To: Ministry of the Environment

Large-Scale JCM Feasibility Studies in 2014
for Achievement of Low-Carbon Society in Asia

Project on feasibility study on comprehensive resource circulation system for low carbon society in Republic of Palau

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[Report]

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AMITA Institute for Sustainable Economies Co., Ltd.

Overview

○ Present situation and issues of Republic of Palau

Republic of Palau is an island nation that has almost the same area as Yakushima Island, Japan with the population of about 20,000. The main industry is tourism. Seventy percent of the citizens are concentrated in Koror state where the previous capital located and almost ninety percent live there or in Babeldaob Island, which is connected with the state by bridges.

The country has increasingly serious problems of waste year after year. There is a landfill site in Koror state that is managed by the country. It is already full and raising the levees prolongs the life. Other states possess their own small-scale landfill site, which is operated as open dumping to just dig a pit and bury the matter. Every landfill site has a concern of marine pollution due to the leachate. Though the country-led deposit and recycle system of beverage bottles and the Koror state's activity of composting and plastic-to-oil conversion are promoted, the effects are still limited.

In Koror state, about 70% of area is provided with sewerage. The sewage treatment plant adopts the percolating filter purification method. A large amount of sludge is accumulated for years in the initial sedimentation basin and the sedimentation basin after purification and the treatment of it is an issue. In addition, new hotels are opened one after another in association with increase in tourists in recent years and the sewage treatment capacity does not come up with it. In the regions without sewerage, installation of purification tanks (septic tanks) is mandatory. However, many purification tanks are not serviced with sludge collection that is regularly required and cause a problem of overflow when it rains.

The country has little public transportation and major means of mobility is automobiles. The tires used in the country are mostly imported as secondhand and have a short service life. Therefore, a large number of waste tires are generated due to changing tires and the landfill sites have mountains of wasted tires carried in and piled up for several dozens of years. The waste tires have water collect on them and provide the source of mosquitos that transmit infections. Thus, a significant problem arises.

○ System and technology to propose

It is extremely difficult for small island nations like Palau to individually consider and embody solutions to the problems described above. Meanwhile, everything gathers in a small area and human relationship is very close, which leads to the feature to easily address each issue and conduct comprehensive actions across the sectors. A resource circulation system is planned, taking into account the situation above. This system combines the technologies of the following together: (i) conversion into solid fuel, (ii) bio-gasification, and (iii) waste tire recycling into cement material. Thus, comprehensive resource circulation is intended and achievement of "a circulation-based low-carbon society model as the entire islands" is aimed at, involving multifaceted benefits such as reduction in greenhouse gas emission, reduction in the amount of waste landfilled, creation of renewable energies and promotion of agriculture and tourism. The system factors are described respectively below:

(i) Waste with low water content (plastics, paper, textile, pruned branches, etc.) are turned into solid fuel and used for air-conditioning of buildings such as the Capitol by a biomass boiler and an absorption refrigerator.

(ii) Organic waste with high water content (food waste, organic residues, etc.) and sewage treatment sludge are converted into biogases and liquid fertilizer by a wet methane fermentation method. The biogases are used as energy by cogeneration of heat and electricity while the liquid fertilizer is utilized for agriculture. Additionally, Napier grass, which grows fast, is cultivated using the liquid fertilizer and used as a biogas material to enhance the amount of power generation.

(iii) Waste tires are shred and exported to countries that demand them to use as cement material and fuel.

○ Description of the study in this year

On development of the project plan, there was no valid input data of types and volumes of the waste. Therefore, the FS in this year involved the survey on the amounts carried into landfill sites and the examination of the waste compositions derived from household and business facilities (restaurants, hotels, and retail stores). The results indicated that the estimated amount carried into landfill sites was 16 tons per day; 4.6 to 5.0 tons per day out of it could be expected as the input amount for solid fuel and 1.6 to 1.9 tons per day for bio-gasification. The draft of project scheme/plan was developed based on these survey data and discussion and consensus building with relevant parties were carried out.

In addition, it is required to sort waste properly based on the recycle standards in order to realize this system. In this study, waste sorting tests were conducted on families in order to understand how properly the waste could be separated at that time and to devise the methods of sorted collection, instruction and enlightenment and incentives to match the actual situation (Three categories were specified: A. recycle, B: food waste and C: other waste). The results indicated that 60 to 80 percent of the total waste was sorted into the recyclable categories A and B. While some issues were extracted, many positive comments were filled in the posterior questionnaires. Thus, adequate feasibility was confirmed.

For the purpose of familiarization and education of biogas technology and consideration of operating conditions, a small biogas plant was assembled and operated with the use of the materials that could be procured mainly from local home-improvement centers and relevant people were invited to a facility tour. In the tour, biogas that was actually generated from sludge and food waste was used in a stove to cook a simple dish to serve as well as connected to a small generator to obtain electricity that could turn on fans and LED bulbs. The visitors experienced the real process to produce energy and resource (liquid fertilizer) from “waste.” The participants submitted positive comments like “Good technology. I am eager for introduction to Palau” and “Many Palauans still have farms and liquid fertilizer is beneficial.”

○ Summary and issues

In the project of this year, the JCM committee members in Palau and both of the Ministers of Public Infrastructure, Industries, and Commerce and Natural Resources, Environment and Tourism, which are the counterpart sectors, are all positive to the current draft of the project plan and approve continuing the FS in the next year. The PPUC to work together in the bio-gasification project also examines them positively. The issues in the future include: (i) continuous consensus building with regard to the project scheme/plan and relevant legal systems (especially, financial resources and implementation structure); (ii) understanding yield and cost of Napier grass cultivation using biogas digestive juice (liquid fertilizer) and establishment of efficient growth and control methods; and (iii) coordination of plant location and development of detailed plant/system design and operation plan. Solving these issues substantially increases the certainty of realizing this project.

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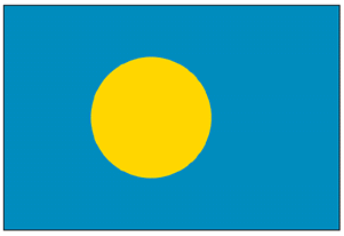
- List of acronyms -

Acronyms	Official name
AFPAC	Automatic Fuel Price Adjustment Clause
BPW	Bureau of Public Works
CIP	Capital Improvement Project
DSWM	Division of Solid Waste Management
EQPB	Environmental Quality Protection Board
FAO	Food and Agriculture Organization
JICA	Japan International Cooperation Agency
MPIIC	Ministry of Public Infrastructure, Industries, and Commerce
MRD	Ministry of Resource and Development
NSWMP	Draft of National Solid Waste Management Plan
PPUC	Palau Public Utilities Corporation
PWSC	Palau Water and Sewer Corporation
WHO	World Health Organization

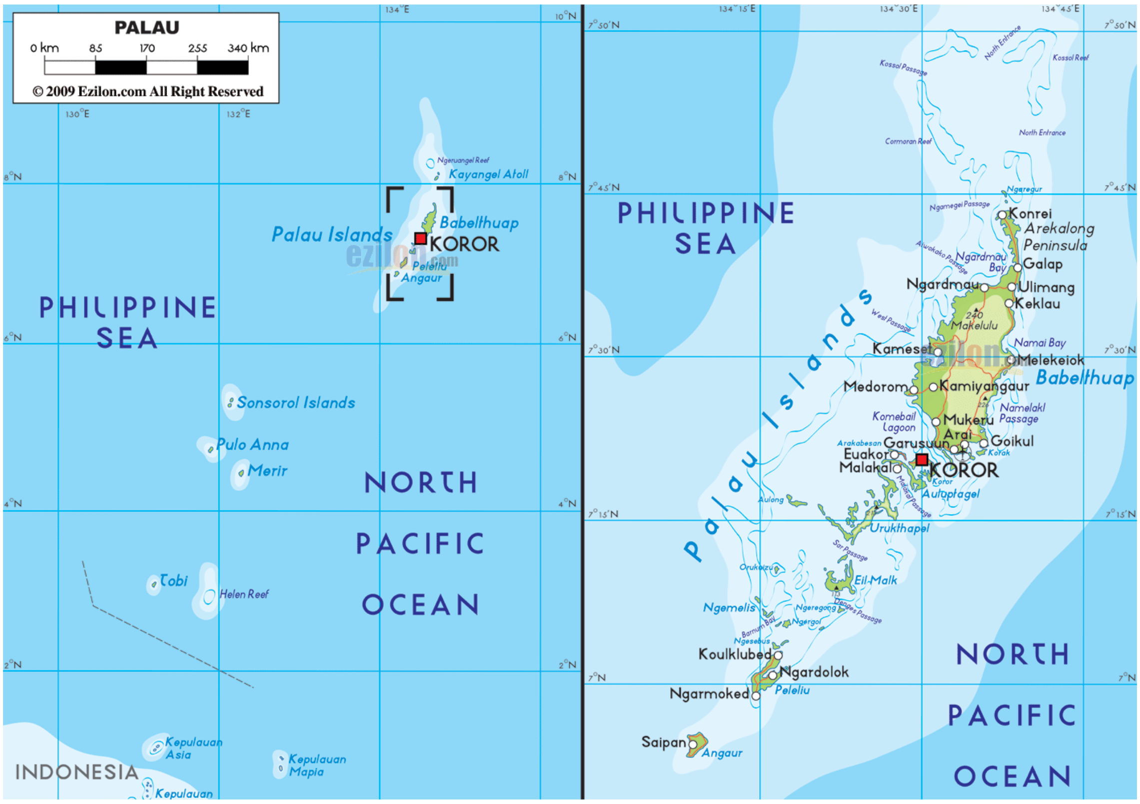
Chapter 1 Systems in the Target Country and Cities and Project Circumstances

1.1 Basic Information of Republic of Palau



Population	17,501 (in 2012)
Area	488 km^2 (similar to Yakushima Island) Nine islands out of 386 are inhabited.
Capital	Melekeok (Relocated from the former capital of Koror in October 2006)
GDP	247.0 million US$ (in 2013)
Per capita income	13,574 US$ (in 2013)
Main industry	Tourism (146,867 tourists in 2014)
Major products imported	Petroleum, vehicles, machines, food, etc.
Major products exported	Seafood, etc.

Note that the exchange rate in this report is US$1 = JPY 100.



(Source: Ezilon map http://www.ezilon.com/maps/oceania/palau-physical-maps.html)

Project site

1.2 Burdens on Environment Related to the Project

The current situation on environment, resources, and food and their problems are described below.

1.2.1 Tight Capacity of Final Disposal sites

In Palau, the collected waste is carried into landfill sites. M-dock landfill in Koror state employs the Fukuoka-type system and the national government manages it. While it has already been used for more than 50 years and a stringent situation is developed, there is an anxiety that the leachate causes marine pollution. Though the levees were raised in 2012, it is expected to become full in 5 years. As for Airai state, a landfill site established in 1995 accepts open dumping but has a plan of relocation because it is in vicinity of the most densely populated area in Airai state. Though a plan to construct a new landfill site is now proceeding in Aimeliik state, it seems the revenue of several million dollars has not been ensured yet. Note that the burden of the disposal cost for landfilling is not imposed and the residents or the business operators do not need to bear the cost.

Picture 1.2.1.1 Accumulated garbage exceeds the acceptable capacity.

Picture 1.2.1.2 Vent pipe in the Fukuoka method landfill of M-dock

Concerning incineration of combustible waste, though an NGO of Japan donated incinerators to Airai state in 2006 and 2007, incineration of only paper is permitted by the Environmental Quality Protection Board (EQPB), and they are seldom operated.

As for pick-up and separation by type of household waste, state governments chiefly collect them. Household waste stations for sorted collection were introduced in some regions in Koror state. However, sorting garbage is not thoroughly performed. In consideration of this actual situation, a new system and stations are to be introduced across Koror state in 2015.

1.2.2 Leakage of Sewage/Purification Tank Sludge

In Palau, sewage treatment facilities have been installed in Malakal Island, Koror state and the capital Melekeok. Sewage is transferred from the first reservoir tank to the second and the third sedimentation basins and then released to the sea. Current sewage treatment plants let sludge accumulated in the sedimentation basins and face significant problems in controlling sewage sludge such as overflow of seepage from tanks due to rainfall.

In the regions where sewer systems are not provided, installation of a purification tank is obliged by the EQPB and a violator pays a heavy fine of 10,000 dollars per day. If a family uses a purification tank, a private operator pumps out the sludge in the purification tank. As the soil in Airai state is muddy, sludge in a purification tank may overflow when it rains.

Regarding sewage treatment in accommodations, Palau Pacific Resort (PPR) uses private systems for both clean water and sewage and the sewage is treated in anaerobic tanks. The sewage sludge is carried to a sewage treatment plant every several years. Palau Royal Resort (PRR) connects their purification tanks to sewers to dispose of the sludge.

The sewer control in Palau is currently managed and operated by new Palau Public Utilities Corporation (PPUC), which was created in September 2013 by consolidation of old PPUC and Palau Water and Sewer Corporation (PWSC). The coverage of sewer systems in Koror state is about 70% and sewerage is provided free of charge.

Picture 1.2.2.1 First reservoir tank

Picture 1.2.2.1 Third (final) sedimentation basin

1.2.3 Dependence of Energy on Imported Fossil Fuel

The electrical power and energy policy in Palau is administrated by Ministry of Resource and Development (MRD) and PPUC is a sole operator to conduct electricity business.

There are five power generation plants in Palau and 95% of the total power needs are covered by the Koror-Babeldaob power system from the Malakal and Aimeliik power plants. All power is generated by diesel systems. The place that consumes power the most is Koror state that occupies about 80% of the entire power needs. Breakdown of the power consumption is 42% for commercial use, 30% for households, and 23% for government demand.

While the peak power demand in Palau was 12.5 MW as of 2011, the available power supply capacity was as tight as 14.4 MW. A fire in the Aimeliik power plant in November 2011 caused scheduled power outages and the supply capacity of the plant has not been recovered so far. They continue to supply power under the circumstances with the existing decrepit facilities and chronic shortage in supply reserves for maintenance works. Not a few large-scale hotels cover their electricity needs by in-house power generation.

Meanwhile, considering that the population in Palau was increased by 0.6 to 0.7% per year from 2009 to 2012 and the number of tourists is on a rapidly elevating trend with more than 140,000 tourists in FY 2014, the power needs are growing and stable power supply is positioned as an urgent issue.

1.2.4 Dependence of Food on Imports

As for food self-sufficiency of the nation, most food depends on imports. While ingredients of local products are partly used for food service of hotels and primary and junior-high school lunch, imported food is basically used and diverse types of food including rice, corned beef, canned tuna and other flakes, vegetables, fruits are imported. Stable supply of local ingredients is difficult and poor amounts of fish and local vegetables are supplied. Under such circumstances, the Food and Agriculture Organization (FAO) conducts a food security program that instructs how to handle soils to grow crops and encourages organic farming though organic fertilizers are lacking. Note that, while pineapple and watermelon used to be grown on a large scale in the age of rule by Japan, they only produce tapioca, cassava, banana, pineapple, and coconut on a smaller scale now. The younger generation does not engaged in agriculture and the labor of farming is mostly provided by foreigners such as Philippine and Bangladeshi.

Pig farming, which was active as a livestock business in 1970s, is now rarely found in Koror state with dense population. Today, pig farmers, which are scattered in Airai and Aimeliik states, do not organize a company, but run the farms as a second job. The scale is generally 20 to 30 pigs and at most 50 to 60.

1.2.5 Problems Caused by Waste Tires

Landfill sites have had waste tires piled nakedly over dozens of years (exact statistical data is not available). The majority of transportation of people in Palau is automobiles. Though several thousands of cars are used in Palau, most of the tires applied are second-hand, imported ones. Therefore, tires are frequently changed, resulting in generation of a huge amount of waste tires. It is a critical issue because the waste tires that have a puddle are a hotbed of mosquitos that transmits infections and a fire occurred to burn waste tires in 2014.

Picture 1.2.5.1 Piles of waste tires

Since Palau is geographically the closest to the Philippines and Indonesia among island countries in the Pacific Ocean and has a geographical advantage on international resource circulation, a great need of international resource circulation on waste tires is assumed. On the other hand, having the background that most of food and consumer discretionary rely on importing, Palau receives about 2,000 containers imported per year. However, the amount of exports is small and some containers to export are even empty. The export cost is probably low when the economics of international resource circulation in Palau is considered. The process to export the mixture of incineration ash and waste tires, which are recycled solid fuels, to cement factories in the Philippines may be acceptable.

1.3 Provision of Infrastructures and Facilities Related to the Project

Situation of provision of infrastructures and facilities related to this project is described below.

1.3.1 Electricity

For electricity billing in Palau, metered fees based on the electricity use in addition to fixed charges are employed. For the metered fees, the basic rate and the Automatic Fuel Price Adjustment Clause (AFPAC) rate that is adjusted according to the movement of petroleum prices are specified.

The following tables show electricity billing of Palau and Japan (Tokyo Electric Power Company, TEPCO).

<table>
<tr><th>Category</th><th colspan="2">Amount used
(kWh/month)</th><th>Charge
(cent/kWh)</th></tr>
<tr><td rowspan="4">Residence</td><td colspan="2">Basic fee</td><td>$3.00/month</td></tr>
<tr><td rowspan="3">Metered</td><td>0-150</td><td>31.7</td></tr>
<tr><td>151-500</td><td>39.1</td></tr>
<tr><td>501 or more</td><td>44.0</td></tr>
<tr><td rowspan="4">Business and public offices</td><td colspan="2">Basic fee</td><td>$11.00/month</td></tr>
<tr><td rowspan="3">Metered fee</td><td>0-150,000</td><td>44.0</td></tr>
<tr><td>151,001-250,000</td><td>43.0</td></tr>
<tr><td>250,001 or more</td><td>42.0</td></tr>
</table>

Chart 1.3.1.1 Electricity charge in Palau (effective from April 2013)

(Created based on the tariff submitted by *PPUC*)

<table>
<tr><th>Category</th><th colspan="2">Amount used
(kWh/month)</th><th>Charge
(cent/kWh)</th></tr>
<tr><td rowspan="4">Residence</td><td colspan="2">Basic fee</td><td>$2.808/month</td></tr>
<tr><td rowspan="3">Metered</td><td>0-120</td><td>19.43</td></tr>
<tr><td>121-300</td><td>25.91</td></tr>
<tr><td>301 or more</td><td>29.93</td></tr>
<tr><td rowspan="3">Business</td><td colspan="2">Basic fee</td><td>$16.848/month</td></tr>
<tr><td rowspan="2">Energy charge</td><td>Summer
(July 1 to September 30)</td><td>17.13</td></tr>
<tr><td>Other seasons
(October 1 to June 30)</td><td>15.99</td></tr>
</table>

Chart 1.3.1.2 Electricity charge in Japan (TEPCO)

(Created based on the tariff detailed on the TEPCO website *http://www.tepco.co.jp/index-j.html*,
Converted at a rate of 100yen/dollar)

Particularly, the electricity fee for business use in Palau is more than twice higher than in Japan, and there is a business environment that is easy to popularize renewable energies. Moreover, fixed-price buyback system does not exist and the risk caused by policy changes is determined low.

1.3.2 Water Service

Palau has a tropical oceanic climate featured by a yearly average temperature of 28 degrees C and a narrow annual range. While there are two different seasons of the rainy season (May to October) and the dry season (November to April), it rains even during the dry season and a hot, humid environment exists as the annual average humidity is said to exceed 80%. According to the Quarantine Information Office, Ministry of Health, Labour and Welfare (MHLW) Japan, tap water in Palau is not potable and bottled mineral water is recommended for drinking. The hot, humid environment facilitates growth of bacteria and fungus and attention is required from a perspective of food sanitation. Some tourists suffer digestive diseases including food poisoning.

(http://www.forth.go.jp/destinations/country/palau.html Quarantine Information Office, MHLW)

Though a crisis situation with regard to water resources has not been generally discussed when tropical islands in the Pacific Ocean are considered, adequate, stable water supply is a significant issue in many islands. Palau is no exception. They have to face the challenges in water resources caused by external factors such as climate change and internal ones including increased population and economic development. In 2014, the submarine piping connecting Babeldaob Island that has a sole rainwater dam and Koror Island was partly damaged and they suffered partial water outage for several months. In view of limited land area, resources, technical capacity and population growth, Palau is required to find the technique for long-term control of resources.

The causes of the water issues in Palau partly consist of intra-national factors, such as a rise in population, but most of the factors are recognized as external. These problems must be solved within the limited ranges of economic, engineering and human resources in the country but the problem solving is considered difficult without assistance of developed countries. (Reference: Open information of the government "Comprehensive water resource management in Palau")

1.4 Governmental Organizations Related to the Project and Their Roles

The overall governance of solid waste management administration is a role of the Division of Solid Waste Management (DSWM) of the Bureau of Public Works (BPW), the Ministry of Public Infrastructure, Industries and Commerce (MPIIC) of the national government. It has four office staff members now. While pick-up and disposal of garbage are managed by the state governments, only the landfill sites in the Koror state are controlled by the national government and about ten field staff members of the national government DSWM are assigned to the largest final disposal site in Palau, M-dock landfill. The landfill sites in the other states are managed by the state government. The background is assumed that, M-dock landfill in Koror state, which had the previous capital, was the only landfill site in the past in Palau.

Concerning the solid waste management in Koror state, the Koror state solid waste management office is in charge of it. The number of staff members is presently 60 and planned to increase to about 75 in the future. Note that the Environmental Quality Protection Board (EQPB) is a regulatory authority and an implementing agency of the laws. It supervises implementation of regulatory and legal systems in public institutions of the ministries and state governments including the MPIIC as well as in private agencies and has 13 staff members.

The annual budget of the DSWM is 35,000 to 45,000 US dollars (hereinafter shortened to "dollars") and most of it is used as the operating cost of M-dock landfill. The budget of the Koror state solid waste management office is addressed to either the Capital Improvement Project (CIP) or the Public Works Department. The budget to the CIP is used for materials and equipment to conduct programs, expenses for office operation and awareness-raising and educational activities while that to the Public Works Department includes labor cost and electricity fee. Whereas the public works-related budget of Koror state was two million dollar in FY 2013, the budget of the solid waste management office to the CIP was 650,000 dollars, which means that about one third is for solid waste management facilities. In addition, the budget to the CIP is increasing yearly as 200,000 dollars in 2011, 300,000 dollars in 2012, 650,000 dollars in 2013, and 750,000 dollars planned in 2014.

1.5 Systems Related to the Project

In 2008, the "Draft of National Solid Waste Management Plan" (NSWMP) was developed during the Project for Improvement on Solid Waste Management in the Republic of Palau, a technical cooperation project of Japan International Cooperation Agency (JICA). In this plan, in order to aim at independent, constructive solid waste management through waste reduction policy with 3Rs (reduce, reuse and recycle), selection of proper techniques and promotion of participation of stakeholders, the following three strategies were proposed: all the stakeholders related to a policy level, capacity development, information sharing or environmental education/enlightenment activities are united to address the targets; waste reduction is promoted to decrease the amount of waste; and existing management and treatment systems of solid waste are improved and modified. However, the NSWMP has not obtained the final approval as a policy and most of the action plans developed have not been implemented yet.

Chapter 2 Project Items to Survey

2.1 Project overview and targets

The overview and targets/points of this project are listed below:

- Not only contribution to reduction of greenhouse gas emissions but also comprehensive resolution of the environmental issues related to waste and sewage treatment sludge and energy and food security problems is aimed at by constructing the resource circulation system shown below.
- In particular, the waste on the islands is featured by a wide variety and small amounts. In order to convert such diverse waste into versatile resource/energy, the technology to turn them into recycled solid fuels is adopted for dry waste and bio-gasification for wet waste.
- Waste tires and solid fuel incineration ash are turned into fuel and raw material of cement in cement factories in neighbor countries.

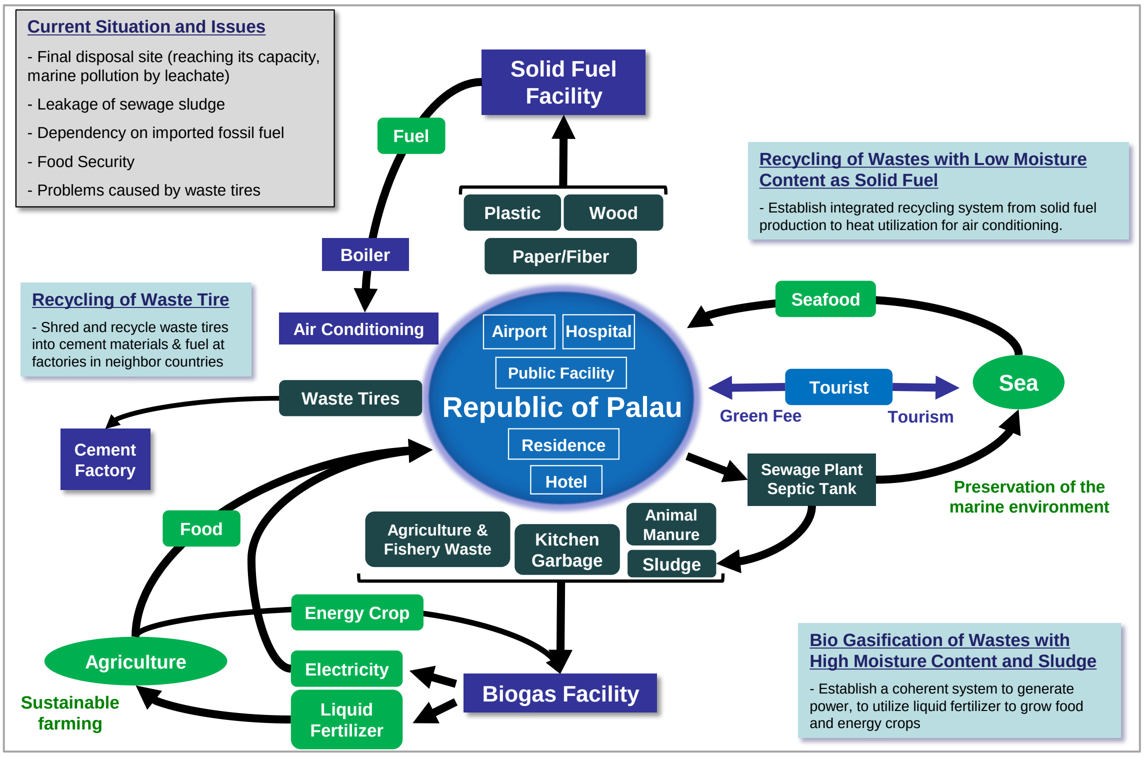
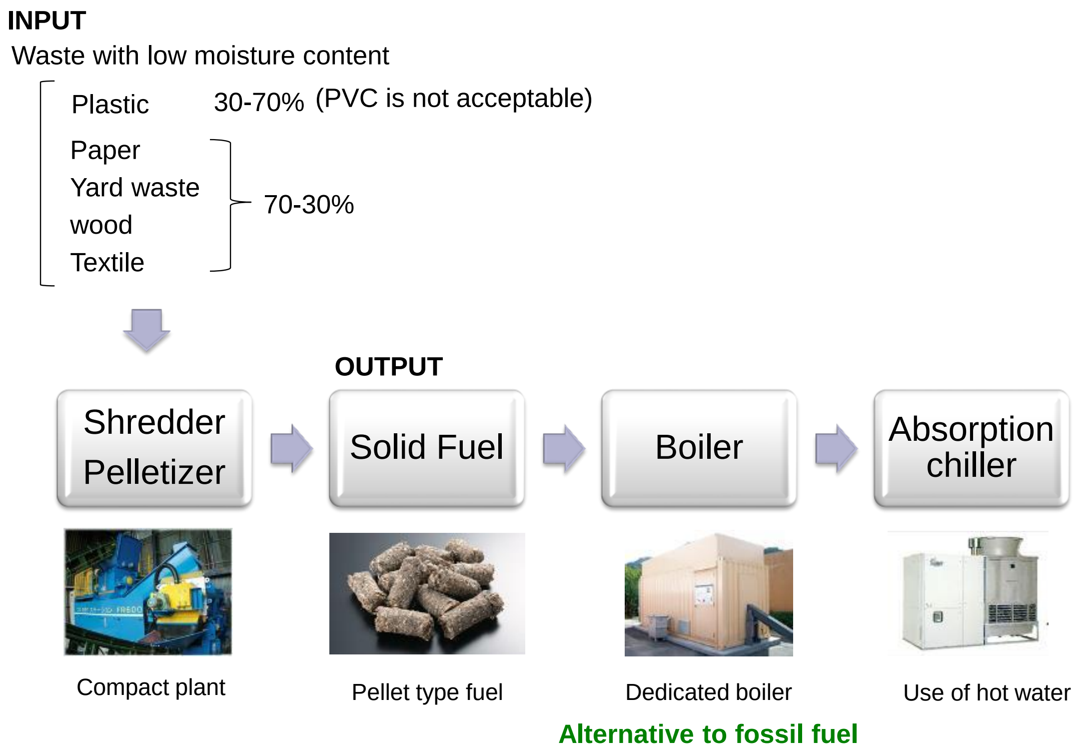


Chart 2.1.1 Project overview

2.2 Major Technologies Introduced

2.2.1 Technology for Producing Recycled Solid Fuels

We proposed a mechanism to burn the fuels manufactured using solid fuel production facilities and to convert heat into air-cooling using an absorption chiller as follows.



○ About solid fuel production facilities

Recycled Solid Fuels are produced by sorting and crushing the above raw materials, applying heat and pressure to them using a molding machine, and then cooling the molded pellets. Since the plastics contained in the raw materials melt with heat to solidify the molded pellets, approximately 30 percent of the raw materials need to contain plastics.

○ Characteristics of solid fuels

Recycled Solid Fuels have the following characteristics:

- They are usable as petroleum substitution fuels because their calories can be adjusted uniformly (5,000–8,000 kcal/kg)

- Their calories can be adjusted by changing the proportion of plastics and other raw materials
- They can be formed into compact and uniform sizes for better handling
- They can burn stably
- They have superior storage properties

In Japan, solid fuels made from waste are generally categorized into the following two types: RPF (Refuse Paper & Plastic Fuel) and RDF (Refuse Derived Fuel). According to the Japan RPF Association (http://www.jrpf.gr.jp/index.html), RPF represents high-grade solid fuels made mainly from waste paper and plastic, which are difficult to material-recycle among industrial waste. RPFs are utilized in many industries such as major paper-manufacturing, steel and lime companies as alternatives for fossil fuels such as coal and coke. In addition, JIS has determined the grading categories according to the calorific power and components as follows:

Type/Grade	RPF-coke	RPF			Measurement method
	-	A	B	C	
Higher calorific power MJ/kg	33 or higher	25 or higher	25 or higher	25 or higher	JIS Z 7302-2
Mass fraction of moisture (%)	3 or lower	5 or lower	5 or lower	5 or lower	JIS Z 7302-3
Mass fraction of ash (%)	5 or lower	10 or lower	10 or lower	10 or lower	JIS Z 7302-4
Mass fraction of total chlorine content (%)	0.6 or lower	0.3 or lower	Higher than 0.3 and 0.6 or lower	Higher than 0.6 and 2.0 or lower	JIS Z 7302-6

*) Sampling was conducted according to JIS Z 7302-1.

Figure 2.2.1.2 RPF grading categories determined by JIS
(excerpted from the website of the Japan RPF Association)

2.2.2 Bio-gasification Technology (Wet Methane Fermentation Technology)

In biogas facilities, methane gas, which is collected by methane-fermenting organic matters, such as human waste, septic tank sludge, and food waste, is used as energy for power generation and fuels. The digestive juice (residue) gained after methane fermentation is utilized as liquid fertilizer and recycled by composting them through dehydration process. The basic configuration of biogas facilities is as follows:

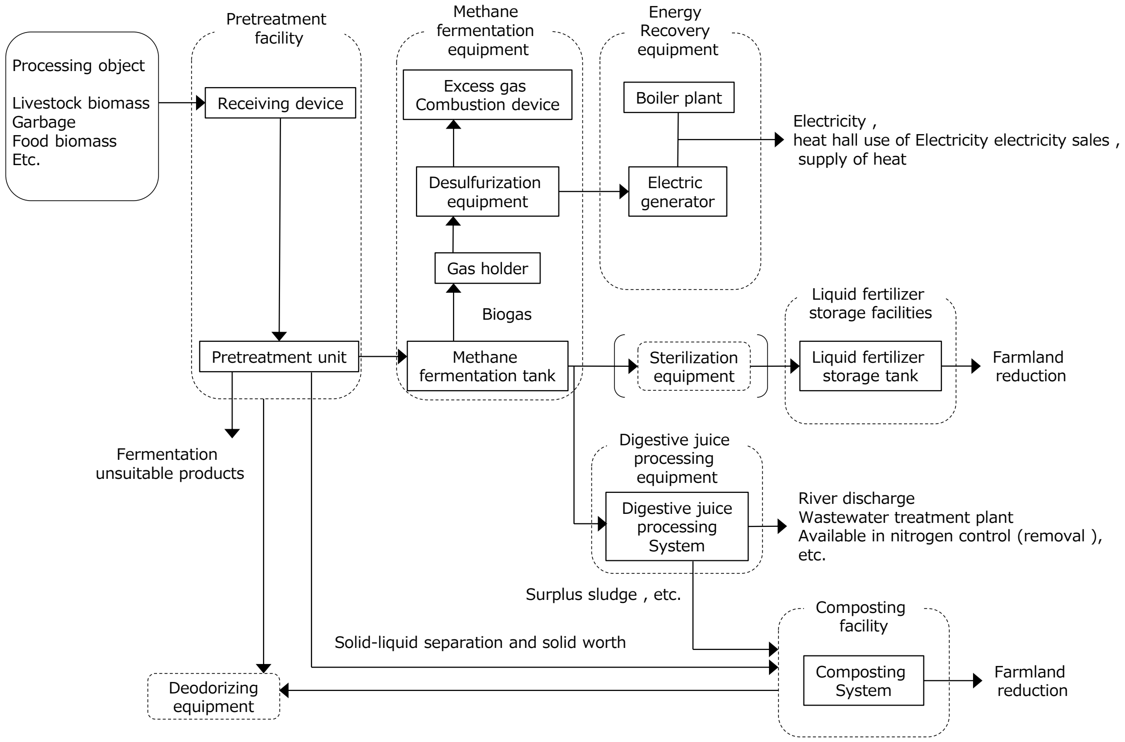


Figure 2.2.2.1 The basic configuration of biomass facilities

Methane fermentation, which is a process where organic substances are degraded by microbial activity under anaerobic conditions to finally generate methane (CH4) and carbon dioxide (CO2), has been utilized in sanitary treatment from long ago. The organic substance degradation process in methane fermentation consists of four stages, which are (1) solubilization and hydrolytic degradation for degrading solid or macromolecular organic substances to low-molecular organic substances, (2) acid production for generating organic acid and alcohols, etc. from low-molecular organic substances, (3) acetic acid generation for generating acetic acid (CH3COOH) and hydrogen (H), and (4) methane (CH4) generation for generating methane (CH4) and carbon dioxide (CO2) from acetic acid (CH3COOH) and hydrogen (H).

Since biogas facilities play a central role in this business as a recycling system for sewage sludge and food waste, we organized domestic case examples. First, we organized major facilities which treat not only human waste and septic tank but also food waste. At the same time, we added some facilities that do not treat “food waste” but use methane fermentation digestion liquid as liquid fertilizer. Furthermore, we also added some case examples where treatment is conducted based on the aerobic fermentation method and digestion liquid is utilized as liquid fertilizer. Based on these conditions, we categorized and organized the facilities according to fermentation temperature and scale (Large: 60 t per day or more, Medium: 20–50 t per day, Small: 1–20 t per day).

Figure 2.2.2.2 Case examples of leading methane fermentation facilities

Business operator	Treating capacity	Object to be treated	Treatment method	Scale	Utilization of digestion liquid as liquid fertilizer	Year of completion
Ikoma city (Nara prefecture)	14.7 t per day	R, H, ST	High temperature	Small	Total volume	2001
Nara city (Nara prefecture)	14.9 t per day	R, H, ST	Medium temperature	Small	Total volume	2003
North Nagoya Hygiene Association (Aichi prefecture)	19.9 t per day	R, H, ST	High temperature	Small	Total volume	2005
Oki Town Health Promotion Public Corporation (Fukuoka prefecture)	41.4 t per day	R, H, ST	Medium temperature	Medium	Total volume (6,000 t)	2006
Suzu city (Ishikawa prefecture)	32.9 t per day	R, H, ST, S, RS	Medium temperature	Medium	Total volume	2007
Koka Wide-Area Administrative Association (Shiga prefecture)	34.2 t per day	R, H, ST	Medium temperature	Medium	Partial volume, Incinerated	2006
Shikaoi town (Hokkaido)	65.8 t per day	C, O	Medium temperature	Large	Total volume (18,000 t)	2007
Yamaga city （Kumamoto prefecture）	50 t per day	R, RU, C, P	Medium temperature	Large	Total volume （13,000 ｔ）	2005
Yagi Agriculture Public Corporation （Nantan city, Kyoto prefecture）	65.2 t per day	F, C, P	Medium temperature	Large	Partial volume （1,300 ｔ）	1997, Expanded in 2001

* The above treating capacity represents the input into a methane fermenter and includes dilution water (t=m^3=kl).
* **R**: Business-related and household food waste, **H**: Human waste, **ST**: Septic tank sludge, **S**: Sewage sludge, **RS**: Rural sewage sludge, **C**: Cow dung, **P**: Pig dung, **F**: Food residue, **O**: Others such as poultry litter

Figure 2.2.2.3 A case example of the utilization of digestion liquid in the aerobic thermophilic fermentation method

Implementing body	Treatment method	Treating capacity	Object to be treated	Remark
Chikujo town (Fukuoka prefecture)	Aerobic thermophilic fermentation	18.7 t per day	R, H, ST	Total volume is used as liquid fertilizer on farms

2.2.3 Technology for Producing Raw Materials and Fuels for Manufacturing Cement

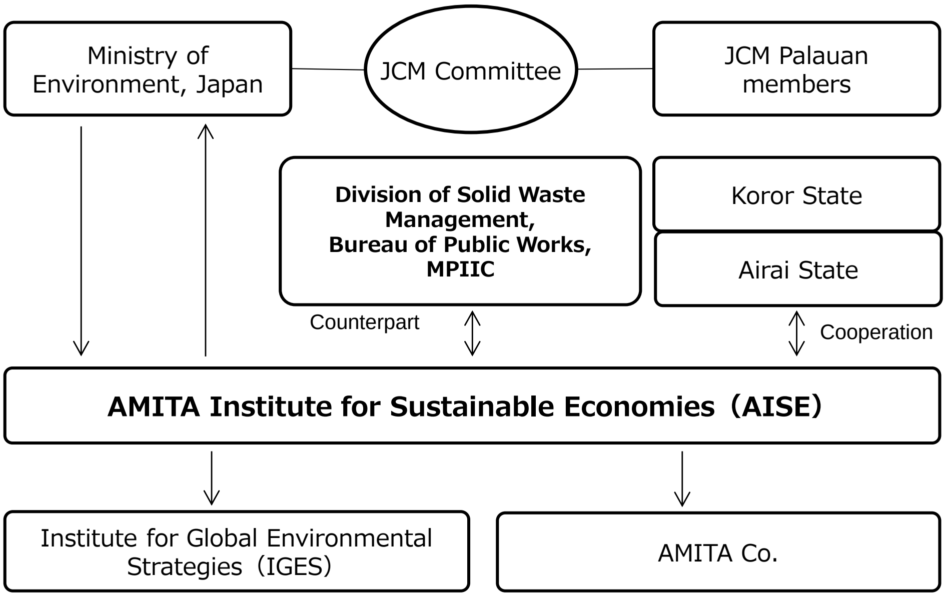
The cement manufacturing process that is characterized by high temperature burning will recycle a large amount of waste safely. For example, coal ash, sludge, incineration ash, and slag, which have similar constituents to cement raw materials can be used as parts of the raw materials (alternative raw materials). In addition, waste tires, oils, and plastics, which have high calorific power, can be utilized as an aid to the fuels used for burning cement (alternative fuels). Since such waste is burned in cement kilns at high temperatures, they not only do not pollute the atmosphere, but also incineration residue, which is normally generated by general incinerators, is incorporated into cement and no secondary waste is discharged.

On the other hand, there are generally a number of conditions for converting waste into the raw materials and fuels for manufacturing cement. For example, since chlorine (Cl) is contraindicated for use in the cement manufacturing process, organic substances and waste with organic substances are disqualified in many cases from the aspect of good hygiene. For converting waste tires from Palau into raw materials and fuels for manufacturing cement, the cleaning process before export is important.

Chapter 3 Investigation System and Content

3.1 Investigation Implementation System

We implemented the investigation based on the following system:



3.2 Investigation Subject and Content

3.2.1 The Goal of Investigation

We implement feasibility investigation projects toward the following goals, aiming to realize the "island-wide recycle-based low-carbon society model," which establishes a comprehensive waste circulation system using the technologies for converting waste into solid fuels and biogas and have multifaceted benefits, such as reduction of greenhouse emissions, reduction of waste landfill and disposal volume, creation of renewable energy, and promotion of agriculture and tourism industry.

(1) To devise sorted collection, teaching, edification, and incentive methods, which are suitable for the nationality and reality, and to develop efficient and feasible methods through the verification-by-verification study in order to recycle the waste discharged from business facilities such as hotel and homes according to the following system.

(2) To convert dry waste with low moisture content into solid fuels, to investigate and verify the possibility of the unified system utilized for the air-conditioning in a building by means of a biomass boiler and an absorption chiller, and to create feasible business plans.

(3) To convert wet waste and sludge with high moisture content into biogas and liquid fertilizer using the wet methane fermentation technology to utilize biogas as energy in cogeneration power plants as well as to investigate and verify the possibility of the unified system for utilizing liquid fertilizer in agriculture to create feasible business plans.

(4) To investigate and verify the possibility of the system for cutting waste tires, exporting them to neighboring countries and utilizing them as the raw materials and fuels for manufacturing cement overseas to create feasible business plans.

(5) To understand the GHG reduction potential of the above project to develop a proposal for the MRV methodology as well as to prepare project design documents (PDD).

3.2.2 Investigation Content

3.2.2.1 Investigation of the amount and composition of waste generated

We carried out an investigation of the composition and amount of waste generated by business operators, such as hotels and restaurants, and homes to use the results as the basic data for basic designs and business plans. In addition, we also conducted the investigation on the amount of waste carried into the M-dock landfill because it was assumed difficult to figure out the amount of emission by extrapolation.

<Implemented items>

- Investigation of the amount and composition of household waste
- Investigation of the composition of business-related waste
- Investigation of the amount of office-related paper waste
- Investigation of the amount of waste carried into the M-dock landfill

3.2.2.2 Verification study of sorted waste collection

In order to convert household waste into resources, we devised the sorted collection method, teaching and edification methods, and incentive method, which are suitable for our nationality and actual conditions, to develop efficient and feasible methods through the validation by the verification study.

<Implemented items>

- Implementation of the verification study of sorted waste collection for homes
- Consideration and development of sorted collection methods

3.2.2.3 Investigation of solid fuel production

We investigated and verified the possibility of the unified system utilized for converting dry waste (plastics, papers, fibers and pruned branches, etc.) into solid fuels to use them for the air-conditioning in buildings by means of biomass boilers and absorption chillers in order to create feasible business plans.

<Implemented items>

- Investigation of the composition of waste for solid fuel production
- Thermal demand investigation and identification of candidate buildings into which the system is introduced
- Approximate calculation of system introduction and running costs, and verification of return on investment
- Development of basic design and business plans

3.2.2.4 Investigation of the commercialization of biogas

We not only converted wet waste (food waste and organic residue) and sludge into biogas and liquid fertilizer (digestion liquid) using the wet methane fermentation technology to utilize them in cogeneration power plants but also investigated and verified the possibility of the unified system for utilizing liquid fertilizer for agriculture to create feasible business plans. In addition, we also designed, assembled and operated a simplified biogas plant, studied appropriate raw material constitution and held an observation tour for relevant parties in order to popularize and edification of

the meanings and effects of this business model and biogas technology.
<Implemented items>

- Investigation of the possibility of input (raw material) procurement
- Investigation of the utilization of output (electricity and liquid fertilizer)
- Implementation of bio-gasification test and a demonstration plant observation tour
- Investigation of the availability of liquid fertilizer
- Approximate calculation of the system introduction and running costs, and the verification of return on investment
- Basic design and creation of business plans

3.2.2.5 Investigation of the recycling of waste tires

We investigated the possibility of a system for exporting waste tires that are cut off to meet the demand countries for use as a raw material and fuel for manufacturing cement and created feasible business plans.
<Implemented items>

- Investigation of the transportation routes to cement plants in the demand countries and legal issues
- Investigation of the issues and costs in the waste tire export process
- Investigation of the actual conditions of the distribution of tires and handling of waste tires
- Design of the charging system and creation of business plans

3.2.2.6 Development and Proposal of Comprehensive Resource Recycling Business Plans

We designed and proposed a feasible and comprehensive resource recycling system and institution for waste.
<Implemented items>

- Design of comprehensive resource recycling system for waste based on the investigations described in above sections 3.2.2.1 – 3.2.2.5, and estimation of total cost
- Design of a national-level institution which enables to continuously obtain financial resources necessary to realize the resource recycling system
- Design of the business scheme which realizes the resource recycling system through PPP (public-private partnership)
- Consolidation of relevant legal systems in connection with the introduction of the resource recycling system, and design and proposal of the outline of necessary legal systems (introduction/revision) and administrative policies by reference to the policies and legal systems of Japan (national and local governments)

- Consideration of the compliance with the National Solid Waste Management Plan (NSWMP)
- To summarize the above information and propose it to government officials in order to exchange opinions and brush up the business plans to enhance the feasibility toward commercialization concretely

3.2.2.7 Investigation of the Establishment of the MRV Methodology

We establish a draft of the MRV methodology of this business as well as to prepare a draft of the project design document (PDD).

<Implementation item>

- Preparation of a draft of the MRV methodology and coordination with the committee on JCM Palau side
- Preparation of a draft of the project design document (PDD)

The business execution flow of this year is as follows:

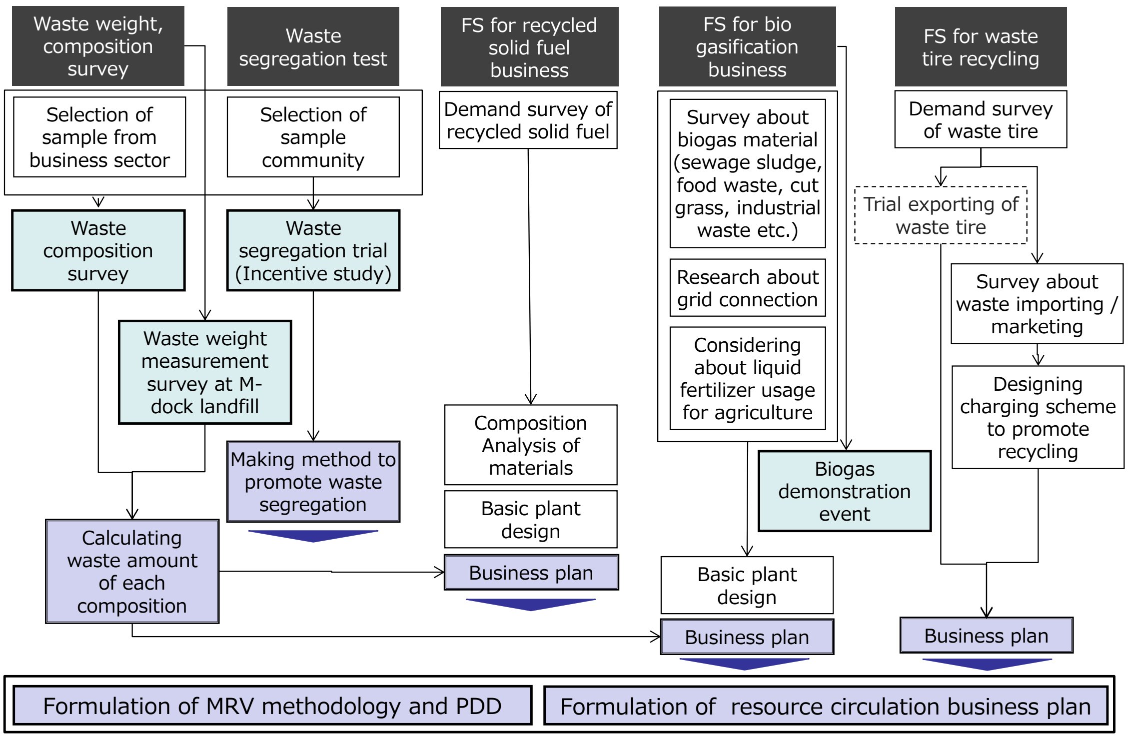


Figure 3.2.1.1 The business execution flow of this year

Chapter 4 Investigation Results

4.1 Investigation of the Emission Amount and Composition of Waste

4.1.1 Investigation of the Emission Amount and Composition of Household Waste

○ Objective

To figure out the emission amount per person and composition of household waste and use this information as the basic data for estimating the amount of input into this system.

○ Investigation method

After selecting two districts each from Koror and Airai which are the top two populous states as investigation objects (The State of Koror: Ngrmid district and Madalaii district, The State of Airai: Ked district and Kaseberau district), we extracted 20 households from each district and asked for cooperation.

In each district, sorted food waste was collected and weighed every day and other types of garbage were collected once a week and weighed after being classified into 19 categories. Detailed investigation flow and categories are as shown below. Bulk waste and home electronics were excluded from the investigation objects because they were complex waste and their weight varied significantly.

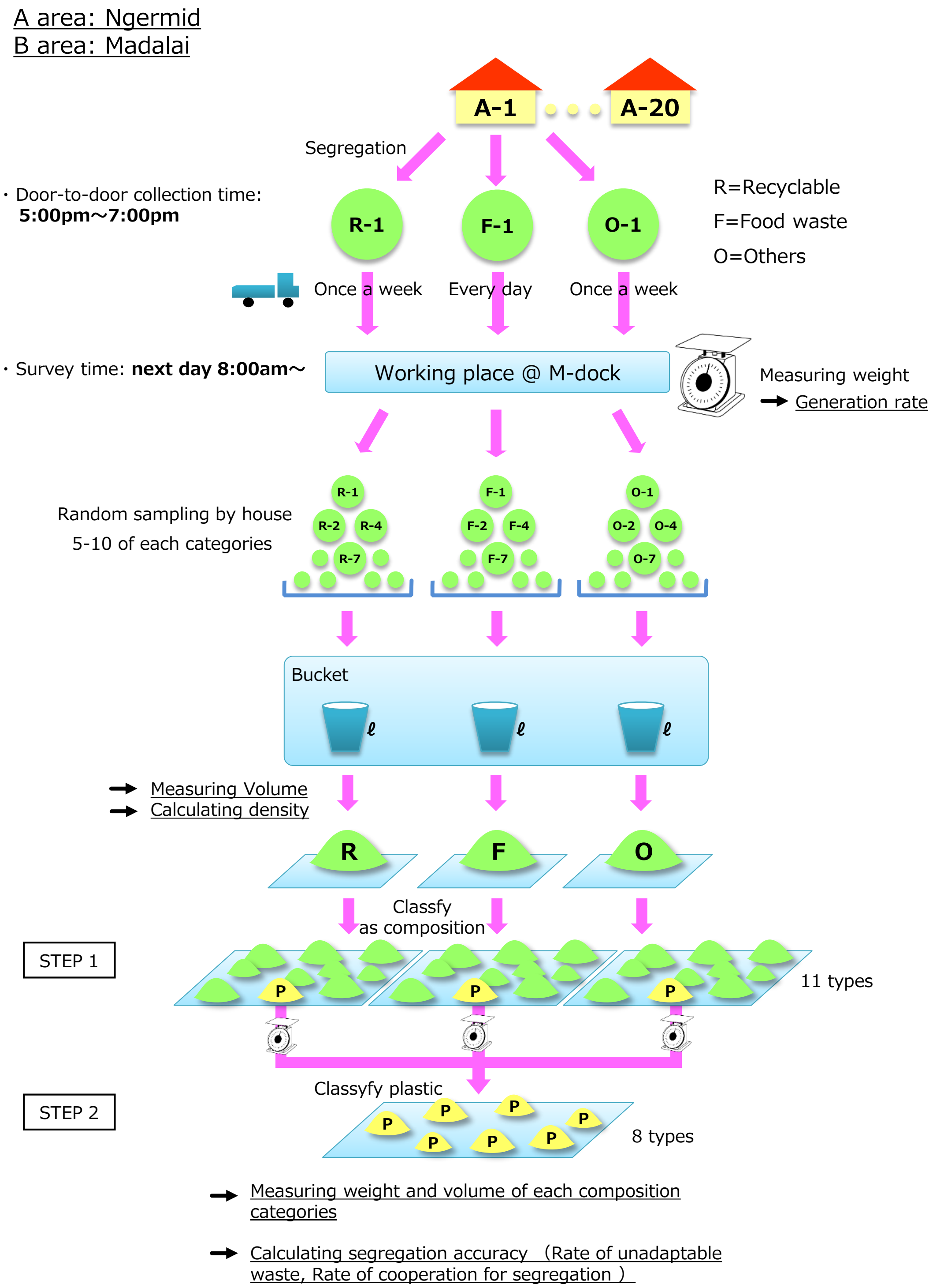


Figure 4.1.1.1 The flow of the investigation of the emission amount and composition of household waste (in the State of Koror)

No.	Category			
1	vegetable/putrescible			
2	Bones, Egg shell, Fish bones, Sea shell			
3	Cooking oil			
4-1	paper	Clean		
4-2		Not clean		
5	textiles			
6-1	plastics	PP/PE	Soft type	Clean
6-2				Not clean
6-3			Hard type	Clean
6-4				Not clean
6-5		PVC		
6-6		Other unsuitable plastics for solid fuel (Mainly plastics harden by heat)		
6-7		Other plastics	Clean	
6-8			Not clean	
7	grass/leaves/wood			
8	leather/rubber			
9	Metals			
10	glass/ceramic			
11	Miscellaneous (Including complex or dirty waste such as diaper, cigarette butt etc.)			

・Excluding bulky refuse and household appliance as carrying into M-dock on this composition investigation.

Figure 4.1.1.2 Waste composition classification table

○ Investigation period

The State of Koror: From September 1, 2014 to September 15, 2014 (Date of composition investigation: September 9 and 16)

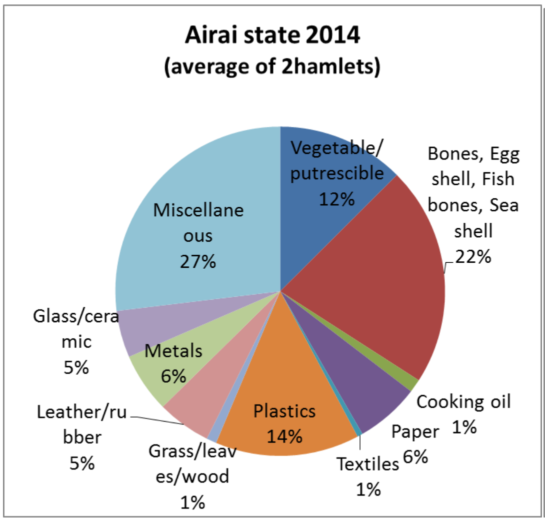
The State of Airai: From September 10, 2014 to September 17, 2014 (Date of composition investigation: September 17)

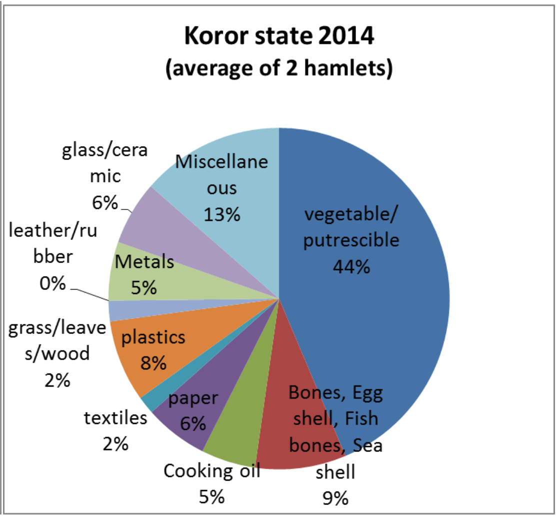
* The investigation was conducted for two weeks in the State of Koror because the sort experiment was also conducted.

○ Investigation results

The average compositions and the estimated amounts of emission a day per person of household waste in each state are as follows:

* Plastic and paper show their compositions before being segmentalized.





	Waste generation rate [kg/day･person]	Population (2012)
Koror state	0.405	11,665
Airai state	0.218	2,537

Photo 4.1.1.1 Collection and measurement of waste

Photo 4.1.1.2 Disposition of waste according to segregation categories

Photo 4.1.1.3 Measurement of individual bags

Photo 4.1.1.4 Measurement of waste volume

Photo 4.1.1.5 Sort of waste

Photo 4.1.1.6 Sort of waste

Photo 4.1.1.7 Sort of waste

Photo 4.1.1.8 Measurement of individual categories

4.1.2 Investigation of the Composition of Business-related Waste

○ Objective

To figure out the composition of the waste generated by the sightseeing and service industries (hotels, restaurants and retail stores) which are major business sectors in Palau and use this information as the basic data for determining the volume of input from such sectors into this circulation system together with the results of the investigation of the amount of waste carried into the M-dock landfill which is separately conducted.

○ Implementation method

We extracted samples from such sectors as shown below to conduct the composition investigation. For this investigation, one day's waste were collected, classified into 19 categories and then measured in the same manner as household waste.

Category		Name of the place of business or store
Hotel	Large scale	Palau Pacific Resort (PPR)
	Medium scale	Papago International Resort
	Small scale	Penthouse Hotel, DW motel
Restaurant		Rock Island café, JYU JYU, Suriyotai
Retail store (Medium and large scale)		WCTC Shopping Center, Payless Market

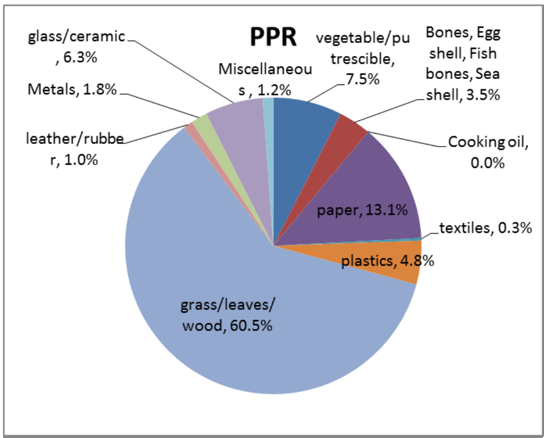
○ Investigation period

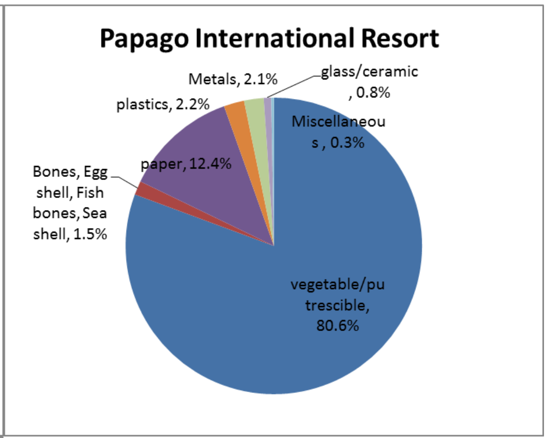
From August to October 2014

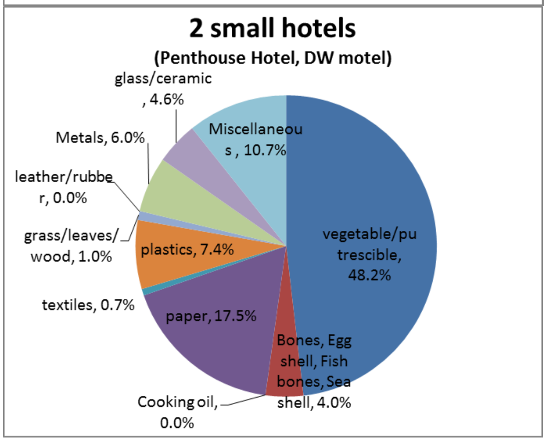
○ Investigation result

Investigation results are as follows:

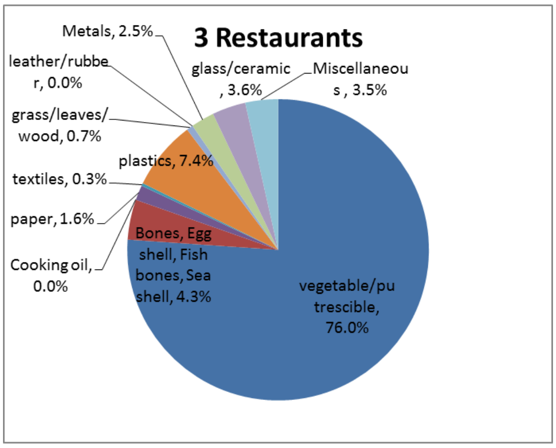
<Hotel>



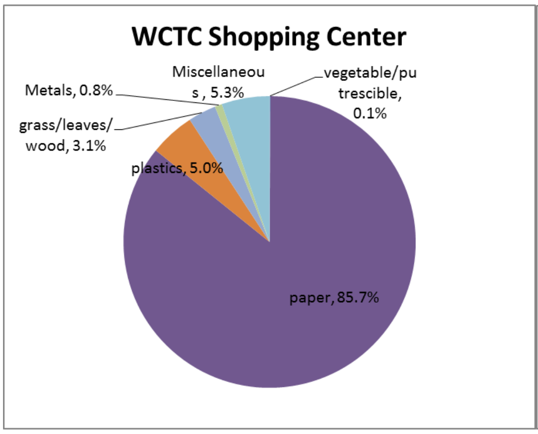




<Restaurant>



<Retail store>



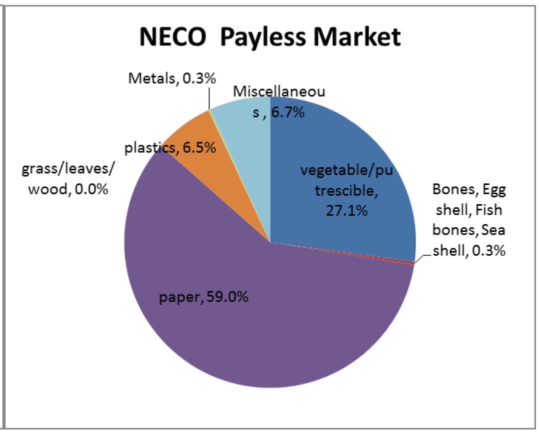


Photo 4.1.2.1 Collection of waste from a hotel

4.1.3 Investigation of the Amount of Waste Generated from Offices

○ Objective

According to the statistics, approximately 20 percent of the population of Palau is engaged in the government or governmental institutions. Therefore, the amount of waste generated from such offices is estimated to be substantial. In this investigation, the amount of government office waste (mainly waste paper) emission per employee working in the office is figured out to use it as the basic data for estimating the input into this system.

○ Implementation method

Eleven typical offices were extracted from the governments of Palau and the State of Koror, and the total amount of waste and the amount of waste paper emitted during a certain period were measured with a spring scale. The extraction of offices was conducted following the advice of the Division of Solid Waste Management of the government of Palau.

○ Investigation period

September 12, 2014 (Ministry of Finance, National Government)

November 20, 2014 (Eight departments from the Koror State’s government)

○ Investigation result

Because of collecting, counting, and calculating the data for 82 people in total, we found the amount of waste emitted by an office worker a day was as follows:

Total amount of waste: 0.37 kg/person a day

Paper waste: 0.24 kg/person a day

4.1.4 Investigation of the Amount of Waste Carried into a Landfill

○ Objective

It is especially difficult to figure out the amount of waste of each business sector at the instant of generation because the scale of business operators varies. Therefore, we measured the amount of waste carried into the M-dock landfill that accommodates the waste generated in the State of Koror to estimate the amount of potential input into this system.

In addition, we also conducted simple hearings about the business sector to which each business operator belonged to provide a clear breakdown of the amount of waste carried into this landfill by each business sector.

○ Implementation method

The amount of waste was measured using a truck scale installed at the entrance before and after carrying the waste into the M-dock landfill. In addition, hearings were conducted about carrier category and carried waste at the time of measurement.

○ Investigation period

October 13 to 19, 2014

○ Investigation result

Average amount of wastes in car: 219 kg/car[1]

Average number of cars that carried waste in this landfill for a week: 73 cars

Therefore, the estimated amount of waste carried a day is: 15,958 kg/day

The estimated breakdown of the waste according to the type of waste generator is as follows. This shows the ratio of business-related waste and resident-related waste is approximately 7:3. This shows similar tendency to that was observed in the investigation performed previously by JICA.

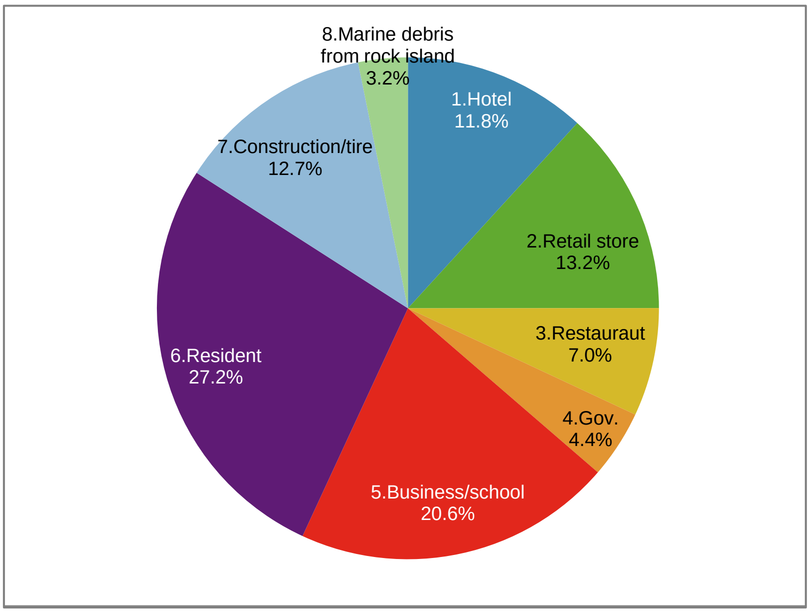


Figure 4.1.4.1 The breakdown of the composition of the waste carried into the M-dock landfill according to the type of waste generator

[1] Due to the investigation design and the accuracy of the truck scale used in this investigation, the error of the results of investigation conducted on and after the second day was large. Therefore, this estimation is based on the result of the investigation conducted on the first day (October 13).

Photo 4.1.4.1 Investigation scene

4.2 Verification Investigation of Sorted Waste Collection

4.2.1 Implementation of the Verification Investigation of Sorted Waste Collection on Households

○ Objective

We consider that the understanding of the circumstances and recycling of waste as well as economic incentive are important to gain the cooperation of the residents for waste sort. The objective of this investigation was to verify whether economic incentive has a positive effect on the sort accuracy in order to contribute to effective incentive design.

○ Investigation method

This investigation was conducted in combination with the investigation of the emission amount and composition of household waste.

<Investigation object>

Two districts in the State of Koror (District A: Ngrmid district, District B: Madalaii district)[2]

<Sort category>

Category	Description	Detail
Category 1	Recyclable waste	Plastic, paper, fiber cut-off branch, wooden waste
Category 2	Food waste	Food waste
Category 3	Others	Other kind of waste (including dirty and complex waste)

In addition, we prepared a leaflet as shown below in cooperation with the Division of Solid Waste Management before implementing the investigation to ask for the cooperation for segregating waste.

---

[2] About community property: With the cooperation of the State of Koror, we chose the communities whose properties are as similar as possible to ask for cooperation. Actually, the residents in the Ngrmid district are in the middle-income bracket but are ecologically-minded. On the other hand, we have information that the residents in the Madalaii district are in the high-income bracket and have relatively higher individual consciousness.

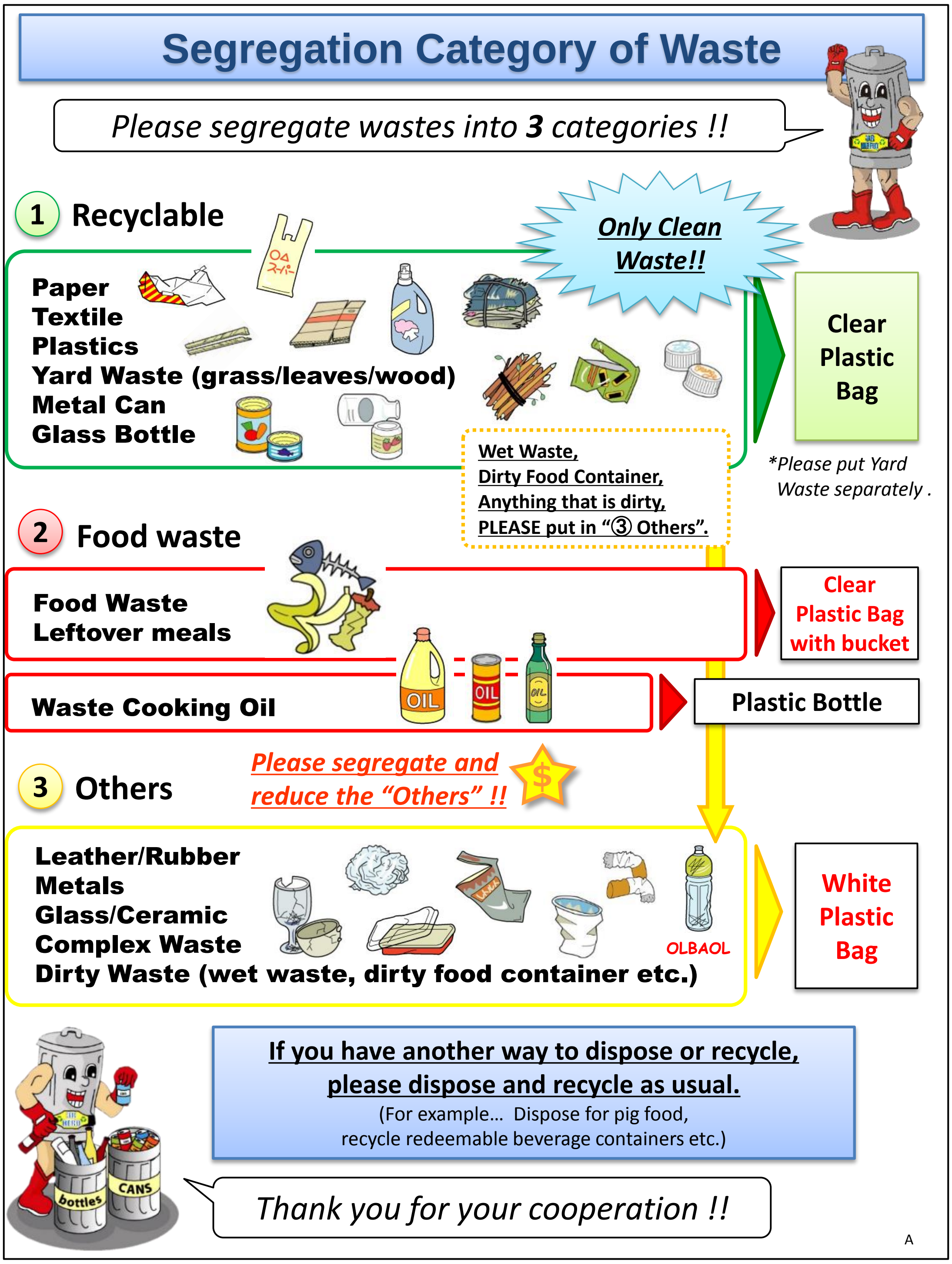


Figure 4.2.1.1 A leaflet for explaining sort standards (for the State of Koror)

<Incentive>

Only for the District A, we provided an incentive to segregate waste. However, following the advice of the State of Koror which is a local cooperative institution, we referred to our intention to "provide an incentive for the households which cooperated in the sort of waste for recycling" but did not mention the details of the incentive. Actually, we provided rewards in three stages according to the percentage of "Others" category (the category for non-recyclable waste) as follows:

1. If the percentage of waste in the "Others" category is less than 20 %:	$ 10
2. If the percentage of waste in the "Others" category is 20 % or higher and lower than 40 %:	$ 8
3. If the percentage of waste in the "Others" category is 40 % or higher:	$ 6
4. If the waste collection period is less than three days:	$ 6

<Subsequent questionnaire investigation>

We also conducted a questionnaire investigation subsequently to interview about the issues in and consciousness of waste sort.

○ Investigation period

From September 1 to 15, 2014 (Waste collection period)

In addition, the composite investigation was also performed on September 8 and 16 to verify the sort accuracy.

○ Investigation result

As a result of the test, 77 percent of the waste generated in the District A and 59 percent of the waste generated in the District B which received an incentive were classified into the "Recyclable" category (recyclable waste and food waste). The followings are the amount of waste in three sort categories generated in each district (kg/person a day) and their proportions. It was difficult to identify the cause of the difference in the proportion of waste classified into the "Recyclable" category due to the difference in the community properties of the two districts extracted this time. However, we can learn from the subsequent questionnaire investigation that an incentive is effective in promoting the sort of waste to some extent.

District A (Ngermid district)

category	Generation rate [kg/person/day]	%
Recyclable	0.111	28%
Food waste	0.190	49%
Others	0.089	23%
Total	0.390	100%

No.	Category		Weight composition [%]
1	vegetable/putrescible		0.0%
2	Bones, Egg shell, Fish bones, Sea shell		0.0%
3	Cooking oil		0.0%
4	paper	Clean	3.9%
		Not clean	6.8%
5	textiles		0.0%
6	plastics	Clean	4.2%
		Not clean	10.0%
7	grass/leaves/wood		21.7%
8	leather/rubber		0.0%
9	Metals		9.1%
10	glass/ceramic		3.8%
11	Miscellaneous		40.6%
	Total		100.0%

District B (Madalaii district)

category	Generation rate [kg/person/day]	%
Recyclable	0.047	12%
Food waste	0.181	47%
Others	0.157	41%
Total	0.385	100%

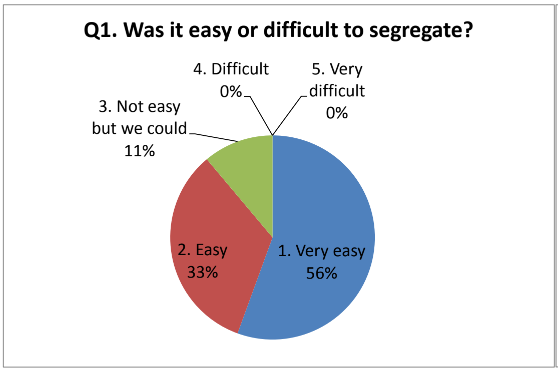
No.	Category		Weight composition [%]
1	vegetable/putrescible		1.6%
2	Bones, Egg shell, Fish bones, Sea shell		0.0%
3	Cooking oil		0.0%
4	paper	Clean	9.3%
		Not clean	8.8%
5	textiles		0.0%
6	plastics	Clean	9.8%
		Not clean	12.0%
7	grass/leaves/wood		0.0%
8	leather/rubber		0.0%
9	Metals		11.3%
10	glass/ceramic		8.4%
11	Miscellaneous		38.8%
	Total		100.0%

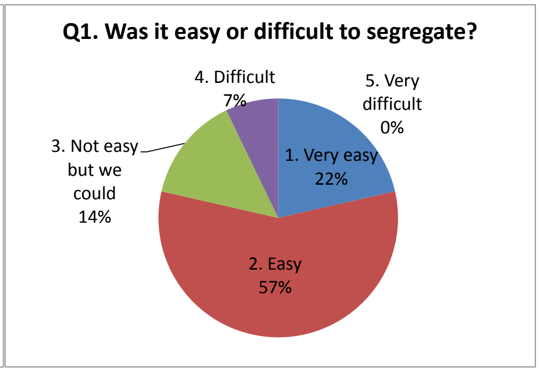
Figure 4.2.1.2 The proportions of waste in each sort category and the breakdown of the waste in the “Others (the category for non-recyclable waste)”

<Results of the subsequent questionnaire investigation>

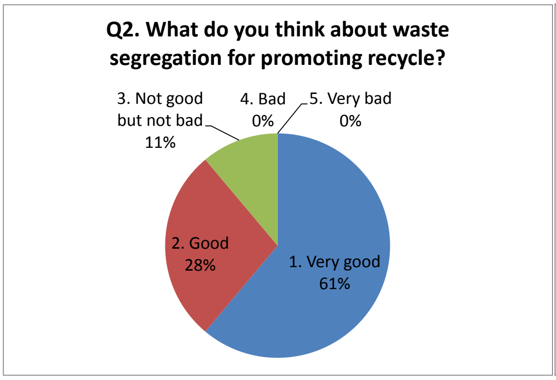
The summary results of the subsequent questionnaire investigation are as follows. The valid responses were obtained from 18 out of 19 households in the District A and 15 out of 20 households in the District B that cooperated in the investigation. The number of valid responses obtained from the District B was smaller than those obtained from the District A, because detailed information on the sort test was not shared with housekeepers who were in charge of waste in some households.

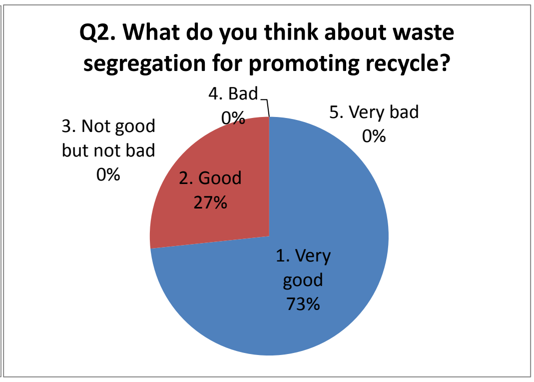
Q1. Was it easy or difficult to segregate? (District A/District B)





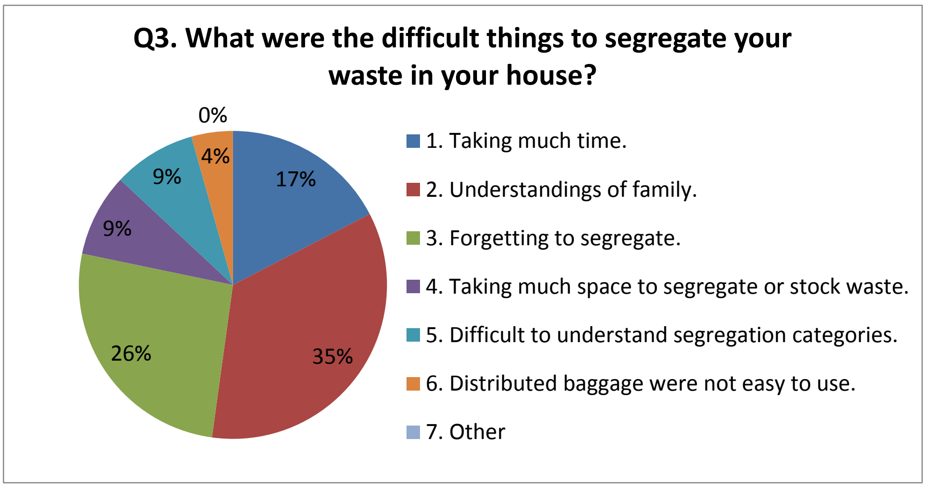
Q2. What do you think about waste sort for promoting recycling? (District A/District B)



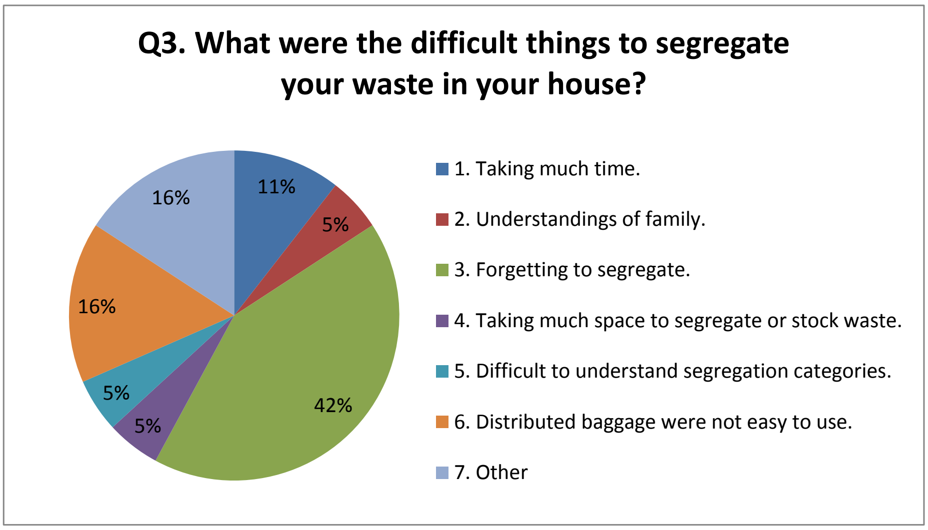


Q3. What were the difficult things to segregate your waste in your house?

(District A)



(District B)



Q4. Was there any waste that you did not decide easily which category is right? What was the waste?

(District A)

Q4. Were there any wastes that you didn't decide easily which category is right? What were the wastes?

Food containers(plastics)
Food containers(dirty waste)
Food containers(form)
Consumer goods ex.canned food
Others(plastics)
Juice bottle
Dirty waste
Butane (2)

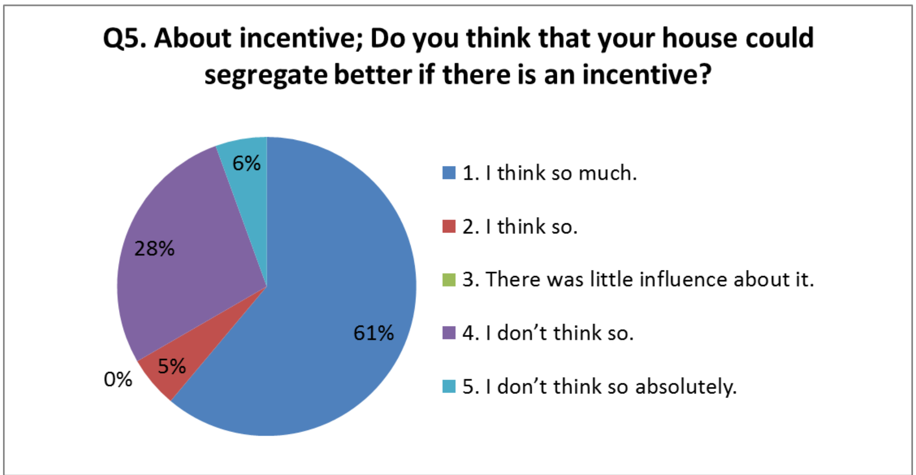
(District B)

Q4. Were there any wastes that you didn’t decide easily which category is right? What were the waste?

food waste, left-over (2)
Plastic, plastic bags (4)
Paper
food container (2)
Can
Metal (2), Used machine
Others (2)
Foam plates
Dirty waste, is it dirty or not?
Recyclable or Others?

Q5. About the incentive, do you think that your house could segregate better if there is an incentive?

(District A only)



Q5. Were there any problems or question about sort?

Do you have opinion or idea about this program (open question)?

(District A)

Q6. Were there any problems or question about segregation? Do you have opinion or idea about this program?

<Main Opinion, Idea>
Daily collection (2)
Good program / Continue this program (14)
Clalify dirty waste (1)

(District B)

Q6. Were there any problems or question about segregation? Do you have opinion or idea about this program?

<Main Opinion, Idea>
Good program / Continue this program (11)
Clalify dirty waste (1)
Need Education, habit (2)
Need more backet, plastic bag (2)

4.2.2 Consideration and Development of Sorted Collection Methods

As a result of implementing house-to-house collection, we could minimize the burdens of residents and hear their opinions that it was good to communicate directly with the staffs in charge of waste collection. However, implementing the house-to-house collection in broader areas requires higher waste collection cost. Therefore, we consider that deploying staffs at the waste collection station on a fixed day of the week and at a fixed time to collect waste is the best way.

According to the results of the subsequent questionnaire investigation, some households in the District A found that “it is difficult to obtain consent from the family members,” “it is difficult not to forget to segregate waste,” and “it takes time to segregate waste” were problems. We consider the reason why “it was difficult to obtain consent from the family members” was because those who received the explanation on waste sort at the briefing (mothers in most cases) and those who actually cook (such as grandmothers) and are in charge of throwing away the trash (children in most cases) are different and they don’t understand the meaning of and methods for segregating waste.

On the other hand, in the District B, the proportions of the households that found “it was difficult not to forget to segregate waste” was a problem were much greater. We guess this is attributed to larger number of families who have busier lives than the residents in the District A because the residents in the District B are characterized by a larger number of families who work in government offices. In addition, the next largest group of those questioned answered, “it was hard to understand how to use or to use the plastic bags for each sort category.”

Taking into account these opinions, we need to make the following efforts when building a system for sorted collection in the future.

- Staffs are deployed at a fixed waste collection time to make sure provide guidance about waste sort in the course of communication (Waste is collected at the waste collection station on a fixed day of the week and at a fixed time).
- In the explanation on waste sort, consideration is made so that those who actually in charge of waste collection can understand the mechanism of sort (Coordination with school education is preferred)
- Waste sort boxes that make sort easier and realize the sort categories and standards visually are also distributed.
- A poster that provides a rough guideline for waste whose sort standards are hard to understand and for the severity of dirt using photos is distributed.

4.3 Investigation of Solid Fuel Production

4.3.1 Investigation of the Composition of Waste for Producing Solid Fuels

We analyzed the contained calories and components (moisture, chlorine, and ash contents) of paper and plastics, which are expected to be used as major raw materials for solid fuels, among the waste collected in Section 4.1.1 "Investigation of the Emission Amount and Composition of Household Waste," and the analysis results are as follows:

	Analysis results			
	Unit	Paper	Plastics	Compliance
Total chlorine	%	0.08	0.56	JIS Z 7302-6
Higher calorific value	kcal/kg	4,400	8,800	JIS Z 7302-2
Lower calorific value	kcal/kg	4,200	8,400	JIS Z 7302-2
Ash content	%	7.4	3.7	JIS Z 7302-4

The calorific value becomes 6,600 kcal/kg if paper and plastics are mixed at a rate of 50 % and 50 %, and it becomes 5,720 kcal/kg if they are mixed at a rate of 70 % and 30 %. Compared to the JIS standard on RPF, this value can be said to be almost equivalent to the grade B if paper and plastics are mixed at a rate of 70 % and 30 % (25 MJ/kg = 5,975 kcal/kg).

4.4 Investigation of the Commercialization of Biogas

4.4.1 Input Investigation

We studied the procurability and potential procurable amount of food waste (household and business-related), edible oils, sewage treatment sludge, and grasses cut off at the time of road maintenance as raw materials for bio-gasification.

4.4.1.1 Food Waste (Household and Business-Related)

Currently, household food waste is landfilled or utilized as the peed for pigs or pets (such as dog or chicken), and the amount and proportion of which differs depending on the area and lifestyle. The investigation we conducted this time showed that 44 percent of the waste collected in the state of Koror and 13 percent of the waste collected in the state of Airai were food waste. In addition, the efforts to install home compost in some houses are made in the State of Koror, but it has been introduced to only 20 houses in a limited way.

This time, potential procurable amount of household food waste was estimated based on the investigation of the composition of waste generated by residents and was found to be 2.1 t/day in the State of Koror and 0.07 t/day in the State of Airai (excluding the amount of food waste utilized as the feedstuff for pigs and pets).

Although business-related food waste was assumed to be generated mainly by restaurants, hotels and food-processing companies, we heard from the commerce and industry association of Palau that there were no business operators that process food industrially. Therefore, we conducted the fact-finding and procurable amount investigations of restaurants and hotels.

Currently, most of the food waste generated from restaurants and hotels is collected and utilized by pig farmers. The food waste generated from large-scale resort hotel, such as the Palau Pacific Resort (PPR), is composted at a recycling center in the State of Koror on a trial basis.

This time, potential procurable amount of business-related food waste was estimated based on the investigation of the amount waste carried into a landfill and the investigation of the composition of waste generated from restaurants and hotels and was found to be 0.6 t/day from hotels and 0.5 t/day from restaurants (excluding the amount of food waste utilize as the feedstuff for pigs, based on the assumption that 70 percent of the food waste is utilized as the feedstuff for pigs).

4.4.1.2 Edible Oil and Grease Trap

We conducted hearings with restaurants to check the emission amount, types and disposal method of waste edible oil and the existence of grease trap.

However, we decided not to include edible oil and grease traps as raw materials in the original plan because they increase the load at the time of fermentation and requires attention to the mechanism and operation of plants.

No.	Name of the restaurant/shop	Waste cooking oil			Grease trap		
		Emission amount /week	Type	Disposal way	Existence	Emission amount /week	Disposal way
1	Arirang / Island Yakiniku Restaurant	–	Vegetable	–	○	5 gallons	Feed for pigs
2	Best Coffee & Donuts House	–	Vegetable	Use for cooking	○	2 gallons	Landfill Personal use
3	Carp Restaurant	–	Vegetable	Use for cooking Feed for pigs	○	7 gallons	–
4	Jive Seaside Restaurant & Bar	2 gallons	–	Personal use	○	2 gallons	Landfill
5	Mog Mog Restaurant	5 gallons	–	Feed for pigs Landfill	–	–	–
6	Neco Plaza convinence Store	6 gallons	Vegetable	–	○	–	–
7	Pinoy Restaurant	9 gallons	Vegetable	Feed for pigs	–	–	–
8	Rip Tide	–	Vegetable	–	○	2 gallons	–
9	Rock Island Cafe	4 gallons	Vegetable	Feed for pigs	–	–	–
10	The Taj	–	–	–	–	–	–
11	Uab's Restaurant	–	–	–	○	10 gallons	Landfill
12	Waves	–	Vegetable	–	○	11 gallons	Feed for pigs
13	WCTC Shopping Deli	3 gallons	–	Landfill	–	–	–
14	Yano Market	5 gallons	–	Use for cooking	○	3 gallons	Use as fertilizers
15	Suriyothai Restaurant	6 gallons	Vegetable	Entrusting to waste collecting business	○	2 gallons	Entrusting to waste collecting business
	Average	5 gallons			Average	5 gallons	

Figure 4.4.1.2.1 The results of hearings about waste edible oil and grease trap sludge

4.4.1.3 Sewage Treatment Sludge

Concerning sewage treatment, PPUC with jurisdiction over sewage treatment is currently promoting the sewage-treatment plant renovation project. We estimated the amount of concentrated sludge that is expected to be generated in the new project. On the other hand, concerning septic tanks that accounts for 30 percent in the State of Koror, there is no governmental department with jurisdiction over it and we do not have any valid information on the status.

Planned sewage treatment population after major renovation	27,000	people	Planned to be 24,000 people in the State of Koror and 3,000 people in the State of Airai.
Actual operation rate	80 %		
Basic water discharge unit per capita	0.25	m^3/day	The value of the planned sewage volume for the urban area of Malaysia (0.25 m^3) is used temporarily (0.4 m^3 in the case of Japan).

Inflow	5,400	m^3/day	
Sludge generation rate	3.2	%	The website of the Sewage Works Association: http://www.jswa.jp/data-room/data.html
Amount of sludge treated	172.8	m^3/day	Sludge of primary sedimentation tank + Excess sludge, concentration of 0.48 % (Japan Data)
Condensation rate	17.0	%	The website of the Sewage Works Association
Concentrated sludge withdrawal volume	**29.4**	**m^3/day**	Concentration rate of 2.8 % (Japan Data)

4.4.1.4 Grasses That Are Cut Off at the Time of Road Maintenance

We conducted hearings with the Road/Equipment Division of the Bureau of Public Works, which is in charge of road maintenance. Approximately 60 staffs perform road maintenance including the cutting of grasses at the sides of the roads. Although we heard that the amount of grasses cut off a day was approximately 5 tons, we consider it will be actually smaller because it may vary depending on the season and not all the grasses cut off are collected and carried in to the M-dock landfill in the State of Koror.

4.4.2 Investigation of the Utilization of Outputs

4.4.2.1 Utilization of Electricity

We also had consultations with PPUC on the assumption that the electricity generated is connected to the distribution network of PPUC. There is no problem with connection and electric power selling at this moment, and the electric power selling price will be discussed and negotiated concretely in the next year based on the power generation cost unit price of PPUC.

4.4.2.2 Utilization of Liquid Fertilizer

Since there are few large-scale commercial farms, we are planning the introduction of a fuel crop called “Napier grass,” aiming for the synergy of the increase of the utilization of liquid fertilizer and of power generation amount, in addition to the utilization of liquid fertilizer in small-scale farms. According to the plan, the total amount of liquid fertilizer obtained after solid-liquid separation can be consumed in the Napier grass farm (30 ha).

Napier grass (*Pennisetum purpureum*) is a gramineous plant originated in Africa, which is attracting attention as fuel crop because it has significantly high vitality and can be harvested 5–8 times a year. Several varieties are growing wild also in Palau and are called pasture grass. We are currently considering the introduction of improved variety with high vitality bred in Thailand, and the coordination with the Agricultural Bureau of the government of Palau is in process.

Figure 4.4.2.1 Napier grass

4.4.3 Implementation of the Bio-Gasification Test and Demonstration Plant Observation Tour

<Objective>

We assembled and operated a simple biogas demonstration plant to study raw material constitution as well as conducted an observation tour inviting a wide range of relevant parties for the purpose of popularization and edification of the meanings and effects of this business model and biogas technology.

<Implemented items>

○ Design and assembly of a simple demonstration plant

In cooperation with Amita Corporation and Mr. Sato who is the representative director of the Renewable Energy Promotion Association (REPA), we designed and assembled a simple demonstration plant using the materials that can be purchased at local do-it-yourself stores (such as water tank of approximately 500 – 1,000 L and UPVC pipes).

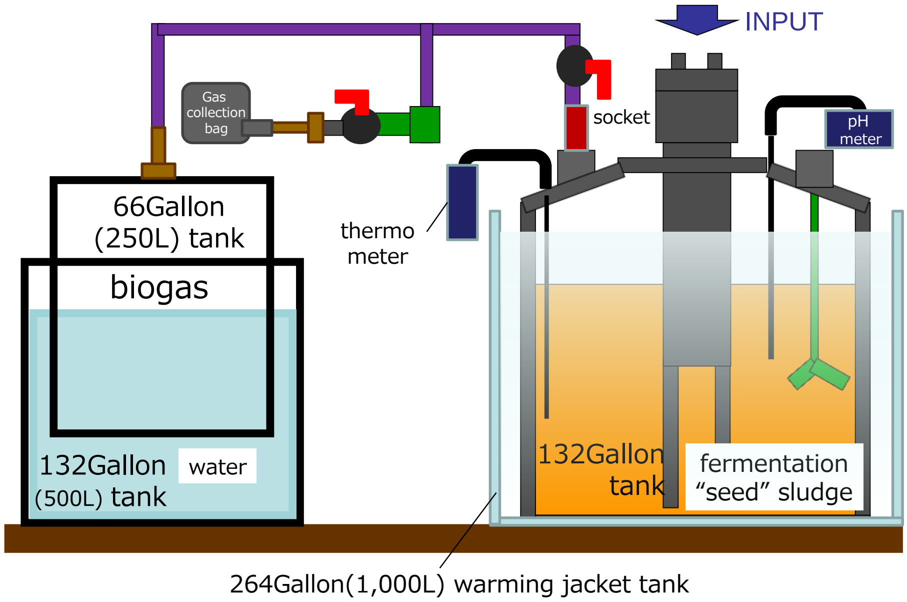


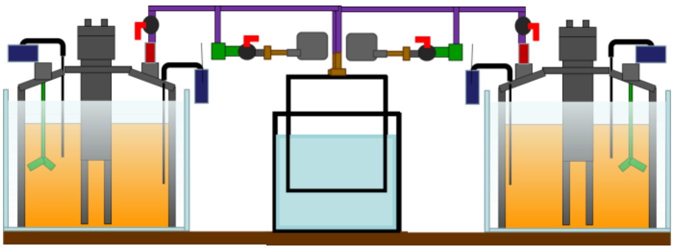
Figure 4.4.3.1 Plant outline diagram

Photo 4.4.3.1 Assembly of the plant

Photo 4.4.3.2 Completed plant

○ Operation of the simple plant

We operated the plant using the raw materials that are assumed to be used. During the operation, we monitored the amount of biogas generation to use it as the reference data for basic plant design (Operation period: From October to November 2015).



	Tank A	Tank B
Contents	Sewer Sludge + Food waste	Sewer Sludge + Grass waste
Input / day	Food waste 5kg	Grass waste 2kg

	Operation
Moring (1-2h)	･Check the volume of biogas in gas tank ･Mix ･Extract surplus sludge ･Measure temperature, PH ･Check concentration of Biogas, H_2S
Evening (1-2h)	･Check the volume of biogas in gas tank ･Put in food waste / grass ･Mix

○ Implementation of an observation tour

During the operation period, we invited major parties concerned to conduct a demonstration plant observation tour.

Date	Time	Visitor
October 23 (Thu)	14:00 - 15:00	Mr. Obichang, the Ministry of Public Infrastructure, Industries, and Commerce Members of the committee on the JCM Palau side
October 28 (Tue)	15:30 - 16:30	State government officials (the States of Koror, Airai, Ngardmau, Ngarchelong and Ngiwal)
October 31 (Fri)	15:30 - 16:30	Directors and cooperation volunteers of EQPB and JICA
November 4 (Tue)	15:30 - 16:30	Business operators and farmers who cooperated in the investigation (The Agricultural Bureau of the government and OISCA)
November 7 (Fri)	17:00 - 18:00	Residents who cooperated in the investigation (The States of Koror and Airai)

Photo 4.4.3.3 Observation tour scene (at the PPUC sewage treatment plant on the Malakal Island)

Photo 4.4.3.3 Observation tour scene (at the PPUC sewage treatment plant on the Malakal Island)

At the observation tour, we served simple dishes cooked on the stove using the biogas generated from sludge and food waste as well as generated electricity through the connection to a small generator to activate electric fans and LED bulbs so that participants can actually experience the process in which energy and resource (liquid fertilizer) are generated from “waste”. We have a lot of positive feedback from participants, such as “I do hope this superior technology is introduced into Palau”, “Liquid fertilizer is useful in Palau because many people in Palau still have farms.”

In addition, this observation tour was picked up by a local newspaper “Island Times” twice, demonstrating the high level of interest.

4.4.4 Survey on Possibility of Using Liquid Fertilizer

4.4.4.1 Component Analysis

Regarding the sewage treatment sludge that are the main ingredient, component analysis was conducted at an analysis lab in Japan in order to confirm the nutritional component content and whether or not it contains aversive substances. The test samples were collected from the final settling pond at the PPUC sewage treatment center on Malakal Island. The results are as follows. There were no values that were of particular concern.

Unit		Palau Sewage Sludge
TS	%	2.30
VTS	%/TS	36.8
CODcr	mg/kg _wet	31000
Total nitrogen	mg/kg _wet	1010
Nitrate nitrogen	mg/L	＜0.1
Ammonia nitrogen	mg/L	39
Total carbon	mg/L	4080
Total phosphate	mg/kg _wet	120
Potassium	mg/kg _wet	35
Magnesium	mg/kg _wet	230
Calcium	mg/kg _wet	430
Sodium	mg/kg _wet	330
Arsenic	mg/kg _wet	＜1
Mercury	mg/kg _wet	0.06
Cadmium	mg/kg _wet	＜0.5
Nickel	mg/kg _wet	1

Chromium	mg/kg _wet	2
Lead	mg/kg _wet	4
Copper	mg/kg _wet	23
Zinc	mg/kg _wet	64
pH	pH	6.9/23 degrees C

Additionally, component analysis was conducted on the liquid fertilizer produced at the biogas demo plant (ingredients: sewage sludge + food waste, fermentation period: Approx. 20 days) to confirm the percentage of nutritional components.

Unit		Liquid fertilizer for external water
TS	%	3.61
VTS	%/TS	61.1
pH	pH	7.2/11 degrees C
Total nitrogen	mg/kg _wet	1890
Ammonia nitrogen	mg/kg _wet	480
Phosphate (P2O5)	mg/kg _wet	1540
Potassium (K2O)	mg/kg _wet	260
Total carbon	mg/kg _wet	11700

4.4.4.2 Survey on Cultivation of Agricultural Crops Using Liquid Fertilizer

<Purpose>

Cultivate agricultural crop using liquid fertilizer obtained from a biogas demo plant, and verify whether or not the same level of growth effect can be obtained on agricultural crops when compared with conventional fertilizer in Palau.

<Details of Implementation>

With the cooperation of OISCA Palau Chapter, a cultivation test was conducted on agricultural crops using liquid fertilizer at the OISCA Palau Training Center in Aimeliik.

○Liquid fertilizer used

・Liquid fertilizer in Tank A (sewage treatment sludge + food waste)

・Collect liquid fertilizer after 20 days of stable operation

○Target agricultural crop for comparative cultivation

・Komatsuna greens

○Test zone, application rate, and results

The following are the results. A significant difference was not seen between (1) through (3), but based on a comprehensive examination of the thickness of the stems, length, and spread of leaves, the results were in the order of (1) > (2) > (3). However, we were able to determine that the use of liquid fertilizer had a growth effect that was comparable to conventional fertilizer. In this trial, the concentration of the liquid fertilizer was slightly low, and we believe we can obtain more positive effects by changing the concentration.

Results			
Fertilization	(1) Compost + Bokashi (Slow acting fertilizer) (Conventional fertilizer)	(2) Liquid fertilizer	(3) No fertilizer
Frequency /Amount	Once a week × Bokashi 100 g	Once a week × (liquid fertilizer 333 ml + 1L of water)	-
Period	3 weeks (From the beginning of December)		

Photo 4.4.4.1 View of Test Zone

4.5 Introduction to the MRV Methodology

The following is an introduction to the MRV methodology and the PDD proposal.

4.5.1 MRV–Solid Fuel Business

We considered the MRV methodology that can be applied to JCM project for the recycled solid fuel business. In considering this, we referred to "J Credit Methodology EN-S-019 ver. 1.0 (Replacement of fossil fuels and system power through refuse derived fuel)", "J Credit Methodology EN-S-004 ver. 1.0 (Adopting air conditioning equipment)" with the purpose of creating a simple methodology that could be applied in Palau.

Target of methodology:

This methodology is to be used for emission reduction activities that replace conventionally used system power by producing heat source (hot water) using recycled solid fuels or adopt an air conditioning facility (hot water boiler and absorption chiller) at a newly constructed heat source facility (hereinafter referred to as target facility).

This methodology can be applied if all of the following criteria are met.

		Confirmed
Criterion 1	The electricity generated using recycled solid fuels must replace system power, etc.	☑
Criterion 2	All or part of the heat and power produced by the target facility using recycled solid fuels must be self-consumed.	☑
Criterion 3	The ingredients of recycled solid fuels must be unused waste, etc.	☑
Criterion 4	Recycled solid fuels must be solid fuel (RPF or RDF) for which the default value of the emission coefficient can be set. Additionally, it must meet technical standards such as the Japanese Industrial Standards (JIS) or the standards provided in the contract between the manufacturer and user.	☑
Criterion 5	If it involves the adoption of new facilities, the application criteria prescribed by the methodology for the target facility in question must be met. However, this excluded the criteria regarding improvement of efficiency of target facility before and after the project.	☑
Criterion 6	A maintenance plan including inspection checklist, operation structure, and safety standards must be prepared.	☑
Criterion 7	Regarding the collected heat quantity from recycled solid fuels, the test results of third-party verification before the start of facility operations shall be submitted during the project validation screening.	☑

Criterion 8	The absorption chiller to be adopted must be a air conditioning facility that is more efficient than the air conditioning facility in the reference scenario.	☑
Criterion 9	All or part of the cool air produced by the air conditioning facility must be self-consumed.	☑

GHG to be considered when calculating emission reduction volume:

Reference emissions	
Emission activity	Type of GHG
CH4 release from landfill disposal site	CH4
Estimated CO2 emissions in cases where power, to be generated by the target facility after the project is implemented, is sourced from system power at a facility in the reference scenario	CO2
CO2 emissions from use of electricity from the use of air conditioning facilities (air conditioning before update) in the reference scenario	CO2
Emissions from coolant leak of air conditioning facility in the reference scenario	Alternative CFC

Project emissions	
Emission activity	Type of GHG
Use of target facility (boiler): Emissions from use of refuse derived fuel due to the use of the target facility after the project is implemented	CO2 CH4 N2O
Waste transport: Emission from use of fossil fuels when transporting waste from extraction site to the pre-treatment site	CO2
Use of fuel treatment facility: Emissions from use of electricity in fuel treatment	CO2
Transport of refuse derived fuel (RPF): Emissions from use of fossil fuels for the transport of refuse derived fuel from manufacturing site to location of use	CO2
Emissions from use of electricity from the use of the air conditioning facility (absorption chiller) after the project is implemented	CO2
Emissions from coolant leak at air conditioning facility(absorption chiller) after project is implemented	Alternative CFC
Emissions from waste of air conditioning facility before renewal	Alternative CFC

Setting and calculating the reference emissions

Concept of reference emissions

The reference scenario is a scenario that represents the GHG emissions that can be expected if our proposed project activities are not implemented. Therefore, the major reference emissions if the project was not implemented are the CO2 emissions released into the atmosphere as methane gas from the degradation of organic substances in the waste landfill disposal site and the CO2 emissions expected if the amount of heat generated where obtained from the facility in the reference scenario (standard heat source facility) instead of the heat source facility after project is implemented, and the CO2 emissions from the use of electricity in order to use the air conditioning facility (before renewal) of the reference scenario to be used if the project activities were not conducted.

Calculation of reference emissions

$$RE_y = RE_{y, CH4,SWDS} + RE_{y, M\_RPF} + RE_{y, M\_aircon} + RE_{y, sub\_aircon}$$

Symbols	Definition	Unit
RE_y	Reference CO2 emissions in year y	tCO2/year
$RE_{y, CH4,SWDS}$	Reference emissions released from the waste treatment site in year y	tCO2/year
RE_{y, M_RPF}	CO2 emissions expected if the heat generated at the heat source facility in year y after the project is implemented is obtained from the baseline heat source facility (boiler)	tCO2/year
RE_{y, M_aircon}	CO2 emissions expected if the heat generated from the air conditioning facility in year after project is implemented is obtained from the use of electricity at the air conditioning facility (before renewal of the air conditioning facility) in the reference scenario	tCO2/year
RE_{y, sub_aircon}	Reference emissions from coolant leak at air conditioning facility in year y	tCO2e/year

$$RE_{CH4,SWDS,y} = \varphi_y * (1-f_y) * GWP_{CH4} * (1-OX) * 16/12 * F * DOC_{f,y} * MCF_y * \sum \sum W_{j,x} * DOC_j * e^{-kj*(y-x)} \bullet (1 - e^{-kj})$$

Symbols	Definition	Units
φ_y	Adjustment factor for uncertainty in year y	
f_y (=0)	Percentage of CH4 flared, combusted, or used out of all the	

	CH4 collected in year y	
GWP_{CH4}	Global warming potential of CH4	
OX	Oxidation rate	
F	Percentage of CH4 in the waste treatment site gas	
$DOC_{f,y}$	Percentage of degradable organic carbon that is degraded in year y	
MCF_y	Methane corrective coefficient in year y	
$W_{j,x}$	Quantity of waste that was disposed in the waste treatment landfill site or organic waste type j that avoided landfill disposal in year x	
DOC_j	Percentage of degradable organic carbon in waste j	
k_j	Degradation rate of waste j	
J	Waste classification	
X	Year the waste was disposed in the landfill (Value x is the value from the year the landfill was opened (x=1) to the year the CH4 emissions is calculated (x=y))	
Y	Year used to calculate CH4 emissions	

$$\mathbf{RE}_{\mathbf{y,\ M\_RPF}} = Q_{y,\ BL,\ boiler\_heat,\ output} \times 100/\varepsilon_{BL\_boiler} \times EF_{BL,\ fuel,\ y}$$

$$(Q_{y,\ BL,\ boiler\_heat,\ output} = Q_{y,\ PJ,\ boiler\_heat,\ output})$$

Symbols	Definition	Units
$Q_{y,\ BL,\ boiler\_\ heat,\ output}$	Heat generated at baseline target facility in year y	GJ/year
$Q_{y,\ PJ,\ boiler\_heat,\ output}$	Heat generated at target facility in year y after project is implemented	GJ/year
ε_{BL_boiler}	Energy consumption efficiency of baseline target facility	%
$EF_{BL,\ fuel,\ y}$	CO2 emission coefficient per unit calorific value of fuel used at baseline target facility	tCO2/GJ

*If it is possible to use a calorimeter to measures the heat generated ($Q_{y,\ PJ,\ heat,\ output}$) at target facility after project is implemented, use figures that were measures directly.

$$\mathbf{RE}_{\mathbf{y,\ M\_aircon}} = Q_{y,\ BL,\ aircon\_heat,\ output} \times 100/\varepsilon_{BL\_aircon} \times 1/(3.6*10^{-3}) \times EF_{electricity,\ y}$$

$$(Q_{y,\ BL,\ aircon\_heat,\ output} = Q_{y,\ PJ,\ aircon\_heat,\ output})$$

Symbols	Definition	Units
$Q_{y,\ BL,\ aircon\_heat,\ output}$	Heat generated at the air conditioning facility in the reference scenario in year y	GJ/year
$Q_{y,\ PJ,\ aircon\_heat,\ output}$	Heat generated at the air conditioning facility in year y after project is implemented	GJ/year
ε_{BL_aircon}	Energy consumption efficiency of air conditioning facility in the reference scenario	%
$EF_{electricity,\ y}$	CO2 emission coefficient for electricity	tCO2/kWh

*If it is possible to show the relationship (heat exchange rate, etc.) between the Heat generated from boiler $Q_{y,\ PJ,\ boiler\_heat,\ output}$ and heat generated from air conditioning facility (absorption chiller) after project is implemented $Q_{y,\ PJ,\ aircon\_heat,\ output,}$ you can consider $RE_{M\_RPF,\ y}$ and $RE_{M\_aircon,\ y}$ together as one value.

$$\mathbf{RE}_{\mathbf{y,\ sub\_aircon}} = LA_{BL} \times GWP_{BL}$$

Symbols	Definition	Units
LA_{BL}	Amount of coolant leaked from air conditioning facility in reference scenario (At the air conditioning facility before renewal, measure the coolant added during maintenance, and uses this value as the amount of coolant leaked.)	t/year
GWP_{BL}	Global warming potential of coolants in the air conditioning facility of the reference scenario	tCO2e/t

Monitoring amount of activity

Monitoring item		Monitoring method
j	Composition ratio of waste j (based on weight)	Default value
$\mathbf{W_{j,x}}$	Quantity of waste that was disposed in the waste treatment landfill site or organic waste type j that avoided landfill disposal in year x	Measurement by the Solid Waste Management Division of the Bureau of Public Works in the Republic of Palau
$\mathbf{Q_{y,\ PJ,\ boiler\_heat,}}$	Heat generated (GJ/year) by the target facility(heat source facility) in year y after project is implemented	Measurement using calorimeter

output		
$Q_{y, PJ, aircon\_heat, output}$	Cool energy generated (GJ/year) by the air conditioning facility (absorption chiller) in year y after project is implemented	Measurement using calorimeter
LA_{BL}	Amount of coolant leaked (t/year) from the air conditioning facility in the reference scenario	Measure coolant added during maintenance

Coefficient monitoring

Monitoring item		Monitoring method
φ	Adjustment factor for uncertainty	Methodology tool
GWP_{CH4}	Global warming potential of CH4	Calculation method and list of emission coefficients of the Calculation, Reporting, and Disclosure Program (Ministry of the Environment)
OX	Oxidation rate	IPCC 2006 Guideline
F	Percentage of CH4 in the waste treatment site gas	IPCC 2006 Guideline
DOC_f	Percentage of degradable organic carbon that is degraded	IPCC 2006 Guideline
MCF	Methane corrective coefficient	IPCC 2006 Guideline
DOC_j	Percentage of degradable organic carbon in waste j	Default value
k_j	Degradation rate of waste j [1/year]	Default value
$EF_{BL, fuel, y}$	CO2 emission coefficient per unit calorific value of fuel used at baseline target facility(heat source facility) in year y	Default value
ε_{BL_boiler}	Energy consumption efficiency (%) at baseline target facility (heat source facility)	Catalog value listed on the manufacturer's specifications
$EF_{electricity, y}$	CO2 emission coefficient of electricity in year y	Palau-Japan Joint Committee
ε_{BL_aircon}	Energy consumption efficiency (%) of air conditioning facility in the reference scenario (before renewal)	Catalog value listed on the manufacturer's specifications
GWP_{BL}	Global warming potential(tCO2e/t) of coolant filled in air conditioning facility(absorption chiller) after project is implemented	Calculated based on the catalog value listed on the manufacturer's specifications

Set and calculate project emissions

Concept of project emissions

The emissions after project is implemented shall be the total amount of emissions from the use of target facility (boiler), emissions from transport of waste, emissions from refuse derived fuel (RPF) manufacturing facility, emissions from transport of refuse derived fuel (RPF), emissions from use of electricity for the use of air conditioning facility (absorption chiller), emissions from coolant leak at air conditioning facility (absorption chiller), and emissions from disposal of air conditioning facility before renewal, all after project is implemented.

Calculation of project emissions

The project emissions are calculated as follows.

$$\mathbf{PE}_{\mathbf{y}} = \mathbf{PE}_{\mathbf{y, M, boiler}} + \mathbf{PE}_{\mathbf{y, transport, waste}} + \mathbf{PE}_{\mathbf{y, process, RPF}} + \mathbf{PE}_{\mathbf{y, transport, RPF}} + \mathbf{PE}_{\mathbf{y, M, aircon}} + \mathbf{PE}_{\mathbf{y, CFC, leak}} + \mathbf{PE}_{\mathbf{CFC, waste}}$$

Symbols	Definition	Units
PE_{y}	Emissions after project is implemented in year y	tCO2e/year
$PE_{y, M, boiler}$	Emissions from use of refuse derived fuel(RPF) at the target facility(heat source facility) in year y	tCO2/year
$PE_{y, M, aricon}$	Emissions from the use of air conditioning facility in year y after project is implemented	tCO2/year
$PE_{y, transport, waste}$	Emissions from transport of waste in year y after project is implemented	tCO2/year
$PE_{y, process, RPF}$	Emissions from use of refuse derived fuel (RPF) manufacturing facility in year y after project is implemented	tCO2/year
$PE_{y, transport, RPF}$	Emissions from transport of refuse derived fuel (RPF) in year y after project is implemented	tCO2/year
$PE_{y, CFC, leak}$	Emissions from coolant leak at air conditioning facility in year y after project is implemented	tCO2e/year
$PE_{CFC, waste}$	Emissions from disposal from air conditioning facility before renewal that uses coolant after project is implemented	tCO2e/year

[Major emission activity]

Emissions from the use of a heat source facility (boiler) after project is implemented

$$\mathbf{PE}_{\mathbf{y, M, boiler}} = \Sigma(F_{y, RPF, i} \times EF_{CO2, RPF, i}) + \Sigma(F_{y, RPF, i} \times HV_{RPF, i} \times EF_{CH4, RPF,}$$

$_i \times 21) + \Sigma(F_{y, RPF, i} \times HV_{RPF, i} \times EF_{N2O, RPF, i} \times 310)$

Symbols	Definition	Units
$F_{y, RPF, i}$	Usage of refuse derived fuel(RPF) i at target facility in year y after project is implemented	t/year
$HV_{RPF, i}$	Unit calorific value of refuse derived fuel (RPF) i at target facility after project is implemented	GJ/t
$EF_{CO2, RPF}$	CO2 emission coefficient of refuse derived fuel (RPF) i at target facility after project is implemented	tCO2/t
$EF_{CH4, RPF}$	CH4 emissions per unit calorific value of recycled solid fuels i used at target facility after project is implemented	tCH4/GJ
$EF_{N2O, RPF}$	N20 emission coefficient per unit calorific value of refuse derived fuel (RPF) i used at target facility after project is implemented	tN2O/GJ

If calculating heat generated by the air conditioning facility (absorption chiller) after project is implemented

$$\mathbf{PE}_{\mathbf{y, M, aircon}} = Q_{y, PJ, aircon\_heat, output} \times 100 / \varepsilon_{PJ} \times EF_{PJ, fuel, y}$$

$$Q_{y, PJ, aircon\_heat, output} = FL_{y, PJ, heat} \times \Delta T_{y, PJ, heat} \times C_{PJ, heat} \times \rho_{PJ, heat} \times 10^{-3}$$

Symbols	Definition	Units
$Q_{y, PJ, aircon\_heat, output}$	Heat generated by air conditioning facility in year y after project is implemented	GJ/year
ε_{PJ}	Energy consumption efficiency of air conditioning facility after project is implemented	%
$EF_{PJ, fuel, y}$	CO2 emission coefficient per unit calorific value of fuel* used after project is implemented (*Assume that the fuel used is RPF)	tCO2/GJ
$FL_{y, PJ, heat}$	Volume of air used that was heated or cooled by the air conditioning facility after project is implemented	m^3/year
$\Delta T_{y, PJ, heat}$	Difference in temperature before and after heat use of air that was heated or cooled by the air conditioning facility after project is implemented	K
$C_{PJ, heat}$	Specific heat of air	MJ/(t•K)
$\rho_{PJ, heat}$	Air density	t/m^3

*If it is possible to show the relationship (heat exchange rate, etc.) between the heat generated from the boiler $Q_{y, PJ, boiler\_heat, output}$ and heat generated from absorption chiller after project is implemented $Q_{y, PJ, aircon\_heat, output}$, obtain the value of $Q_{y, PJ, aircon\_heat, output}$ from $Q_{y, PJ, boiler\_heat, output}$.

[Incidental emission activity]

$$\mathbf{PE}_{\mathbf{y, transport, waste}} = F_{y, transport, waste} \times HV_{transport, waste} \times EF_{transport, waste}$$

Symbols	Definition	Units
$F_{y, transport, waste}$	Volume of fuel used in the transport of waste in year y after project is implemented	kL/year
$HV_{transport, waste}$	Unit calorific value of fuel used to transport waste after project is implemented	GJ/kL
$EF_{transport, waste}$	CO2 emission coefficient per unit calorific value of fossil fuel used to transport waste after project is implemented	tCO2/GJ

*Consider the CO2 emissions from the transport of waste and refuse derived fuel (RPF), and degree of influence on expected overall reduction of emissions, and if the degree of influence is expected to be low, do not exclude it from the calculations for GHG emissions.

$$\mathbf{PE}_{\mathbf{y, process, RPF}} = EL_{y, PJ, process} \times PV_{y, PJ} / PV_{y, PJ, all} \times EF_{electricity, y}$$

Symbols	Definition	Units
$EL_{y, PJ, process}$	Electricity use in process for making all fuels (RPF) in year y after project is implemented	kWh/year
$PV_{y, PJ}$	Weight of refuse derived fuel (RPF) manufactured for this project in year y after project is implemented	t/year
$PV_{y, PJ, all}$	Weight of all refuse derived fuel(RPF) manufactured in year y after project is implemented	t/year
$EF_{electricity, y}$	CO2 emission coefficient of electricity in year y	tCO2/kWh

*Assume cases where electricity is being used at the fuel creating (RPF) process facility.
(When using fossil fuels, refer to (Formula 6) on p.7 of EN-S-019 (ver. 1.0).)

$$\mathbf{PE}_{\mathbf{y, transport, RPF}} = F_{y, transport, RPF} \times HV_{transport, RPF} \times EF_{transport, RPF}$$

Symbols	Definition	Units
$F_{y, transport, RPF}$	Fuel usage for transport of RPF in year y after project is	kL/year

	implemented	
$HV_{transport, RPF}$	Unit calorific value of fuel used to transport RPF after project is implemented	GJ/kL
$EF_{transport, RPF}$	CO2 emission coefficient per unit calorific value of fossil fuels used to transport RPF after project is implemented	tCO2/GJ

*Consider the CO2 emissions from the transport of waste and refuse derived fuel (RPF), and degree of influence on expected overall reduction of emissions, and if the degree of influence is expected to be low, do not exclude it from the calculations for GHG emissions.

$\mathbf{PE}_{\mathbf{y, CFC, leak}} = 0$ (*Because lithium bromide is being used in the coolant)

$\mathbf{PE}_{\mathbf{CFC, waste}} = FA_{before} \times GWP_{before} = 0$ (*Because an existing air conditioner is being used as backup)

Symbols	Definition	Units
FA_{before}	Amount of coolant initially filled in the air conditioning facility before renewal	t
GWP_{before}	Global warming potential of coolant filled in the air conditioning facility before renewal	tCO2e/t

Monitoring items

- **Monitoring amount of activity**

Monitoring items		Monitoring methods
$\mathbf{F}_{\mathbf{y, RPF, i}}$	Usage (t/year) of refuse derived fuel(RPF) i at target facility in year y after project is implemented	Measurement using weight scale
$\mathbf{F}_{\mathbf{y, transport, waste}}$	Fuel usage (kL/year) for the transport of waste in year y after project is implemented	Measurement using weight scale, etc.
$\mathbf{EL}_{\mathbf{y、PJ, process}}$	Power usage (kWh/year) in the entire fuel creation process in year y after project is implemented	Measurement using weight scale, calculation based on bill from electric company, calculation based on facility specification (rated power conspumtion) and operation time

$PV_{y, PJ}$	Weight (t/year) of refuse derived fuel (RPF) manufactured for this project in year y after project is implemented	Measurement using weight scale
$PV_{y, PJ, all}$	Weight (t/year) of all refuse derived fuel(RPF) manufactured in year y after project is implemented	Measurement using weight scale
$F_{y, transport, RPF}$	Fuel usage (kL/year) for transport of RPF in year y after project is implemented	Measurement using weight scale, etc.
$Q_{y, PJ, aircon\_heat, output}$	Heat generated (GJ/year) from air conditioning facility in year y after project is implemented	Measurement using weight scale
$FL_{y, PJ, heat}$	Usage of air (m^3/year) heated or cooled by the air conditioning facility after project is implemented	Measurement using weight scale, etc.
FA_{before}	Amount of coolant (t) initially filled in the air conditioning facility before renewal	Catalog value listed on the manufacturer's specifications

- **Coefficient monitoring**

Monitoring item		Monitoring method
$HV_{RPF, i}$	Unit calorific value (GJ/t) of refuse derived fuel(RPF) i used at target facility after project is implemented	Based on JIS Z 730 2-2, etc. measure refuse derived fuel using analysis device or measuring equipment (calorimeter, etc.) (Once a year)
$EF_{electricity, y}$	CO2 emission coefficient (tCO2/kWh) of electricity in year y	Palau-Japan Joint Committee
$EF_{CO2, RPF}$	CO2 emission coefficient(tCO2/t) of refuse derived fuel (RPF) i used at target facility after project is implemented	Use default value
$EF_{CH4, RPF}$	CH4 emission coefficient (tCO2/GJ) per unit calorific value of refuse derived fuel(RPF) i used at target facility after project is implemented	Use default value
$EF_{N2O, RPF}$	N2O emission coefficient (tCO2/GJ) per unity calorific value of refuse derived fuel (RPF) i used at target facility after project is implemented	Use default value
$HV_{transport, waste}$	Unit calorific value(GJ/kL) of fuel used to transport waste after project is implemented	Use default value
$EF_{transport, waste}$	CO2 emission coefficient (tCO2/GJ) per unit calorific value of fossil fuels used to transport waste after project is	Use default value

	implemented	
$HV_{transport, RPF}$	Unit calorific value (GJ/kL) of fuel used to transport RPF after project is implemented	Use default value
$EF_{transport, RPF}$	CO2 emission coefficient (tCO2/GJ) per unit calorific value of fossil fuel used to transport RPF after project is implemented	Use default value
ε_{PJ}	Energy consumption efficiency (%) of air conditioning facility after project is implemented	Catalog value listed on the manufacturer's specifications
$EF_{PJ, fuel, y}$	CO2 emission coefficient (tCO2/GJ) per unit calorific value of fuel used after project is implemented	Use default value
$\Delta T_{y, PJ, heat}$	Difference in temperature (K) before and after heat use of air heated or cooled by the air conditioning facility after project is implemented	Measurement using thermometer
$C_{PJ, heat}$	Specific heat of air (MJ/(t•K))	Use literature value
$\rho_{PJ, heat}$	Air density (t/m^3)	Use literature value
GWP_{before}	Global warming potential (tCO2e/t) of coolant filled in air conditioning facility (heat pump) before renewal	Use default value

4.5.2 MRV-Bio gas business

Regarding the biogas business, we considered MRV methodology that could be applied to the JCM project. In conducting deliberations, we referred to the J Credit Methodology EN-R-007 ver.1.0 (Replacement of fossil fuel or system power using bio gas (methane gas from anaerobic fermentation)), feasibility study (FS) for new mechanism such as binational credit program result database "Organic waste methane fermentation and cogeneration in wholesale market" survey report, J Credit Methodology EN-R-003 ver.1.0 (Adoption of heat source facility using renewable energy heat), J Credit Methodology EN-R-009 ver.1.0 (Adoption of power generator using renewable energy heat), etc. with the purpose of creating a simple methodology that could be applied locally in Palau.

Target of methodology:

The target of this methodology is emission reducing activities that replace conventionally used fossil fuels and system power by using bio gas (methane gas from anaerobic fermentation) in cogeneration at a newly constructed private power generator (hereinafter referred to as target facility).

This methodology may be applied if the following criteria are met.

		Checked
Criterion 1	Must replace all or part of system power, etc. with electricity generated using biogas.	☑
Criterion 2	As a rule, all or part of the electricity generated at the target facility using biogas must be self-consumed.	☑
Criterion 3	The ingredients of the bio gas must be unused waste, etc.	☑
Criterion 4	The ingredients of the biogas must not be stored outdoors or anywhere not sealed for a period that exceeds 6 months.	☑
Criterion 5	If in addition to replacing fossil fuels with biogas, it involves an addition of new facilities, the application conditions prescribed by the methodology for the target facility in question must be met. However, this excludes the criteria regarding improvement of efficiency of target facility before and after the project.	☑
Criterion 6	A maintenance plan including inspection checklist, operation structure, and safety standards must be prepared.	☑
Criterion 7	Regarding the biogas collection amount for the anaerobic digestive device, the test results from third-party verification before the start of facility operations shall be submitted during the project validation screening.	☑
Criterion 8	After installing the facility, conduct a seal test on the anaerobic digestive device before start of operations and confirm that the biogas is not leaking.	☑
Criterion 9	Install a desulfurization device in the system.	☑

GHG to be considered when calculating emissions reduction:

Reference emissions	
Emission activity	Type of GHG
CH4 released from landfill disposal site	CH4
Total amount of CO2 emissions expected when obtaining power from system power instead of power generated from target facility after project is implemented and from use of fossil fuels at facility in the reference scenario after project is implemented instead of heat generated at the target facility.	CO2

Project emissions	
Emission activity	Type of GHG
Use of target facility: Emissions from use of bio gas at target facility after project is implemented	—
Use of bio gas process facility: Emissions during use of fossil fuels or electricity during bio gas process	CO_2
Transport of bio mass: Emissions from use of fossil fuels for transport of bio mass ingredients from extraction site to processing site	CO_2
Transport of bio gas: Emissions from use of fossil fuels for transport of bio gas from manufacturing site to location of use	CO_2

*Consider the emissions from use of fossil fuels for the transport of bio mass ingredients and bio gas, and degree of influence on expected overall reduction of emissions, and if the influence is expected to be low (less than 1%), do not exclude it from the calculations for GHG emissions.
*Regarding the treatment of residue after fermentation, since the digestive fluid is used effectively as liquid fertilizer, etc., it is not included in the calculations for GHG emissions.

Supplement to Criterion 2:

If supplying electricity generated at target facility using biogas to electric company, be sure to sign a contract between the project operator and the electric company stating that the environmental value (CO_2 reduction, etc.) from supplying electricity belongs to the project operator, and be able to submit document, etc. as proof of this fact.

Setting and calculation of reference emissions

Concept of reference emissions

The reference scenario is a scenario that represents the GHG emissions that can be expected if our proposed project activities are not implemented. Therefore, the reference emissions are the CO_2 emissions released into the atmosphere as methane gas from the degradation of organic substances in the waste landfill disposal site if the project were not implemented and the CO_2 emissions calculated by multiplying the electricity generated through cogeneration after project is implemented by the emissions coefficient of system power, and the CO_2 emissions calculated by multiplying fuel consumption from standard technology (facility in reference scenario) that would have been used if the project activities were not conducted by the emissions coefficient of fossil fuels.

Calculation of reference emissions

$$\mathbf{RE_y = RE_{y,\,CH4,SWDS} + RE_{y,\,electricity} + RE_{y,\,heat}}$$

Symbols	Definition	Units
RE_y	Reference CO2 emissions in year y	tCO2/year
$RE_{y, CH4,SWDS,y}$	Emissions converted to CO2 from the reference CH4 emissions released from waste treatment sites in year y	tCO2/year
$RE_{y, electricity}$	CO2 emissions expected when obtaining electricity from system power instead of the electricity generated from the target facility (Cogeneration) in year y after project is implemented	tCO2/year
$RE_{y, heat}$	CO2 emissions expected from the use of fossil fuel in the reference scenario (standard facility) instead of the heat generated at the target facility (Cogeneration) in year y after project is implemented	tCO2/year

$$\mathbf{RE_{y,\ CH4,\ SWDS}} = \varphi_y * (1-f_y) * GWP_{CH4} * (1-OX) * 16/12 * F * DOC_{f,y} * MCF_y * \sum \sum W_{j,x} * DOC_j * e^{-kj*(y-x)} \bullet (1 - e^{-kj})$$

Symbols	Definition	Units
φ_y	Adjustment factor for uncertainty in year y	
f_y (=0)	Percentage of CH4 flared, combusted, or used out of all the CH4 collected in year y	
GWP_{CH4}	Global warming potential of CH4	
OX	Oxidation rate	
F	Percentage of CH4 in the waste treatment site gas	
$DOC_{f,y}$	Percentage of degradable organic carbon degraded in year y	
MCF_y	Methane corrective coefficient in year y	
$W_{j,x}$	Quantity of waste that was disposed in the waste treatment landfill site or organic waste type j that avoided landfill disposal in year x	
DOC_j	Percentage of degradable organic carbon in waste j	
k_j	Degradation rate of waste j	
j	Waste classification	
x	Year the waste was disposed in the landfill (Value x is the value from the year the landfill was opened (x=1) to the year the CH4 emissions is calculated (x=y))	
y	Year used to calculate CH4 emissions	

$$\mathbf{RE}_{\mathbf{y,\ electricity}} = EL_{BL,\ grid} \times EF_{electricity,\ y}$$

$$(EL_{BL,\ grid} = EL_{PJ})$$

Symbols	Definition	Units
$EL_{BL,\ grid}$	Reference system power usage	kWh/year
$EF_{y,\ electricity}$	CO2 emission coefficient of system power in year y	tCO2/kWh
EL_{PJ}	Electricity generated through cogeneration after project is implemented	kWh/year

$$\mathbf{RE}_{\mathbf{y,\ heat}} = Q_{BL,\ heat,\ output} \times 100/\varepsilon_{BL} \times EF_{BL,fuel}$$

$$(Q_{BL,\ heat,\ output} = Q_{PL,\ heat,\ output})$$

Symbols	Definition	Units
$Q_{BL,\ heat,\ output}$	Heat generated by target facility (Cogeneration) in the reference scenario	GJ/year
ε_{BL}	Energy consumption efficiency of facility (standard cogeneration) in the reference scenario	%
$EF_{BL,\ fuel}$	CO2 emission coefficient per unit calorific value of fuel (light oil) used at facility (standard cogeneration) in the reference scenario	tCO2/GJ
$Q_{PJ,\ heat,\ output}$	Heat generated by target facility (Cogeneration) after project is implemented	GJ/year

*For the heat generated ($Q_{PJ,\ heat,\ output}$) at target facility after project is implemented, use the value measured directly using a calorimeter.

Monitoring amount of activity

Monitoring items		Monitoring method
$\mathbf{EL_{PJ}}$	Electricity generated (kWh/year) by target facility (Cogeneration) after project is implemented	Measurement using power meter
$\mathbf{Q_{PJ,\ heat,\ output}}$	Heat generated (GJ/year) by target facility (Cogeneration) after project is implemented	Measurement using calorimeter
j	Composition ratio of waste j (based on weight)	default value
$\mathbf{W_{j,x}}$	Quantity of waste that was disposed in the waste treatment landfill site or organic waste type j that avoided landfill	Measurement by the Solid Waste Management Division

	disposal in year x	of the Bureau of Public Works in the Republic of Palau

Coefficient monitoring

Monitoring item		Monitoring method
$EF_{electricity, y}$	CO_2 emission coefficient (tCO_2/kWh) for system power in year y	Palau-Japan Joint Committee
$EF_{BL, fuel}$	CO_2 emission coefficient per unit calorific value of fuel used at baseline target facility (Cogeneration)	Default value
ε_{BL}	Energy consumption efficiency (%) at baseline target facility (Cogeneration)	Catalog value
φ	Adjustment factor for uncertainty	Methodology tool
GWP_{CH4}	Global warming potential of CH_4	Calculation method and list of emission coefficients of the Calculation, Reporting, and Disclosure Program (Ministry of the Environment)
OX	Oxidation rate	IPCC 2006 Guideline
F	Percentage of CH_4 in the waste treatment site gas	IPCC 2006 Guideline
DOC_f	Percentage of degradable organic carbon that is degraded	IPCC 2006 Guideline
MCF	Methane corrective coefficient	IPCC 2006 Guideline
DOC_j	Percentage of degradable organic carbon in waste j	Default value
k_j	Degradation rate of waste j [1/year]	Default value

Setting and calculating project emissions

Concept of project emissions

The emissions after project is implemented is the total of emissions from the bio gas process facility, emissions from transport of bio mass ingredients, transport of bio gas, and emissions from post-treatment facility for residue after fermentation, all after project is implemented.

Calculation of Project Emissions

The project emissions are calculated as follows.

$$PE_{y} = PE_{y, M} + PE_{y, process, biogas} + PE_{y, transport, feedstock} + PE_{y, transport, biogas} + PE_{y, treat}$$

Symbols	Definition	Units
PE_y	Emissions after project is implemented in year y	tCO2e/year
$PE_{y, M}$	Emissions from the use of target facility (Cogeneration) in year y after project is implemented	tCO2/year
$PE_{y, process, biogas}$	Emissions from bio gas process facility in year y after project is implemented	tCO2/year
$PE_{y, transport, feedstock}$	Emissions from use of fossil fuel in the transport of bio mass ingredients in year y after project is implemented	tCO2/year
$PE_{y, transport, biogas}$	Emissions from use of fossil fuels in the transport of bio gas in year y after project is implemented	tCO2/year
$PE_{y, treat}$	Emissions from post-treatment facility for residue after fermentation in year y after project is implemented	tCO2e/year

[Major emission activities]

Since the energy is created using recyclable fuel for the emissions from the use of biogas at the target facility (Cogeneration) after project is implemented, the GHG emissions is zero.

$$\mathbf{PE_{y, M}} = 0$$

[Incidental emission activity]

$$\mathbf{PE_{y, process, biogas}} = EL_{y, PJ, process} \times PV_{y, PJ} / PV_{y, PJ, all} \times EF_{electricity, y}$$

Symbols	Definition	Units
$EL_{y, PJ, process}$	Electricity usage for bio gas process in year y after project is implemented	kWh/year
$PV_{y, PJ}$	Weight (Note) of bio gas manufactured for this project in year y after project is implemented	t/year
$PV_{y, PJ, all}$	Weight of all bio gas manufactured in year y after project is implemented	t/year
$EF_{electricity, y}$	CO2 emissions coefficient of system power in year y	tCO2/kWh

(Note) The amount self-consumed in also included. However, if the electricity is consumed by multiple copartners in the project, or if the electricity is to be sold to the electric company, it shall be counted as self-consumed. (In the case of this project, the entire amount of biogas generated is self-consumed, so it is assumed that $PV_{y, PJ}/PV_{y, PJ, all} = 1$.)

$$PE_{y,\ transport,\ feedstock} = F_{y,\ transport,\ feedstock} \times HV_{transport,\ feedstock} \times EF_{transport,\ feedstock}$$

Symbols	Definition	Units
$F_{y,\ transport,\ feedstock}$	Fuel usage for transport of bio mass ingredient in year y after project is implemented	kL/year
$HV_{transport,\ feedstock}$	Unit calorific value of fuel used to transport bio mass ingredients after project is implemented	GJ/kL
$EF_{transport,\ feedstock}$	CO2 emission coefficient per unit calorific value of fuel used in transport of bio mass ingredients after project is implemented	tCO2/GJ

*Biomass ingredients refer to bio mass ingredients charged other than waste such as Napier grass. Additionally, regarding emissions from the use of fossil fuel to transport bio mass ingredients, consider the degree of influence on the overall expected reduction in emissions, and if the influence is expected to be low, include it in the calculation for GHG emissions.

$$PE_{y,\ transport,\ biogas} = 0$$

The biogas-manufacturing site and the location used are the same location.

$$PE_{y,\ treat} = 0$$

Regarding emissions from the use of post-treatment facilities for residue after fermentation and purification of fermentation residue of livestock excreta, if the digestive fluid is used effective as a liquid fertilizer, etc., they do not need to be calculated.

<u>Monitoring items</u>

- **Monitoring amount of activity**

Monitoring item		Monitoring method
$EL_{y、PJ,\ process}$	Electricity usage (kWh/year) for all bio gas processes in year y after project is implemented	Measurement using power meter, calculation based on bill from electric company, calculation based on facility specification (rated power conspumtion) and operation time
$PV_{y,\ PJ}$	Weight (t/year) of bio gas manufactured for this project in year y after project is implemented	Measured using weight scale

$PV_{y, PJ, all}$	Weight (t/year) of all bio gas manufactured over a certain period in year y after project is implemented	Measured using weight scale
$F_{y, transport, feedstock}$	Fuel usage (kL/year) for transport of bio mass ingredient in year y after project is implemented	Measured using weight scale

- **Coefficient monitoring**

Monitoring items		Monitoring methods
$EF_{y, electricity}$	CO2 emission coefficient (tCO2/kWh) of electricity in year y	Palau-Japan Joint Committee
$HV_{transport, feedstock}$	Unit calorific value(GJ/kL) of fuel used to transport biomass ingredients after project is implemented	Use default value
$EF_{transport, feedstock}$	CO2 emission coefficient (tCO2/GJ) per unit calorific value of fuel used to transport biomass ingredients after project is implemented	Use default value

4.5.3 PDD Proposal

A. Project Overview

A.1. JCM Project title

Project to establish a comprehensive recycling system in order to realize a low-carbon society in the Republic of Palau

A.2. Project overview and technology and measures adopted

This purpose of this project is to establish a comprehensive recycling system in Palau where there are concerns of strain on current landfill disposal and environmental pollution. The following is an explanation of the major technical components.

1) Dry waste (plastic, paper, textile, cut branches, etc.) is turned into solid fuel, and the energy generated from the biomass boiler and absorption chiller are used to cool building such as the Capitol Building which houses the National Congress.

2) Wet waste (food waste, organic residue, etc.) and sewage sludge are transformed into biogas and liquid fertilizer through wet methane fermentation technology and the biogas is used as energy for cogeneration power generators and the liquid fertilizer is used in agriculture, etc. Additionally, the liquid fertilizer is used to cultivate fast-growing Napier grass, which is then used as bio gas ingredient to reinforce power generation capacity.

3) Waste tires are shredded and exported to countries with a demand and used as raw material and

fuel for cement, etc. Through the establishment of this recycling system, we aim to realize a “Island-wide recycling low-carbon society model” with multifaceted benefits such as the reduction of greenhouse gas emissions, reduction of landfill waste disposal, creation of renewable energy, and promotion of agriculture and tourist industry.

A.3. Project site

Country	Republic of Palau
Region, State, County, etc.:	Koror, Airai
City, Town, Community, etc.:	-
Latitude, Longitude	-

A.4. Project members

The Republic of Palau	Government, State Government (To be determined)
Japan	AMITA Institute for Sustainable Economies Co., Ltd. (AISE)

A.5. Period

Starting date of project operation	2016 or 2017
Expected operational lifetime of project	10 years (Estimate)

A.6. Contribution from developed countries

Through the adoption of this system at AISE, it will be possible to contribute to the reduction of garbage, reduction of environmental risk through appropriate treatment of sewage treatment sludge, reduction of landfill disposal site costs, improvement of energy security in Palau through the creation of renewable energy, increase in food security through the promotion of organic farming, and added-value to tourism resources. Additionally, financial support will be provided from Japan through JCM.

B. Application of an approved methodology(ies)

* “B.1. Selection of methodology(ies)” and “B.2. Explanation of how the project meets eligibility criteria of the approved methodology” are omitted because it is the same as the MRV methodology (Refer to Introduction)

C. Calculation of emission reductions

* “C.1. All emission sources and their associated greenhouse gases relevant to the JCM project” and “C.2. Figure of all emission sources and monitoring points relevant to the JCM project” are omitted

because it is the same as for MRV methodology (Refer to "Reference emissions", "Project emissions" and "Monitoring amount of activity")

C.3. Estimated emissions reductions in each year

*Test calculations were not conducted using this methodology, but we provide our own test calculation results for reduction of CO2 emission from energy sources as reference.

Year	Estimated Reference emissions (tCO_{2e})	Estimated Project Emissions (tCO_{2e})	Estimated Emission Reductions (tCO_{2e})
2016	-	-	2,252
2017	-	-	4,504
2018	-	-	4,504
2019	-	-	4,504
2020	-	-	4,504
2021	-	-	4,504
2022	-	-	4,504
2023	-	-	4,504
2024	-	-	4,504
2025	-	-	4,504
Total (tCO_{2e})	-	-	42,787

D. Environmental impact assessment	
Legal requirement of environmental impact assessment for the proposed project	YES

Revision history of PDD		
Version	**Date**	**Contents revised**
Ver.1.0	**2015/2/13**	-