year	0	1	2	3	4	5	6
1. Income(USD)	0	524,900	524,900	524,900	524,900	524,900	524,900
		524,900	524,900	524,900	524,900	524,900	524,900
2. Expenses(USD)	-1,254,000	-700,000	-1,020,000	-700,000	-1,020,000	-700,000	-1,020,000
Electric tricycle	-450,000						
Battery	-160,000						
Solar charging station	-650,000						
JCM Subsidy	6,000						
Fuel cost (electricity charge)		0	0	0	0	0	0
Maintenance cost		-120,000	-120,000	-120,000	-120,000	-120,000	-120,000
Battery replacement cost			-320,000		-320,000		-320,000
Personnel expenses		-220,000	-220,000	-220,000	-220,000	-220,000	-220,000
Ground rent		-360,000	-360,000	-360,000	-360,000	-360,000	-360,000
3. Profit before depreciation(USD)	-1,254,000	-175,100	-495,100	-175,100	-495,100	-175,100	-495,100
4. Depreciation(USD)	0	242,500	242,500	242,500	242,500	130,000	0
Depreciation of Electric tricycle		112,500	112,500	112,500	112,500		
Solar charging station		130,000	130,000	130,000	130,000	130,000	
5. Profit after depreciation(USD)	-1,254,000	-417,600	-737,600	-417,600	-737,600	-305,100	-495,100
6. Tax(USD) Corporation Tax(20%)		0	0	0	0	0	0
7. Profit of the current term(USD)	-1,254,000	-417,600	-737,600	-417,600	-737,600	-305,100	-495,100
8. Cash flow(USD)	-1,254,000	-175,100	-495,100	-175,100	-495,100	-175,100	-495,100
Accumulation of Cash	-1,254,000	-1,429,100	-1,924,200	-2,099,300	-2,594,400	-2,769,500	-3,264,600

Table 2.2.12 Cash-flow worksheet (Case2: taxi business operator does not bear costs of charging stations + model of annual income A (fares are equal to fares of current LPG tricycles))

Year	0	1	2	3	4	5	6
1. Income(USD)	0	524,900	524,900	524,900	524,900	524,900	524,900
		524,900	524,900	524,900	524,900	524,900	524,900
2. Expenses(USD)	-604,000	-340,000	-660,000	-340,000	-660,000	-340,000	-660,000
Electric tricycle	-450,000						
Battery	-160,000						
Solar charging station	0						
JCM Subsidy	6,000						
Fuel cost (electricity charge)		0	0	0	0	0	0
Maintenance cost		-120,000	-120,000	-120,000	-120,000	-120,000	-120,000
Battery replacement cost			-320,000		-320,000		-320,000
Personnel expenses		-220,000	-220,000	-220,000	-220,000	-220,000	-220,000
Ground rent		0	0	0	0	0	0
3. Profit before depreciation(USD)	-604,000	184,900	-135,100	184,900	-135,100	184,900	-135,100
4. Depreciation(USD)	0	112,500	112,500	112,500	112,500	0	0
Depreciation of Electric tricycle		112,500	112,500	112,500	112,500		
5. Profit after depreciation(USD)	-604,000	72,400	-247,600	72,400	-247,600	184,900	-135,100
6. Tax(USD) Corporation Tax(20%)		-14,480	0	-14,480	0	-36,980	0
7. Profit of the current term(USD)	-604,000	86,880	-247,600	86,880	-247,600	221,880	-135,100
8. Cash flow(USD)	-604,000	199,380	-135,100	199,380	-135,100	221,880	-135,100
Accumulation of Cash	-604,000	-404,620	-539,720	-340,340	-475,440	-253,560	-388,660

Table 2.2.13 Cash-flow worksheet (Case1: taxi business operator bears costs of charging stations + model of annual income C (fares increase up to 1.0USD/km))

Year	0	1	2	3	4	5	6
1. Income(USD)	0	1,424,900	1,424,900	1,424,900	1,424,900	1,424,900	1,424,900
		1,424,900	1,424,900	1,424,900	1,424,900	1,424,900	1,424,900
2. Expenses(USD)	-1,254,000	-700,000	-1,020,000	-700,000	-1,020,000	-700,000	-1,020,000
Electric tricycle	-450,000						
Battery	-160,000						
Solar charging station	-650,000						
JCM Subsidy	6,000						
Fuel cost (electricity charge)		0	0	0	0	0	0
Maintenance cost		-120,000	-120,000	-120,000	-120,000	-120,000	-120,000
Battery replacement cost			-320,000		-320,000		-320,000
Personnel expenses		-220,000	-220,000	-220,000	-220,000	-220,000	-220,000
Ground rent		-360,000	-360,000	-360,000	-360,000	-360,000	-360,000
3. Profit before depreciation(USD)	-1,254,000	724,900	404,900	724,900	404,900	724,900	404,900
4. Depreciation(USD)	0	242,500	242,500	242,500	242,500	130,000	0
Depreciation of Electric tricycle		112,500	112,500	112,500	112,500		
Solar charging station		130,000	130,000	130,000	130,000	130,000	
5. Profit after depreciation(USD)	-1,254,000	482,400	162,400	482,400	162,400	594,900	404,900
6. Tax(USD) Corporation Tax(20%)		-96,480	-32,480	-96,480	-32,480	-118,980	-80,980
7. Profit of the current term(USD)	-1,254,000	578,880	194,880	578,880	194,880	713,880	485,880
8. Cash flow(USD)	-1,254,000	821,380	437,380	821,380	437,380	843,880	485,880
Accumulation of Cash	-1,254,000	-432,620	4,760	826,140	1,263,520	2,107,400	2,593,280

Table 2.2.14 Cash-flow worksheet (Case 2: taxi business operator does not bear costs of charging stations + model of annual income B (fares/km increase up to 0.5USD/km))

Year	0	1	2	3	4	5	6
1. Income(USD)	0	824,900	824,900	824,900	824,900	824,900	824,900
		824,900	824,900	824,900	824,900	824,900	824,900
2. Expenses(USD)	-604,000	-340,000	-660,000	-340,000	-660,000	-340,000	-660,000
Electric tricycle	-450,000						
Battery	-160,000						
Solar charging station	0						
JCM Subsidy	6,000						
Fuel cost (electricity charge)		0	0	0	0	0	0
Maintenance cost		-120,000	-120,000	-120,000	-120,000	-120,000	-120,000
Battery replacement cost			-320,000		-320,000		-320,000
Personnel expenses		-220,000	-220,000	-220,000	-220,000	-220,000	-220,000
Ground rent		0	0	0	0	0	0
3. Profit before depreciation(USD)	-604,000	484,900	164,900	484,900	164,900	484,900	164,900
4. Depreciation(USD)	0	112,500	112,500	112,500	112,500	0	0
Depreciation of Electric tricycle		112,500	112,500	112,500	112,500		
5. Profit after depreciation(USD)	-604,000	372,400	52,400	372,400	52,400	484,900	164,900
6. Tax(USD) Corporation Tax(20%)		-74,480	-10,480	-74,480	-10,480	-96,980	-32,980
7. Profit of the current term(USD)	-604,000	446,880	62,880	446,880	62,880	581,880	197,880
8. Cash flow(USD)	-604,000	559,380	175,380	559,380	175,380	581,880	197,880
Accumulation of Cash	-604,000	-44,620	130,760	690,140	865,520	1,447,400	1,645,280

2.3 Examination of monitoring method

The formulas for calculating reference emissions and project emissions are below. Methods for setting parameters are shown in Table 2.3.1. Parameter that needs to be monitored is the average travel distance of vehicle in the project DD_y. It will be set by measuring and aggregating with devices such as GPS.

【Reference emissions】

$$RE_y = \sum_i((DD_y/SFC_{RE}) \times IR_y \times NCV_{LPG} \times EF_{LPG} \times N_y)$$

【Project emissions】

$$PE_y = 0$$

Table 2.3.1 Method of parameters calculation in formula for calculating referenced emissions

Parameter	Explanation	Calculation method
DD_y	Average travel distance of vehicles used in the project in y year (km)	・Install a device for measuring distance (GPS) on all electric tricycles used in the project to measure daily travel distances, then aggregate them.
SFC_{RE}	Fuel consumption capacity of referenced vehicle (Km/L)	・Specifications of LPG tricycles (values announced by makers)
IR_y	Coefficient of improvement on fuel consumption capacity of referenced vehicle in y year (－)	・Check default values in C D M AMS-111.C. ・In case of announced national data available , use that data.
NCV_{LPG}	net calorific value of LPG (MJ/L)	・Results calculated with values given in anamnestic report[6,7], specifically, NCV = 44.8MJ/kg and Fuel density = 522.2kg/m^3. ・In case of announced national data available , use that data.
EF_{LPG}	CO2 emission coefficient of LPG (tCO2/MJ)	・Set based on anamnestic report[6]. ・In case of announced national data available , use that data.
N_y	Number of vehicles used in the project in y year (vehicle)	・Number of vehicles put into use in the project

2.4 Examination of business structure

The business structure of the project is expected to be built based on international consortium, including a representative company (Japanese company), and a partner participant (a local company with Japanese capital) acts as practical operator of taxi business. Fig. 2.4.2 shows the role of representative business operator, partner participant and other related parties.

Regarding a partner participant, it is desirable not to be an existing local taxi operator but a Japanese-affiliated company that can operate a Japanese taxi (Attendance management of drivers, driving training for drivers, response to accidents, maintenance of cars etc.).

In addition, if taxi project by electric tricycle is carried out independently, CO2 emission reduction is not much, so it will be difficult to get financial aid from JCM. Therefore, it is necessary to cooperate with renewable energy providers such as in solar power or biomass power field in order to get financial aid, and reduce project costs.

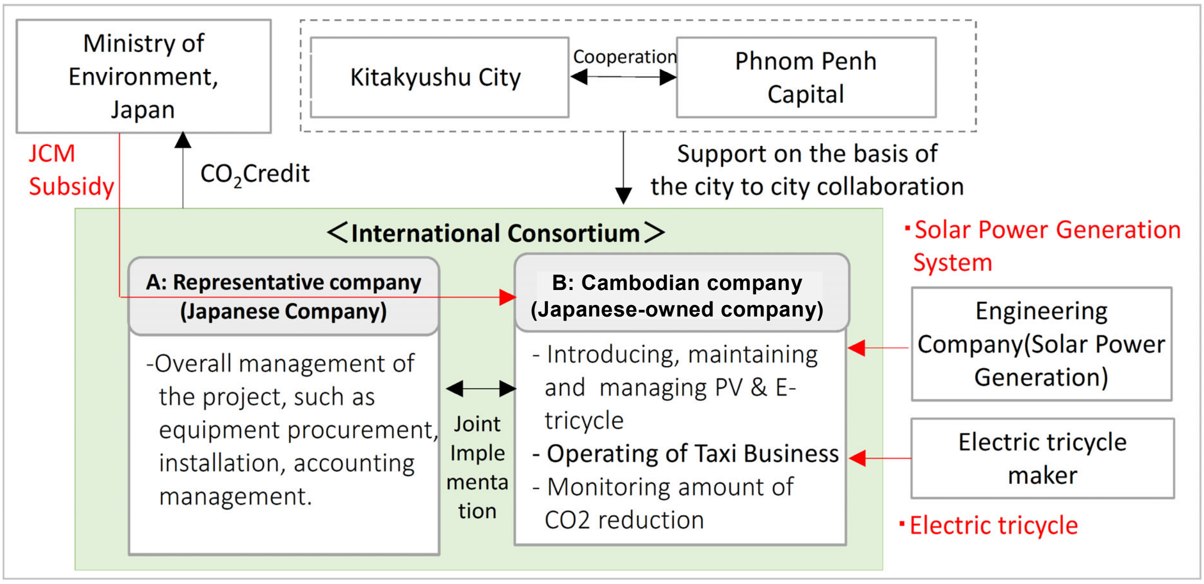

Fig. 2.4.3 Project implementation structure (taxi business by electric tricycles)

2.5 Examination of fund procurement methods

Basically, the remaining business funds (initial cost) excluding JCM facility subsidies will be self-funded by the partner participant. Besides, capital will be mobilized via income sources from vehicle advertisements.

2.6 Examination of project implementation schedule

After being selected as a JCM subsidized project, implementation schedule is estimated as follows: 1) Charging station

1) Charging station

・In case of using solar power:

Design・Equipment procurement・installation・test run: about 6 months

・In case of using biomass power:

Design・Equipment procurement・installation・test run: about 1.5 years

2) Electric tricycle

・Tricycle procurement: about 2 months

・Development & implementation on drivers' attendance management system, etc.: about 1 year

2.7 Summary and challenges for the future

・In the electric tricycle business, it is essential to cooperate with the dispatch application service and the bus location system that JICA is introducing as the existing LPG tricycles carry out.

・Regarding the profitability of electric tricycle project, if transport fares are equal to fares of current

LPG tricycles, it is not profitable. However, if fares/km are increased from 0.25 to 0.5 USD/km (equivalent to 28~56 Yen/km), profitability will be higher. By then, target customers of this service are expected to be people with good income and tourists. It is necessary for the electric tricycle to differentiate it from LPG tricycle by appealing its technological advancement, environmental friendliness, noticeability, and innovative car body design, safe and secure driving, high-quality customer service with Japanese style.

・In case only taxi business by electric tricycles is considered, CO2 emission reduction is not much, so it is likely that it will not be eligible for JCM subsidized project. In order to take advantage of JCM subsidy, it is necessary to cooperate with another company which will introduce the solar power/biomass power, etc. to ensure that CO2 emissions reduction and meet JCM criteria (The electricity company will become the representative company).

・According to the comprehensive urban transport plan (PPUTMP), tuk-tuk is still expected to serve as a feeder system for bus and train system in the suburbs. It is important not only to simply introduce electric tricycles but also to work on environmentally sustainable transportation (EST), such as contributing to the promotion of use of public route buses in cooperation with “The Project for Improvement of Public Bus Operation in Phnom Penh” of JICA.

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[3] JETRO, Basic knowledge of Cambodia economy, Department of Public Works and Transport

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[5] FY2016 Feasibility Study of Joint Crediting Mechanism Project by City to City Collaboration (Phnom Penh City Climate Change Strategic Action Plan(Kitakyushu City - Phnom Penh City Collaboration Project)), Nikken Sekkei Civil Engineering Ltd, Kitakyushu Asian Center for Low Carbon Society (Project to support strategic climate change action planning for Phnom Penh (Collaborative project between Kitakyushu city and Phnom Penh city))

[6] 2006 IPCC Guidelines for National Greenhouse Gas Inventories

[7] IEA、Energy Statistics Manual

Chapter 3 Feasibility study for JCM project (Green production field: Agricultural biomass power plant project)

3.1 Current situation

3.1.1 Abundance of biomass resource

When considering the implementation of biomass power plant project, it is crucial to ensure that a sufficient supply of agricultural residues can be secured as fuel for the production process; therefore, we first conducted a survey on agricultural residues in Cambodia.

Fig. 3.1.1 and Fig. 3.1.2 show the cultivation area and agricultural output of Cambodia in 2016. In terms of cultivated area, rice ranked as the most cultivated crop, followed by cassava, and natural rubber respectively. Cassava and rice are the most pre-eminent crops in terms of output. According to interview results with local trading broker and supermarkets, there are no agricultural legal entities to secure a stable and large supply of fruits and vegetables, resulting in dependency on imported sources. It is thus far difficult to ensure agricultural residues supply.

On the other hand, according to "National Strategic Development Plan 2014-2018", coupled with improving productivity in the agricultural sector, the Cambodian government has also promoted the slogan of "crops diversification"; nevertheless, it seems that agricultural facilities related to three kinds of crops like rice, cassava and natural rubber can be stably secured agricultural residues which become fuel for biomass power plant at present.

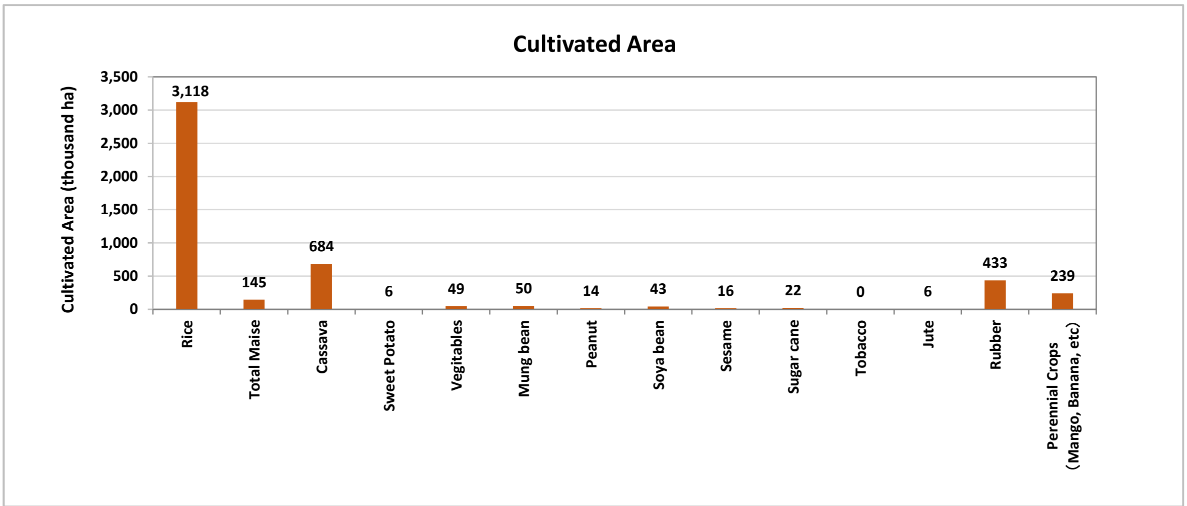
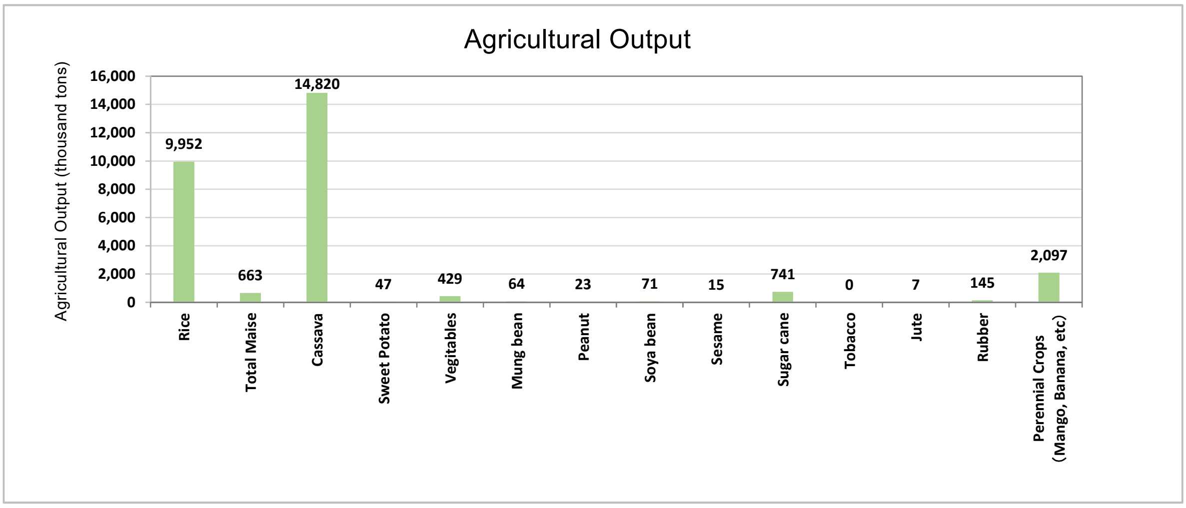


Fig. 3.1.1 Crop cultivation area (2016)[1]



Fig, 3.1.2 Agricultural Output (2016) [1]

Furthermore, based on field survey results, we found that there is a considerable large amount of unused residues in palm oil production plant. This suggests that it may be possible to use them as a fuel to produce biomass electricity.

Contents regarding production situation of agricultural residues generated by rice, cassava, natural rubber industry, and unused residues from palm oil mills; usage method, and their potential as biomass fuel are represented in following sections.

(1) Rice

■ Output

Changes in annual rice production and cultivation are shown in Fig. 3.1.3 which exhibits a rising trend in both production and cultivated area.

Despite being decidedly overtaken by Thailand, Myanmar, output per hectare of harvested land in Cambodia has edged upward, compared to those of other countries in the region. However, it only stood at a rate of 60 %, compared to Vietnam (see Fig. 3.1.4). This is because Cambodia, given the lack of a good irrigation system in many areas, could afford only one crop in rainy season (from May to October) compared to Vietnam where the twon or three cropping is basically popular. In the future, when irrigation system is better developed, the rice production will be further increased.

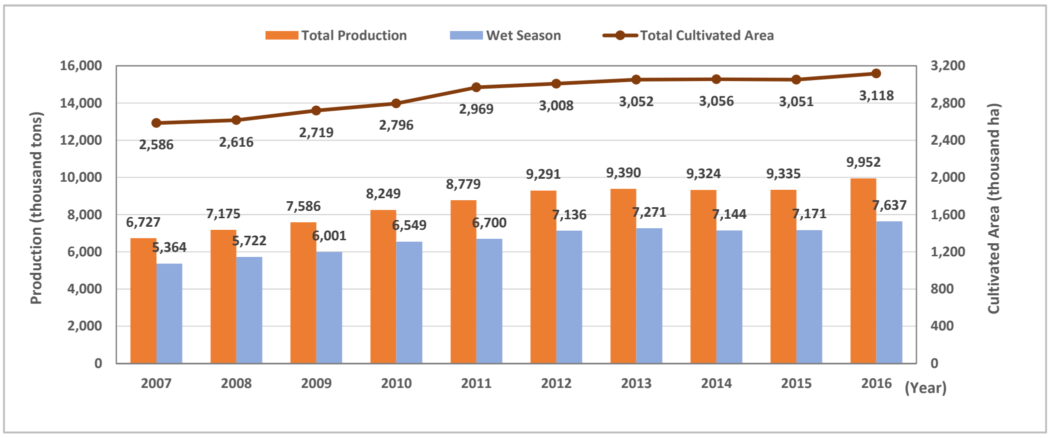


Fig. 3.1.1 Annual changes in rice yields and cultivated area in Cambodia [1]

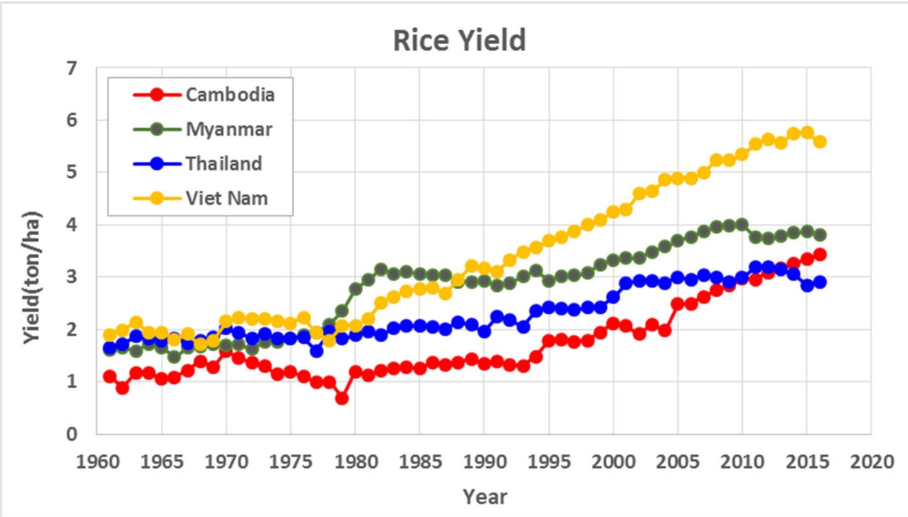


Fig. 3.1.4 Comparison of rice yield per 1ha with other countries in the region [2]

■ Usability and usage method as biomass fuel

Rice husk – byproduct of rice milling can be used as fuel for biomass power plant. There are 2 methods to generate electricity from rice husk: direct combustion, and gasification.

Direct combustion is a method in which fuel is burned in a boiler, to generate high-temperature, high-pressure water steams, which rotate the turbine to turn electricity generators.

Gasification is a method of steaming and burning rice husk, using much smaller amount of air compared to conventional combustion, wherein combustible gases (carbon monoxide or hydrogen) are later recovered and transferred to the engine for electricity generation.

As a place to introduce rice husk powr plant, rice mills with easy rice husk securing and power demand is most effective and efficient.

(2) Cassava

■Characteristics and production of cassava

This is a species of perennial plant in the Euphorbiaceae, in which above ground parts grow into shrub, while underground parts parted into fleshy tuberous roots. Cassava is used as staple food, animal food, or raw material to produce starchy staples. Cassava not only offers a high value of crop yield, and high level of dry matter content, but also effortless cultivation, thanks to its resilience to natural disasters such as drought, so that its output can be safely secured.[3]

As shown in Fig. 3.1.7, cassava production or harvested area in Cambodia since 2006 has increased significantly. Since 2006, improving income from cassave has been driven predominantly by a clear and stable demand, which in turn also strengthens domestic price. Backed by its short duration of less than 1 year after planting, and high liquidity, farmers were motivated to grow cassava, leading to the expansion of cassava farming area.[4]

Notwithstanding, at present, price of dried cassava is experiencing a significant deceleration, posing a challenge to Cambodian cassava producers. This results from a structural problem that there are only 2 small-scale cassava processing factories in Cambodia, pushing many producers to export their unprocessed products to neighboring countries, such as Thailand or Vietnam at low prices.[5]

In the interviews with locals, it is learned that in Cambodia, cassava tubers are cut into thin slices and dried after harvest, and then exported, while production of starch which has higher profit is gained in Thailand.

■ Usability and usage method as biomass fuel

For parts of stems and leaves excluding potatoes, except for the seedlings next time planting, they are thought to be piled up and disposed at the edges of the farm; therefore, it is possible to use them as fuel for biomass electricity production system. On contrary, this requires a certain amount of expenditure to collect and transport them from numerous farms.

Cassava is a crop that produces starch; therefore, it is possible to produce ethanol through the process of saccharification. In particular, NEDO conducted practical testing projects on the production of bioethanol from residues (tapioca) discharged from cassava starch production plants.[6]

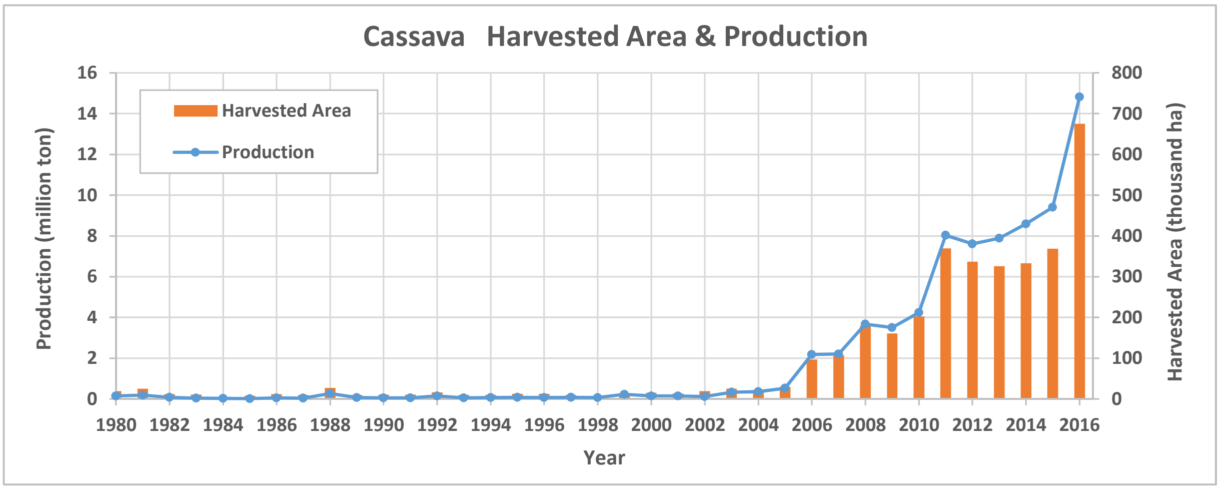


Fig. 3.1.2 Cassava harvest area and production volume

(Data from 1980 ～ 2015: retrieved from FAO data (however, data from 2012 ～ 2015 is estimated value) [2], 2016's data: retrieved from Annual report for Agriculture forestry and fisheries 2016-2017[1])

(3) Natural rubber

■ Characteristics of natural rubber, increase of output and export

Natural rubber is a macromolecular compound whose main constituent is polyisoprene ($(C_5H_8)_n$) contained in latex. It is originated in Brazil but is now afforested and cultivated mainly in Asian countries such as Thailand, Indonesia and Vietnam.[7]

Natural rubber forest was first introduced in Cambodia by the French when they came here in 1898, and it was officially developed from 1920 onwards, when public land was sold at a discounted price to European enterprises for rubber cultivation. After the Second World War, French enterprises started afforestation, and rubber plantation area were estimated to be around 70,000 ha in 1970. [7]

After that, due to the civil war, and sharp decline in world market prices, natural rubber cultivation was largely dissipated; however, Cambodian government still consideres natural rubber production as a major industry. As such, 7 state-owned enterprises were established in 1997, and the number was picked up to 10 as of 2016, following the expansion of rubber plantation area (total afforestation area of state-owned enterprises, other enterprises and household businesses is approx. 433,000 ha[1])

Annual export of natural rubber has been on the rise at a steady pace, and accelerated up to 53.4 % in 2017, compared to 2016. According to report of the Ministry of Agriculture, Forestry and Fisheries, the production of natural rubber is 189,000 tons, price per ton is 1,586 USD, equal to an increase of 24 %, compared to previous year. Leading export trading partner is China, and export volume is also predicted to increase in 2018.[8]

■Usability and usage method as biomass fuel

Rubber trees after reaching the end of their life cycle of latex collection, will be cut down, and sold to wood processing factories. Substantial amount of waste wood generated during wood processing at these factories could be used as fuel for the biomass power plant.

In Cambodia, wood processing factories are established near rubber plantations, whose main materials are rubber trees; therefore, there is enormous potential to establish biomass power plant in these wood processing factories.[9]

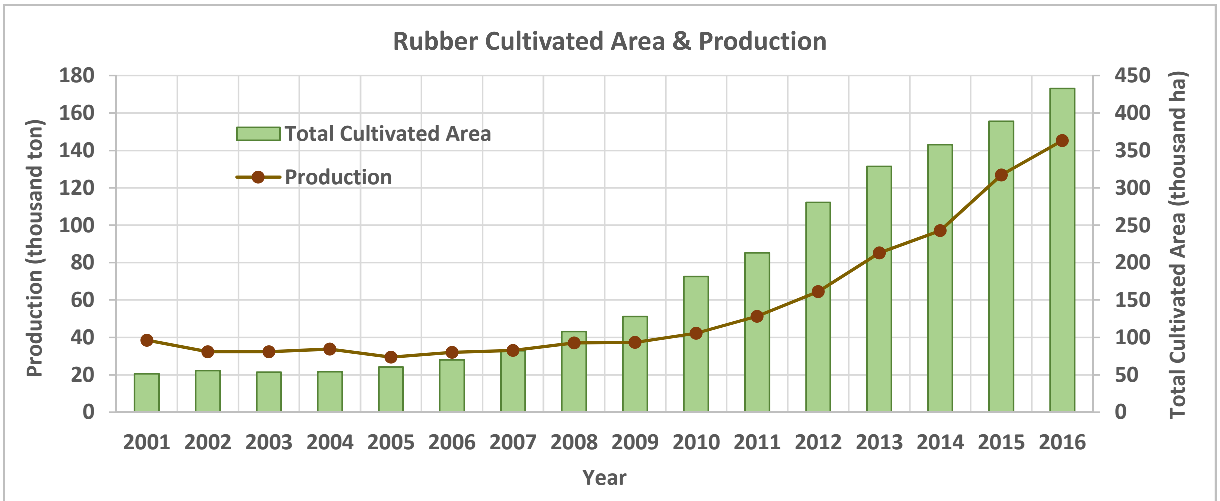


Fig. 3.1.3 Cultivated area and production of natural rubber [1]

Photo 3.1.1 Rubber plantation (Mong Reththy Group's rubber farm)

(4) Unused residues from palm oil mill

■ Survey result of palm oil mill (Mong Reththy Group)

Cambodia's leading conglomerate - Mong Reththy Group [10] founded by Mr. Mong Reththy – a childhood friend with Prime Minister Hun Sen, as they both spent time at a Phnom Penh temple, and is a market leader in import and export and construction industries, owning 2 palm oil mills and palm plantations of approx. 16,000 ha in Preah Sihanouk province.

In addition, in each mill, a biomass power plant (the direct combustion style) is installed, using PKS (Palm Kernel Shell) and palm fiber as fuels which are discharged during the production process and currently used as a power source of each mill. Moreover, excess amount of PKS can also be used for pig farming – another business managed by the same group. This group plans to build a facility to produce methane from POME (Palm Oil Mill Effluent), and aims to effectively use residues from their factories.

However approx. 70% of EFB (Fresh Fruit. Bunch) which can also be used as fuel is finally open dumped in the palm plantation.

Table 3.1.1 Scale of palm oil mills and biomass generation capacity

Contents		First factory	Second factory
Scale of palm oil mill		Fruit consumption 27t/h (max capacity of 30t / h), 20 % for palm oil production	Fruit consumption 45t/h, 20 % for palm oil production
Year of establishment		2011	2014
Operation time		24h/day×28days/month	As mentioned in left column
Power plant	capacity	750KW	1.5MW (current capacity of 1.0MW)
	Installation cost	1.5million USD (used)	2.5million USD (new)
	Fuel	Residues from palm oil production (PKS, palm fiber)	As mentioned in left column
Remarks		—	Planning to build a facility to produce methane from liquid waste (estimate of 2millions USD)

Photo 3.1.2 EFB piles outdoors / outside of palm oil mill

Photo 3.1.3 Boiler (made in Malaysia)

Photo 3.1.4 EFB

Photo 3.1.5 Turbine/ Generator

Photo 3.1.6 PKS (after processed as animal feed)

Photo 3.1.7 Palm Fiber

Photo 3.1.8 Palm fruit

Photo 3.1.9 Crude Palm Oil

■ Capacity and residues usage method

The reason why EFB is not yet used widely as a fuel for biomass power plants is fundamentally due to its high content of potassium. Potassium lowers the melting point of burning ash which is known to be around 1,300 ～ 1,500 °C, down to 500 °C, in case of potassium-rich grass ash. If ash is burned at a temperature above this melting point for a long period time, it will melt, and turn into solid state after cooling. When this process is repeated continuously, it will turn into clinker. Therefore, in case the boiler is not suitable for EFB, it will generate a large amount of clinker which will block the air vents and ash discharge outlet, hindering the proper operation of the boiler. As such, it is necessary to have a boiler compatible with EFB, with temperature control function to set the temperature in the furnace not exceeding 800 ℃, alongside with a grate to prevent ash from being exposed to other temperatures for a long period of time.

For reference, the amount of EFB generated from the bunches consumed by the two mills of the Mong Reththy Group is estimated to be about 16 t / h, and powr plant of about 8 WM is possible. However, at present, Feed-in Tarriff (FIT) on the purchase of renewable-generated electricty is not applied in Cambodia, posing a challenge of securing reasonable rates for selling electricity.

In addition, Japanese companies are starting attempts to supply EFB which semi-carbonaized or pelletized to thermal power plants.[11,12]

3.1.2 Survey of rice mills

The possibility of utilizing rice husk, stem and leaves of cassava, old rubber trees and unused residue (EFB) from palm oil mill, as fuel for biomass power plant is mentioned in section 3.1.1; however, based on the following reasons, it is considered most feasible to set up a biomass power plant with rice husk as fuel in a rice mill.

・At rice mill, securing bulky of rice husk is fairly simple, and the rice mill itself also needs electricity to run rice miller or dryer.

・In Cambodia, there are numerous rice mills having experience in running rice husk powr plant in the past (They are currently broken down and not moving as will be described later in many cases.). Additionally, the rice husk power plant project has been implemented under CDM project (CMD

Project 0363: Angkor Bio Cogen Rice Husk Power Project).

・Cambodia's Second National Communications based United Nations Framework Convention on Climate Change has mentioned the objective of reduction of CO2 emissions by installing rice husk power plants and the feasibility of spreading of this plant seems to be remarkably high.

Thus, we have conducted a feasibility (FS) study of installation of biomass power plnt using rice husk, with main targets being rice mills. In the future, it is desirable to conduct other FS studies in the case of using agricultural residues such as cassava's steams and leaves, old rubber trees and EFB as fuel from the view point of a universal diversification of biomass, suitable to each region in Cambodia.

(1) Scale and numbers of rice mill

According to previous report [13], Cambodia had approx. 20,000 factories which the Ministry of Industry, Minerals and Energy (MIME) grasps in 2012. Notwithstanding, other reports[14] have shown the actual number of rice mill in operation is only about 1/10 of this number (approx. 20,000) , and as mentioned in 3.1.2, the number of large and medium scale rice mills where biomass power plant can be installed is even more limited. In this study, we conducted interviews in Takeo province which prouds to have the second largest rice output in Cambodia from 2016 ~ 2017 and confirmed that there are only 2 medium-large scale mills. In addition, large and medium scale rice mills mainly have their output exported, while output from small and medium-sized rice mills and micro rice mills is for the domestic market.

Table 3.1.2 Table 3.1.2 Number of rice mills by scale (estimated in 2012)[14]

Segment	Rice milling scale	Sales channel	Number of rice mills (factories)
Large scale	More than 10t/h	Direct export	Approx. 10
Medium scale	4～8t/h	Entrusted export	Approx. 30
Small and medium scale	1～2t/h	Domestic market orientation	Approx. 200
Manual	Less than 1t/h	Local end user orientation	Approx. 1,000～1,500

(2) Field survey result

■ Camboida Rice Federation

In order to find rice mills with a high possibility of introducing a biomass power plnat, we visited the Cambodia Rice Federation during the first visit, asked them to introduce mid to large rice mills, and conducted an interview on issues towards implementation of this project and the current situation of rice mills.

Table 3.1.3 illustrates the overview of associations and interview results. Cambodian rice mills are tackling a major problem with high cost of national grid electricity; therefore, there will be a high demand for electricity from rice husk, in order to lower the expense on electricity bills.

At the same time, Thai or Chinese enterprises also express their interest in purchasing rice husk, reflecting an increase in the price of rice husk, and difficulities in sustaining a sufficient supply of rice husk for biomass power plant. Nevetherless, in this survey, calculating the income and expenditure based on the profit on sale of rice hulls and grid electricity at the present time revealed that it is more economical to utilize it as fuel for power generation than to sell rice hsuk.

■ Candidate rice mill for biomass power plant installation

Following the Federation’s introduciton, we visited and discussed with 3 plant mills; two of which - Khmer Foods Group Co., Ltd. and Golden Daun Keo Rice Mill Co., Ltd are planning to install biomass power plant. Survey results at these two factories are highlighted in Table 3.1.4 and 3.1.5.

Khmer Foods Group anticipates to install a 500KW power plant using a rice husk, while Golden Daun Keo Rice Mill expects to implement a 1～2MW plant. Regarding to project implementation method, both companies wish to join the power sale business with Specific purpose company (SPC) established by Japanese companies.

Table 3.1.3 Overview and interview results with Cambodia Rice Federation

Contents	Descripstion
Founded	・2014
Members	・There are 310 organizations in export industry, rice mills, banks, agricultural banks and association members (in which, there are 60 export companies and 169 rice mills) ・Companies that are allowed to join are medium to large scale rice mills
Function	・It is a private association officially recognized by the government, and engages in planning policies related to rice, and liaisonning with the government regarding various issues. ・It acts as an information/ public relations center ・Recently, due to higher electricity prices compared to neighboring countries, the Federation has also submitted to the government, asking for a lower electricity price, upon receiving requests from rice mills. ・The Federation once proposed a plan to establish special agricultural economic zones
Interview Result	・Rice husks are currently of high value, making it difficult to secure a stable supply. Warehouse enterprises of Thailand or China are signing contracts with suppliers to ensure their source of procurement. ・Battambang province and Banteay Meanchey province have 75 rice mills in total. Also, there are many other rice mills in Prey Veng Province, Kampong Cham Province, and Tboung Khmum Province.

Table 3.1.4 Overview of rice mill (Khmer Foods Group Co., Ltd.)

Contents	Khmer Foods Group Co., Ltd.		
Rice mill location	Kam Pong Speu province	Battambang province	Prey Veng province
Capacity	240t/day	480t/day	240t/day
Amount of rice husk generated	60t/day	120t/day	60t/day
Current usage of rice husk	35t/day: Used as fuel for dryer 25t/day: Sold to others	35t/day: Used as fuel for dryer 85t/day: Sold to others	35t/day: Used as fuel for dryer 25t/day: Sold to others
Energy consumption	National grid: 100%	National grid: 100% (Having one 625kW home generator)	National grid: 100%
Grid electricity rate	0.126USD/kWh	0.162USD/kWh	0.162USD/kWh
Operating time	20hours/day×300days	20hours/day×300days	20hours/day×300days
Capacity	・Desired power plant capacity is 500kW		
Project implementation method	・A proposal was made by these rice mills, in hope of coordinating with Japanese enterprises to establish Specific purpose company (SPC), and to implement biomass milling and power project.		
Others	・At first, a pilot 500kW powr plant system will be installed, and if it operates smoothly, the model will be extended to other facilities which have rice husk as their byproduct.		

Table 3.1.5 Overview of rice mill (Golden Daun Keo Rice Mill Co., Ltd.)

Contents	Description	
Rice mill location	Battambang province	Rice mill's address
Capacity	65,000～75,000 t/year	Capacity
Volume of rice husk generated	16,250～18,750 t/year	Volume of rice husk generated
Current usage of rice husk	・Sold to cement plants (18USD/t) ・Partly used as fuel for drying boiler	
Energy consumption	・National grid ・Diesel is partly used as fuel to run the generator	
Grid electricity unit price	・0.16USD/KWh	
Operating time	10hours/day×180days	10hours/day×210days
Capacity	・Desired power plant capacity is 1～2WM (Place of installation: Battambang province)	
Project implementation method	・ It is desired that Japanese-invested specific purpose company (SPC) bears initial cost, then sells power to the rice mill.	

Table 3.1.6 Overview of rice mill (Golden Daun Keo Rice Mill Co.,Ltd) (continued)

Photos (Takeo province)	 Photo: Rice mill from outside   Photo: Miller Photo: Rice sorting machine (Satake brand)

■ Current situation of the universalization of biomass power plant at rice mill

In previous survey [15], it was found that about 80 % of medium and large scale rice mills in the country had experience in installing gasification styles using rice husks (equipment was made in Cambodia, using Indian technology). In addition, it is believed that insufficient management of rice husk coal or waste water, caused by gasification styles had imposed a certain impact on environment at that time.

All 3 factories visited in this survey had installed biomass power plants (in which, 2 using gasification method, 1 using direct combustion style); however, the systems have broken, and left idle ever since.

Moreover, the rice mill surveyed in 2016[16] (Golden Rice Co., LTD.) was located in area without national electricity grid access at that time, thus it used both gas and diesel generators. For gas generator, it is necessary to remove tar residued inside the engine every 10 days, otherwise it cannot run properly (tar were not treated whatsoever, and discharged). It is noted that from 2017, the plant has been able to access to national grid, and the gas generators have been left unused ever since.

As mentioned above, in the year of 2012 and 2013 when some surveys conducted, biomass power plants were once used in medium and large scale mills; however, the areas where these plants located were electrified eventually with national grid, putting these short-lived powr plants made by Indian manufacturers away.

(3) Future concern (Impact of the abolition of preferential duties by the EU)

Regarding the future management situation of medium- to large-scale rice mills targeted for introduction of biomass power plants, future concerns will be the impact of the abolition of preferential duties by the EU.

Currently, Cambodian rice is exported to 65 countries, and export volume has surged in recent years. Export volume in 2016 was about 5 times higher than that of 2010 (see Fig. 3.1.5)

Fragrant rice of Cambodia (Jasmine rice) has contributed a significant share of the prosperity of Cambodia's rice exports, for it has earned World's Best Rice Award for 3 consecutive years since 2012, from World Rice Conference (Quality Evaluation Boards) held by rice traders belongining to world-class Agency for Rice Quality Assessment[17], Along with its high quality, Cambodian rice can enjoy tax exemptions thanks to EBA (Everything But Arms trade agreement) with EU, and competitive advantage in terms of pricing. As seen in Figure 3.1.6, which shows the export volume and ratio by country (2016), the proportion of EU exports to the total export volume is very large, the export volume to EU in 2017 is about 43% (Khmer Times).

Nonetheless, tax will be imposed on Cambodia's and Myanmar's rice when EU adopts safeguard mesure on imported rice, in an effort to protect the rice production in EU country members for 3 years, starting from January 2019. According to local reports and interviews with rice mills, they are worried that there will be major impacts on producers and exporters of rice in Cambodia, and we need to pay attention to upcoming trends.

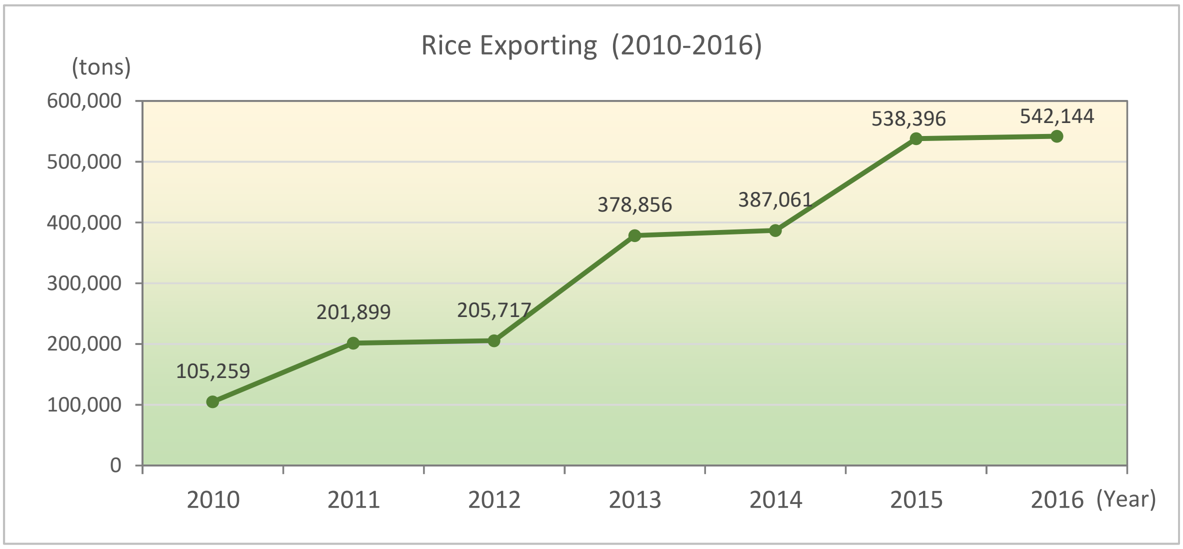


Fig. 3.1.4 Rice exports volume (2010 ~ 2016) [1]

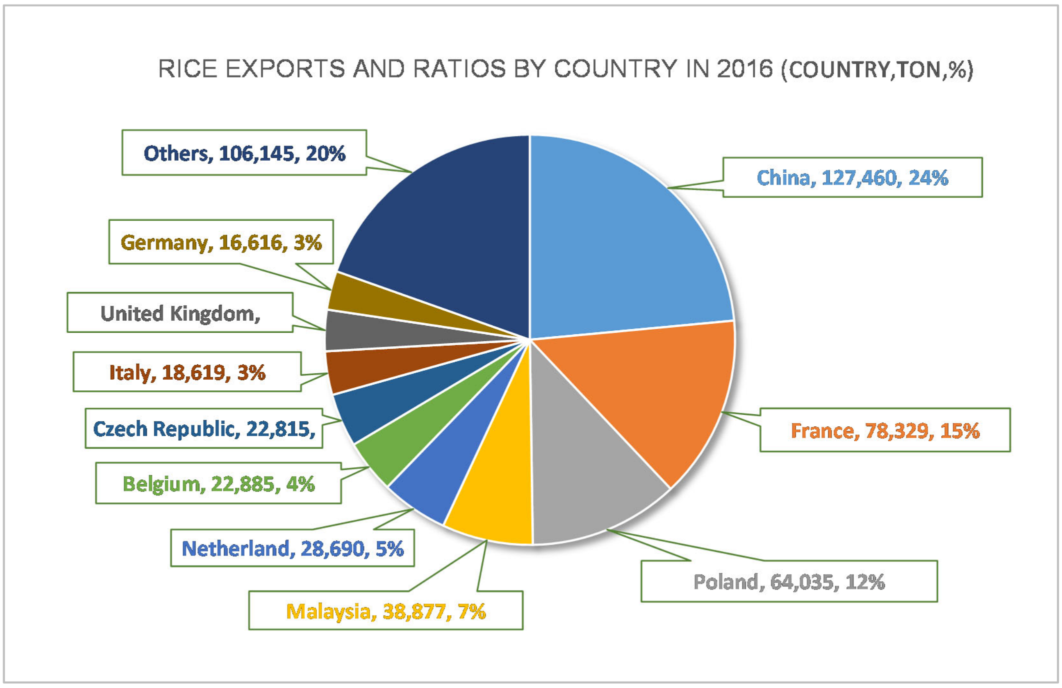


Fig. 3.1.5　Cambodia's rice exports volume and Rice exporters, by Volume in % (2016) [1]

3.2 Examination of introduction technology

In this project, installation of biomass power plant using rice husk to run the equipment rice mills, replacing current electricity supply from national grid, contributes to CO2 emissions reduction. Below are targeted rice mills and their desiered powr plant capacity (according to interview results). Furthermore, we have considered both direct combustion and gasification styles.

1) Khmer Foods Group, powr plant capacity: 500kW

2) Golden Daun Keo Rice Mill, powr plant capacity: 1,000kW

3.2.1 Contents of introduction technology

(1) Direct combustion style

Direct combustion is a method of burning fuel in a boiler, producing high-temperature, high-pressure steam, which rotates the turbine to generate electricity. Generating efficiency is determined by fuel combustion efficiency, turbine performance, generator performance, and power consumption of auxiliary equipment. This style requires a considerable amount of auxiliary equipment which comsumes 10 ~ 12 % of the total power used for the operation of the system. Therefore, in case of a 500kW ～ 2MW, generating efficiency is estimated to be 10 % level.

Fig. 3.2.1 shows system diagram. Fig. 3.2.2 shows Plan and elevation of the facility (Direct combustion style 500kW). Fig. 3.2.3 shows Plan and elevation of the facility (Direct combustion style 1,000kW). Table 3.2.1 shows specification of direct combustion style, and Table 3.2.2 shows facility cost.

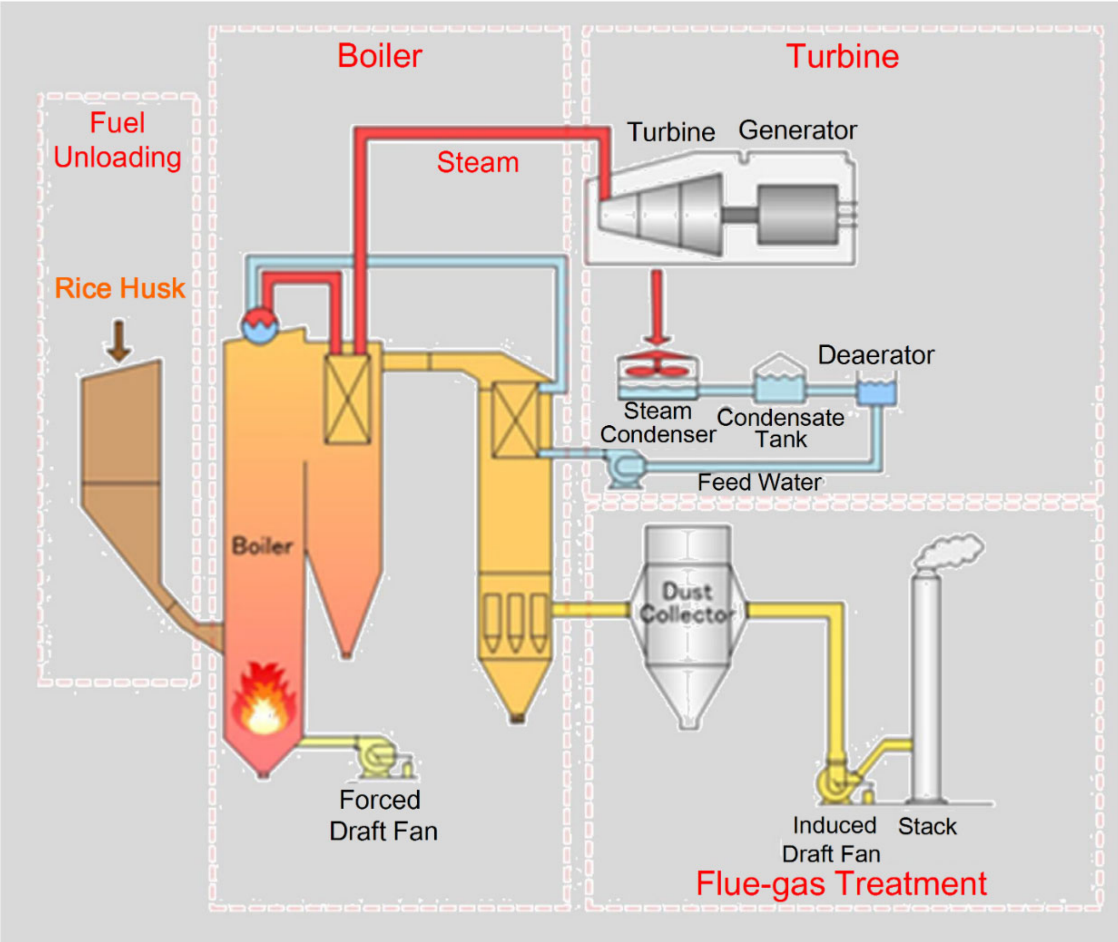


Fig. 3.2.1 System diagram (Direct combustion style)

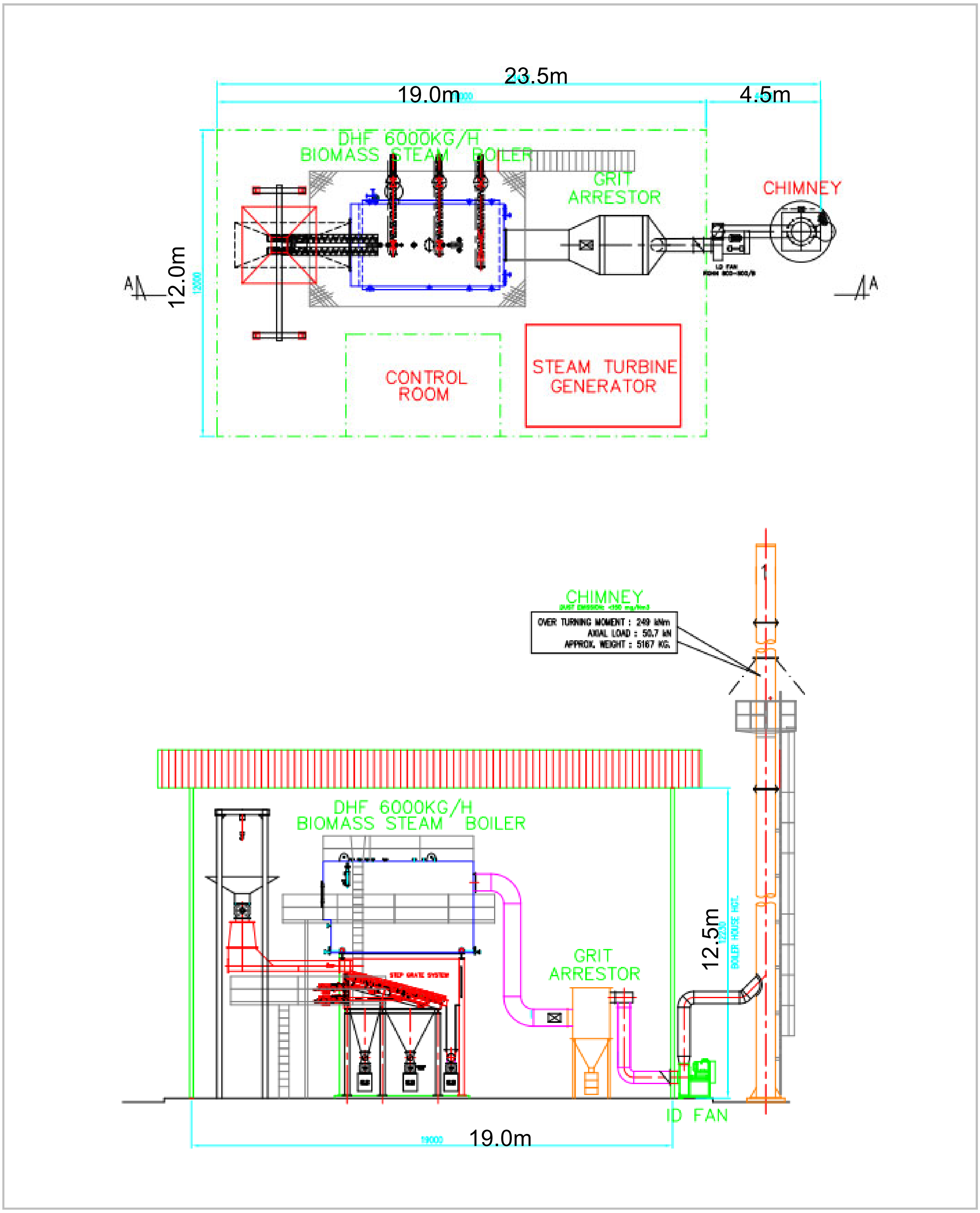


Fig. 3.2.2 Plan and elevation of the facility (Direct combustion style 500kW)

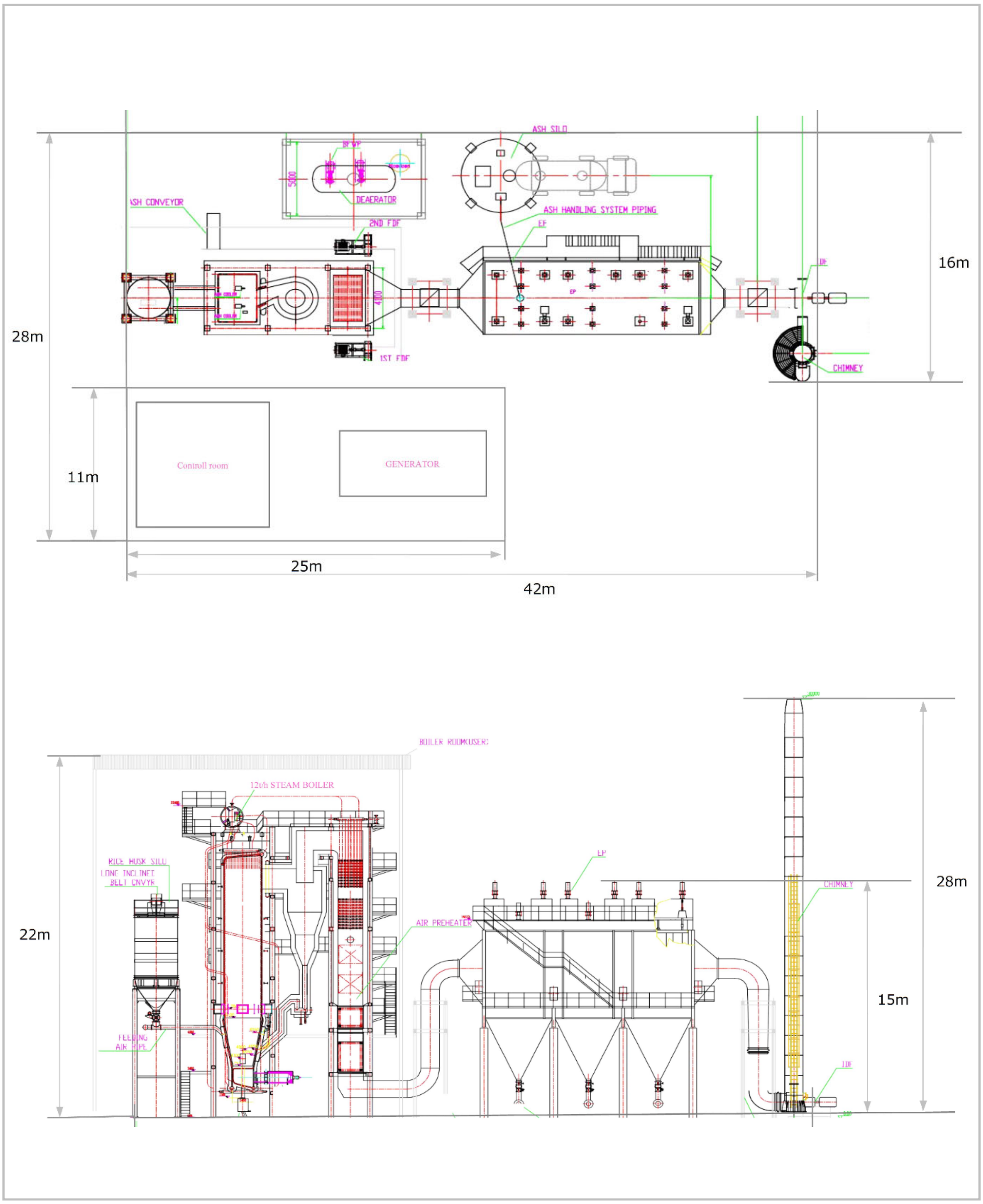


Fig.3.2.3 Plan and elevation of the facility (Direct combustion style 1,000kW)

Table3.2.1 Specification of direct combustion style

Classification	Item	Unit	500kW	1,000KW
Main item	Gross electricity generation	kW	500	1,000
	Power of plant-home use	kW	75	150
	Auxiliary power ratio	%	15	15
	Net electricity generation	kW	425	850
	Generation efficiency(Power generation terminal)	%	18	18
	Generation efficiency(Power transmission end)	%	15	15
Fuel	Fuel	—	Rice husk	Rice husk
	Lower heating value	MJ/kg	13.4	13.4
	Moisture content	%(WB)	10	10
	Fuel consumption	kg/h	800	1,600
Operation	Annual operation time	hours/year	7800 (=325*24)	7800 (=325*24)
	Annual operation days	Days/year	325	325
Steam turbine	Turbine inlet steam	t/h	6	12
		Mpa.g	4	4
		℃	350	350
Boiler	Combustion type	—	Movable stoker	Movable stoker
	Boiler efficiency	%	85	85
	Feed water	t/day	10	10

Table 3.2.2　Facility cost (Direct combustion style)

No.	Item	500kW	1,000kW
1	Biomass Boiler	330,000	600,000
2	Auxiliary	90,000	150,000
3	Feed water and Cooling System	55,000	70,000
4	Fuel feeding system	55,000	60,000
5	Turbine and Generator	500,000	900,000
6	Electric system	90,000	150,000
7	Civil work	200,000	400,000
8	Plan/Design	70,000	100,000
9	Site expense, Supervising	80,000	100,000
10	General and Administration cost	70,000	100,000
11	Shipping	90,000	180,000
12	Import tax	168,000	289,500
Total facility cost (Total of No.1-12)		1,798,000	3,099,500
Total facility cost (Object of JCM)※		1,568,800	2,660,784

※ Construction cost is not considered as ‘supported facility’, under JCM program. Site management, general and administrative costs are considered as ‘supported facility’, under JCM program.

(2) Gasification style

In this style, biomass is smothered with much less air compared to conventional combustion (25 ~ 40 % of theoretical combustion air). Combustible gas (carbon monoxide or hydrogen) is then recovered, and transferred to gas engine to generate electricity[18]. In comparision with direct combustion style, facility cost of this method is lower and generating efficiency is higher, at 20～30 %.

The reason behind the failure of gasification style in many cases includes its inability to refine and remove all of the tar residue generated inside the gasification furnace, which in turn disrupts the engine operation. This project utilizes a downdraft which produces less amount of tar residue and tar residue can be removed physically by cyclone system, electric vacuum cleaner and water jet cleaning machine. In this regard, equipment maintenance cost would be reduced in less time.

Fig. 3.2.4 shows system diagram, Fig. 3.2.5 shows 3D model diagram (500kW), Fig. 3.2.6 shows 3D model diagram (1,000kW), Table 3.2.3 shows Specification of gasification style, Table 3.2.4 shows facility cost.

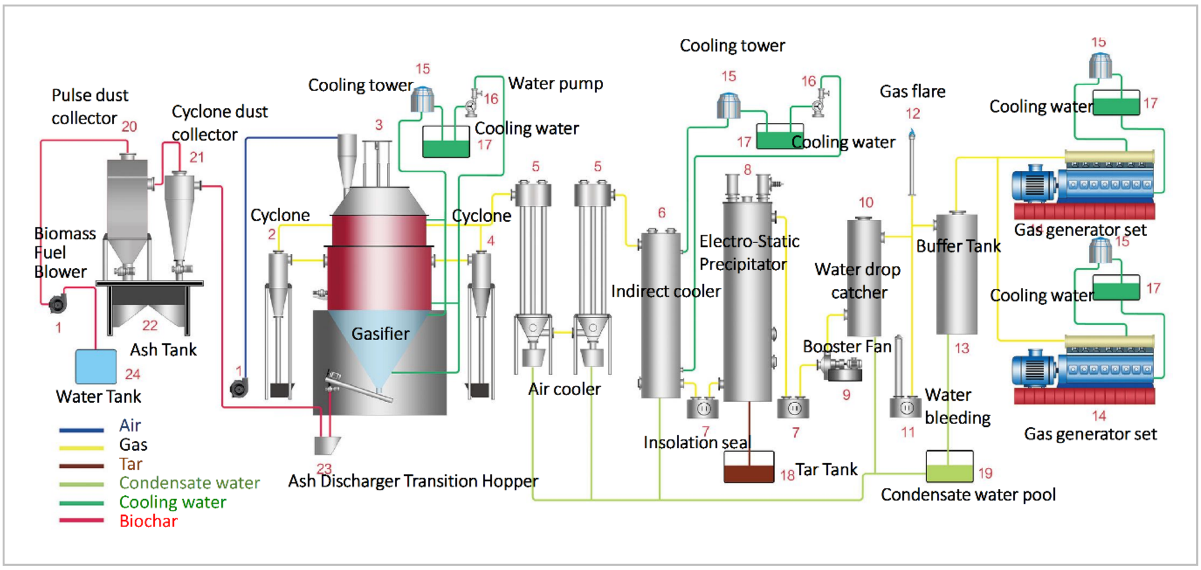


Fig.3.2.4 System diagram (Gasification style)

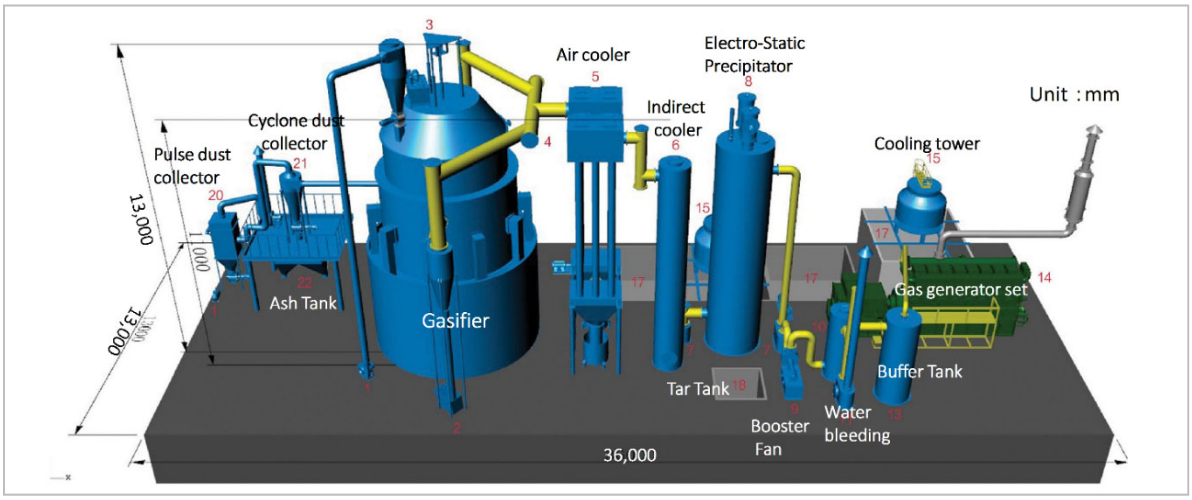


Fig.3.2.5 3D model diagram (Gasification style 500kW)

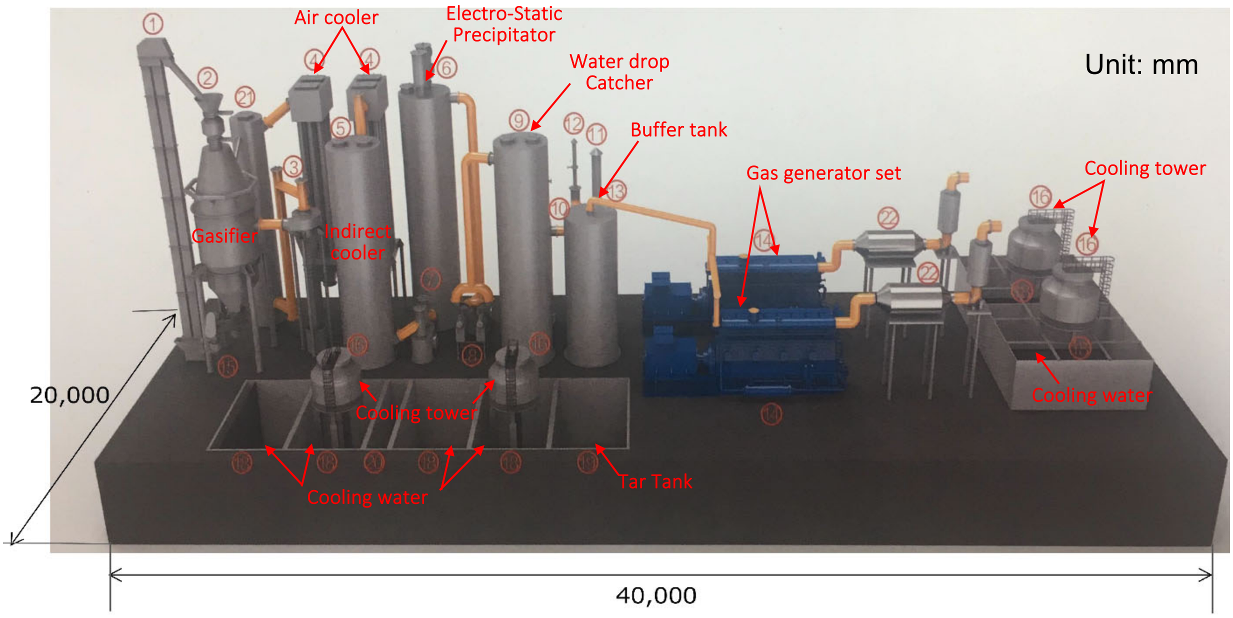


Fig.3.2.5 3D model diagram (Gasification style 1,000kW)

Table 3.2.3 Specification of gasification style

Item	500kW	1,000kW
Gasifier Model	500DFBG	1000DFBG
Gasifier Type	Downdraft Fixed Bed Gasifier	Downdraft Fixed Bed Gasifier
Gas Purification System	Dry Type ESP	Dry Type ESP
Fuel Specifications	Rice husk Moisture content <16%	Rice husk Moisture content <16%
Gross electricity generation	500 kW	1,000kW
Auxiliary power ratio	10%	10%
Net electricity generation	450kW	900kW
Rated Gas Flow	1250-1500N ㎥/hr	2,500-3,000N ㎥/hr
Average Gas Calorific Value	1050kcal	1,050kcal
Max Fuel Consumption	800kg/hr<	16,00kg/hr<
Tar Content of Gas	＜10 mg /N ㎥	<10mg/N ㎥
Gasification temperature	800°C	800°C
Temp of Gasifier Outlet	300-400°C	300-400°C
Typical Gas Composition	CO：15±2% H2：10±2% CO2：10±2% CH4：3±2% N2：50±5%	CO:15±2% H_2:10±2% CO_2:10±2% CH_4:3±2% N_2:50±5%

Table 3.2.4 Facility cost (Gasification style)

No.	Item	Expense (USD) (Power generation capacity: 500kW)	Expense (USD) (Power generation capacity: 1,000kW)
1	Gasification system	350,000	550,000
2	Biomass gas generator set	280,000	450,000
3	Auxiliary	60,000	100,000
4	Water treatment system	50,000	60,000
7	Civil work	180,000	300,000
8	Plan/Design	40,000	60,000
9	Site expense, Supervising	100,000	150,000
10	General and Administration cost	80,000	150,000
11	Shipping	90,000	180,000
12	Import tax	111,000	174,000
Total facility cost(Total of No.1-12)		1,341,000	2,174,000
Total facility cost (Object of JCM)※		1,161,000	1,874,000

※ Construction cost is not considered as 'supported facility', under JCM program. Site management management, general and administrative costs are considered as 'supported facility', under JCM program.

3.2.2 Efficiency of CO2 reduction

CO2 emissions reduction was calculated with reference to AMS-I.F. methodology on small-sized CDM "Renewable electricity generation for captive use and mini-grid".

(1) Reference emissions

Power source used for rice mills currently comes from national grid; therefore, reference emissions is equivalent to CO2 emissions in accordance with grid electricity consumption in the region. Table 3.2.5 and Table 3.2.6 exhibit setting value for parameter and reference emissions of systems with gross generating capacity of 500kW, and 1,000kW respectively.

$$RE_y = EG_{PJ,y} \times EF_{elec,y}$$

where

RE_y : Reference emissions in year y (tCO2/y)

$EG_{PJ,y}$: Quantity of net electric power generation under the project activity in year y (MWh/y) ;

$EF_{elec,y}$: Grid power CO2 emission factor of Cambodia (tCO2/MWh)

Table 3.2.5 Reference emissions, parameter settings (power generation capacity (gross): 500kW)

Parameter	Direct combustion style	Gasification style	Source/ Basis
RE_y	1,272.9(tCO2/y)	1,347.8(tCO2/y)	—
$EG_{PJ,y}$	425kW×7,800hours ＝3,315 (MWh/y)	450kW×7,800hours ＝3,510 (MWh/y)	・Power generation capacity by direct combustion style (net): 425kW ・Power generation capacity by gasification method (net): 450kW ・Annual operation time of equipment in this project: 7,800 hours
$EF_{elec,y}$	0.384(tCO2/MWh)	0.384(tCO2/MWh)	・Emission coefficient of grid electricity in Cambodia (The instruction of the second public offering for JCM subsidized project in FS 2018)

Table 3.2.6 Reference emissions, parameter settings (power generation capacity (gross): 1,000kW)

Parameter	Direct combustion style	Gasification style	Source/ Basis
RE_y	2,545.9(tCO2/y)	2,695.6(tCO2/y)	—
$EG_{PJ,y}$	850kW×7,800hours ＝6,630 (MWh/y)	900kW×7,800hours ＝7,020 (MWh/y)	・Power generation capacity by direct combustion style (net): 850kW ・Power generation capacity by gasification method (net): 900kW ・Annual operation time of equipment in this project: 7,800 hours
$EF_{elec,y}$	0.384(tCO2/MWh)	0.384(tCO2/MWh)	・Emission coefficient of grid electricity in Cambodia (Public offer, secondary offer guideline, Facilities support project under JCM program in 2018)

(2) Project emissions

The amount of emissions from this project is the amount of emissions generated from diesel fuel consumed by energy generation facility, and is quantified based on the following formula.

$$PE_y = \sum_i FC_{i,y} \times EF_{i,y}$$

where

PE_y : Project emissions due to fossil fuel in year y (tCO2/y)

$FC_{i,y}$: Fossil fuel i consumed in year y (L/y)

$EF_{i,y}$: Emission factor of fossil fuel i (tCO2/L)

Table 3.2.7 Reference emissions, parameter settings (power generation capacity [Gross]: 500kW)

Parameter	Value	Source/ Basis
PE_y	Direct combustion: 0.4(tCO2/y) Gasification: .1(tCO2/y)	—
$FC_{i,y}$	Direct combustion: 180(L/y) Gasification: 40(L/y)	・Diesel consumption during startup ＝45L/ 1time ×4 times ・Diesel consumption during startup ＝10L/1time ×4 times
$EF_{i,y}$	2.54×10^{-3}(tCO2/L)	・Diesel combustion emission factor (kgCO2/L) ＝Calorific value (TJ/Gg)[19]× Fuel density (kg/m^3)[20] × CO2 emission factor per one unit of calorific value (kgCO2/TJ) ／10^9 ＝41.4(TJ/Gg)×843.9(kg/m^3)×72,600(kgCO2/TJ)／10^9 ＝2.54(kgCO2/L)

Table 3.2.8 Reference emissions, parameter settings (power generation capacity [Gross]: 1,000kW)

Parameter	Value	Source/ Basis
PE_y	Direct combustion: 0.9(tCO2/y) Gasification: 0.2(tCO2/y)	—
$FC_{i,y}$	Direct combustion: 360(L/y) Gasification: 80(L/y)	・Diesel consumption during startup ＝90L/1time ×4 times ・Diesel consumption during startup ＝20L/1time ×4 times
$EF_{i,y}$	2.54×10^{-3}(tCO2/L)	・Diesel combustion emission factor (kgCO2/L) ＝Calorific value (TJ/Gg)[19]× Fuel density (kg/m^3)[20] × CO2 emission factor per one unit of calorific value (kgCO2/TJ) ／10^9 ＝41.4(TJ/Gg)×843.9(kg/m^3)×72,600(kgCO2/TJ)／10^9 ＝2.54(kgCO2/L)

(3) Emissions reduction

Total amount of emissions reduction is calculated by the difference between reference emissions and emissions generated from this project (see Fig. 3.2.9). Also, emissions reduction during project period (statutory useful life) is calculated by multiplying project period (number of years) by annual emissions reduction (see Fig. 3.2.10)

As for legal durable years, considering that this project is the power sale business for rice mills, statutory useful life shall be set to 15 years in case of direct combustion style, corresponding to “Steam-electric power generation system/ Equipment for power industry” stated in “Ministerial Ordinance Concerning the Useful Life of Depreciable Assets”, and 15 years in case of gasification method, corresponding to “Internal combustion engine–based power generation system/ Equipment for power industry” also cited from the same ministerial ordinace.

1) Annual emissions reduction ER_y

$$ER_y = RE_y - PE_y$$

where

ER_y : Emissions reduction in year y (tCO2/y)

RE_y : Reference emissions in year y (tCO2/y)

PE_y : Project emissions due to fossil fuel in year y (tCO2/y)

Table 3.2.9 Annual emission reduction

Power generation capacity	Gross 500kW		Gross 1,000 kW	
Combustion method	Direct combustion	Gasification	Direct combustion	Gasification
ER_y	1,272(tCO2/y)	1,347(tCO2/y)	2,545(tCO2/y)	2,695(tCO2/y)
RE_y	1,272.9(tCO2/y)	1,347.8(tCO2/y)	2,545.9(tCO2/y)	2,695.6(tCO2/y)
PE_y	0.4 (tCO2/y)	0.1(tCO2/y)	0.9(tCO2/y)	0.2(tCO2/y)

2) Emissions reduction during project period ER_p

$$ER_p = ER_y \times P$$

where

ER_p : Emissions reduction during the period P (tCO2)

P : Project Period (y) : 15years

Table 3.2.10 Amount of emission reduction during project period

Power generation capacity	Gross 500kW		Gross 1,000 kW	
Combustion method	Direct combustion	Gasification	Direct combustion	Gasification
ER_p	19,080(tCO2)	20,205(tCO2)	38,175(tCO2)	40,425(tCO2)
ER_y	1,272(tCO2/y)	1,347(tCO2/y)	2,545(tCO2/y)	2,695(tCO2/y)
p	15(y)	15(y)	15(y)	15(y)

3.2.3 JCM equipment subsidy・Cost effectiveness

The JCM equipment subsidy is the lesser price among the amounts obtained by the following two methods. (see Table 3.2.11)

1) Amount of money determined by the product of cost-effectiveness (4,000 Yen/t) and CO2 emissions reduction during the project period.

2) 50% of the total of equipment cost (Equipment subject to JCM equipment subsidy project)

Table 3.2.11 JCM equipment subsidy

Power generation capacity	Gross 500kW		Gross 1,000 kW	
Combustion method	Direct combustion	Gasification	Direct combustion	Gasification
Amount of financial support under JCM program (USD)	687,567	580,500	1,330,392	937,000
1)Cost effectiveness rate × Amount of CO2 emission reduction (USD)	687,567	728,108	1,375,675	1,456,756
2)50% Total facility cost (facilities shall be those supported by JCM program) (USD)	784,400	580,500	1,330,392	937,000

※ 1USD = 111 Yen

3.2.4 Business profitability

In this project, Specific purpose company (SPC) invested by Japanese enterprises will install biomass power plants using rice husk, and later sell electricity to a rice mill. Business profitability is assessed based on following prerequisite conditions.

＜Prerequisite conditions＞

- Project period is 15 years, and its purpose is to sell electricity generated by SPC's to rice mills.
- SPC shall bear all of the initial costs related to the installation of the biomass power plan.
- Electricity rate sold by SPC to rice mills shall be lower than that of national grid in the project's area, and shall be fixed during project period.
- SPC shall operate, manage and maintain the biomass power plant; related costs shall be covered by SPC.
- The rice mill shall provide a business site and rice husk to SPC for free of charge
- SPC shall operate the biomass power plant in 7,800 hours (24 hours x 325 days) / year

(1) Initial cost

Initial cost paid by SPC is the amount of facility cost minus JCM equipment subsidy (see Table 3.2.12).

Table 3.2.12 The amount of financial support under JCM program, and Initial cost borne by SPC

Power generation capacity	500kW		1,000 kW	
Combustion method	Direct combustion	Gasification	Direct combustion	Gasification
1) Total facility cost (USD)	1,798,000	1,341,000	3,099,500	2,174,000
2) Amount of financial support under JCM program (USD)	687,567	580,500	1,330,392	937,000
3) Initial cost (USD)(＝1－2)	1,110,433	760,500	1,769,108	1,237,000

※ 1USD = 111 yen

(2) Income and expenses

Table 3.2.13 ~ Table 3.2.20 exhibit revenue and expenditure of SPC, and changes in profit of the rice mill before and after the installation of biomass power plants. Profits of the rice mill will increase because cheap electricity can be used although the benefit of selling rice husk will be lost by introducing biomass power plant.

・Direct combustion style: 500kW → Revenue and expenditure of SPC: Table 3.2.13
Profit of the rice mill: Table 3.2.14
・Gasification method: 500kW → Revenue and expenditure of SPC: Table 3.2.15
Profit of the rice mill: Table 3.2.16
・Direct combustion style: 1,000kW → Revenue and expenditure of SPC: Table 3.2.17
Profit of the rice mill: Table 3.2.18
・Gasification method: 1,000kW → Revenue and expenditure of SPC: Table 3.2.19
Profit of the rice mill: Table 3.2.20

Table 3.2.13 Annual income and expenditure of SPC (Direct combustion・500kW)

＜Income＞										
Selling Electricity (to Rice Mill)					265,200					USD
	(=	425	kW×	24	hours/day×	325	days×	0.08		USD/kWh)
＜Expenditure＞										
Buying Rice Husk					0					USD
	(=	0.8	ton/h×	24	hours/day×	325	days×	0		USD/ton)
Diesel Consumption					-167					USD
	(=	45	L/time	4	times×	0.93	USD/L)			
O&M					-78,000					USD
	(=	500	kW×	24	hours/day×	325	days×	0.02		USD/kWh)
＜Profit＞										
					187,033					USD

Table 3.2.14 Annual revenue before and after project implementation of the rice mill (Direct combustion・500kW)

【Before implementation】

＜Income＞									
Selling Rice Husk					112,320				USD
	(=	0.8	ton/h×	24	hours/day×	325	days×	18	USD/ton)
＜Expenditure＞									
Electricity Charge (Grid)					-417,690				USD
	(=	425	kW×	24	hours/day×	325	days×	0.126	USD/kWh)
＜Profit＞									
					-305,370				USD

【After implementation】

＜Income＞									
Selling Rice Husk					0				USD
	(=	0.8	ton/h×	24	hours/day×	325	days×	0	USD/ton)
＜Expenditure＞									
Electricity Charge (Biomass Power)					-265,200				USD
	(=	425	kW×	24	hours/day×	325	days×	0.08	USD/kWh)
＜Profit＞									
					-265,200				USD
＜Benefit (After-Before)＞									
					40,170				USD

Table 3.2.15 Annual income and expenditure of SPC (Gasification・500kW)

＜Income＞									
Selling Electricity					280,800				USD
(to Rice Mill)	(=	450	kW×	24	hours/day×	325	days×	0.08	USD/kWh)
＜Expenditure＞									
Buying Rice Husk					0				USD
	(=	0.8	ton/h×	24	hours/day×	325	days×	0	USD/ton)
Diesel Consumption					-37				USD
	(=	10	L/time	4	times×	0.93	USD/L)		
O&M					-78,000				USD
	(=	500	kW×	24	hours/day×	325	days×	0.02	USD/kWh)
＜Profit＞									
					202,763				USD

Table 3.2.16 Annual revenue before and after project implementation of the rice mill (Gasification・500kW)

【Before implementation】

＜Income＞									
Selling Rice Husk					112,320				USD
	(=	0.8	ton/h×	24	hours/day×	325	days×	18	USD/ton)
＜Expenditure＞									
Electricity Charge					-442,260				USD
(Grid)	(=	450	kW×	24	hours/day×	325	days×	0.126	USD/kWh)
＜Profit＞									
					-329,940				USD

【After implementation】

＜Income＞									
Selling Rice Husk					0				USD
	(=	0.8	ton/h×	24	hours/day×	325	days×	0	USD/ton)
＜Expenditure＞									
Electricity Charge					-280,800				USD
(Biomass Power)	(=	450	kW×	24	hours/day×	325	days×	0.08	USD/kWh)
＜Profit＞									
					-280,800				USD
＜Benefit (After-Before)＞									
					49,140				USD

Table 3.2.17 Annual income and expenditure of SPC (Direct combustion・1,000kW)

＜Income＞									
Selling Electricity					663,000				USD
(to Rice Mill)	(=	850	kW×	24	hours/day×	325	days×	0.10	USD/kWh)
＜Expenditure＞									
Buying Rice Husk					0				USD
	(=	1.6	ton/h×	24	hours/day×	325	days×	0	USD/ton)
Diesel Consumption					-335				USD
	(=	90	L/time	4	times×	0.93	USD/L)		
O&M					-156,000				USD
	(=	1,000	kW×	24	hours/day×	325	days×	0.02	USD/kWh)
＜Profit＞									
					506,665				USD

Table 3.2.18 Annual revenue before and after project implementation of the rice mill (Direct combustion・1,000kW)

【Before implementation】

＜Income＞									
Selling Rice Husk					224,640				USD
	(=	1.6	ton/h×	24	hours/day×	325	days×	18	USD/ton)
＜Expenditure＞									
Electricity Charge					-1,060,800				USD
(Grid)	(=	850	kW×	24	hours/day×	325	days×	0.16	USD/kWh)
＜Profit＞									
					-836,160				USD

【After implementation】

＜Income＞									
Selling Rice Husk					0				USD
	(=	1.6	ton/h×	24	hours/day×	325	days×	0	USD/ton)
＜Expenditure＞									
Electricity Charge					-663,000				USD
(Biomass Power)	(=	850	kW×	24	hours/day×	325	days×	0.10	USD/kWh)
＜Profit＞									
					-663,000				USD
＜Benefit (After-Before)＞									
					173,160				USD

Table 3.2.19 Annual income and expenditure of SPC(Gasification・1,000kW)

＜Income＞									
Selling Electricity	702,000								USD
(to Rice Mill)	(=	900	kW×	24	hours/day×	325	days×	0.10	USD/kWh)
＜Expenditure＞									
Buying Rice Husk	0								USD
	(=	1.6	ton/h×	24	hours/day×	325	days×	0	USD/ton)
Diesel Consumption	-74								USD
	(=	20	L/time	4	times×	0.93	USD/L)		
O&M	-156,000								USD
	(=	1,000	kW×	24	hours/day×	325	days×	0.020	USD/kWh)
＜Profit＞									
	545,926								USD

Table 3.2.20 Annual revenue before and after project implementation of the rice mill (Gasification・1,000kW)

【Before implementation】

＜Income＞									
Selling Rice Husk	224,640								USD
	(=	1.6	ton/h×	24	hours/day×	325	days×	18	USD/ton)
＜Expenditure＞									
Electricity Charge	-1,123,200								USD
(Grid)	(=	900	kW×	24	hours/day×	325	days×	0.16	USD/kWh)
＜Profit＞									
	-898,560								USD

【After implementation】

＜Income＞									
Selling Rice Husk	0								USD
	(=	1.6	ton/h×	24	hours/day×	325	days×	0	USD/ton)
＜Expenditure＞									
Electricity Charge	-702,000								USD
(Biomass Power)	(=	900	kW×	24	hours/day×	325	days×	0.10	USD/kWh)
＜Profit＞									
	-702,000								USD
＜Benefit (After-Before)＞									
	196,560								USD

(3) Business profitability

For the four cases set up in the previous section, the cash flow, the recovery period of the initial cost and internal rate of return (IRR) was calculated based on the initial cost, income and expenditure in order to evaluate the project profitability of SPC.

As shown in Table 3.2.21, it can be evaluated that the profitability of each case is high. However, the direct combustion style is somewhat less profitable in the case of a 500 kW power generation scale. Compared to direct combustion style, gasification style has lower initial cost, so it is possible to recover initial cost in about 60% of time compared with direct combustion style.

Cash flow calculation table for each case is shown in Table 3.2.22～Table 3.2.25

Table 3.2.21 Business profitability of SPC for each case

Power generation capacity	Gross 500kW		Gross 1,000 kW	
Combustion method	Direct combustion	Gasification	Direct combustion	Gasification
Recovery period of initial cost	6.2 years	3.8 years	3.5 years	2.4 years
Internal rate of return (IRR)	12.2%	23.5%	25.7%	40.0%

Table 3.2.22 Cash flow calculation table of SPC (Direct Combustion・500kW)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Income(USD)	0	265,200	265,200	265,200	265,200	265,200	265,200	265,200	265,200	265,200	265,200	265,200	265,200	265,200	265,200	265,200
Selling Electricity to the rice mill		265,200	265,200	265,200	265,200	265,200	265,200	265,200	265,200	265,200	265,200	265,200	265,200	265,200	265,200	265,200
2. Expenses(USD)	-1,110,433	-78,167	-78,167	-78,167	-78,167	-78,167	-78,167	-78,167	-78,167	-78,167	-78,167	-78,167	-78,167	-78,167	-78,167	-78,167
Total Equipment Cost	-1,798,000															
JCM Subsidy	687,567															
Diesel Consumption		-167	-167	-167	-167	-167	-167	-167	-167	-167	-167	-167	-167	-167	-167	-167
O&M		-78,000	-78,000	-78,000	-78,000	-78,000	-78,000	-78,000	-78,000	-78,000	-78,000	-78,000	-78,000	-78,000	-78,000	-78,000
3. Profit before depreciation(USD)	-1,110,433	187,033	187,033	187,033	187,033	187,033	187,033	187,033	187,033	187,033	187,033	187,033	187,033	187,033	187,033	187,033
4. Depreciation(USD)		359,600	359,600	359,600	359,600	359,600	0	0	0	0	0	0	0	0	0	0
5. Profit after depreciation(USD)	-1,110,433	-172,567	-172,567	-172,567	-172,567	-172,567	187,033	187,033	187,033	187,033	187,033	187,033	187,033	187,033	187,033	187,033
6. Tax(USD) Corporation Tax(20%)	0	0	0	0	0	0	-46,758	-46,758	-46,758	-46,758	-46,758	-46,758	-46,758	-46,758	-46,758	-46,758
7. Profit of the current term(USD)	-1,110,433	-172,567	-172,567	-172,567	-172,567	-172,567	140,275	140,275	140,275	140,275	140,275	140,275	140,275	140,275	140,275	140,275
8. Cash flow(USD)	-1,110,433	187,033	187,033	187,033	187,033	187,033	140,275	140,275	140,275	140,275	140,275	140,275	140,275	140,275	140,275	140,275
Accumulation of Cash	-1,110,433	-923,400	-736,367	-549,334	-362,301	-175,268	-34,993	105,282	245,556	385,831	526,106	666,381	806,655	946,930	1,087,205	1,227,480

IRR・Recovery period of initial cost

Project IRR(15years)	12.2%
Recovery period of initial investment(year)	6.2

Table 3.2.23 Cash flow calculation table of SPC (Gasification・500kW)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Income(USD)	0	280,800	280,800	280,800	280,800	280,800	280,800	280,800	280,800	280,800	280,800	280,800	280,800	280,800	280,800	280,800
Selling Electricity to the rice mill		280,800	280,800	280,800	280,800	280,800	280,800	280,800	280,800	280,800	280,800	280,800	280,800	280,800	280,800	280,800
2. Expenses(USD)	-760,500	-78,037	-78,037	-78,037	-78,037	-78,037	-78,037	-78,037	-78,037	-78,037	-78,037	-78,037	-78,037	-78,037	-78,037	-78,037
Total Equipment Cost	-1,341,000															
JCM Subsidy	580,500															
Diesel Consumption		-37	-37	-37	-37	-37	-37	-37	-37	-37	-37	-37	-37	-37	-37	-37
O&M		-78,000	-78,000	-78,000	-78,000	-78,000	-78,000	-78,000	-78,000	-78,000	-78,000	-78,000	-78,000	-78,000	-78,000	-78,000
3. Profit before depreciation(USD)	-760,500	202,763	202,763	202,763	202,763	202,763	202,763	202,763	202,763	202,763	202,763	202,763	202,763	202,763	202,763	202,763
4. Depreciation(USD)		268,200	268,200	268,200	268,200	268,200	0	0	0	0	0	0	0	0	0	0
5. Profit after depreciation(USD)	-760,500	-65,437	-65,437	-65,437	-65,437	-65,437	202,763	202,763	202,763	202,763	202,763	202,763	202,763	202,763	202,763	202,763
6. Tax(USD) Corporation Tax(20%)	0	0	0	0	0	0	-50,691	-50,691	-50,691	-50,691	-50,691	-50,691	-50,691	-50,691	-50,691	-50,691
7. Profit of the current term(USD)	-760,500	-65,437	-65,437	-65,437	-65,437	-65,437	152,072	152,072	152,072	152,072	152,072	152,072	152,072	152,072	152,072	152,072
8. Cash flow(USD)	-760,500	202,763	202,763	202,763	202,763	202,763	152,072	152,072	152,072	152,072	152,072	152,072	152,072	152,072	152,072	152,072
Accumulation of Cash	-760,500	-557,737	-354,974	-152,211	50,552	253,315	405,387	557,460	709,532	861,604	1,013,676	1,165,749	1,317,821	1,469,893	1,621,965	1,774,038

IRR・Recovery period of initial cost

Project IRR(15years)	23.5%
Recovery period of initial investment(year)	3.8

Table 3.2.24 Cash flow calculation table of SPC (Direct Combustion・1,000kW)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Income(USD)	0	663,000	663,000	663,000	663,000	663,000	663,000	663,000	663,000	663,000	663,000	663,000	663,000	663,000	663,000	663,000
Selling Electricity to the rice mill		663,000	663,000	663,000	663,000	663,000	663,000	663,000	663,000	663,000	663,000	663,000	663,000	663,000	663,000	663,000
2. Expenses(USD)	-1,769,108	-156,335	-156,335	-156,335	-156,335	-156,335	-156,335	-156,335	-156,335	-156,335	-156,335	-156,335	-156,335	-156,335	-156,335	-156,335
Total Equipment Cost	-3,099,500															
JCM Subsidy	1,330,392															
Diesel Consumption		-335	-335	-335	-335	-335	-335	-335	-335	-335	-335	-335	-335	-335	-335	-335
O&M		-156,000	-156,000	-156,000	-156,000	-156,000	-156,000	-156,000	-156,000	-156,000	-156,000	-156,000	-156,000	-156,000	-156,000	-156,000
3. Profit before depreciation(USD)	-1,769,108	506,665	506,665	506,665	506,665	506,665	506,665	506,665	506,665	506,665	506,665	506,665	506,665	506,665	506,665	506,665
4. Depreciation(USD)		619,900	619,900	619,900	619,900	619,900	0	0	0	0	0	0	0	0	0	0
5. Profit after depreciation(USD)	-1,769,108	-113,235	-113,235	-113,235	-113,235	-113,235	506,665	506,665	506,665	506,665	506,665	506,665	506,665	506,665	506,665	506,665
6. Tax(USD) Corporation Tax(20%)	0	0	0	0	0	0	-126,666	-126,666	-126,666	-126,666	-126,666	-126,666	-126,666	-126,666	-126,666	-126,666
7. Profit of the current term(USD)	-1,769,108	-113,235	-113,235	-113,235	-113,235	-113,235	379,999	379,999	379,999	379,999	379,999	379,999	379,999	379,999	379,999	379,999
8. Cash flow(USD)	-1,769,108	506,665	506,665	506,665	506,665	506,665	379,999	379,999	379,999	379,999	379,999	379,999	379,999	379,999	379,999	379,999
Accumulation of Cash	-1,769,108	-1,262,443	-755,778	-249,113	257,552	764,217	1,144,216	1,524,215	1,904,213	2,284,212	2,664,211	3,044,210	3,424,208	3,804,207	4,184,206	4,564,205

IRR・Recovery period of initial cost

Project IRR(15years)	25.7%
Recovery period of initial investment(year)	3.5

Table 3.2.25 Cash flow calculation table of SPC (Gasification・1,000kW)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Income(USD)	0	702,000	702,000	702,000	702,000	702,000	702,000	702,000	702,000	702,000	702,000	702,000	702,000	702,000	702,000	702,000
Selling Electricity to the rice mill		702,000	702,000	702,000	702,000	702,000	702,000	702,000	702,000	702,000	702,000	702,000	702,000	702,000	702,000	702,000
2. Expenses(USD)	-1,237,000	-156,074	-156,074	-156,074	-156,074	-156,074	-156,074	-156,074	-156,074	-156,074	-156,074	-156,074	-156,074	-156,074	-156,074	-156,074
Total Equipment Cost	-2,174,000															
JCM Subsidy	937,000															
Diesel Consumption		-74	-74	-74	-74	-74	-74	-74	-74	-74	-74	-74	-74	-74	-74	-74
O&M		-156,000	-156,000	-156,000	-156,000	-156,000	-156,000	-156,000	-156,000	-156,000	-156,000	-156,000	-156,000	-156,000	-156,000	-156,000
3. Profit before depreciation(USD)	-1,237,000	545,926	545,926	545,926	545,926	545,926	545,926	545,926	545,926	545,926	545,926	545,926	545,926	545,926	545,926	545,926
4. Depreciation(USD)		434,800	434,800	434,800	434,800	434,800	0	0	0	0	0	0	0	0	0	0
5. Profit after depreciation(USD)	-1,237,000	111,126	111,126	111,126	111,126	111,126	545,926	545,926	545,926	545,926	545,926	545,926	545,926	545,926	545,926	545,926
6. Tax(USD) Corporation Tax(20%)	0	-27,782	-27,782	-27,782	-27,782	-27,782	-136,482	-136,482	-136,482	-136,482	-136,482	-136,482	-136,482	-136,482	-136,482	-136,482
7. Profit of the current term(USD)	-1,237,000	83,345	83,345	83,345	83,345	83,345	409,445	409,445	409,445	409,445	409,445	409,445	409,445	409,445	409,445	409,445
8. Cash flow(USD)	-1,237,000	518,145	518,145	518,145	518,145	518,145	409,445	409,445	409,445	409,445	409,445	409,445	409,445	409,445	409,445	409,445
Accumulation of Cash	-1,237,000	-718,856	-200,711	317,434	835,578	1,353,723	1,763,167	2,172,612	2,582,056	2,991,501	3,400,945	3,810,390	4,219,834	4,629,279	5,038,723	5,448,168

IRR・Recovery period of initial cost

Project IRR(15years)	40.0%
Recovery period of initial investment(year)	2.4

3.3 Examination of monitoring method

Calculation formula of project emissions, and reference emissions is stated below. Method of setting parameter is shown in Table 3.3.1 and Table 3.3.2

Parameter that needs to be monitored is the annual generation of $EG_{PJ,y}$, resulting from project activity, and annual fossil fuel consumption $FC_{i,y}$. $EG_{PJ,y}$, is set by measuring and aggregating the power generation amount of the biomass power plant introduced in the project with a wattmeter. $FC_{i,y}$ is set by measuring and aggregating fossil fuel consumption of the plant to be introduced in the project with a flow meter,etc.

【Reference Emissions】

$$RE_y = EG_{PJ,y} \times EF_{elec,y}$$

【Project Emissions】

$$PE_y = \sum_i FC_{i,y} \times EF_{i,y}$$

Table 3.3.1 Method of setting parameters in reference emissions formula

Parameter	Data explanation	Setting method
$EG_{PJ,y}$	Annual generation resulting from project activity (MWh)	Based on electricity generation statistics from the power plant in the project, collected from wattmeter
$EF_{elec,y}$	Emmision factor of grid power in the site	Based on data publized by Cambodia government

Table 3.3.2 Method of setting parameters in Project emissions formula

Parameter	Data explanation	Setting method
$FC_{i,y}$	Annual fossil fuel consumption	Based on fossil fuel consumption statistics from the power plant in the project, collected from flowmeter
$EF_{i,y}$	Emmision factor of fossil fuel (tCO2/y)	Based on the exsiting report[19,20]. (refer to Table3.2.7 & Table 3.2.8) In case Camodia issues their own guideline, use data from the issued value.

3.4 Examination of business structure

In this project, it is assumed that SPC established by the representative company (Japanese enterprises) will become a partner participant and SPC will pay the initial cost in order to reduce the initial cost burden of the rice mill.

The representative company and SPC shall form an International Consortium, to introduce the equipment and conduct monitoring after the installation of equipment. The role of the representative company, the partner participant, and related organizations are shown in Fig. 2.4.2.

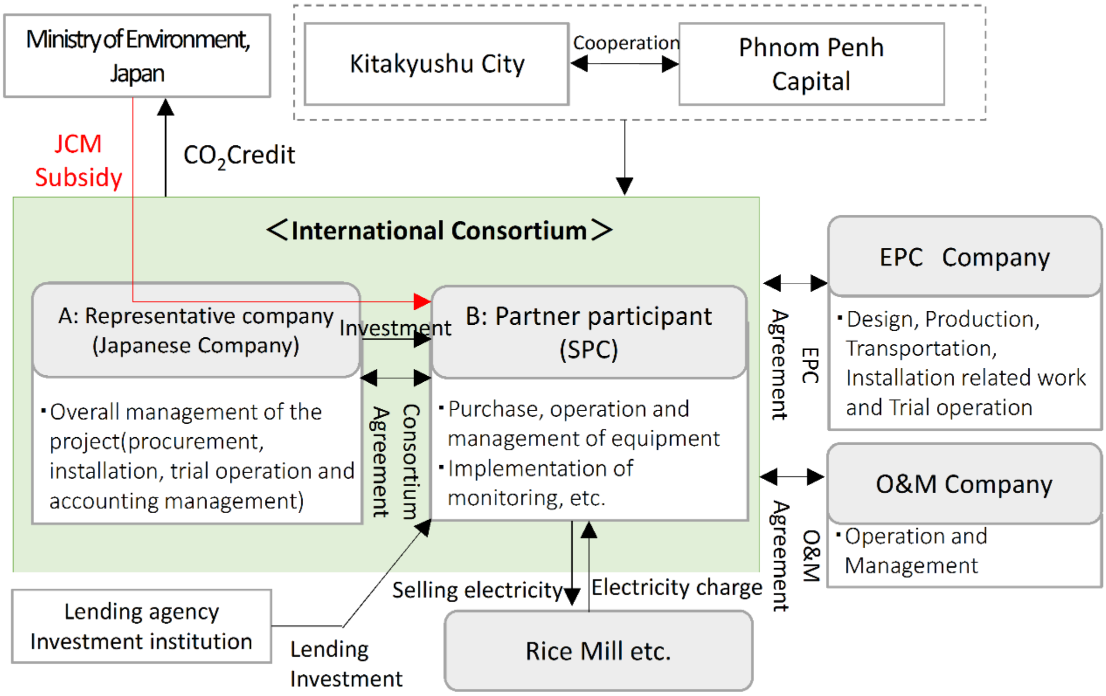


Fig. 3.4.1 Organizational chart of project implementation

3.5 Examination of fund procurement methods

Remaining project cost (initial costs) after deducting the JCM equipment subsid program will be paid by SPC which is established by representative company (Japanese enterprise). SPC will recover this initial cost by selling electricity back to rice mills.

3.6 Examination of project implementation schedule

After selecting project to be supported by JCM, the im schedule is as follows.

- Design : approx. 6 months
- Purchase of equipment, construction, and commission: approx. 1 year

3.7 Summary and challenges for the future

- In this survey, we were able to propose a low-cost biomass power plant, with high profit potential to rice mills. In the future, equipments and business structure needs to be considered more concretely after detailed data collected such as the amount of rice husk available and power demand which are Seasonally fluctuating.
- In terms of combustion method, gasification proves to have better financial gains; however, decisions should be made upon surveying and comparing actual results of both methods (direct combustion and gasification), accompanied with consideration of cost, and scope of management and maintenance.
- It may be a challenge to ensure the power supply destination during non-opeating time of the rice mill. The ability to generate electricity over a long period of time will enhance business profitability of the project, provided that necessary supply of rice husks can be secured. In view of current price of rice husk (18USD/t), it is clear that using rice husk as fuel for the power plant will be more profitable than

just selling them away. It is also recommended that biomass-based electricity is used for other equipment, other than just those related to rice milling activity, for example, the plants could consider installing wooden pallet machines, and power them with biomass electricity (see Fig. 3.7.1 and Table 3.7.1)

・As for the study of the profitability of the survey in this survey, the cost of electricity sale to the EDC (Electricite de Cambodge, Cambodia Electricity public corporation) is low, so it is targeted for business models that consume electricity of biomass power generation inside the rice mill. However, it is desirable to consider a model that effectively utilizes waste heat in the future. For example, focus could be shifted to rice mill adjacent to factoried in need of heat energy.

・Moreover, we will also consider the method of using ash discharged from the biomass power plant. In the case of gasification plant, it is possible to operate the plant so that about 40 to 50% of carbon remains in the ash, and if it can be processed and fueled for sale, it will lead to improvement in profit of the business operator (SPC and the rice mill).

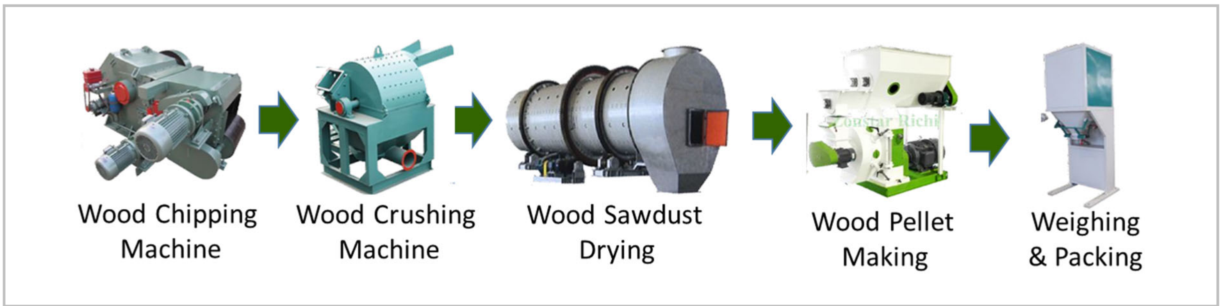


Fig. 3.7.1 Types of equipment used in wooden pallet production line

Table 3.7.1 Cost of installing wooden pallet machines, annual revenue

No.	Item	Value	Remarks
1	Installation cost	500,000USD	
2	Production capacity	2t/h	
3	Annual operation time	2,160h/y	=24hours×30days×3months
4	Annual output	4,320t/y	=2)×3)
5	Pallet unit price	70USD/t	
6	Annual revenue	302,400USD/y	=4)×5)

Citations and Reference

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Chapter 4 Feasibility study for JCM project (Environmental conservation Field：Organic wastewater treatment project)

4.1 Current situation

The issue of organic wastewater treatment lies in large-scale food factories and livestock facilities, which are greatly affected by the environment. The results of the survey are shown in the food factory and the livestock below.

(1) Food factory

Most of large-scale food manufacturing factories are located in Phnom Penh Industrial Park (PPSEZ). After being pretreated, wastewater will be treated by stabilization pond with aeration to meet the national wastewater standards in PPSEZ.

Because other large-scale food factories that are not in the PPSEZ (in the city they mainly are breweries) are not periodically inspected by the administrative authority, wastewater treatment is not performed properly in them.

We asked some breweries for a visit or investigation but declined and they told us that their wastewater is properly treated. Although the investigation has not been performed, colored wastewater and detergent foam discharged to the nearby ponds from one brewery was confirmed in the capital city.

Photo 4.1.1 Waste water from breweries in the capital city (colored wastewater with detergent foam)

(2) Livestock facility

As shown in Fig. 4.1.1, the number of domestic livestock in Cambodia is increasing. This increase is attributed to economic and population growth as well as changes in the eating habits of Cambodian people; its increase is expected to continue. The number of swine housing is 575 and the number of cow shed is 93 in 2016[1]. However, In Cambodia, families are often breeding livestock for self-consumption and cultivation, and there are few cases where companies are doing livestock raising. The number of domestic animals raised by companies in 2016 is about 19% of the total livestock number.

As shown in Figure 4.1.2, paying attention to demanded pigs, in Cambodia the total number of pigs and the number of pigs raised by companies tend to increase. However, while the number of pigs is increasing, livestock wastewater has not been properly processed (See the survey results for swine housings in the latter part).

According to the report[2] from the Cambodian Ministry of the Environment, the current domestic demand for pork is about 4,000 items per day, while the supply capacity from domestic livestock facilities does not exceeded 2,000items per day. The missing demand portion is now imported from neighboring countries. With current increasing domestic demand for meat nowadays, the scale and increase of livestock facilities in the country are expected to progress. Therefore, it is important to promote proper treatment method of wastewater at an early stage. Cambodian Ministry of the Environment also considers ambient environment pollution (water, soil and air) caused by livestock wastewater because it leads to health damage of neighboring residents, destruction of ecosystems and loss of urban landscape. As solutions for them, they implemented wastewater treatment facilities, strengthened environmental management, thoroughly monitor livestock facilities by the administration. As solutions, they showed the introduction of wastewater treatment facilities, strengthened environmental management and thorough monitoring at livestock facilities by the administration.[1]

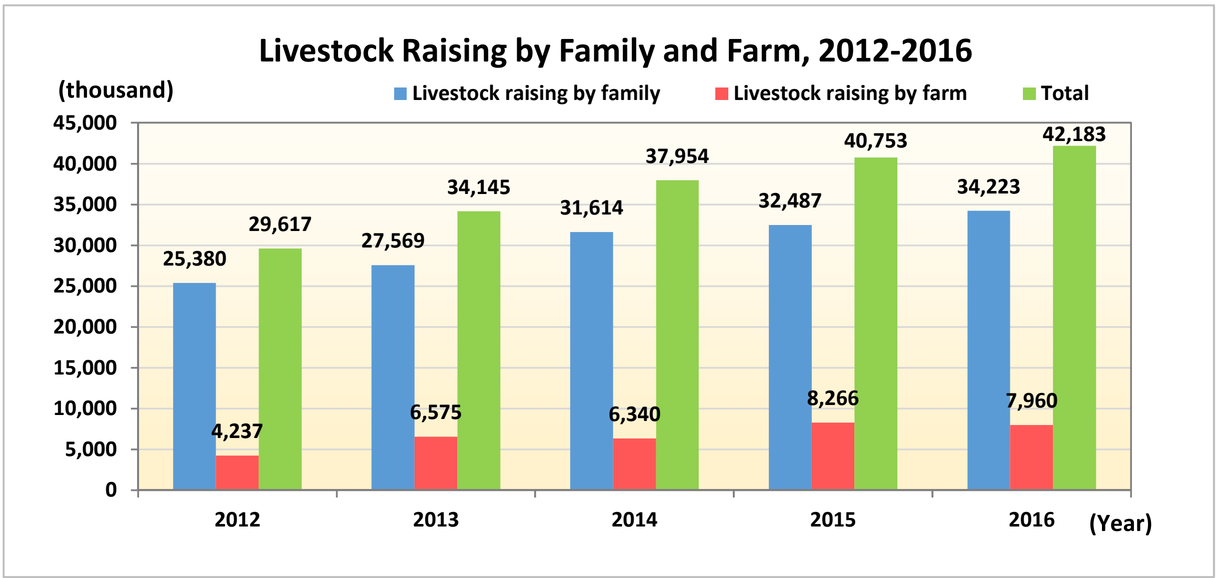

Fig. 4.1.1 Changes in the number of livestock in Cambodia
(Cows, buffaloes, pigs, chickens, horses, sheep, goats and elephants)

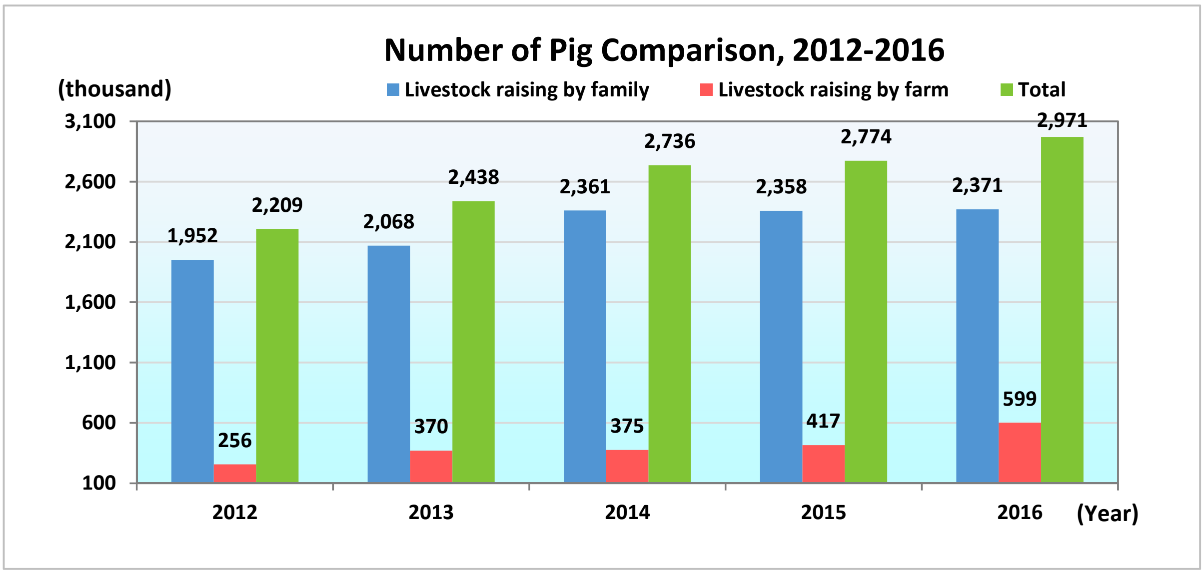

Fig. 4.1.2 Changes in the number of pigs in Cambodia

■Field survey of swine housings

We have visited and interviewed the 3 following swine housings. These interview results are shown in the Table 4.1.1 ～ 4.1.3.

At these swine housings, wastewater is treated by methane fermentation method (anaerobic treatment); After recovering the biogas, the wastewater (digestive juice) has been stored in the pond for a while and then discharged to adjacent rivers etc. without proper treatment.

In Japanese swine housings, in general, aerobic treatment is performed instead of methane fermentation treatment. This is because, in the case of pig farming facilities, digestive juice remaining after methane fermentation treatment is useless unlike the nursery facility that grazes pasture pastures, and processing of digestive juice is expensive. Also, the fact that the methane fermentation tank is expensive is also a major reason.

In contrast, in Cambodia, the recovered biogas will be used as an on-site power source - it is prioritized than if treated wastewater quality meets environmental standards or not, Therefore the methane fermentation method is applied (it means that digestive juice is not fully treated). Although there are national standards of waste water but wastewater treatment has not been well implemented in swine housings because of lack of direction and management by administrative agencies.

Table 4.1.1 Results of interviewing the swine housing (A Company)

Item	Contents
Quantity	・Farm 1: sows: 3,000 items, porkers: 12,000 items
	・Farm 2: sows: 3,000 items, porkers: 17,000 items
Treatment method	・Methane fermentation process ・Pig manure is processed by the methane fermentation method, collected wastewater is treated in two large lakes, then discharged to nearby rivers. The aeration is performed in the first pond but is limited within 2 hours/day. The aeration technique is taken from Vietnam. The second pond is bigger than the first one. This first pond is used for sludge sedimentation. ＜Farm 1＞ Pond No 1 20m×24m×3m (depth) With aeration Pond No 2 40m×60m×5-6m (depth) With aeration ＜Farm 2＞ Pond No 1 22m×50m×6m (depth) With aeration Pond No 2 32m×80m×6m (depth) With aeration ・The Director of the company himself also conducted a survey of the quality of treated wastewater together with each farm but he also not very sure about the accuracy of the survey results.
Power generation	・Biogas generated from the methane fermentation is used to generate electricity; the electricity generated from it covers up to about half of the electricity demand in the factory. ・400kW×12 hours
Requests	・Introduction of an appropriate wastewater treatment method

Table 4.1.2 Results of interviewing the swine housing (B Company)

Item	Contents
Quantity	・Farm 1: Sows: 700 items, porkers: 8,000 items
	・Farm 2: Sows: 1,300 items, porkers: 1,000 items
Treatment method	・Methane fermentation process ・After methane fermentation, waste solution is temporarily stored in containing pond, then discharges into the nearby river with a frequency of 1 time/day.
Requests	・Utilizing manure as biogas and fertilizer and introducing an effective wastewater treatment facility based on this.

Table 4.1.3 Results of interviewing the swine housing (C Company)

Item	Contents
Quantity	・Farm 1: Sows: 3,200 items, porkers: 37,000 items
	・Farm 2: Sows: 600 items, porkers: 7,000 items
Treatment method	・Methane fermentation process (tank is produced in Thailand, investment cost: 500,000USD) ・Wastewater after methane fermentation, after being stored in the pond, discharges into artificial canal, then flows to the river and sea. The residual sludge in the methane fermentation tank will be removed every 2 years and used as fertilizer.
Power generation quantity	・Currently 210,000kWh / month is generated. The facility perform methane fermentation themselves. ・Wish to generate from 300,000 ~ 350,000kWh / month. If they cannot use up, they can sell electricity.
Requests	・Establishment of methane fermentation treatment facility,
Picture	  Photo: Power generator (800KVA) Photo: Methane fermentation tank

4.2 Examination of introduction technology

In this survey, we examined the introduction of a high efficiency methane fermentation treatment facility to the swine housing. By using facilities with higher biogas recovery rate than the existing ones, the amount of electricity generated from renewable energy will increase. The result is that the amount of electricity consumed in the swine housing as well as CO_2 emissions reduction. The scale of the fermentation treatment facility is calculated according to the number of pigs raised by two swine housings of company C (sows: 3,800; porkers: 44,000).

4.2.1 Contents of introduction technology

Methane fermentation treatment is a technology to decompose organic matter to recover biogas (methane gas) thanks to the action of anaerobic microorganisms. The process of decomposing organic matter is divided into 3 reaction stages with different functions as follow 1) decomposing organic matter into monosaccharides, short-chain fatty acids and amino acids due to acidogenesis, 2) decomposing those substances into acetic acid due to acetogenesis, 3) decomposing acetic acid into methane gas and carbon dioxide gas due to methanogenesis.[3]

The system diagram is shown in Fig. 4.2.1. After separating manure etc. excreted from the swine housing into solid and liquid, after adjusting the pH, send the liquid to the methane fermentation tank, recover the biogas by methane fermentation. After that use the recovered biogas as a fuel and power generation is performed by a power generator (gas engine).Then use the recovered biogas as a fuel for a power generation device (gas engine) to generate electricity., Table 4.2.1 shows the technical specifications and Table 4.2.2 is the applied cost of the methane fermentation processing facilities.

In case fermentation residue remaining after methane fermentation (digestive juice) discharges into the river, it should be treated by activated sludge method etc. to meet Cambodia's wastewater standards (Table 4.2.3). However, the treatment for digestive juice will be much costly. That is why, in this survey, it is assumed that digestive juice is sprayed as liquid fertilizer to the surrounding palm plantation after sterilizing digestive juice (owned by a group company of company C).

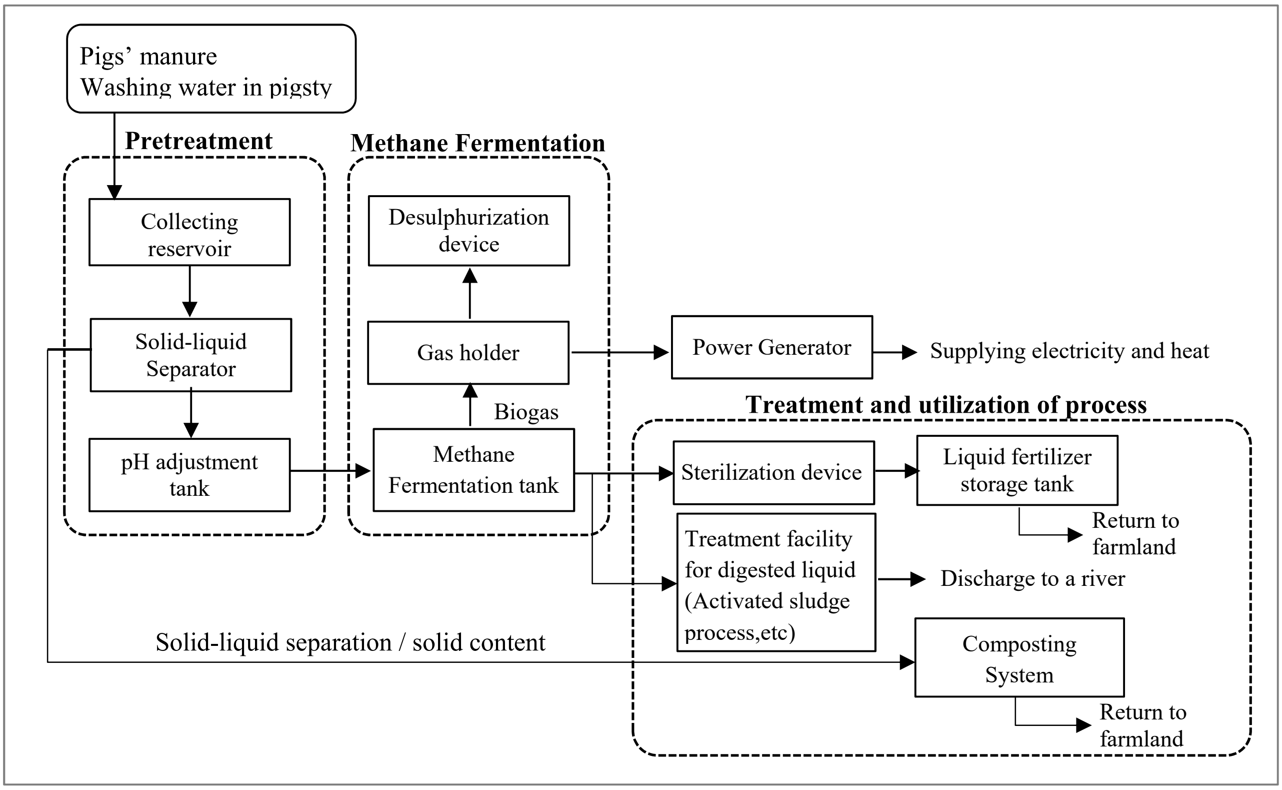

Fig. 4.2.1 Methane fermentation system

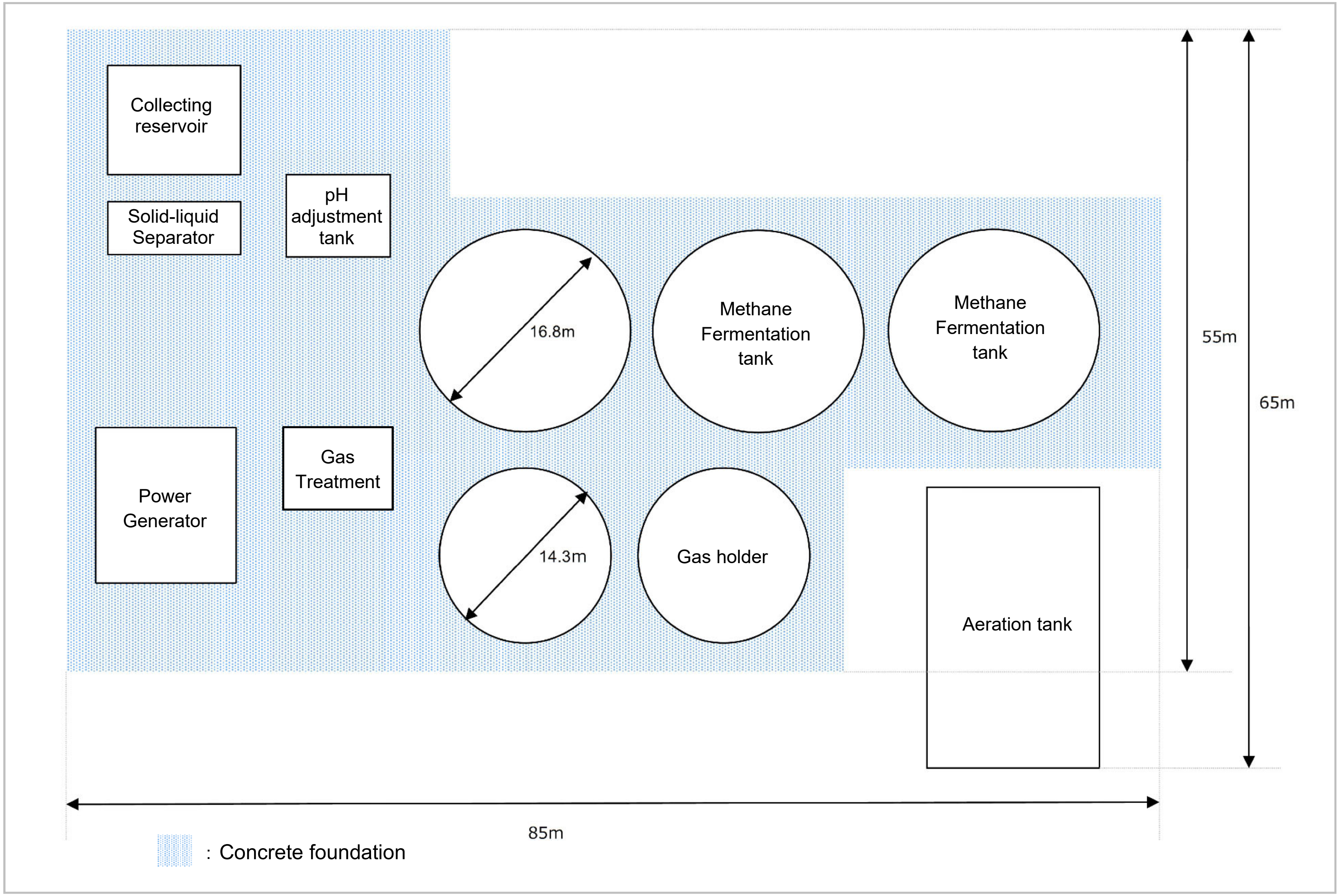

Fig.4.2.2 Plan view of methane fermentation facility

Table 4.2.1 Specifications of the equipment (Wet medium temperature fermentation)

No.	Equipment	Parameters	Remarks
1	Collection pond(raw material receiving tank)	50 m3	
2	Solid-liquid separation equipment	40t/hr	
3	pH adjustment tank	600 m3	
4	Methane fermentation tank	8800m3 (2928 m3×3 tanks)	Diameter: approx.16.8m Height: approx.13.2m
5	Biogas holder	3000 m3 (1500 m3×2 tanks)	Diameter: approx.14.3m Height: approx.10.72m
6	Desulfurization and dewatering equipment		
7	Gas engine	800kW	

Photo 4.2.1 Methane fermentation tank※

Photo 4.2.2 Biogas holder※

※Boselan Tanks Co.,Ltd

Table 4.2.2: Cost for equipment application (Wet medium temperature fermentation)

No.	Equipment	Cost (USD)
1	Fermentation and electricity generation equipment	1,400,000
2	Electrical & measuring accessories	100,000
3	Construction cost	500,000
4	Facility designing and managing cost	200,000
5	General management costs	200,000
6	Transportation costs	300,000
7	Tax	225,000
Total		2,925,000

Table 4.2.3 Cambodia waste water standards エラー! ブックマークが定義されていません。

No.	Item	Unit	Allowable limits for pollutant substance discharging to	
			Protected public water area	Public water area and sewer
1	Temperature	℃	< 45	< 45
2	pH	—	6 – 9	5 - 9
3	BOD5 (5 days at 20 ℃)	mg/L	< 30	< 80
4	COD	mg/L	< 50	< 100
5	Total Suspended Solids	mg/L	< 50	< 80
6	Total Dissolved Solids	mg/L	< 1000	< 2000
7	Grease and Oil	mg/L	< 5.0	< 15
8	Detergents	mg/L	< 5.0	< 15
9	Phenols	mg/L	< 0.1	< 1.2
10	Nitrate (NO3)	mg/L	< 10	< 20
11	Chlorine (free)	mg/L	< 1.0	< 2.0
12	Chloride (ion)	mg/L	< 500	< 700
13	Sulphate (as SO4)	mg/L	< 300	< 500
14	Sulphide (as Sulphur)	mg/L	< 0.2	< 1.0
15	Phosphate (PO4)	mg/L	< 3.0	< 6.0
16	Cyanide (CN)	mg/L	< 0.2	< 1.5
17	Barium (Ba)	mg/L	< 4.0	< 7.0
18	Arsenic (As)	mg/L	< 0.10	< 1.0

4.2.2 Efficiency of CO2 reduction

"Reference equipment" is the existing methane fermentation treatment facility; "project equipment" is the proposed equipment (Table 4.2.1) which is expected to give a higher biogas recovery rate; the generated of power generated is large compared to the reference equipment. The amount of emission reductions is calculated according to the following formula using the actual power generation parameters of the current equipment (data from the hearing result) and the planned power generation of the proposed equipment.

(1) Annual emissions reduction ER_y

$$ER_y = (EG_{PJ,y} - EG_{RE,y}) \times EF_{elec,y}$$

where

ER_y : Emissions reduction per year in year y(tCO2/y)

$EG_{PJ,y}$: Quantity of net electric power generation under the project activity in the year y (MWh/y)

$EG_{RE,y}$: Quantity of net electric power generation under the reference activity in the year y (MWh/y)

EFelec, y : Grid power CO2 emission factor of Cambodia (tCO2/MWh)

Table 4.2.4 Emissions reduction・Value set for the parameter

Parameter	Setting value	Setting rationale / source
ER_y :	2,527(tCO2/y)	—
$EG_{PJ,y}$	6,451.2 (MWh/y)	・Planned power generation amount of the proposed equipment which was examined assuming the number of horses of company C pig farm as a prerequisite (=800kW×24hours×28days×12months)
$EG_{RE,y}$	2,520.0 (MWh/y)	・Monthly power generation amount of the existing facility(Results of hearing to Company C:210,000kWh)×12months
$EF_{elec,y}$	0.643(tCO2/MWh)	・Grid power CO2 emission factor of Kampot-Sihnouk Grid in Cambodia (The instruction of the second public offering for JCM subsidized project in FS 2018)

(2) Emissions reduction during project period ER_p

The emissions reduction during the project period (statutory useful life) was calculated by multiplying the annual emissions reduction by the project period (years). The statutory useful life of this project shall be set to 7 years because the facility used in methane fermentation processes is corresponding to part "agricultural machinery" in "Ministerial Ordinance Concerning the Useful Life of Depreciable Assets"

$ER_p = ER_y \times P$

$= 2{,}527 \times 7$

$= 17{,}689 (tCO2)$

where

ER_p : Emissions reduction during the period P (tCO2)

p: Project Period (y): 7 years

4.2.3 JCM equipment subsidy・Cost effectiveness

The JCM equipment subsidy, based on the following formula, will be 637,000 USD. That is the product of cost-effectiveness 4,000 JPY / tCO2), the minimum level to be chosen for JCM subsidized project, and CO2 emissions reduction during project period.

【JCM equipment subsidy】

=【Cost-effectiveness (4,000 JPY/tCO2)】×【Emissions reduction during project period (17,689tCO2)】

= 70,756,000 JPY ≒ 637,000USD (1USD = 111 JPY)

4.2.4 Business profitability

The following are the calculation of recovery period of initial cost and IRR (internal rate of return) when the reference equipment is replaced with the project equipment, based on 1) Burden of increasing initial cos and 2) Increase in power generation derived from increasing renewable energy (in other words, the amount saved from grid electricity reduction).

(1) Increase in initial cost

The initial cost increase when applying the project equipment (compared to when applying the reference equipment) deducting the JCM equipment subsidy is 1,788USD. (Table 4.2.5)

Table 4.2.5 Initial increase in cost

No.	Item	Cost	Remarks
1)	Initial cost(project equipment)	2,288,000USD	=Total equipment cost 2,925,000 －JCM equipment subsidy 637,000
2)	Initial cost(reference equipment)	500,000USD	According to hearing result
3)	Initial increase cost	1,788,000USD	＝1)－2)

(2) Annual electricity cost reduction

Compared to the reference equipment, the project equipment can help to increase the electricity generation by up to 3,931,200kWh / y (Annul power generation of the project equipment: 6,451,200 kWh / y — Annul power generation of the reference equipment: 2,520,000 kWh / y).

Therefore, the amount of money saved from grid electricity reduction cost will be calculated from the formula to multiply the amount of electricity increased by the unit price of grid electricity.

Annual amount of money due to grid electricity reduction

＝ increased electricity (3,931,200kWh / y) × grid electricity unit price (0.16USD / kWh)

＝ 628.992 USD / y

(3) Maintenance costs

Maintenance work of the project equipment will be simpler than the maintenance of reference equipment; therefore apart of the cost can be reduced; however, that reduction is not estimated in this survey from a conservative point of view.

(4) Business profitability

We have carried out the cash-flow calculation of the project based on the increase in initial cost and the amount of money saved from grid electricity reduction mentioned above. As a result, the IRR (internal rate of return) within 7 years of the project is 27.2%, recovery period of initial cost is 2.9 years (Table 4.2.6).

Table 4.2.6 Cash flow calculation table (Methane fermentation treatment equipment)

Year	0	1	2	3	4	5	6	7
1. Income(USD)	0	628,992	628,992	628,992	628,992	628,992	628,992	628,992
Reduction of electricity charge		628,992	628,992	628,992	628,992	628,992	628,992	628,992
2. Expenses(USD)	-1,788,000	0	0	0	0	0	0	0
Total Equipment Cost (Project case)	-2,925,000							
Total Equipment Cost (Reference case)	500,000							
JCM Subsidy	637,000							
3. Profit before depreciation(USD)	-1,788,000	628,992	628,992	628,992	628,992	628,992	628,992	628,992
4. Depreciation(USD)		585,000	585,000	585,000	585,000	585,000	0	0
5. Profit after depreciation(USD)	-1,788,000	43,992	43,992	43,992	43,992	43,992	628,992	628,992
6. Tax(USD) Corporation Tax(20%)	0	-10,998	-10,998	-10,998	-10,998	-10,998	-157,248	-157,248
7. Profit of the current term(USD)	-1,788,000	32,994	32,994	32,994	32,994	32,994	471,744	471,744
8. Cash flow(USD)	-1,788,000	617,994	617,994	617,994	617,994	617,994	471,744	471,744
Accumulation of Cash	-1,788,000	-1,170,006	-552,012	65,982	683,976	1,301,970	1,773,714	2,245,458

IRR・Recovery period of initial investment(year)

Project IRR(7years)	27.2%
Recovery period of initial investment(year)	2.9

4.3 Examination of monitoring method

The Annual emissions reductions - like the following formula - is calculated by multiplying the increase in electricity generation when the reference equipment is replaced with the project equipment, with the grid emission factor.

For power generation of project equipment ($EG_{PJ,\ y}$), use monitoring value during project time. The amount of electricity generated by the reference equipment ($EG_{RE,\ y}$) is calculated by multiplying the total number of pigs raised or the volume of urine and urine discharged during the project period with a predetermined coefficient (Table 4.3.1).

■ Formula to calculate annual emissions reduction ER_y

$$ER_y = (EG_{PJ,y} - EG_{RE,y}) \times EF_{elec,y}$$

Where

ER_y : Emissions reduction in year y (Emission reductions in year y) (tCO2 / y)

ER_y : Amount of electricity generated from the project activity in the year y (MWh / y)

$EG_{RE,y}$: Amount of electricity generated from the reference activities in the year y (MWh / y)

$EF_{elec,y}$: Grid electricity emission rate in Cambodia (tCO2 / MWh)

Table 4.3.1 Coefficient for calculating emissions reduction / Method for setting parameter

Coefficient / parameters	Explanation	Setting method
$EG_{PJ,y}$	Annual electricity generation after the introduction of equipment. (kWh / y)	・Actual measured value
$EG_{RE,y}$	The Annual amount of electricity estimated from the number of livestock after the introduction of equipment.	・Multiply the number of livestock or the quantity of manure after the introduction of equipment. ・ The above mentioned predetermined coefficient is taken from the value set in the current equipment's specification or "■Coefficient estimating electricity generation of reference equipment $EG_{RE,y}$ " as below.
$EF_{elec,y}$	Emission factor of grid power in the project in the site	・Set up based on the Cambodia published data

■Coefficient estimating electricity generation of reference equipment $EG_{RE,y}$

As shown in the following formula, the electricity generation generated by the reference equipment will change according to linearly with the quantity of manure etc. of livestock; that is why it is possible to calculate electricity generated per livestock or per manure ton (= coefficient) based on data such as the quantity of manure (the number of livestock) and electricity generation in the past.

$$EG_{RE,y} = MRA \times NCV \times EF_{generator} \times 10^6 / 3,600$$

In which,

MRA: Methane recovery amount (t / y)

NCV : NET calorific value (GJ / t) : 50.0 (GJ / t)

EF : Efficiency of generator : the value of the catalog of the machine

In which methane recovery amount (MRA) is calculated according to the following formula (Reference: AMS-III.D. Methane recovery in cattle manure management systems).

$$MRA = UF \times D_{CH4} \times \Sigma(MCF \times B_{0,LT} \times N_{LT,y} \times VS_{LT,y})$$

In which:

UF : Model correction factor

D_{CH4} : CH4 density (t / m3) 0.00067 t / m3

MCF : Annual methane conversion factor of the reference facility

$B_{0,LT}$: Maximum CH4 generation potential of unit ignition loss of livestock excreta by type of livestock (m3 / kg-dm)

$N_{LT,y}$: Number of target livestoc in year y (animals)

$VS_{LT,y}$: Loss on ignition per head of livestock by type of livestock in year y (kg-dm / animal / y)

4.4 Examination of business structure

Regarding the project implementation structure, it is expected that the international consortium will be followed. It includes the representative company (Japanese company) and the partner participant (local livestock facility). The consortium will install equipment and monitor, etc. Fig. 4.4.1 shows the role of each party such as the representative company, the partner participant and other related parties.

If the burden of initial costs becomes an obstacle to the implementation of the project, the representative company will bear the initial cost, introduce the equipment, and lease to the partner participant to do business.

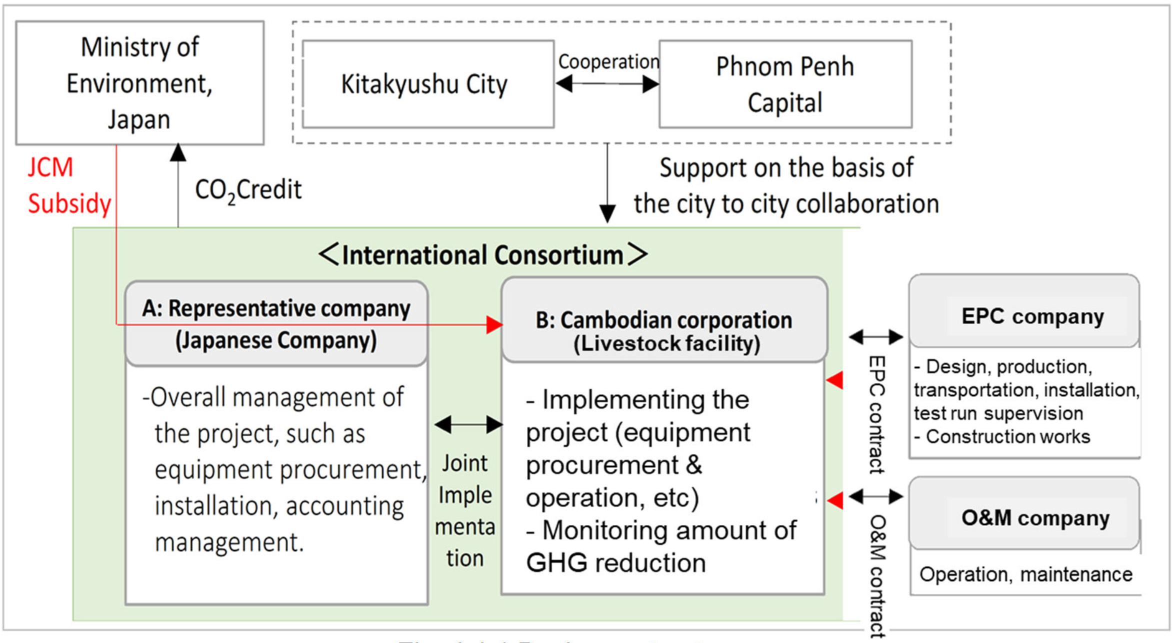

Fig. 4.4.1 Business structure

4.5 Examination of fund procurement methods

Basically, except for JCM equipment subsidy, the partner participant will be responsible for the remaining operating capital (initial cost). If the burden of initial costs becomes an obstacle to the implementation of the project, the representative company will bear the initial cost, introduce the equipment, and lease to the partner participant to do business.

4.6 Examination of project implementation schedule

After being selected as a JCM subsidized project, implementation schedule is estimated as follows.

- Investigation and design: about 1 month
- Purchase of equipment, installation, construction and commissioning: about 6 months

4.7 Summary and challenges for the future

- In this survey, we could propose an inexpensive methane fermentation facility with high profitability. By introducing this proposed facility, it is possible to efficiently recover biogas and increase electricity generation than existing facilities (methane fermentation tank made of rubber).
- In the future, we need to collect detailed data such as the composition and quantity of wastewater from the livestock facility and introduction cost of existing facilities, amount of electric power generation, etc. Furthermore, it is necessary to further study the facilities and the project implementation system.
- At the present time, the digestive juice is in a state of being discharged to a river through a waterway without proper treatment. Therefore we need to consider spraying drainage (digestive juice) after biogas recovery to the surrounding palm plantation and rubber plantation.
- If the methane fermentation treatment facility which is inexpensive and has a high recovery efficiency of biogas and proper use / treatment method of wastewater are established with this proposal, there is a possibility that this equipment and the proper use / treatment method will spread in Cambodia where livestock are expected to become larger and larger in the future.

Citations and Reference

[1] The figure is created based on the data of "Kingdom of Cambodia、 Annual report for Agriculture forestry and fisheries 2016-2017 and direction 2017-2018"

[2] Mr. PHIN Rady (Director of Water Quality Management Dept., EPA, MoE), Pig Wastewater Management in Cambodia,WEPA Group Workshop on Pig Wastewater Management in Asia 21-22 February 2017,Chiang Mai, Thailand

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