3.3 Environmental Management Sector

3.3.1 Preconditions for the sector

JICA provides technical cooperation for the central and local governmental authorities of developing countries to enhance their capacity to deal with environmental problems. In developing countries, rapid urbanization and the progress of industrialization has led to worsening air and water pollution and waste management, however, the appropriate environmental management has not been implemented.

JICA conducts the following activities:

1) Support of the environmental centre
2) Air pollution control measures
3) Acid rain measures
4) Water pollution control measures
5) Solid waste management

The environmental management sector is categorized into solid waste management, water pollution control measures and air pollution control measures (including acid rain measures). It is assumed that most of the technical assistance to the environmental centre is included in activities of solid waste management, water pollution control measures and air pollution control measures.

In the environmental management sector, there is a capacity development project regarding CDM projects. Since CDM projects are implemented through solid waste management, water pollution control measures and air pollution control measures, etc., they are related to each of the above categories. In addition, this capacity development project is implemented with the aim of promoting GHG reduction activity and the GHG emission reduction effect of specific projects are quantified based on the CDM methodology. Therefore, the capacity development project regarding CDM projects is excluded from this project study.

3.3.2 Summary of quantification methods

By subtracting the "With the activity" (project) emissions (PE_{with}) from the "Without the activity" (baseline) emissions ($BE_{without}$), GHG emission reductions ($ER=BE_{without}-PE_{with}$) was obtained. GHG quantification methods in the environmental management sector are outlined as indicated below.

Table 3.3.1 Outline of GHG quantification methods in the environmental management sector

Component	Sector	Quantification methods
GHG emissions associated with electrical consumption	Common to all sectors	"CO_2 emission factor for electrical consumption" × "Electrical consumption"
GHG emissions associated with fossil fuel consumption	Common to all sectors	"CO_2 emission factor for fossil fuel consumption" × "Energy consumption"
GHG emissions from a waste disposal site	Solid waste management	First Order Decay Model (FOD Model) Calculation of CH_4 emissions by waste type for each calculation target year
GHG emissions associated with use of vehicles	Solid waste management Air pollution control	"CO_2 emission factor for fossil fuel by vehicle type" × "vehicle kilometres" × "fuel economy" "CO_2 emission factor for fossil fuel by vehicle type" × "fossil fuel consumption"
GHG emissions associated with composting process	Solid waste management Water pollution control	N_2O emissions: "Emission factor" × "Composting amount" CH_4 emissions: "Emission factor" ×"Composting amount"
GHG emissions associated with treatment process of wastewater	Water pollution control	"BOD pollutant loads or COD pollutant loads " × "B" ×"MCF" B : Maximum CH_4 producing capacity MCF : CH_4 conversion factor

3.3.3 GHG emission reduction activities of JICA projects

Regarding the solid waste management sector, water pollution control sector and air pollution control sector, the effectiveness of GHG emission reductions was reviewed qualitatively.

The study of the effectiveness resulted in dividing the components into three classifications as shown in table 3.3.2. The table 3.3.3-1(1) - table 3.3.3-3(3) show the results.

Table 3.3.2 The qualitative classification of the GHG emission reduction effect

Classification	Definition	Legend
Effective	Implementing this component definitely reduces GHG emissions.	○
Effective depending on the terms	Additional action beyond implementing this component is required in order to reduce GHG emission.	▲
Ineffective	Even if this component is implemented GHG emission is not reduced.	×

Project examples listed in Table 3.3.3-1(1) to Table 3.3.3-3(3) consist of the projects that were recognized to be effective for mitigation of climate change in the research called “JICA’s Assistance for Mitigation to Climate Change - The Co-Benefits Approach to Climate Change”. And they also include the projects that JICA specified as the mitigation projects from JICA projects of year 2008.

Therefore, these project examples do not contain all of JICA projects. In other words, there are other JICA projects with other GHG reduction components shown in Table 3.3.3-1(1) to Table 3.3.3-3(3).

Table 3.3.3-1(1) List of components of GHG reduction activities (solid waste management)

Project example	**Ensuring proper generation, storage and discharge**		**Expanding and improving collection service**			
	Raising public awareness about SWM (environmental education)	**Ensuring that proper discharge methods are used**	**Establishing a collection system/ Formulating collection plans/ Expanding collection service**	**Improving collection efficiency**	**Improving the quality of collection service**	**Improving public area sanitation**
Waste management plan	▲	▲	▲			
Waste management capacity development project	▲	▲	▲	○	○	▲
Industrial park waste management improvement plan						
Recycling-based society promotion project	▲		▲	○	○	▲

Table 3.3.3-1(2) List of components of GHG reduction activities (solid waste management)

Project example	**Introducing and improving intermediate treatment**			
	Volume reduction (Introducing and improving size-reduction facilities and compaction process)	**Waste reduction (Introducing and improving incineration facilities and composting facilities, collection of recyclables)**	**Stabilization and detoxification (Introducing and improving incineration facilities, sterilization facilities and chemical treatment facilities)**	**Energy recovery (Introducing and improving waste-to-energy plants and plants using biomass energy)**
Waste management plan		○		
Waste management capacity development project		○	▲	○
Industrial park waste management improvement plan				
Recycling-based society promotion project		○		

Table 3.3.3-1(3) List of components of GHG reduction activities (solid waste management)

Project example	Improving final disposal			
	Institutional building	**Final disposal planning**	**Preventing or reducing the environmental impacts of final disposal sites**	**Proper operation of final disposal sites**
Waste management plan	▲	▲	▲	○
Waste management capacity development project	▲	▲	▲	○
Industrial park waste management improvement plan	▲	▲	▲	○
Recycling-based society promotion project	▲	▲	▲	○

Table 3.3.3-1(4) List of components of GHG reduction activities (solid waste management)

Project example	Promoting recycling and waste reduction		
	Promoting recycling (Promoting separate collection of recyclables)	**Promoting recycling (Promoting the use of recyclables)**	**Promoting waste reduction**
Waste management plan	○		
Waste management capacity development project	○	○	○
Industrial park waste management improvement plan			
Recycling-based society promotion project	○	▲	▲

- ✓ The classification of ○, ▲ and × are decided through the review of JICA's technical cooperation project.
- ✓ Table 3.3.3-1(1) - Table 3.3.3-1(4) show the evaluation result of each 4 project examples in the solid waste management sector, namely, Waste management plan, Waste management capacity development project, Industrial park waste management improvement plan and Recycling-based society promotion project.

Table 3.3.3-2(1) List of components of GHG reduction activities (water pollution control)

Project example	**Measures regarding domestic wastewater**			**Measures regarding industrial/commercial wastewater**		
	Introduction of sewage treatment facility	**Introduction of on-site units for primary wastewater treatment**	**Measures against pollution in urban areas, waste disposal sites, etc.**	**Introduction of industrial wastewater treatment facilities**	**Improvement of environmental efficiency at production (cleaner production, etc.)**	**Measures regarding wastewater from farmland, livestock etc.**
Study on specific area sewerage system development	○					
Study on river-basin sewerage system development	○	○				○
Study on nationwide sewerage system development	○			○	○	
Capacity development on environmental monitoring						

Table 3.3.3-2(2) List of components of GHG reduction activities (water pollution control)

Project example	**Developing the environmental management capacity of public administration (Identifying major causes of pollution, assessing hydrological and hydraulic characteristics, monitoring, environmental pollution predictive analysis methods, etc.)**	**Developing the environmental management capacity of industry (Introduction of internal voluntary monitoring systems, information disclosure, etc.)**	**Developing the water pollution control capacity of academia (monitoring, development of analysis methods, etc.)**	**Developing the water pollution control capacity of civil society (environmental education, disclosure of pollution information, etc)**
Study on specific area sewerage system development	▲			
Study on river-basin sewerage system development	▲			
Study on nationwide sewerage system development	▲	▲		
Capacity development on environmental monitoring	▲			

- ✓ The classification of ○, ▲ and × are decided through the review of JICA's technical cooperation project.
- ✓ Table 3.3.3-2(1) and Table 3.3.3-2(2) show evaluation result of each 4 project examples in the water pollution control sector, namely, Study on specific area sewerage system

development, Study on river-basin sewerage system development, Study on nationwide sewerage system development and Capacity development on environmental monitoring.

Table 3.3.3-3(1) List of components of GHG reduction activities (air pollution control)

Project example	**Measures for the stationary emission sources**				
	Improvement of environmental efficiency at production (cleaner production)	**Introduction of smoke and soot treatment facilities (Introduction of flue gas desulfurization equipment, improvement of combustion facilities, etc.)**	**Fuel control (improvement of fuel properties, fuel shift, etc.)**	**Environmental management of industry (the pollution control manager system, ISO 14000 certification, etc.)**	**Introduction of regulatory instruments (introduction of effluent standards, total pollutant load control, on-site guidance, etc.)**
Study on air pollution control plan		×		▲	▲
Acid deposition control strategy	○	×	○	▲	
Capacity development on environmental monitoring					

Table 3.3.3-3(2) List of components of GHG reduction activities (air pollution control)

Project example	**Measures for the mobile emission sources**		
	Measures for source (emission gas control standard, standard of fuel economy, fuel shift, etc.)	**Traffic control (conversion to use of public transportation, improvement of the efficiency of distribution systems, restraint of the use of automobiles, etc.)**	**Development of smooth traffic flow (Increase in travelling speed through measures on road structures, improvement of traffic control system, etc.)**
Study on air pollution control plan			
Acid deposition control strategy	○	○	
Capacity development of environmental monitoring			

Table 3.3.3-3(3) List of components of GHG reduction activities (air pollution control)

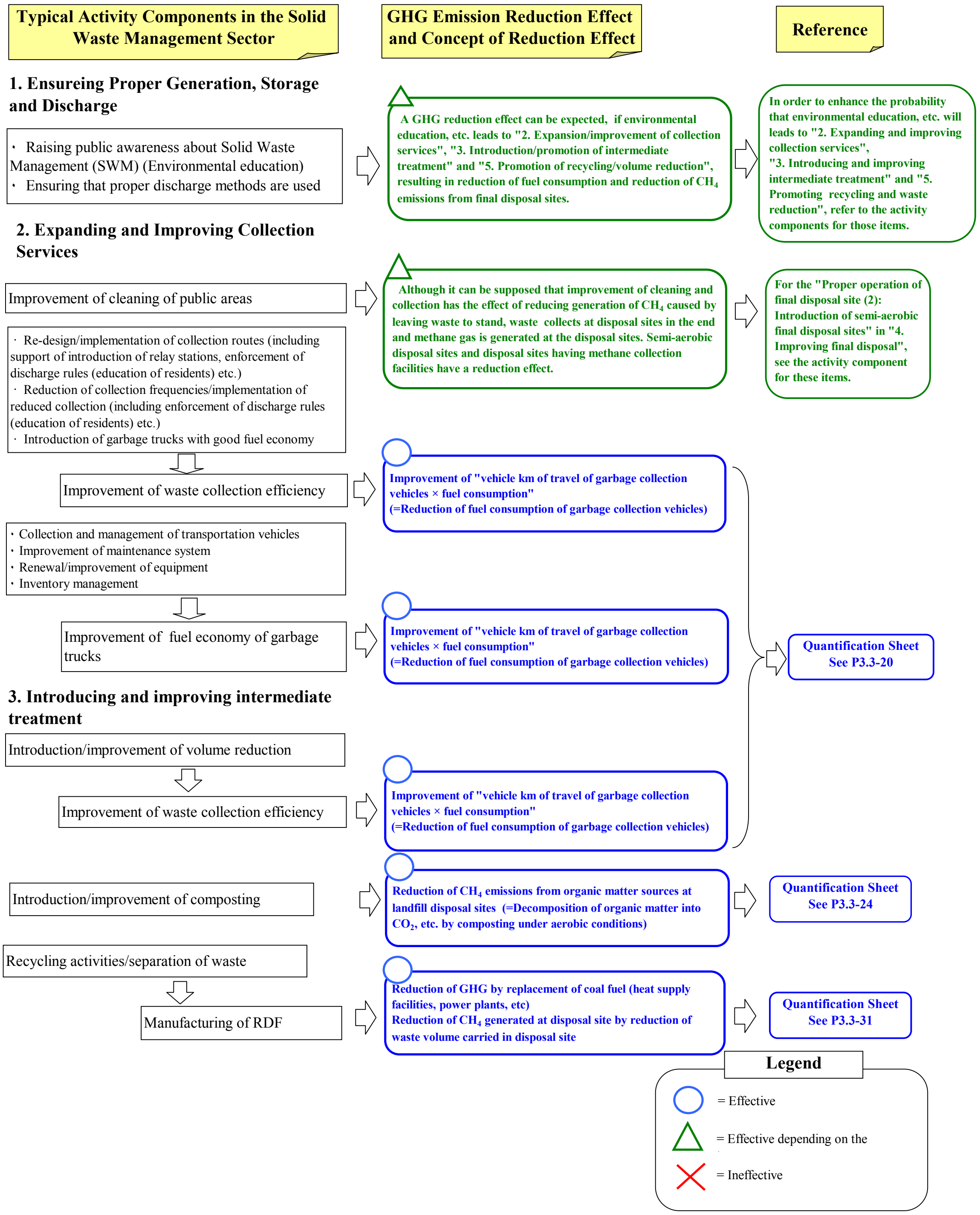
Project example	**Developing the environmental management capacity of public administration (monitoring, preparation of inventory, environmental pollution predictive analysis methods, etc.)**	**Developing the environmental management capacity of industry (Introduction of internal voluntary monitoring systems, information disclosure, etc.)**	**Developing the water pollution control capacity of academia (environmental epidemiologic investigation, monitoring, development of analysis methods, etc.)**	**Developing the water pollution control capacity of civil society (environmental education, disclosure of pollution information, spread of green purchase, etc.)**
Study on air pollution control plan	▲	▲		
Acid deposition control strategy	▲			
Capacity development on environmental monitoring	▲		▲	▲

- ✓ The classification of ○, ▲ and × are decided through the review of JICA's technical cooperation project.
- ✓ Table 3.3.3-3(1) - Table 3.3.3-2(3) show evaluation result of each 3 project examples in the air pollution control sector, namely, Study on air pollution control plan, Acid deposition control strategy and Capacity development on environmental monitoring.

3.3.4 Summary of GHG emission reduction scenarios and quantification sheet by activity

The environmental management sector is classified under the solid waste management sector, water pollution control sector and air pollution control sector.

In the solid waste management sector, the following 5 kinds of activities were conducted: (1) Ensuring proper generation, storage and discharge, (2) Expanding and improving collection service, (3) Introducing and improving intermediate treatment, (4) Improving final disposal, (5) Promoting recycling and waste reduction.



A GHG reduction effect can be expected, if environmental education, etc. leads to "2. Expansion/improvement of collection services", "3. Introduction/promotion of intermediate treatment" and "5. Promotion of recycling/volume reduction", resulting in reduction of fuel consumption and reduction of CH_4 emissions from final disposal sites.

In order to enhance the probability that environmental education, etc. will leads to "2. Expanding and improving collection services", "3. Introducing and improving intermediate treatment" and "5. Promoting recycling and waste reduction", refer to the activity components for those items.

Although it can be supposed that improvement of cleaning and collection has the effect of reducing generation of CH_4 caused by leaving waste to stand, waste collects at disposal sites in the end and methane gas is generated at the disposal sites. Semi-aerobic disposal sites and disposal sites having methane collection facilities have a reduction effect.

For the "Proper operation of final disposal site (2): Introduction of semi-aerobic final disposal sites" in "4. Improving final disposal", see the activity component for these items.

Improvement of "vehicle km of travel of garbage collection vehicles × fuel consumption" (=Reduction of fuel consumption of garbage collection vehicles)

Improvement of "vehicle km of travel of garbage collection vehicles × fuel consumption" (=Reduction of fuel consumption of garbage collection vehicles)

Improvement of "vehicle km of travel of garbage collection vehicles × fuel consumption" (=Reduction of fuel consumption of garbage collection vehicles)

Reduction of CH_4 emissions from organic matter sources at landfill disposal sites (=Decomposition of organic matter into CO_2, etc. by composting under aerobic conditions)

Reduction of GHG by replacement of coal fuel (heat supply facilities, power plants, etc)
Reduction of CH_4 generated at disposal site by reduction of waste volume carried in disposal site

Figure 3.3.1(1) Quantification possibility of each component (solid waste management)

Typical Activity Components in the Solid Waste Management Sector		**GHG Emission Reduction Effect and Concept of Reduction Effect**	**Reference**
4. Improving final disposal			
Proper operation of final disposal sites (1): Soil covering, leachate treatment	△	If landfill disposal sites become semi-aerobic as a result of introduction of soil covering or leachate treatment plants, a CH_4 emissions reduction effect can be expected. The effect is determined to be the effect of introduction of semi-aerobic landfill.	The same quantification method are used for "Proper operation of final disposal site (2): Introduction of semi-aerobic final disposal sitesl" in "4. Improving final disposal" Quantification Sheet See P3.3-13
Proper operation of final disposal sites (2): Introduction of semi-aerobic final disposal sites	○	CH_4 emissions reduction by introduction of semi-aerobic landfill (At the existing final disposal sites, all the CH_4 is released in the air. Therefore, it is assumed that more CH_4 is emitted at the existing final disposal sites than from semi-aerobic landfill.)	Quantification Sheet See P3.3-13 Case study See P3.3-86
Proper operation of final disposal sites (3): Data management (incoming waste amount, density, etc.) and operation based on data	✕	No reduction effect by improvement of data management is expected .	
Proper operation of final disposal sites (4): Improvement of operational conditions of heavy-duty machine used in landfill works including carrying in, transportation and rolling compaction (compacting waste by applying pressure from the top with heavy-duty machines)	○	If introduction of heavy-duty machines of good fuel economy for incoming waste, transportation, surface compaction, etc. and improvement of operation of final disposal sites result in reduction of fuel consumption, a GHG reduction effect is expected.	Quantification Sheet See P3.3-28
Support of expansion (including expansion works) of final disposal sites	△	If semi-aerobic landfill is introduced in the new expansion part, the quantification process for introduction of semi-aerobic landfill shall be used. If a methane gas collection facility is introduced in the new expansion part, a reduction effect is expected, but it is unlikely that a methane gas collection facility will be introduced in the JICA technical cooperation project.	The same quantification method as "Proper operation of final disposal site (2): Introduction of semi-aerobic landfill" in "4. Improvement of final disposal" Quantification Sheet See P3.3-13
Equipment procurement/equipment operation (for operation and management of final disposal site)	✕	There is no reduction effect through equipment procurement. GHG will increase by operation of procured equipment. "Proper management of disposal site" regarding operation of equipment will produce a reduction of CH_4. This should be evaluated together with other GHG reduction components for proper operation of the final	
5. Promoting recycling and waste reduction			
Promotion of separated collection (reduction of waste volume)	○	Reduction of fuel consumption by improvement of collection and transportation of reduced volume of waste to disposal site	Quantification Sheet See P3.3-20
Promotion of separated collection (composting of garbage)	○	Reduction of CH_4 emissions from organic matter sources at landfill disposal sites	Quantification Sheet See P3.3-24
Promotion of recycling projects (development of implementation plan, implementation of pilot project) ・Recycling of resources such as metal products	△	CO_2 emission per 1t of "recycled bullion" produced by recycling of aluminium cans, etc. is 309 kg CO_2/t, which is only about 3% of CO_2 emission per 1t of producing new bullion, 9,218 kg CO_2/t. Therefore, in a case where as a result of recycling activity, recycled bullion is produced as an alternative new bullion, a GHG reduction effect can be expected. It is essential to determine the reduction effect in view of the LCA (Life Cycle Assessment).	Quantification of GHG reduction in view of LCA shall be excluded from determination.
Developing an awareness of waste volume reduction and reuse (enlightenment projects for residents, business proprietors, etc.) ・"Illegal dumping prevention" enlightenment activities ・"Promotion of separated collection" enlightenment activities ・"Promotion of recycling projects" enlightenment projects	△	If enlightenment activities result in promotion of recycling projects and separated collection, "5. Promotion of recycling/volume reduction" is expected. As a result, if fuel consumption and CH_4 emissions from final disposal sites are reduced, a GHG reduction effect is expected. If a garbage incineration plant exists, the effect of reducing CO_2 emissions associated with incineration of products of oil origin can be expected.	In order to increase the probability that the activities will lead to "5. Promoting recycling and waste reduction", see the activity components for that item.

Legend

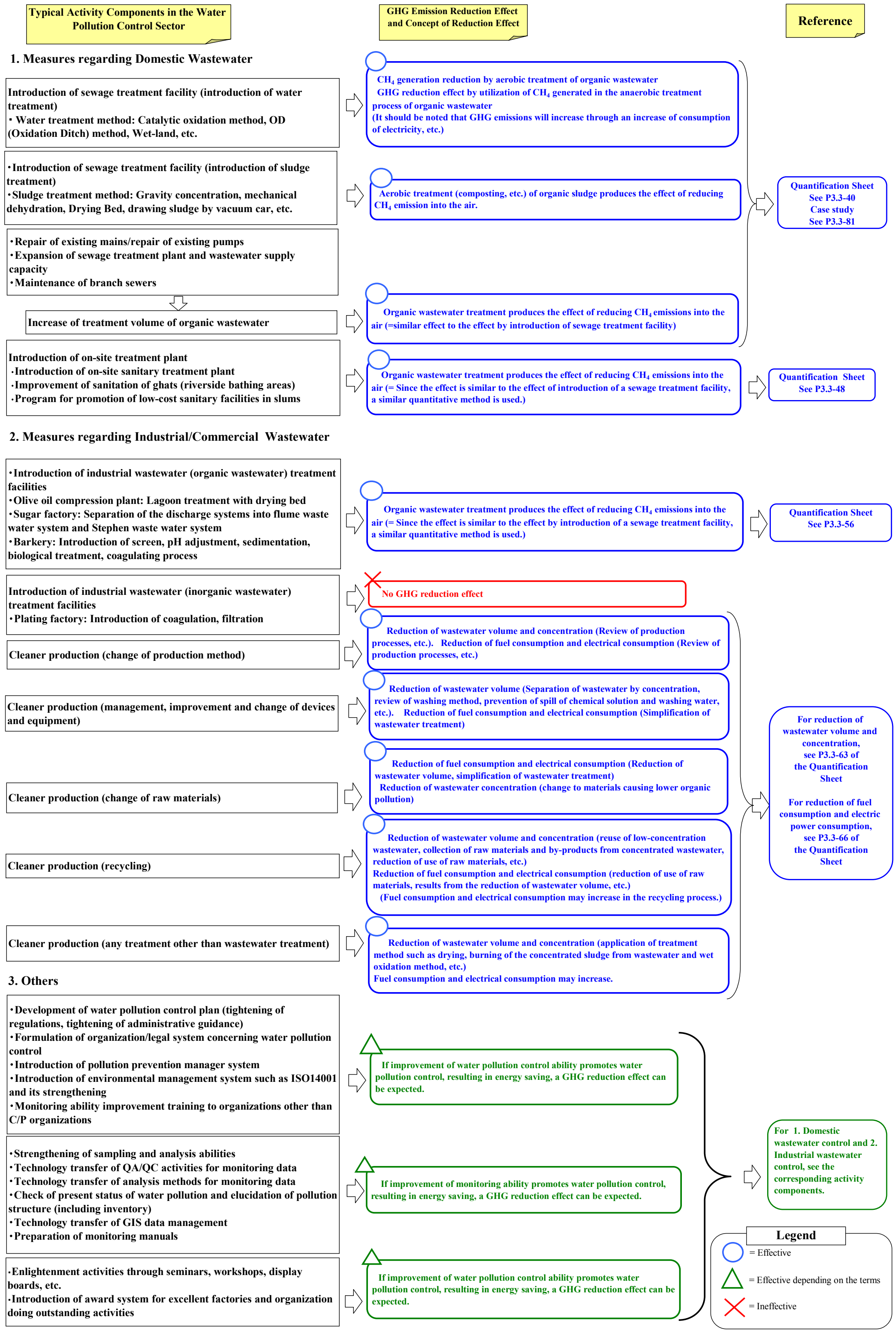
○ = Effective

△ = Effective depending on the

✕ = Ineffective

Figure 3.3.1(2) Quantification possibility of each component (solid waste management)

In the water pollution control sector, the following 3 kinds of activities were conducted: (1) measures regarding domestic wastewater, (2) measures regarding industrial/commercial wastewater, and (3) others.



Typical Activity Components in the Water Pollution Control Sector

GHG Emission Reduction Effect and Concept of Reduction Effect

Reference

1. Measures regarding Domestic Wastewater

Introduction of sewage treatment facility (introduction of water treatment)
• Water treatment method: Catalytic oxidation method, OD (Oxidation Ditch) method, Wet-land, etc.

○ CH_4 generation reduction by aerobic treatment of organic wastewater
GHG reduction effect by utilization of CH_4 generated in the anaerobic treatment process of organic wastewater
(It should be noted that GHG emissions will increase through an increase of consumption of electricity, etc.)

•Introduction of sewage treatment facility (introduction of sludge treatment)
•Sludge treatment method: Gravity concentration, mechanical dehydration, Drying Bed, drawing sludge by vacuum car, etc.

○ Aerobic treatment (composting, etc.) of organic sludge produces the effect of reducing CH_4 emission into the air.

•Repair of existing mains/repair of existing pumps
•Expansion of sewage treatment plant and wastewater supply capacity
•Maintenance of branch sewers

Increase of treatment volume of organic wastewater

○ Organic wastewater treatment produces the effect of reducing CH_4 emissions into the air (=similar effect to the effect by introduction of sewage treatment facility)

Quantification Sheet
See P3.3-40
Case study
See P3.3-81

Introduction of on-site treatment plant
·Introduction of on-site sanitary treatment plant
·Improvement of sanitation of ghats (riverside bathing areas)
·Program for promotion of low-cost sanitary facilities in slums

○ Organic wastewater treatment produces the effect of reducing CH_4 emissions into the air (= Since the effect is similar to the effect of introduction of a sewage treatment facility, a similar quantitative method is used.)

Quantification Sheet
See P3.3-48

2. Measures regarding Industrial/Commercial Wastewater

•Introduction of industrial wastewater (organic wastewater) treatment facilities
•Olive oil compression plant: Lagoon treatment with drying bed
•Sugar factory: Separation of the discharge systems into flume waste water system and Stephen waste water system
•Barkery: Introduction of screen, pH adjustment, sedimentation, biological treatment, coagulating process

○ Organic wastewater treatment produces the effect of reducing CH_4 emissions into the air (= Since the effect is similar to the effect by introduction of a sewage treatment facility, a similar quantitative method is used.)

Quantification Sheet
See P3.3-56

Introduction of industrial wastewater (inorganic wastewater) treatment facilities
•Plating factory: Introduction of coagulation, filtration

✗ No GHG reduction effect

Cleaner production (change of production method)

○ Reduction of wastewater volume and concentration (Review of production processes, etc.). Reduction of fuel consumption and electrical consumption (Review of production processes, etc.)

Cleaner production (management, improvement and change of devices and equipment)

○ Reduction of wastewater volume (Separation of wastewater by concentration, review of washing method, prevention of spill of chemical solution and washing water, etc.). Reduction of fuel consumption and electrical consumption (Simplification of wastewater treatment)

Cleaner production (change of raw materials)

○ Reduction of fuel consumption and electrical consumption (Reduction of wastewater volume, simplification of wastewater treatment)
Reduction of wastewater concentration (change to materials causing lower organic pollution)

Cleaner production (recycling)

○ Reduction of wastewater volume and concentration (reuse of low-concentration wastewater, collection of raw materials and by-products from concentrated wastewater, reduction of use of raw materials, etc.)
Reduction of fuel consumption and electrical consumption (reduction of use of raw materials, results from the reduction of wastewater volume, etc.)
(Fuel consumption and electrical consumption may increase in the recycling process.)

Cleaner production (any treatment other than wastewater treatment)

○ Reduction of wastewater volume and concentration (application of treatment method such as drying, burning of the concentrated sludge from wastewater and wet oxidation method, etc.)
Fuel consumption and electrical consumption may increase.

For reduction of wastewater volume and concentration, see P3.3-63 of the Quantification Sheet

For reduction of fuel consumption and electric power consumption, see P3.3-66 of the Quantification Sheet

3. Others

•Development of water pollution control plan (tightening of regulations, tightening of administrative guidance)
•Formulation of organization/legal system concerning water pollution control
•Introduction of pollution prevention manager system
•Introduction of environmental management system such as ISO14001 and its strengthening
•Monitoring ability improvement training to organizations other than C/P organizations

△ If improvement of water pollution control ability promotes water pollution control, resulting in energy saving, a GHG reduction effect can be expected.

•Strengthening of sampling and analysis abilities
•Technology transfer of QA/QC activities for monitoring data
•Technology transfer of analysis methods for monitoring data
•Check of present status of water pollution and elucidation of pollution structure (including inventory)
•Technology transfer of GIS data management
•Preparation of monitoring manuals

△ If improvement of monitoring ability promotes water pollution control, resulting in energy saving, a GHG reduction effect can be expected.

·Enlightenment activities through seminars, workshops, display boards, etc.
·Introduction of award system for excellent factories and organization doing outstanding activities

△ If improvement of water pollution control ability promotes water pollution control, resulting in energy saving, a GHG reduction effect can be expected.

For 1. Domestic wastewater control and 2. Industrial wastewater control, see the corresponding activity components.

Legend
○ = Effective
△ = Effective depending on the terms
✗ = Ineffective

Figure 3.3.2 Quantification possibility of each component (water pollution control)

In the air pollution control sector, the following 3 kinds of activities were conducted: (1) Measures for the stationary emission sources, (2) Measures for the mobile emission sources, and (3) others.

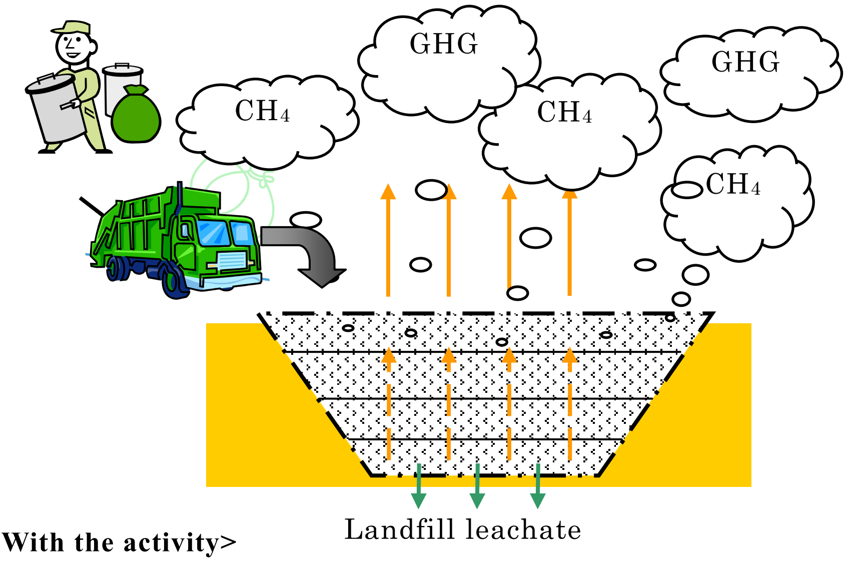
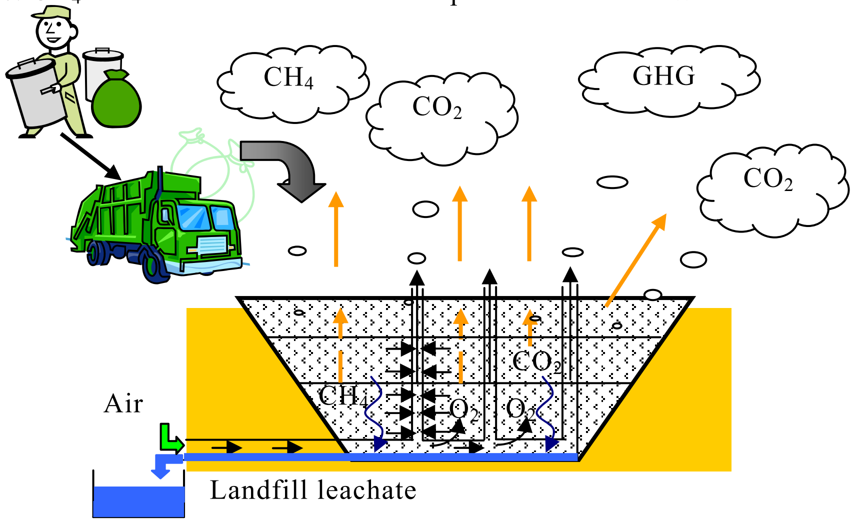
Typical Activity Components in the Air Pollution Control Sector	GHG Emission Reduction Effect and Concept of Reduction Effect	Reference
1.Measures for Stationary Emission Sources		
Clearer production (Fuel shift (conversion to natural gas at fixed sources)	○ Fuel conversion from oil and coal to natural gas (=Use of low carbon fuel)	Quantification Sheet See P3.3-70 Case study See P3.3-97
Cleaner production (Fuel shift (reduction of sulphur content in coal and heavy oil)	✕ No GHG reduction effect	
Cleaner production (Introduction of low NOx combustion technologies)	○ GHG reduction effect by energy saving (reduction of fuel usage)	Quantification Sheet See P3.3-66
Cleaner production (Improvement of energy efficiency by heavy oil burner)	○ GHG reduction effect by energy saving (reduction of fuel usage)	
Cleaner production (Introduction of waste heat recovery process)	○ GHG reduction effect by energy saving (reduction of fuel usage)	
Cleaner production (Introduction of energy-saving process/equipment, etc.)	○ GHG reduction effect by energy saving (reduction of fuel usage)	
Introduction of smoke and soot treatment facilities ・Measures against SO2: Installation of flue gas desulphurization equipment, introduction of furnace desulphurization (inclusion of limestone), water film desulphurization ・Measures against PM10: Bag filter, electrostatic precipitator Measures against SO2, NO2, PM10: Installation of high chimney	✕ No GHG reduction effect (Increase of electric power consumption leads to increase of GHG emissions.)	
2. Measures for the Mobile Emission Sources		
Measures for sources (emission gas control standard for gas mileage, fuel shift, etc.)	○ GHG reduction effect by fuel shift from oil and coal to natural gas (improvement of emission factor). GHG reduction effect by replacement with low-pollution and low-CO_2 emission (improved fuel economy) vehicles (improvement of emission factor)	Quantification Sheet See P3.3-73
Traffic control (conversion to use of public transportation, improvement of the efficiency of distribution system, restraint of the automobiles, etc.)	○ GHG reduction effect by reduction of fuel usage. Study of alternative transportation is required.	
Development of smooth traffic flow (increase in travelling speed through measures regarding road structures, improvement of traffic control system, etc.)	○ GHG reduction effect by reduction of fuel usage. GHG reduction effect associated with improvement of fuel economy by increase of travel speed	
3. Others		
・Sampling, strengthening of analysis ability ・Technology transfer of QA/QC activities of monitoring data ・Technology transfer of analysis method for monitoring data ・Grasping of present status of air pollution and elucidation of pollution structure (including preparation of inventory) ・Technology transfer of model simulation ・Preparation of monitoring manuals	△ If improvement of monitoring ability promotes air pollution control, resulting in energy saving, a GHG reduction effect can be expected.	For 1. Measures for the stationary emission sources and 2. Measures for mobile emission sources, see the corresponding activity components.
・Development of air pollution control plan ・Formulation of organization/legal system concerning air pollution control ・Introduction of pollution prevention manager system ・Introduction of environmental management system such as ISO14001 and its strengthening ・Monitoring ability improvement training to organizations other than C/P organizations	△ If improvement of air pollution control ability promotes air pollution control, resulting in energy saving, a GHG reduction effect can be expected.	
Enlightenment activities through seminars, workshops, display boards, etc.	△ If improvement of air pollution control ability promotes air pollution control, resulting in energy saving, a GHG reduction effect can be expected.	

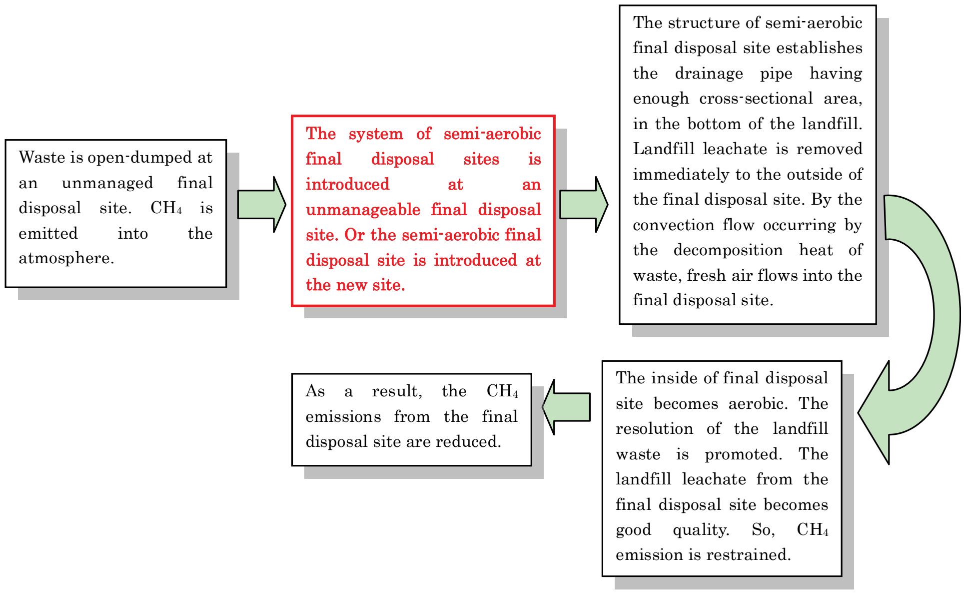
Legend
○ = Effective
△ = Effective depending on the terms
✕ = Ineffective

Figure 3.3.3 Quantification possibility of each component (air pollution control)

Quantification Sheet

Activity: Solid Waste Management
(Introduction of Semi-Aerobic Final Disposal Sites)

Sector	Environmental Management
Sub-sector	Solid Waste Management (Improving Final Disposal)
GHG emission reduction activity	Introduction of semi-aerobic final disposal sites
GHG emission reduction impact	1: Activity will lead to GHG emission reduction 2: Activity will lead to GHG emission reduction subject to condition(s) 3: Activity will not lead to GHG emission reduction
GHG emission reduction scenarios (description of how GHG is reduced)	**<Without the activity>** Waste is under open-dumping at an unmanageable final disposal site.  **<With the activity>** Waste is under sanitary treatment at a semi-aerobic manageable final disposal site. CH_4 emissions are reduced in comparison with the "Without the activity". 

	[Schematics of GHG emission reduction process]  Waste is open-dumped at an unmanaged final disposal site. CH_4 is emitted into the atmosphere. The system of semi-aerobic final disposal sites is introduced at an unmanageable final disposal site. Or the semi-aerobic final disposal site is introduced at the new site. The structure of semi-aerobic final disposal site establishes the drainage pipe having enough cross-sectional area, in the bottom of the landfill. Landfill leachate is removed immediately to the outside of the final disposal site. By the convection flow occurring by the decomposition heat of waste, fresh air flows into the final disposal site. The inside of final disposal site becomes aerobic. The resolution of the landfill waste is promoted. The landfill leachate from the final disposal site becomes good quality. So, CH_4 emission is restrained. As a result, the CH_4 emissions from the final disposal site are reduced.
Calculation of GHG emission reduction	**[Calculation method]** **<u>GHG emission reductions</u>** GHG emission reductions (ER) through introduction of the Semi-aerobic managed solid waste disposal site are determined using the following equation : $ER = BE_{without} - PE_{with}$ $BE_{without}$: CH_4 emissions from open-dumping at an unmanageable final disposal site PE_{with} : CH_4 emissions from a semi-aerobic manageable final disposal site The GHG emissions of "without the activity" and the GHG emissions of "with the activity" are calculated with the following equation. $BE_{CH4,\,SWDS,\,y} = \varphi \times (1-f) \times GWP_{CH4} y \times (1-OX) \times \frac{16}{12} \times F \times DOC_f$ $\times MCF \times \sum_{x=1}^{y} \sum_{j}^{n} W_{j,x} \times DOC_j \times e^{-k_j (y-x)} \times (1-e^{-k_j})$ $= 0.9 \times (1-f) \times 21 \times (1-OX) \times \frac{16}{12} \times 0.5 \times 0.5$ $\times MCF \times \sum_{x=1}^{y} \sum_{j}^{n} W_{j,x} \times DOC_j \times e^{-k_j (y-x)} \times (1-e^{-k_j})$ Where: φ = Model correction factor to account for model uncertainties (0.9) Source ; “Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site f = Fraction of methane captured as the SWDS and flared,

combusted or used in another manner

F = Fraction of methane in the SWDS gas (volume fraction) (0.5) Source; “Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site”, Page 4 and 2006 IPCC Guideline for National Greenhouse Gas Inventories, Volume 5 Waste, TABLE 3.5

DOC_j = Fraction of degradable organic carbon (by weight) in the waste type j (This parameter needs investigation for each project. “2006 IPCC Guideline for National Greenhouse Gas Inventories” has a default value.)

DOC_f = Fraction of degradable organic carbon (DOC) that can decompose (0.5) Source ; “Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site”, Page 4, and 2006 IPCC Guideline for National Greenhouse Gas Inventories, Volume 5 Waste, TABLE 3.5

MCF = Methane correction factor

GWP_{CH4} = Global Warming Potential (GWP) of methane

OX = Oxidation factor (reflecting the amount of methane from SWDS that is oxidized in the soil or other material covering the waste)

Managed covered with CH_4 oxidising material = 0.1

Managed, unmanaged and uncategorized SWDS = 0

$W_{j,\,x}$ = Amount of organic waste type j prevented from disposal in the SWDS in the year x (ton)

k_j = Decay rate for the waste type j

J = Waste type category (index)

x = Year during the crediting period: C runs from the first year of the first crediting period (x=1) to the year y for which avoided emissions are calculated (x=y)

y = Year for which methane emissions are calculated

Source of Estimated Equation : ACM0001” Consolidated baseline and monitoring methodology for landfill gas project activities” and “Tool to determine methane emissions avoided from disposal of waste at a solid waste at a waste disposal site”

Source of the First Order Decay Model : ”2006 IPCC Guideline for National Greenhouse Gas Inventories, Volume 5 Waste”

[Equations]

Without the activity

The amount of GHG emissions of the "Without the activity" is as follows;

$$BE_{without} = 0.9 \times (1 - f) \times 21 \times (1 - OX) \times \frac{16}{12} \times 0.5 \times 0.5$$

$$\times MCF \times \sum_{x=1}^{y} \sum_{j}^{n} W_{j,x} \times DOC_j \times e^{-k_j(y-x)} \times \left(1 - e^{-k_j}\right)$$

MCF (Unmanaged – deep (>5m waste); default value: 0.8 (Refer to Table 2-3)), $W_{j,\,x}$, DOC_j and OX are set in "Without the activity" appropriately.

With the activity

The amount of GHG emissions of the "With the activity" is as follows;

$$PE_{with} = 0.9 \times (1 - f) \times 21 \times (1 - OX) \times \frac{16}{12} \times 0.5 \times 0.5$$
$$\times MCF \times \sum_{x=1}^{y} \sum_{j}^{n} W_{j,x} \times DOC_j \times e^{-k_j(y-x)} \times \left(1 - e^{-k_j}\right)$$

MCF (Managed – semi-aerobic; default value: 0.5 (Refer to Table 2-3)), $W_{j,\ x}$, DOC_j and OX are set in With the activity appropriately.

GHG emission reductions

GHG emission reductions (ER) due to introduction of the Semi-aerobic managed solid waste disposal site are determined using the following equation :

$ER = BE_{without} - PE_{with}$

Required data and data source

(1) Data requiring field investigation

Data obtained through field investigation or reports are as indicated in Table 1. Population, employee numbers in commerce and institutions, seating capacity of restaurants and the number of markets are parameters contributing directly to the amount of solid waste generated.

Table 1 Data, source of data and data acquisition method

Data	Source of data	Data acquisition method
$W_{j,\ x}$ (Amount of organic waste type j prevented from disposal in the SWDS in the year x (ton))	Physical composition of waste and waste amount of the investigation	Final report of project
f (Fraction of methane captured at the SWDS)	Designing specification of the facilities or by the field investigation	Final report of project (Fraction of methane captured as the SWDS at the final disposal site and flared, combusted or used in another manner)
Population	The statistics	Field investigation or on the web.
Employee number in commerce and institutions		
Seating capacity of restaurants		
The number of markets		

(2) Parameters to be selected from the existing parameters

For the parameters specified in “the methodological tools of CDM methodology” or “2006 IPCC Guideline for National Greenhouse Gas Inventories”, DOC_j, MCF, OX and k_j are to be selected according to the conditions of the target area.

Table 2 Parameters to choose among existing default values

<table>
<tr><th>Parameter</th><th>Table of default values and sources</th></tr>
<tr><td>DOC_j</td><td>
Default values of DOC_j and source of DOC_j are Table 2-1 and Table 2-2.

Table 2-1 Default values of DOC_j (part1)

<table>
<tr><th>Waste type j</th><th>DOCj content in % of wet weight</th><th>DOCj content in % of dry weight</th></tr>
<tr><td>Wood and wood products</td><td>43</td><td>50</td></tr>
<tr><td>Pulp, paper and cardboard (other than sludge)</td><td>40</td><td>44</td></tr>
<tr><td>Food, food waste, beverages and tobacco (other than sludge)</td><td>15</td><td>38</td></tr>
<tr><td>Textiles</td><td>24</td><td>30</td></tr>
<tr><td>Garden, yard and park waste</td><td>20</td><td>49</td></tr>
<tr><td>Glass, plastic, metal and other inert waste</td><td>0</td><td>0</td></tr>
</table>

“Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site”, Page 5

Table 2-2 Default values of DOC_j (part2)

<table>
<tr><th>Waste type j</th><th>DOCj content in % of wet weight</th><th>DOCj content in % of dry weight</th></tr>
<tr><td>Paper / cardboard</td><td>40</td><td>44</td></tr>
<tr><td>Textiles</td><td>24</td><td>30</td></tr>
<tr><td>Food waste</td><td>15</td><td>38</td></tr>
<tr><td>Wood</td><td>43</td><td>50</td></tr>
<tr><td>Garden and Park waste</td><td>20</td><td>49</td></tr>
<tr><td>Nappies</td><td>24</td><td>60</td></tr>
<tr><td>Fibre and Leather</td><td>(39)</td><td>(47)</td></tr>
<tr><td>Plastics, Metal ,Glass, and Other, inert waste</td><td>-</td><td>-</td></tr>
</table>

Source: 2006 IPCC Guideline for National Greenhouse Gas Inventories, Volume 5 Waste, TABLE 2.4
</td></tr>
<tr><td>MCF</td><td>
Default values of MCF and source of MCF are shown in Table 2-3 and Table 2-4.

Table 2-3 Default values of MCF (part1)

<table>
<tr><td>MCF=1.0</td><td>Anaerobic managed solid waste disposal sites</td></tr>
<tr><td>MCF=0.5</td><td>Semi-aerobic managed solid waste disposal sites</td></tr>
<tr><td>MCF=0.8</td><td>Unmanaged solid waste disposal sites – deep and/or with high water table</td></tr>
<tr><td>MCF=0.4</td><td>Unmanaged-shallow solid waste disposal sites</td></tr>
</table>

Source : “Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site
</td></tr>
</table>

Table 2-4 Default values of MCF (part2)

Type of Site	MCF Default values
Managed – anaerobic	1.0
Managed – semi-aerobic	0.5
Unmanaged – deep (>5m waste) and/or high waste table	0.8
Unmanaged – shallow (<5m waste)	0.4
Uncategorized SWDS	0.6

Source : 2006 IPCC Guideline for National Greenhouse Gas Inventories, Volume 5 Waste, TABLE 3.1

OX

Default values of Ox and source of MCF is Table 2-5.

Table2-5 Default value of OX

Type of Site	Oxidation Factor (OX) Default Values
Managed, unmanaged and uncategorized SWDS	0
Managed covered with CH_4 oxidising material	0.1

Source : 2006 IPCC Guideline for National Greenhouse Gas Inventories, Volume 5 Waste, TABLE 3.2

k_j

Default values of k_j and source of k_j are Table 2-6 and Table 2-7.

Table 2-6 Default value of k_j (part1)

Waste type j		Boreal and Temperate (MAT ≦20℃)		Tropical (MAT > 20℃)	
		Dry (MAP/PET < 1)	Wet (MAP/PET < 1)	Dry (MAP < 1000 mm)	Wet (MAP ≧ 1000 mm)
Slowly degrading	Pulp, paper, cardboard (other than sludge), textiles	0.04	0.06	0.045	0.07
	Wood, wood products and straw	0.02	0.03	0.025	0.035
Moderately degrading	Other (non-food) organic putrescible garden and park waste	0.05	0.1	0.065	0.17
Rapidly degrading	Food, food waste, sewage sludge, beverages and tocacoo	0.06	0.185	0.085	0.4

Note : MAT--- Mean annual temperature
MAP--- Mean annual precipitation
PET--- Potential evapotranspiration
MAP/PET is the ratio of MAT to PET.

Source : “Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site

Table 2-7 Default value of k_j (part2)

Waste type j		Boreal and Temperate (MAT ≦20℃)		Tropical (MAT > 20℃)	
		Dry (MAP/PET < 1)	Wet (MAP/PET < 1)	Dry (MAP < 1000 mm)	Wet (MAP ≧ 1000 mm)
Slowly degrading	Paper, / textiles waste	0.04	0.06	0.045	0.07
	Wood / straw waste	0.02	0.03	0.025	0.035
Moderately degrading	Other (non-food) organic putrescible / garden and park waste	0.05	0.1	0.065	0.17
Rapidly degrading	Food waste / Sewage sludge	0.06	0.185	0.085	0.4
Bulk Waste		0.05	0.09	0.065	0.17

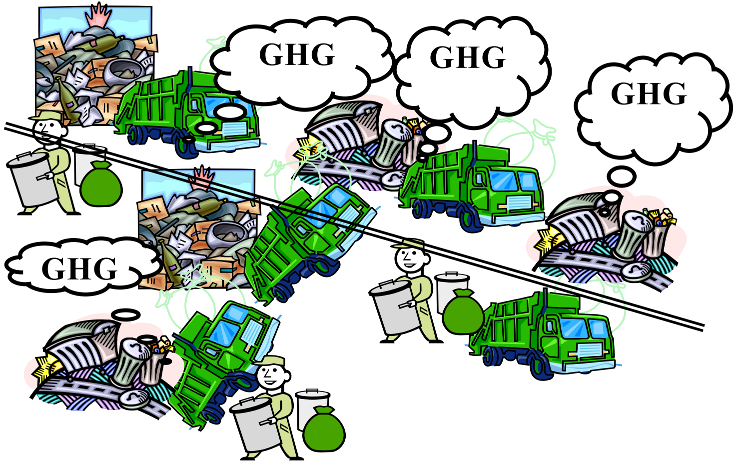
Note : MAT--- Mean annual temperature
MAP--- Mean annual precipitation
PET--- Potential evapotranspiration
MAP/PET is the ratio of MAT to PET.

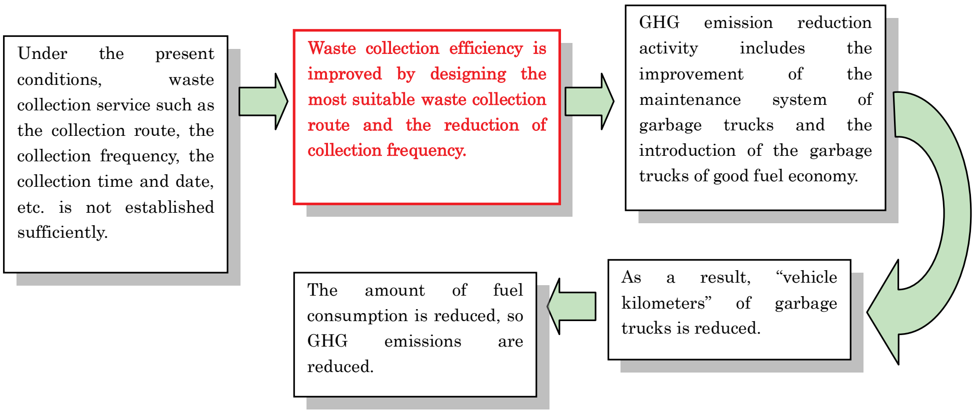
2006 IPCC Guideline for National Greenhouse Gas Inventories, Volume 5 Waste, TABLE 3.3

Preconditions	The amounts of CH_4 emissions are calculated with the First Order Model (FOD model).
Special notes	If the disposal site for "Without the activity" is not regarded as "Unmanaged – deep (>5m waste) and/or high waste table", the MCF (CH_4 correction factor) becomes less than 0.5 and no GHG reduction effect could be expected.

Quantification Sheet

Activity: Solid Waste Management (Improving collection efficiency)

Sector	Environmental Management
Sub-sector	Solid Waste Management (Expanding and improving collection service)
GHG emission reduction activity	Waste collection efficiency is improved by the reviewing of collection routes, the reduction of the collection frequency, etc. As a result, the fuel consumption of garbage trucks is reduced. As a result of improving the maintenance system of garbage trucks, etc., the fuel economy of garbage trucks is improved. Since waste collection efficiency is improved by introduction or improvement of volume reduction, waste collection service is improved. As a result, the fuel consumption of the garbage trucks is improved.
GHG emission reduction impact	1: Activity will lead to GHG emission reduction 2: Activity will lead to GHG emission reduction subject to condition(s) 3: Activity will not lead to GHG emission reduction
GHG emission reduction scenarios (description of how GHG is reduced)	**<Without the activity>** In the situation that the waste collection efficiency is low, large amounts of GHG from garbage trucks are emitted.  **<With the activity>** In the situation that the waste collection efficiency is high, vehicle kilometres of garbage trucks which are necessary for transportation per the unit waste amount are reduced, and GHG emissions are reduced. 

	[Schematics of GHG emission reduction process]  Under the present conditions, waste collection service such as the collection route, the collection frequency, the collection time and date, etc. is not established sufficiently. Waste collection efficiency is improved by designing the most suitable waste collection route and the reduction of collection frequency. GHG emission reduction activity includes the improvement of the maintenance system of garbage trucks and the introduction of the garbage trucks of good fuel economy. As a result, "vehicle kilometers" of garbage trucks is reduced. The amount of fuel consumption is reduced, so GHG emissions are reduced.
Calculation of GHG emission reduction	**[Calculation method]** The vehicle kilometres of the garbage trucks will be reduced for the same amounts of waste collection with the "With the activity" in comparison with the "Without the activity". In other words, the vehicle kilometres of garbage trucks which are necessary for transportation per the unit waste amount are reduced, so GHG emissions are reduced. In the sector of the solid waste management (improving collection efficiency), garbage trucks are the targets. It is assumed that the fuel classes are gasoline, diesel and LPG. It is assumed that the road types are not distinguished. Source of Equations: use the same equations as for improvement of road networks in the transportation traffic sector (national level). Refer to ***Annex 3***. **[Equations]** **Without the activity** The amount of GHG emissions of "Without the activity" is as follows; $BE_{without}$ = Vehicle kilometres of garbage trucks which are necessary for transportation per unit waste amount ×waste amounts × fuel efficiency × EF_{FF} (= the amount of fossil fuel consumption of garbage trucks × EF_{FF}) EF_{FF} = Is the CO_2 emission factor of fossil fuel ($kgCO_2/kJ$) **With the activity** The amount of GHG emissions of "With the activity" is as follows; PE_{with} = Vehicle kilometres of garbage trucks which are necessary for transportation per unit waste amount ×waste amounts × fuel efficiency × EF_{FF} (= the amount of fossil fuel consumption of garbage trucks × EF_{FF})

<table>
<tr><td></td><td>EF_{FF} = Is the CO_2 emission factor of fossil fuel ($kgCO_2/kJ$)

<u>GHG emission reductions</u>
GHG emission reductions (ER) of improving collection efficiency is the following equation:
$ER = BE_{without} - PE_{with}$</td></tr>
<tr><td>Required data and data source</td><td>(1) Data requiring field investigation
Data obtained through field investigation or reports are as indicated in Table 1. Waste amounts are parameters contributing directly to vehicle kilometres.

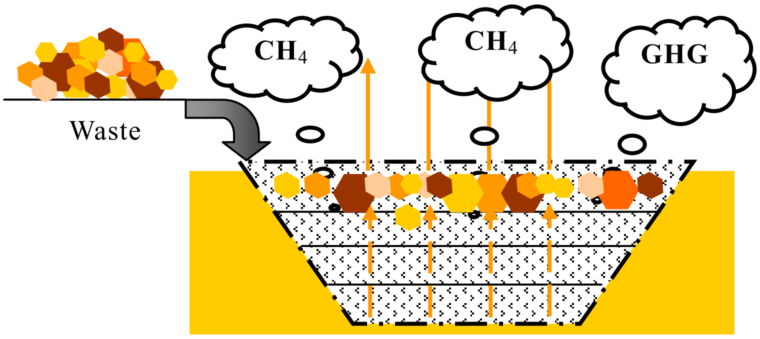
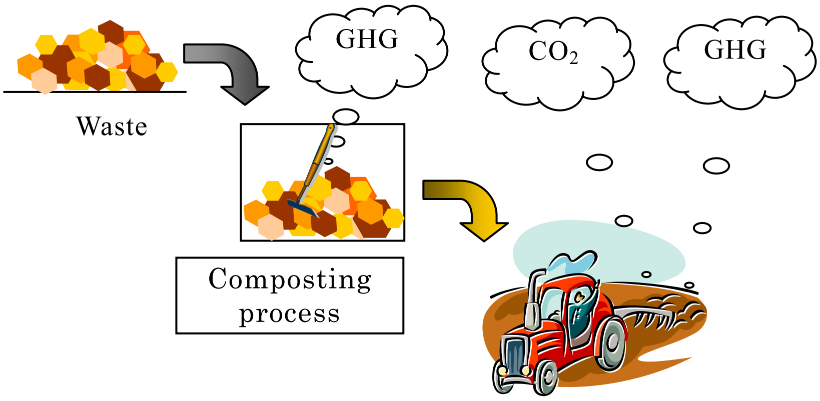
Table 1 Data, source of data and data acquisition method
<table>
<tr><th>Data</th><th>Source of data</th><th>Data acquisition method</th></tr>
<tr><td>Vehicle kilometres</td><td rowspan="5">Designing specification of garbage trucks or field investigation.</td><td rowspan="5">Final report or the values of the existing similar garbage trucks.</td></tr>
<tr><td>Fuel efficiency by fuel type for "without the activity"</td></tr>
<tr><td>Fuel efficiency by fuel type for "with the activity"</td></tr>
<tr><td>The amount of fuel consumption by fuel type for "without the activity"</td></tr>
<tr><td>The amount of fuel consumption by fuel type for "with the activity"</td></tr>
<tr><td>Waste amounts</td><td>Field investigation or statistics of the target country</td><td>Reports about the facility or on the web.</td></tr>
</table>

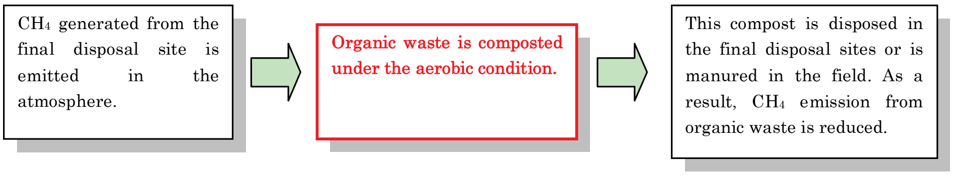
(2) Parameters to be selected from the existing parameters
EF_{FF} : CO_2 emission factor of the fossil fuel consumption ($kgCO_2/kJ$)
Refer to <i>Annex 2</i>.
Fuel efficiency or vehicle kilometres
Refer to <i>Annex 3</i>.</td></tr>
<tr><td>Preconditions</td><td>Amounts of waste collection of “without the activity” and “with the activity” are the same. Therefore, vehicle kilometres of garbage trucks are reduced. In other words, in the case that the area of waste collection expands by implementing the project, it is necessary to estimate GHG emission reductions after setting up another “Without the activity”.
Fuel efficiency is assumed to be unique for each project, but the actual values in Japan are applicable. Especially, fuel efficiency of “without the activity” is preferably a value specific to each project.
If there is an original emission factor for country implementing the project, this emission factor is used preferentially.</td></tr>
<tr><td>Special notes</td><td>In the sector of solid waste management, "vehicle kilometres of garbage trucks" is not practically examined. Therefore the investigation of vehicle kilometres of garbage trucks should be carried out in the future to evaluate GHG emission reduction.</td></tr>
</table>

	There is a case that old garbage trucks with bad fuel economy are replaced with new garbage trucks with good fuel economy without the reduction of the vehicle kilometres of the garbage trucks which are necessary for transportation per the unit waste amount. In this case, GHG emission reductions are calculated by multiplying the CO_2 emission factor by the difference in fuel efficiency between the old garbage trucks and the new garbage trucks.

Quantification Sheet

Activity: Solid Waste Management (Introduction of composting process)

Sector	Environmental Management
Sub-sector	Solid Waste Management (Introducing and Improving Intermediate Treatment)
GHG emission reduction activity	Waste disposed of anaerobically at the final disposal sites in the case of "without the activity" is instead composted in an aerobic condition.
GHG emission reduction impact	[✓ 1: Activity will lead to GHG emission reduction] 2: Activity will lead to GHG emission reduction subject to condition(s) 3: Activity will not lead to GHG emission reduction
GHG emission reduction scenarios (description how GHG is reduced)	**<Without the activity>** CH_4 generated from the final disposal site is emitted into the atmosphere.  **<With the activity>** After waste is composted in an aerobic condition, this compost is disposed in the final disposal sites or is used as fertilizer in the field. As a result, CH_4 emission is reduced. N_2O is emitted in the composting process. Since there is electrical consumption and fossil fuel consumption in the composting process, there are CO_2 emissions. Furthermore, there may be the share of the waste that degrades under anaerobic conditions in the composting process, so CH_4 may be emitted. 

	[Schematics of GHG emission reduction process]  CH_4 generated from the final disposal site is emitted in the atmosphere. Organic waste is composted under the aerobic condition. This compost is disposed in the final disposal sites or is manured in the field. As a result, CH_4 emission from organic waste is reduced.
Calculation of GHG emission reduction	**[Calculation method]** The wastes are composted in "With the activity". On the other hand, in "Without the activity", these wastes are accumulated at the final disposal site, and CH_4 are emitted. In the case of "With the activity", N_2O emissions from the composting process and GHG emissions from electrical consumption and fossil fuel consumption are assumed. Source of Equations: AM0025 "Avoided emissions from organic waste thorough alternative waste treatment processes" **[Equations]** **Without the activity** $BE_{without} = (MB_y - MD_{reg,\,y}) \times GWP_{CH4} + BE_{EN,\,y}$ equation (1) Where : MB_y = Is the methane produced in the landfill in the absence of "With the activity" in year y (tCO_2) (Using the internal amount of composting in "With the activity", the emissions of CH_4 are calculated with the quantification technique sheet for waste management (final disposal site).) $MD_{reg,\,y}$ = Is methane that would be destroyed in the absence of the activity of "With the activity" in year y (tCO_2) GWP_{CH4} = Is the Global Warming Potential (GWP) of methane (tCO_2/tCH_4) $BE_{EN,\,y}$ = "Without the activity" emissions from generation of energy displaced by the activity of "With the activity" in year y (tCO_2) **With the activity** $PE_{with} = PE_{c,\,N2O,\,y} + PE_{c,\,CH4,\,y}$ + the electricity consumption during the composting process × the CO_2 emission factor for electricity generation + the fossil fuel consumption during the composting process × the CO_2 emission factor of the fuel

$$= M_{compost,\,y} \times EF_{c,\,N2O} \times GWP_{N2O} + MB_{compost,\,y} \times GWP_{CH4} \times S_{a,\,y}$$

$$+ EC_{EL} \times EF_{EL} + EC_{FC} \times EF_{FF} \qquad \text{equation (2)}$$

Where :

$M_{compost,\,y}$ = Is the total amount of compost produced in year y (tonnes / a)

$EF_{c,\,N2O}$ = Is the emission factor for N_2O emissions from the composting process (= 0.042 kgN_2O/t compost)

GWP_{N2O} = Is the Global Warming Potential (GWP) of nitrous oxide (tCO_2/tN_2O)

$MB_{compost,\,y}$ = Is the quantity of methane that would be produced in the landfill in the absence of the composting activity in year y (tCH_4). $MB_{compost,\,y}$ is estimated by multiplying MB_y estimated from equation (1) by the fraction of waste diverted from the landfill, to the composting activity (f_c) relative to the total waste diverted from the landfill to all activities of "With the activity" (composting, gasification, anaerobic digestion and RDF/stabilized biomass, incineration).

GWP_{CH4} = Is the Global Warming Potential (GWP) of methane (tCO_2/tCH_4)

$S_{a,\,y}$ = Is the share of the waste that degrades under anaerobic conditions in the composting plant during year y (%). (In the case that data are not provided, this term can be deleted.)

EC_{EL} = Is the amount of electricity consumed from the grid as a result of the composting activity (kWh / year)

EF_{EL} = Is the CO_2 emission factor for electricity generation in the year y ($kgCO_2$/kWh)

EC_{FC} = Is the fossil fuel consumption on site in year y (kJ or TOE / year)

EF_{FF} = Is the CO_2 emission factor of the fossil fuel ($kgCO_2$/kJ)

GHG emission reductions

GHG emission reductions (ER) of the composting process are determined using the following equation :

$$ER = BE_{without} - PE_{with} \qquad \text{equation (2)}$$

Required data and data source

(1) Data requiring field investigation

Data obtained through field investigations or reports are as indicated in Table 1. Waste amounts or Population using the sewage treatment facility are parameters which contribute directly to the amount of compost.

Table 1 Data, source of data and data acquisition method

Data	Source of data	Data acquisition method
Amount of compost	The designing specification of the facility	Final report
CH_4 that would be destroyed in the case of "without the activity"	The designing specification of the facility or field investigation	Final report (basically assumed to be zero.)
Amount of electrical consumption		Final report or the values of existing similar facilities
Amount of fuel consumption		
The share of the waste that degrades under anaerobic condition	Field investigation or literature research	Field investigation or literature research
Waste amounts	Field investigation or statistics of the target country	Reports about the facility or on the web.
Population using sewage treatment facility		

(2) Parameters to be selected from the existing parameters

EF_{FF} : CO_2 emission factor of the fossil fuel consumption ($kgCO_2/kJ$)

Refer to ***Annex 2***.

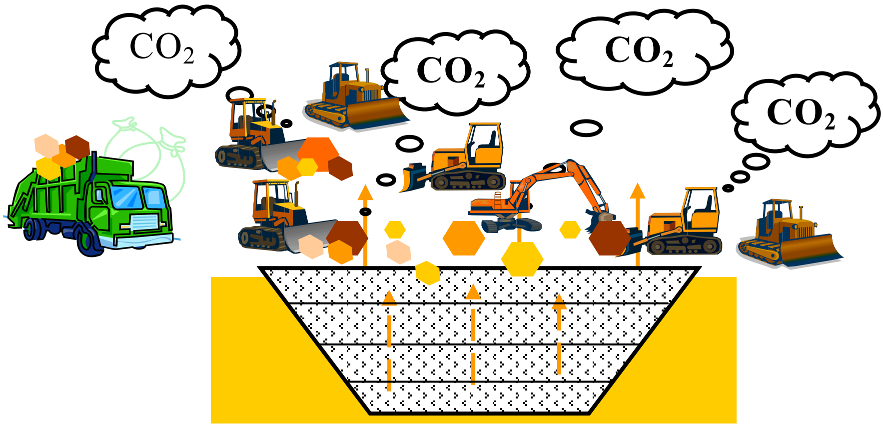
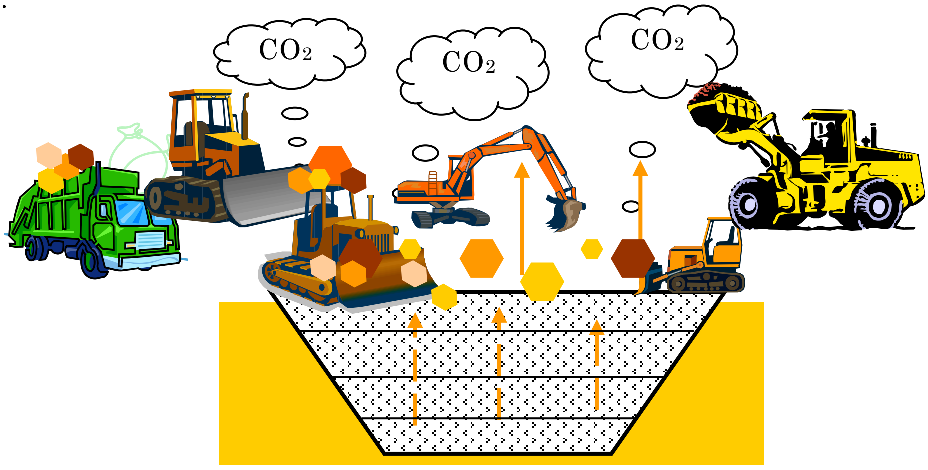
EF_{EL} : CO_2 emission factor for electrical consumption ($kgCO_2/kWh$)

Refer to ***Annex 1***.

Preconditions	The condition of waste "without the activity" is anaerobic in the final disposal sites. Therefore, CH_4 is emitted in these sites.
Special notes	The composting process might produce additional GHG emission reductions by the reduction in the usage of chemical fertilizer, but this is not considered by this study.

Quantification Sheet

Activity: Solid Waste Management (Fuel Consumption Reduction of Heavy-Duty Machines Used in Final Disposal Site)

<table>
<tr><td>Sector</td><td>Environmental Management</td></tr>
<tr><td>Sub-sector</td><td>Solid Waste Management(Improving Final Disposal)</td></tr>
<tr><td>GHG emission reduction activity</td><td>Introduction of heavy-duty machines of good fuel economy for incoming waste, transportation, surface compaction, etc. results in reduction of fuel consumption.
Improvement of operation of final disposal site results in reduction of fuel consumption.</td></tr>
<tr><td>GHG emission reduction impact</td><td>1: Activity will lead to GHG emission reduction
2: Activity will lead to GHG emission reduction subject to condition(s)
3: Activity will not lead to GHG emission reduction</td></tr>
<tr><td>GHG emission reduction scenarios
(description of how GHG is reduced)</td><td><Without the activity>
Operation of disposal sites is carried out using heavy-duty machines of bad fuel economy.

<With the activity>
Operation of disposal sites is carried out using heavy-duty machines of good fuel economy. It is supposed that the small heavy-duty machines are replaced with large heavy-duty machines and that heavy-duty machines of bad fuel economy are replaced with the heavy-duty machines of good fuel economy, etc.
 </td></tr>
</table>

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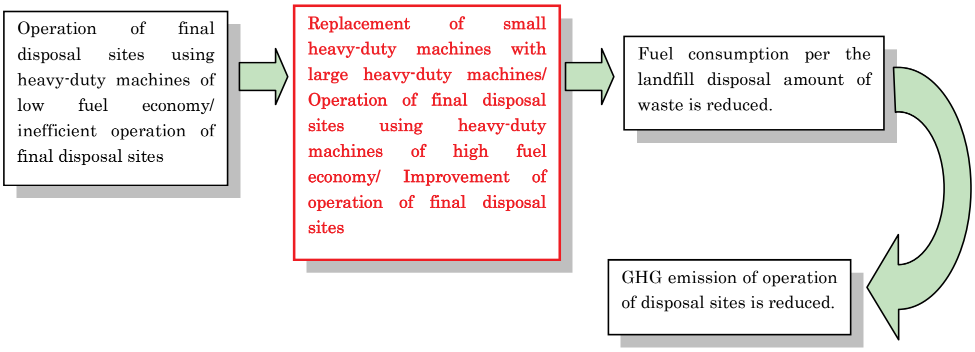
<td>

[Schematics of GHG emission reduction process]



</td>
</tr>
<tr>
<td>Calculation of GHG emission reduction</td>
<td>

[Calculation method]

The fuel consumption of heavy-duty machines will be reduced for same amounts of waste with the “With the activity” in comparison with the “Without the activity”. In other words, the fuel consumption of heavy-duty machines which are necessary for landfill works per the unit waste amount is reduced, so GHG emissions are reduced.

Source of Equations: use the same equations as for the improvement of road networks in the transportation traffic sector (national level).

Refer to ***Annex 3***.

[Equations]

<u>**Without the activity**</u>

$BE_{without}$ = Fuel consumption of heavy-duty machines × CO_2 emission factor

$= EC_{FC} \times EF_{FF}$

EC_{FC} = Fuel consumption of heavy-duty machines of “Without the activity” (kJ or TOE/year)

EF_{FF} = Is the CO_2 emission factor of the fossil fuel (kg- CO_2/kJ)

<u>**With the activity**</u>

PE_{with} = Fuel consumption of heavy-duty machines ×CO_2 emission factor

$= EC_{FC} \times EF_{FF}$

EC_{FC} = Fuel consumption of heavy-duty machines of “With the activity” (kJ or TOE/year)

EF_{FF} = Is the CO_2 emission factor of the fossil fuel (kg- CO_2/kJ)

<u>**GHG emission reductions**</u>

The amount of emission reductions (ER) of “fuel consumption reduction of heavy-duty machines used in final disposal site” is determined using the following equation :

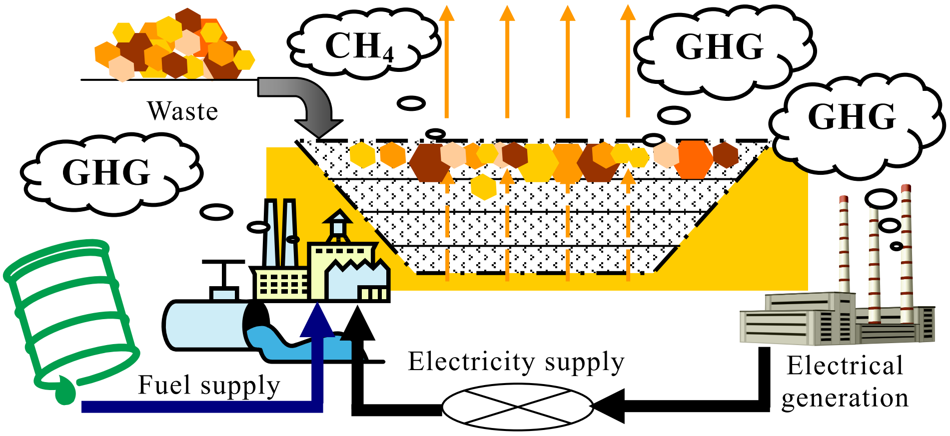
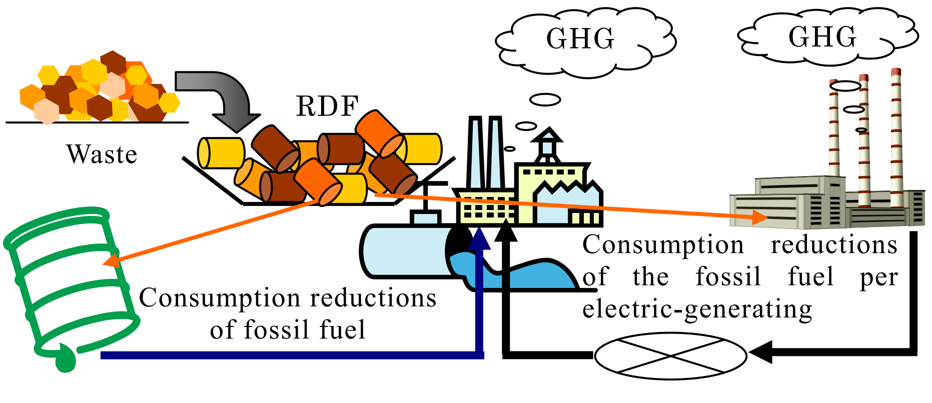
$ER = BE_{without} - PE_{with}$

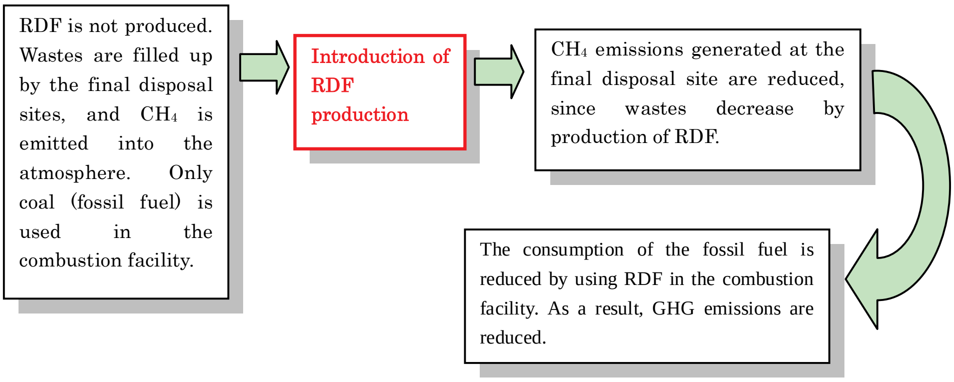
</td>
</tr>
<tr>
<td>Required data and data source</td>
<td>(1) Data requiring field investigation</td>
</tr>
</table>

<table>
<tr>
<td></td>
<td>
<p>Data obtained through field investigations or reports are as indicated in Table 1. Waste amounts are a parameter which contributes directly to the fuel consumption of heavy-duty machines.</p>
<p>Table 1 Data, source of data and data acquisition method</p>
<table>
<tr><th>Data</th><th>Source of data</th><th>Data acquisition method</th></tr>
<tr><td>Vehicle kilometres</td><td rowspan="3">Designing specification of the facilities.</td><td rowspan="3">Final report or the values of existing similar facilities</td></tr>
<tr><td>Fuel efficiency by fuel type, vehicle type, road type;
Fuel efficiency (A),
Fuel efficiency (B),
Fuel efficiency (C)</td></tr>
<tr><td>The amount of fuel consumption for target vehicles;
The amount of fuel consumption (a),
The amount of fuel consumption (b),
The amount of fuel consumption (c)</td></tr>
<tr><td>Amounts of waste</td><td>Field investigation or statistics of the target country</td><td>Reports about the facility or on the web.</td></tr>
</table>
<p>(2) Parameters to be selected from the existing parameters</p>
<p>EF_{FF} : CO_2 emission factor of the fossil fuel consumption ($kg\text{-}CO_2/kJ$)</p>
<p>Refer to <i>Annex 2</i>.</p>
<p>Fuel efficiency or vehicle kilometres</p>
<p>Refer to <i>Annex 3</i>.</p>
</td>
</tr>
<tr>
<td>Preconditions</td>
<td>
<p>Waste amounts of “without the activity” and “with the activity” are the same. In other words it is assumed that (a)/(A) = (b)/(B); where :
(A): fuel efficiency of "Without the activity"
(a): fuel consumption of "Without the activity"
(B): fuel efficiency of "With the activity"
(b): fuel consumption of "With the activity".
In addition, (a) and (b) are original values for each project, but (A) and (B) are preferably values specific to each project.</p>
<p>The GHG emission factors are the default values in the 2006 IPCC Guideline for national greenhouse gas inventories.</p>
</td>
</tr>
<tr>
<td>Special notes</td>
<td>
<p>In the sector of solid waste management, "the fuel consumption of heavy-duty machines" is not practically examined. Therefore investigation of the fuel consumption of heavy-duty machines should be carried out in the future to evaluate the GHG discharge reduction.</p>
</td>
</tr>
</table>

Quantification Sheet

Activity: Solid Waste Management
(Thermal Recycling "RDF" (Production of RDF))

Sector	Environmental Management
Sub-sector	Solid Waste Management (Introducing and Improving Intermediate Treatment)
GHG emission reduction activity	RDF (Refuse Derived Fuel) is produced by recycling paper and plastic waste, etc. This RDF is burned at the existing combustion facilities (power generation plants and/or heating plants) together with coal, etc. Some portion of the coal which is used at these facilities is replaced with RDF. Therefore GHG emission is reduced. In addition, CH_4 emissions generated at the final disposal site are reduced, since wastes decrease by production of RDF.
GHG emission reduction impact	1: Activity will lead to GHG emission reduction 2: Activity will lead to GHG emission reduction subject to condition(s) 3: Activity will not lead to GHG emission reduction
GHG emission reduction scenarios (description of how GHG is reduced)	**<Without the activity>** Wastes are accumulated at the final disposal sites, and CH_4 is emitted into the atmosphere. Only coal (fossil fuel) is used in the combustion facility.  **<With the activity>** The consumption of the fossil fuel is reduced by using RDF in the combustion facility. As a result, GHG emissions are reduced. In addition, CH_4 emissions generated at the final disposal site are reduced, since wastes decrease by production of RDF. 

	[Schematics of GHG emission reduction process]  RDF is not produced. Wastes are filled up by the final disposal sites, and CH_4 is emitted into the atmosphere. Only coal (fossil fuel) is used in the combustion facility. Introduction of RDF production CH_4 emissions generated at the final disposal site are reduced, since wastes decrease by production of RDF. The consumption of the fossil fuel is reduced by using RDF in the combustion facility. As a result, GHG emissions are reduced.
Calculation of GHG emission reduction	**[Calculation method]** In the case of “Without the activity” only coal (fossil fuel) is used in a boiler and fossil fuel and electricity are consumed. In the case of “With the activity” RDF is used for this facility and fossil fuel consumption is reduced. As a result, GHG emissions are reduced. CH_4 emissions generated at the final disposal site are reduced, since wastes decrease by production of RDF. On the other hand, for the use of the electricity or the fuel at the time of the RDF production, GHG emissions increase. Source of Equations: AM0025 ”Avoided emissions from organic waste thorough alternative waste treatment processes” and “Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion” Source of the First Order Decay Model : ”2006 IPCC Guideline for National Greenhouse Gas Inventories, Volume 5 Waste” **[Equations]** **Without the activity** The amounts of GHG emissions are obtained under the situation that coal (fossil fuel) is supplied to the boiler. GHG emissions of "without the activity" are : $BE_{without}$ = CH_4 that wastes equivalent to amounts of RDF production generate in final disposal sites + Energy supply by use of RDF × the CO_2 emission factor of the fossil fuel (coal, etc.) + Electricity supply by use of RDF × the CO_2 emission factor for electricity generation

$$= 0.9 \times (1 - f) \times 21 \times (1 - OX) \times \frac{16}{12} \times 0.5 \times 0.5$$

$$\times MCF \times \sum_{x=1}^{y} \sum_{j}^{n} W_{j,x} \times DOC_{j} \times e^{-k_{j}(y-x)} \times \left(1 - e^{-k_{j}}\right)$$

$$+ EC_{FC} \times EF_{FF} + EC_{EL} \times EF_{EL}$$

Where :

EC_{FC} = Is the fossil fuel consumption of the "without the activity" in year y (kJ or TOE / year)

EF_{FF} = Is the CO_2 emission factor of the fossil fuel (kg- CO_2/kJ)

EC_{EL} = Is the amount of electricity consumed for the RDF use from the grid of without the activity (kWh / year)

EF_{EL} = Is the CO_2 emission factor for electricity generation in the year y (kg- CO_2/kWh)

“CH_4 that wastes equivalent to amounts of RDF production generate in final disposal sites” is calculated by the quantification method of “Solid Waste Management (Introduction of Semi-Aerobic Final Diposal Sites)”.

With the activity

The amounts of GHG emission of combustion of mixed RDF and coal are calculated. Since the RDF includes some fossil fuel ingredients, the CO_2 emissions of these ingredients must be calculated.

GHG emission of "with the activity" is :

PE_{with} = Energy supply by use of RDF × Ratio of fossil fuel content in the RDF × CO_2 emission factor of the fossil fuel (Amounts of GHG emissions of fossil fuel origin among energy supplied by RDF)

\+ Electricity supply by use of RDF × Waste ratio of the fossil fuel origin × CO_2 emission factor for electricity generation (Amounts of GHG emissions of fossil fuel origin among electricity supplied by RDF)

\+ The amount of electrical consumed in the production of RDF × CO_2 emission factor for electricity generation

\+ The amount of fossil fuel consumed in the production of RDF × CO_2 emission factor of the fossil fuel

$= QEC_{FC} \times (1 - \beta) \times QEF_{FF}$

$+ QEC_{EL} \times (1 - \beta) \times QEF_{EL}$

$+ EC_{EL} \times EF_{EL}$

$+ EC_{FC} \times EF_{FF}$

Where :

$Q_{RDF,\,y}$ = It is assumed that the amount of RDF used is equal to the amount of RDF produced.

β = Carbon-free ratio (Ratio of fossil fuel content in the RDF) (%)

1 - β = Ratio of fossil fuel content in the RDF (%)

QEC_{EL} = Electricity supply by use of RDF (kWh/year)

QEF_{EL} = The CO_2 emission factor for electricity generation in the year y (kg- CO_2/kWh)

QEC_{FC} = Energy supply by use of RDF (kJ or TOE/year)
= $Q_{RDF,\,y} \times CEF_{FF}$

CEF_{FF} = Net Calorific Values of RDF (TJ/Gg)

QEF_{FF} = CO_2 emission factor of the fossil fuel (kgCO_2/kJ)

EC_{FC} = Fossil fuel consumption in the production of RDF in year y (kJ or TOE / year)

EF_{FF} = CO_2 emission factor of the fossil fuel (kgCO_2/kJ)

EC_{EL} = The amount of electrical consumption used in the production of RDF (kWh / year)

EF_{EL} = CO_2 emission factor for electricity generation in the year y (kgCO_2/kWh)

GHG emission reductions

GHG emission reductions (ER) due to the production of RDF are determined using the following equation :

$ER = BE_{without} - PE_{with}$

Required data and data source

(1) Data requiring field investigation

Data obtained through field investigations or reports are as indicated in Table 1. Waste amounts are a parameter which contributes directly to the amount of production of RDF.

Table 1 Data, source of data and data acquisition method

Data	Source of data	Data acquisition method
Amount of production of RDF	Designing specification of the facilities	Final report
Net calorific value and carbon content of each waste	Waste quality survey of final report	Final report (If there are no data, method (2) is employed.)
Fossil fuel consumption and electrical consumption used in the production of RDF	Field investigation or designing specification of the facilities.	Final report or the values of the existing similar facilities
Waste amounts	Field investigation or statistics of the target country	Reports about the facilitator on the web

	(2) Parameters to be selected from the existing parameters EF_{FF} : CO_2 emission factor of the fossil fuel consumption (kgO_2/kJ) Refer to ***Annex 2***. EF_{EL} : the CO_2 emission factor for electrical consumption ($kgCO_2/kWh$) Refer to ***Annex 1***. NCV_{FF} : Net calorific values of fuel FF (kJ/mass or volume) Refer to ***Annex 4***. CC_{FF} : Carbon content (kg/GJ) Refer to ***Annex 2***.
Preconditions	Only a project for the production of RDF can be applied.
Special notes	It is assumed that there are few JICA projects involving the production of the RDF. Net calorific value and carbon content of each waste are necessary to calculate the “carbon-free ratio” (β %). It is assumed that a lot of plastic wastes are included in solid wastes. Therefore, since the plastic waste is not "carbon-free", the production of RDF using waste with a high plastic content adversely affects the GHG reduction effect.
Calculation example	Amount of GHG emission reductions due to the production of RDF is calculated in “The Study on Solid Waste Management Plan for Ulaanbaatar City in Mongolia”. Municipal Solid Waste (MSW) in Ulaanbaatar City (UBC) contains a large portion of plastic and paper wastes. Especially in apartment areas established according to the city development plan the portion of plastic and paper wastes such as PET bottles and cardboard paper are recycled and the remaining large portion is taken to disposal sites. These wastes cause many problems in the landfill operation such as waste scattering and creation of unstable land due to difficulty of decomposition and compaction. In order to solve the above-mentioned problems, paper and plastic waste, which are not recycled at present, will be collected and RDF will be produced by using these wastes as raw materials. Produced RDF will be burned at the existing high temperature continuous combustion facilities (power generation plants and heating plants) together with coal and necessary data will be obtained. The RDF in this study is generated from general solid waste. The CO_2 produced by the combustion of the organic matter to be included in general waste does not have to be counted. This is tentatively called "carbon-free". An example of the "carbon-free" waste is shown in Table 2.

Table 2 Classification examples of “carbon-free” solid waste

Classification	Example of waste	Survey item
Carbon-free solid waste	Food, paper, natural fabric, wood, sludge, livestock excreta, etc.	Net calorific value of each waste Carbon content of each waste
Waste types of the calculation object of CO_2 emissions	Plastic, synthesized fibre, etc.	Net calorific value of each waste Carbon content of each waste

Then, paper wastes become “carbon-free”. So, the forecast on composition of MSW (table 3) of the final report it assumes a ratio of plastic wastes and paper wastes in the RDF as shown in table 4.

Table 3 Forecast on composition of MSW

Waste Composition of MSW	2005 Winter (%)	2005 Summer (%)
Kitchen Waste	12.6	33.8
Paper	5.2	18.9
Textile	2.0	4.8
Grass and Wood	0.5	4.8
Plastic	7.8	15.2
Leather and Rubber	0.2	0.6
Combustibles	**28.3**	**78.1**
Metal	1.5	3.5
Bottles and Glass	5.4	10.5
Ceramic and Stone	1.9	6.8
Miscellaneous	2.7	1.1
Non-Combustibles excluding ash	**11.5**	**21.9**
Other Weight (%)	39.8	100.0
Ash Weight (%)	60.2	0.0
Total	**100.0**	**100.0**

Source: Table 5-22 and Table 5-23 on page 5-12 of Main Report

Table 4 Ratio of plastic wastes and paper wastes in the RDF

	2005 Winter (%)	Ratio	2005 Summer (%)	Ratio
Paper	5.2	40%	18.9	55%
Plastic	7.8	60%	15.2	45%

RDF was produced by melting plastics by applying heat from the outside. The combustion test of RDF mixed with coal was conducted twice, February and October 2006. Prior to the test 12 tons of RDF was produced between December 2005 and January 2006, and 24 tons of RDF was produced between August 2006 and September 2006.

The table below presents the quality of RDF and Coal which was used for the combustion test.

Table 5 Quality of RDF and Coal

			RDF		Coal	
Physical composition			1st test	2nd test	1st test	2nd test
Higher calorific value (HCV)		(kcal/kg)	5,820	3,320^{*1}	3,875	4,700^{*1}
Lower calorific value (LCV)		(kcal/kg)	5,290^{*1}	3,200	2,470^{*1}	3,680
Industrial chemical analysis	Moisture	(%)	8.3	0.9	31.3	19.2
	Combustible	(%)	86,0	74.9	59.9	61.2
	Non combustible (ash)	(%)	5,7	24.2	8.8	19.6
Apparent density			0.41	0.43	0.86	0.87

Source: Table 9-6 on page 9-12 of Main Report
Note:*1 is calculation value.
Apparent density was measured by the Study team.

The table presents the following findings:

1. The lower calorific value of RDF produced for the 1st test is more than two times higher than the coal used. It is the quality which is expected.
2. The lower calorific value of RDF produced for the 2nd test is only 60% of that of the 1st test due to burning of the plastic during the production process.
3. On the other hand, the lower calorific value of coal used for the 2nd test was 1.5 times higher than that of the 1st test.

At first, "CH_4 that wastes equivalent to amounts of RDF production generate in final disposal sites" is calculated. Here, it is assumed that the year 2007 is the calculation target year. The calculation target is the plastic wastes and paper wastes used to produce 12 tons of RDF in the winter and 24 tons of RDF in the summer.

Table 6 CH_4 emission from the disposal site of waste becoming RDF

y	x				Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
		Final		Waste Composition	①	②				③		④	
2007	2007	12	Woods, etc.	0.000	0.00	0.43	0	0.020	0.000	1.000000	0.980199	0.019801	0.00
2007	2007	12	Paper, etc.	0.400	4.80	0.40	0	0.040	0.000	1.000000	0.960789	0.039211	0.08
2007	2007	12	Food, etc.	0.000	0.00	0.15	0	0.060	0.000	1.000000	0.941765	0.058235	0.00
2007	2007	12	Textiles	0.000	0.00	0.24	0	0.040	0.000	1.000000	0.960789	0.039211	0.00
2007	2007	12	Garden, etc.	0.000	0.00	0.20	0	0.050	0.000	1.000000	0.951229	0.048771	0.00
2007	2007	12	Inert waste, etc.	0.600	7.20	0.00	0	0.000	0.000	1.000000	1	0	0.00
y	x	Final		Waste Composition	Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
2007	2007	24	Woods, etc.	0.000	0.00	0.43	0	0.020	0.000	1.000000	0.980199	0.019801	0.00
2007	2007	24	Paper, etc.	0.550	13.20	0.40	0	0.040	0.000	1.000000	0.960789	0.039211	0.21
2007	2007	24	Food, etc.	0.000	0.00	0.15	0	0.060	0.000	1.000000	0.941765	0.058235	0.00
2007	2007	24	Textiles	0.000	0.00	0.24	0	0.040	0.000	1.000000	0.960789	0.039211	0.00
2007	2007	24	Garden, etc.	0.000	0.00	0.20	0	0.050	0.000	1.000000	0.951229	0.048771	0.00
2007	2007	24	Inert waste, etc.	0.450	10.80	0.00	0	0.000	0.000	1.000000	1	0	0.00
												Σ	0.28

φ	f	1-f	GWP	OX	1-OX	16/12	F	DOCf	MCF	⑤⑥⑦⑧⑨⑩⑪⑫	
⑤		⑥	⑦		⑧	⑨	⑩	⑪	⑫		
0.9	0	1	21	0.00	1	1.333333	0.5	0.5	0.8	5.04	
	No captured CH4			Unmanaged					Unmanaged - deep > 5m waste		
								Without the activity		CH4（kgCOe	1,423

As a result, GHG emissions are 1,423($kgCO_2$/2weeks). Since these values are emissions from the amounts of waste produced in two weeks, the estimation values **35.6(tCO_2/year)** are provided by multiplying these values by 25. These values are the CH_4 emission reductions from the final disposal site.

Next, in the case that produced RDF will be burned at the existing high temperature continuous combustion facilities together with coal, CO_2 emission reductions are calculated as follows.

Preconditions are that "the calorific value of the combustion of the RDF” is equal to “the calorific value of the combustion of the coal". On the other hand, the "carbon-free" emissions are included in CO_2 emissions of the RDF. In addition, plastic waste is included in the RDF. Since the plastic generally has a smaller CO_2 emission factor than the coal, there is a GHG emission reduction effect. These amounts become the GHG emission reductions.

As above, the GHG emissions of "Without the activity" and the GHG emissions of "With the activity" are calculated. And these differences are the GHG emission reductions.

For calculation of emissions, amounts of activities, net calorific value and emission factors are necessary. The amounts of activities are amounts of RDF production and coal consumption. The net calorific values use the values of the final report. These data are arranged as in Table 7 on the basis of CO_2 emission factors.

Table 7 The activities and emission factor of 1st test

1st test	Amount of RDF produced Amount of coal consumed	Net calorific value	CO_2 emission factor
RDF	12 ton	5,290(kcal/kg)	
Coal	X ton	2,470(kcal/kg)	107,000(kg/TJ)

Amount of coal consumed: X = 5,290×12/2,470 ≅ 25.7(ton)

Amount of GHG emission reduction = 25.7(t) × 1,000(kg/t) × 2,470(kcal/kg) × 4.19(J/cal) × 10^{-9}(TJ/kJ) × 107,000(kg/TJ) = 28,460($kgCO_2$) ≅ 28(tCO_2/week)

Since the β % (“carbon-free ratio”) is 40% of table 4, 60% of 28 (tCO_2/ week) are GHG emission reductions. As a result, GHG emission reductions are 16.8 (tCO_2/ week).

From the amounts of GHG emission reductions in one week, the half year (winter season) reductions can be estimated. The half year should be 25 times as large as these of one week. Therefore 420(tCO_2/year) becomes the estimated amount of GHG emission reductions for a half year (winter season).

Data of 2nd test are shown in Table 8.

Table 8 The activities and emission factor of 2nd test

2nd test	Amount of RDF produced Amount of coal consumed	Net calorific value	CO_2 emission factor
RDF	24 ton	3,200(kcal/kg)	
Coal	X ton	3,680(kcal/kg)	107,000(kg/TJ)

Amount of consumption of coal: X = 3,200×24/3,680 ≅ 20.9(ton)

Amount of GHG emission reductions = 20.9(t) × 1,000(kg/t) × 3,680(kcal/kg) × 4.19(J/cal) × 10^{-9}(TJ/kJ) × 107,000(kg/TJ) = 34,432 (kgCO_2) ≅ 34 (tCO_2/week)

Since the β % ("carbon-free ratio") is 55% of table 4, 45% of 34 (tCO_2/ week) are the GHG emission reductions. As a result, GHG emission reductions are 15.3 (tCO_2/ week).

From the amounts of GHG emission reductions of one week, the reductions for a half year (summer season) can be estimated. A half year should be 25 times as large as these of one week. Therefore 383(tCO_2/year) becomes the estimated amount of GHG emission reductions for a half year (summer season).

Therefore, the GHG emission reductions of combustion of mixed RDF and coal are 420 (tCO_2/year) + 383 (tCO_2/year) = **803 (tonCO_2/year).**

As a result of above the process, the GHG emission reductions due to the production of RDF are estimated to be **35.6 (tonCO_2/year) + 803 (tCO_2/year) ≅ 840(tonCO_2/year).**

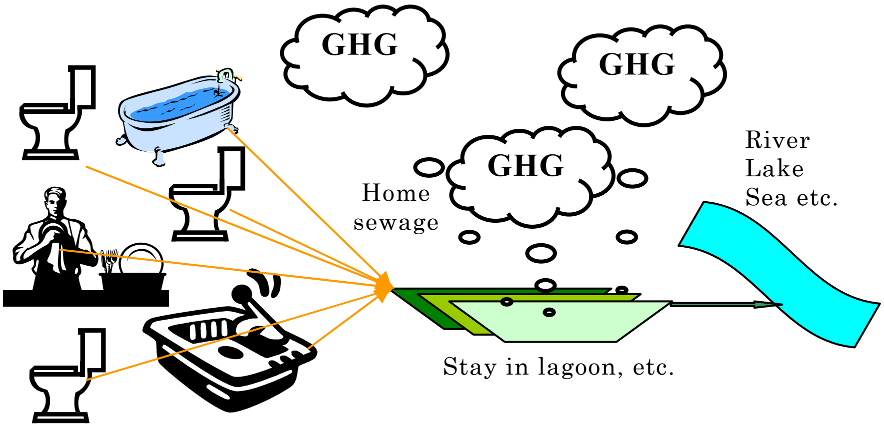
It should be noted that GHG emission increases due to effects such as the consumption of electricity or fossil fuel used in the production of RDF are not calculated. Therefore, it is assumed that actual GHG emission reductions are somewhat less than the calculated value.

Quantification Sheet

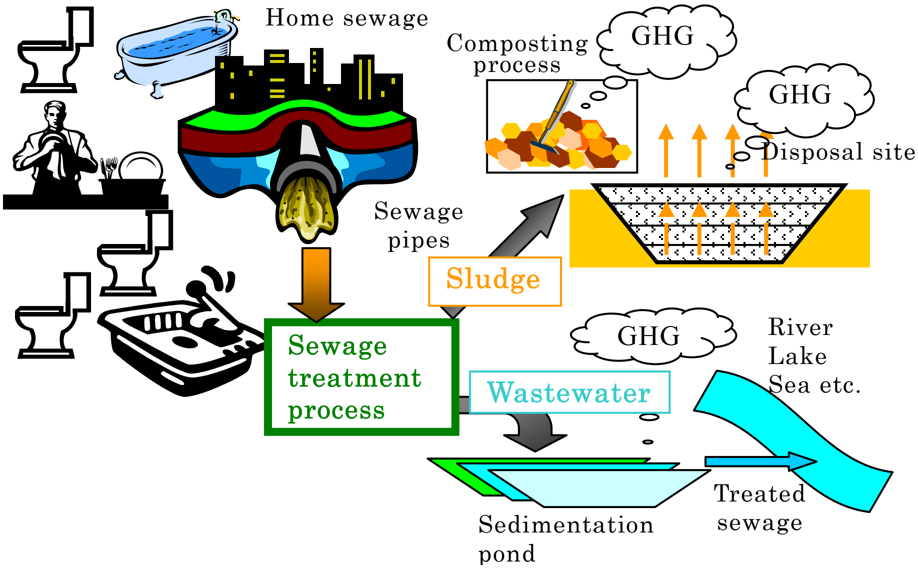
Activity: Water Pollution Control (Introduction of Sewage Treatment Facilities)

<table>
<tr><td>Sector</td><td>Environmental Management</td></tr>
<tr><td>Sub-sector</td><td>Water Pollution Control (Measures regarding Domestic Wastewater)</td></tr>
<tr><td>GHG emission reduction activity</td><td>Home sewage (night soil and miscellaneous drainage) is treated in a sanitary manner by the introduction of sewage treatment facilities.</td></tr>
<tr><td>GHG emission reduction impact</td><td>1: Activity will lead to GHG emission reduction
2: Activity will lead to GHG emission reduction subject to condition(s)
3: Activity will not lead to GHG emission reduction</td></tr>
<tr><td>GHG emission reduction scenarios
(description of how GHG is reduced)</td><td>

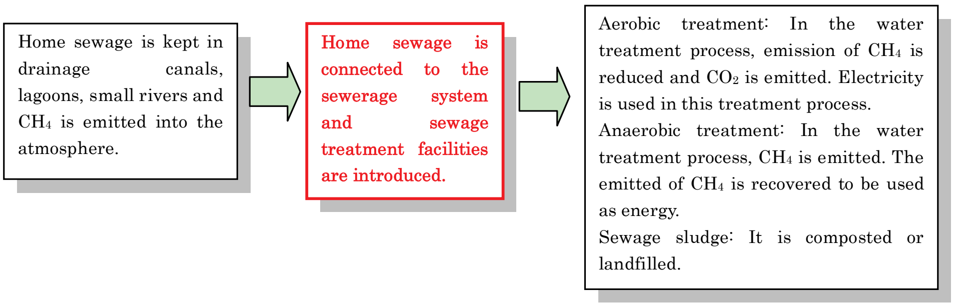
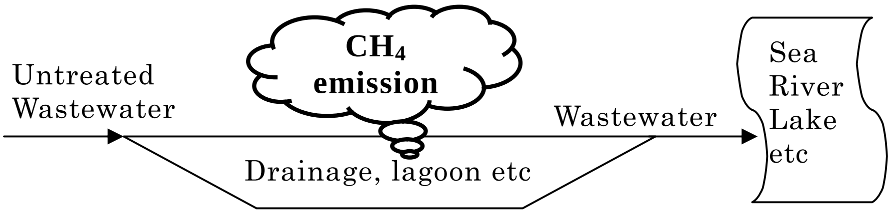
<Without the activity>
There is the situation that home sewage is discharged untreated and is retained or detained in a lagoon, etc.



<With the activity>
There is the situation that home sewage is transported to a sewage treatment site through sewage pipes and treated at the sewage treatment facilities.



</td></tr>
</table>

	[Schematics of GHG emission reduction process]  Home sewage is kept in drainage canals, lagoons, small rivers and CH_4 is emitted into the atmosphere. Home sewage is connected to the sewerage system and sewage treatment facilities are introduced. Aerobic treatment: In the water treatment process, emission of CH_4 is reduced and CO_2 is emitted. Electricity is used in this treatment process. Anaerobic treatment: In the water treatment process, CH_4 is emitted. The emitted of CH_4 is recovered to be used as energy. Sewage sludge: It is composted or landfilled.
Calculation of GHG emission reduction	**[Calculation method]** GHG are emitted from the wastewater treatment process (aerobic process, anaerobic process) and sludge disposal process. In addition, there are GHG emissions due to electricity consumption and fuel consumption. Source of Equations: AMS-III.I “Avoidance of methane production in wastewater treatment through replacement of anaerobic lagoons by aerobic systems”, ACM0014 “Avoided methane emissions from wastewater treatment” and AM0025 ”Avoided emissions from organic waste thorough alternative waste treatment processes” **[Equations]** **Without the activity** There is the situation that home sewage is discharged untreated into the system.  $BE_{without}$ = Emissions of “Without the activity” from electrical consumption in year y ($BE_{elec, y}$) + Emissions of “Without the activity” from fossil fuel consumption in year y ($BE_{fuel, on\text{-}site, y}$) + Emissions of “Without the activity” from treatment of wastewater in year y ($BE_{CH4, w, y}$) In the JICA project for sewerage system development, it is assumed that there is no electrical consumption or fuel consumption associated with "Without the activity". Then this equation becomes $BE_{without}$ = $BE_{CH4, w, y}$.

<Treatment of the wastewater>

$BE_{without} = BE_{CH4,\ w,\ y} = Q_{BOD,\ y} \times P_{BOD,\ y} \times B_0 \times MCF_p$

Where :

$Q_{BOD,\ y}$ = Amount of wastewater (m^3/year)

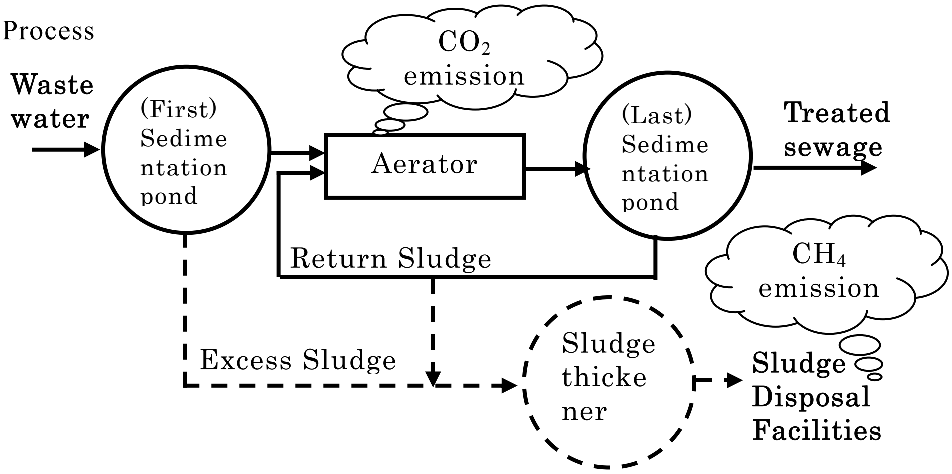
$P_{BOD,\ y}$ = Chemical Oxygen Demand (COD) of wastewater ($tCOD/m^3$) or Biochemical Oxygen Demand (BOD) of wastewater ($tBOD/m^3$)

B_0 = Maximum methane producing capacity = 0.60 ($kgCH_4/kgBOD$) = 0.25 ($kgCH_4/kgCOD$)

MCF_p = Methane conversion factor (fraction)

With the activity 1 :

Wastewater Treatment Process (Aerobic Treatment) + Sludge Disposal Process



PE_{with} =

Emissions of "With the activity" from electrical consumption in year y ($PE_{elec,\ y}$) +

Emissions of "With the activity" from fossil fuel consumption in year y ($PE_{fuel,\ on\text{-}site,\ y}$) +

Emissions of "With the activity" from wastewater treatment in year y ($PE_{CH4,\ w,\ y}$) +

Emissions of "With the activity" from sludge disposal process in year y ($PE_{s,\ y}$)

< Electrical Consumption >

$PE_{elec,\ y} = EC_{EL} \times EF_{EL\ elec}$

Where ;

EC_{EL} = Electrical consumption of sewage treatment facilities (kWh/year)

EF_{EL} = CO_2 emission factor for electrical consumption ($kg\text{-}CO_2/kWh$)

< Fossil Fuel Consumption >

$PE_{fuel,\ on\text{-}site,\ y} = EC_{FC} \times EF_{FF}$

Where ;

EC_{FC} = Energy consumption of sewage treatment facilities (kJ or TOE/year)

EF_{FF} = CO_2 emission factor for fossil fuel consumption (kg- CO_2/kJ)

< Aerobic Treatment Process of Wastewater >

$PE_{CH4,\,w,\,y} = Q_{BOD,\,y} \times P_{BOD,\,y} \times B_0 \times MCF_p$

Where ;

$Q_{BOD,\,y}$ = Amount of wastewater (m^3/year)

$P_{BOD,\,y}$ = Chemical Oxygen Demand (COD) of wastewater (tCOD/m^3) or Biochemical Oxygen Demand (BOD) of wastewater (tBOD/m^3)

B_0 = Maximum methane producing capacity

= 0.60 (kgCH_4/kgBOD)

= 0.25 (kgCH_4/kgCOD)

MCF_p = Methane conversion factor (fraction) (= 0.0 : Centralized, aerobic treatment plant must be well managed.)

< Sludge Disposal Process > (Aerobic process)

$PE_{s,\,y} = S_{\,y} \times DOC_{y,\,s} \times MCF_{ys} \times DOC_{\,F} \times F \times 16/12 \times GWP_{CH4}$

Where:

$PE_{s,\,y}$ = CH_4 emissions from the anaerobic decay of the final sludge generated in the wastewater system in the year y (tCO_2/year).

$S_{\,y}$ = Amount of sludge generated by the wastewater treatment in the year y (ton/year).

$DOC_{y,\,s}$ = Degradable organic content of the sludge generated by the wastewater treatment in the year y (fraction).

IPDD default values = 0.05 (for domestic sludge; wet basis)

= 0.09 (for industrial sludge; wet basis)

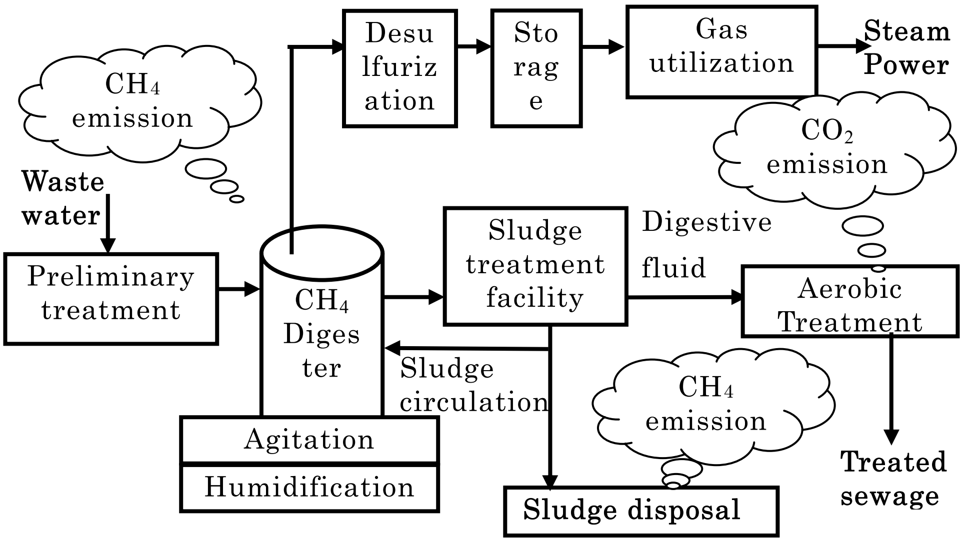
MCF_s = CH_4 correction factor for the landfill that receives the final sludge.

DOC_F = Fraction of DOC dissimilated to biogas (IPCC default value is 0.5).

F = Fraction of CH_4 in landfill gas (IPCC default value is 0.5).

With the activity 2 :

Wastewater Treatment Process (Anaerobic Treatment) + Sludge Disposal Process



PE_{with} =

Emissions of "With the activity" from electrical consumption in year y ($PE_{elec,\ y}$) +

Emissions of "With the activity" from fossil fuel consumption in year y ($PE_{fuel,\ on\text{-}site,\ y}$) +

Emissions of "With the activity" from wastewater treatment in year y ($PE_{CH4,\ w,\ y}$) +

Emissions of "With the activity" from sludge disposal process in year y ($PE_{s,\ y}$)

< Electrical Consumption >

$PE_{elec,\ y} = EC_{EL} \times EF_{EL\ elec}$

Where ;

EC_{EL} = Electrical consumption of sewage treatment facilities (kWh/year)

EF_{EL} = CO_2 emission factor for electrical consumption ($kgCO_2$/kWh)

< Fossil Fuel Consumption >

$PE_{fuel,\ on\text{-}site,\ y} = EC_{FC} \times EF_{FF}$

Where ;

EC_{FC} = Energy consumption of sewage treatment facilities (kJ or TOE/year)

EF_{FF} = CO_2 emission factor for fossil fuel consumption (kg- CO_2/kJ)

<Anaerobic Treatment Process of Wastewater >

$PE_{CH4,\ w,\ y} = Q_{BOD,\ y} \times P_{BOD,\ y} \times B_0 \times MCF_p$

Where ;

$Q_{BOD,\,y}$ = Amount of wastewater (m^3/year)

$P_{BOD,\,y}$ = Chemical Oxygen Demand (COD) of wastewater ($tCOD/m^3$) or Biochemical Oxygen Demand (BOD) of wastewater ($tBOD/m^3$)

B_0 = Maximum methane producing capacity

= 0.60 ($kgCH_4/kgBOD$)

= 0.25 ($kgCH_4/kgCOD$)

MCF_p = Methane conversion factor (fraction) (= 0.8 : Anaerobic reactor.)

<Anaerobic Digestion>

$PE_{a,\,y} = P_l \times M_{a,\,y} + PE_{a\,,s,\,y}$

Where ;

P_l = Physical leakage factor from a digester (fraction).
It is assumed that the value of this parameter is zero.

$M_{a,\,y}$ = Total quantity of methane produced by the digester in year y (tCO_2/year) (= $PE_{CH4,\,w,\,y}$)

$PE_{a\,,s,\,y}$ = Total emissions of CH_4 and N_2O from the stacks of the anaerobic digestion process in year y (tCO_2/year).
It is assumed that this parameter is ignored.

< Sludge Disposal Process > (Aerobic process)

$PE_{s,\,y}=S_{\,y} \times DOC_{y,\,s} \times MCF_{ys} \times DOC_{\,F} \times F \times 16/12 \times GWP_{CH4}$

Where:

$PE_{s,\,y}$ = CH_4 emissions from the anaerobic decay of the final sludge generated in the wastewater system in the year y (tCO_2/year).

$S_{\,y}$ = Amount of sludge generated by the wastewater treatment in the year y (ton/year).

$DOC_{y,\,s}$ = Degradable organic content of the sludge generated by the wastewater treatment in the year y (fraction).
IPDD default values = 0.05 (for domestic sludge; wet basis)
= 0.09 (for industrial sludge; wet basis)

MCF_s = CH_4 correction factor of the landfill that receives the final sludge.

DOC_F = Fraction of DOC dissimilated to biogas (IPCC default value is 0.5).

F = Fraction of CH_4 in landfill gas (IPCC default value is 0.5).

GHG emission reductions

GHG emission reductions (ER) of introduction of sewage treatment facilities are calculated using the following equation :

$ER = BE_{without} - PE_{with}$

Required data and data source

(1) Data requiring field investigation

Data obtained through field investigation or reports are as indicated in Table 1. Population using sewage treatment facilities is a parameter contributing directly to the amount of wastewater and amount of sludge.

Table 1 Data, source of data and data acquisition method

Data	Source of data	Data acquisition method
Concentration and amount of inflow water at sewage treatment facilities	Designing specification of the facilities.	Final report or the values of existing similar facilities
Concentration and amount of outflow water from sewage treatment facilities		
Electrical consumption for wastewater treatment		
Fuel consumption for wastewater treatment		
Amount of sludge		
Population using sewage treatment facilities	Field investigation or statistics of the target country	Reports about the facilities or on the web.

(2) Parameters to be selected from the existing parameters

Appropriate CH_4 conversion factor shall be selected from Table 2.

Table 2 MCF_p default value for waste water treatment

Type of treatment and discharge pathway or system	Comments	MCF_p
Untreated system		
Sea, river and lake discharge	Rivers with high organic loadings and can turn anaerobic.	0.1
Stagnant sewer	Open and warm	0.5
Flowing sewer (open or closed)	Fast moving, clean. (Insignificant amounts of CH_4 from pump stations, etc)	0
Treatment system		
Centralized, aerobic treatment plant	Must be well managed. Some CH_4 can be emitted from settling basins and other pockets.	0
Centralized, aerobic treatment plant	Not well managed. Overloaded.	0.3
Anaerobic digester for sludge	CH_4 recovery is not considered here.	0.8
Anaerobic reactor	CH_4 recovery is not considered here.	0.8
Anaerobic shallow lagoon	Depth less than 2 meters, use expert judgment.	0.2
Anaerobic deep lagoon	Depth more than 2 meters	0.8
Septic system	Half of BOD settles in anaerobic tank	0.5
Latrine	Dry climate, ground water table lower than latrine, small family (3-5 persons)	0.1
Latrine	Dry climate, ground water table lower than latrine, communal (many users)	0.5
Latrine	Wet climate / flush water use, ground water table higher than latrine bottom	0.7
Latrine	Regular sediment removal for fertilizer	0.1

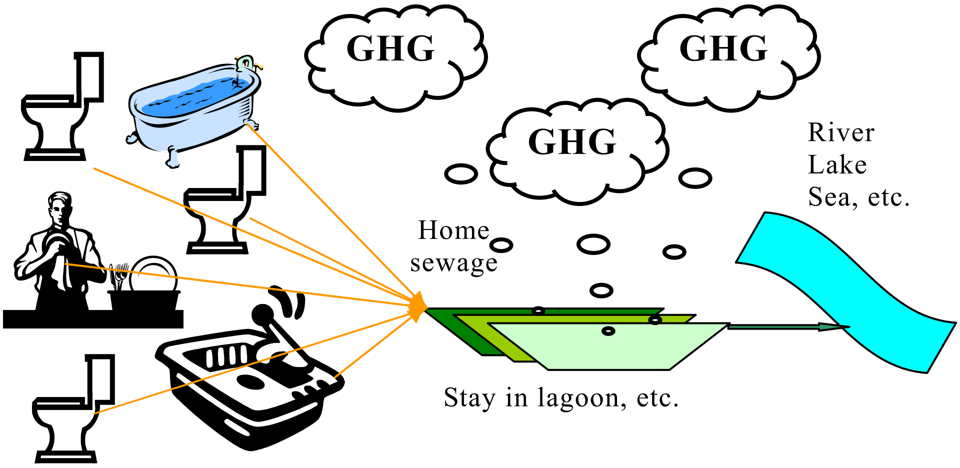
Source : 2006 IPCC Guideline for National Greenhouse Gas Inventories, Volume 5 Waste, TABLE 6.3

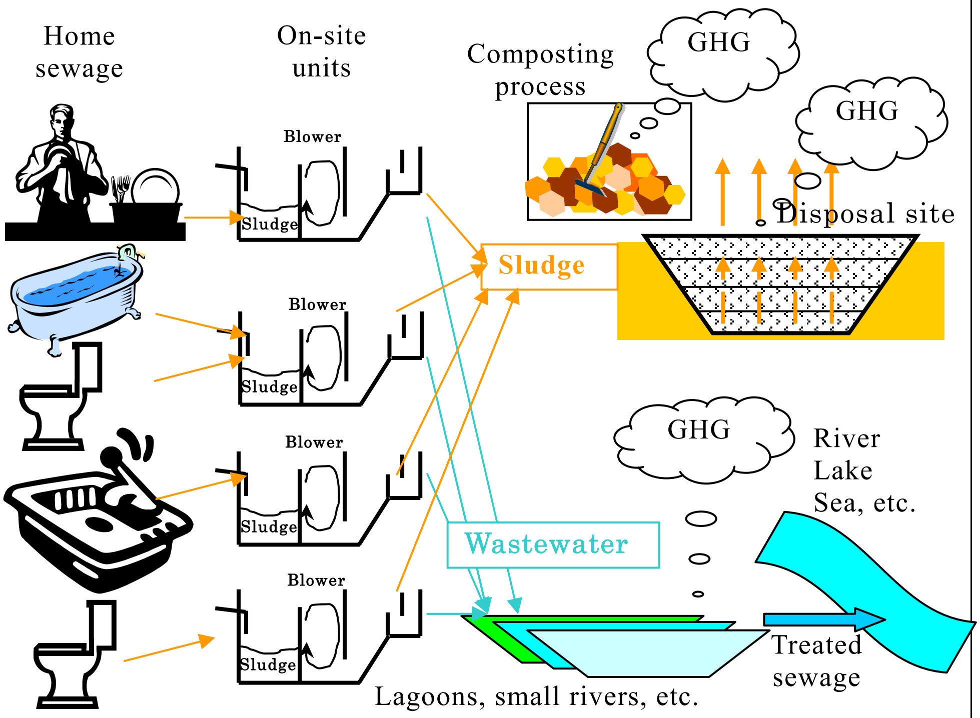
	EF_{FF} : CO_2 emission factor for fossil fuel consumption ($kgCO_2/kJ$) Refer to ***Annex 2***. EF_{EL} : CO_2 emission factor for electrical consumption ($kgCO_2/kWh$) Refer to ***Annex 1***.
Preconditions	In the case of "Without the activity", there is no electrical consumption used for wastewater treatment. In the case of "Without the activity", there is no fuel consumption used for wastewater treatment. In the case that "With the activity" is a form of aerobic wastewater treatment process, it is assumed that the management status is good and CH_4 conversion factor (MCF_p) is 0. In the case that "With the activity" is a form of anaerobic wastewater treatment process, it is assumed that there is no leak from the digester tank (P_l=0).
Special notes	Generally, in many cases, the electrical consumption and fuel consumption of sewage treatment facilities are not measured. In the CDM methodology (ACM0014), the temperature effect of MCF (effect of varying the decomposition speed of organic matter by temperature) and the net COD treatment amounts relative to COD pollutant loads (in consideration of the difference between influent loads and effluent loads) are taken into account. However, this scenario is intended for constructions of a simplified quantification method, and therefore, these factors have been omitted for the sake of simplicity.

Quantification Sheet

Activity: Water Pollution Control

(Introduction of On-Site Units for primary wastewater treatment)

Sector	Environmental Management
Sub-sector	Water Pollution Control (Measures regarding Domestic Wastewater)
GHG emission reduction activity	Wastewater that is outside of an area that is served by a sewage treatment plant is unsanitary. This wastewater includes sewage from those such as homes, toilet facilities, bathing areas, etc. The sanitation of this wastewater is improved. As a result, emissions of GHG (mainly, CH_4 and N_2O) are reduced.
GHG emission reduction impact	1: Activity will lead to GHG emission reduction 2: Activity will lead to GHG emission reduction subject to condition(s) 3: Activity will not lead to GHG emission reduction
GHG emission reduction scenarios (description of how GHG is reduced)	**<Without the activity>** There is the situation that home sewage is discharged untreated into the system and is retained / detained in a lagoon, etc. 

	<Without the activity> There is the situation that home sewage is treated at on-site units for primary wastewater treatment.  **[Schematics of GHG emission reduction process]** Home sewage is kept in drainage canals, lagoons, small rivers and CH_4 is emitted into the atmosphere. ⇨ On-site units for primary wastewater treatment of home sewage are introduced. ⇨ Aerobic treatment: In the water treatment process, emission of CH_4 is reduced avoided and CO_2 is emitted. Electricity is used in this treatment process. Anaerobic treatment: In the water treatment process, CH_4 is emitted. The emitted CH_4 is recovered and used as an energy source. Sewage sludge: It is composted or landfilled.
Calculation of GHG emission reduction	**[Calculation method]** GHG is emitted from the treatment process of wastewater (aerobic process, anaerobic process) and sludge disposal process. In addition, there are GHG emissions from electricity consumption and the fuel consumption due to these processes. Source of Equations: AMS-III.I “Avoidance of methane production in wastewater treatment through replacement of anaerobic lagoons by aerobic systems”, ACM0014 “Avoided methane emissions from wastewater treatment” and AM0025 ”Avoided emissions from organic waste thorough alternative waste treatment processes”

[Equations]

Without the activity

There is the situation that home sewage is discharged untreated into the system.

$BE_{without}$ =

Emissions of "Without the activity" from electrical consumption in year y ($BE_{elec,\ y}$) +

Emissions of "Without the activity" from fossil fuel consumption in year y ($BE_{fuel,\ on\text{-}site,\ y}$) +

Emissions of "Without the activity" from treatment of waste water in year y ($BE_{CH4,\ w,\ y}$)

It is assumed that there will be no electrical consumption or fuel consumption in the case of "Without the activity". Then this equation becomes $BE_{without} = BE_{CH4,\ w,\ y}$.

<Treatment of the wastewater>

$BE_{without} = BE_{CH4,\ w,\ y} = Q_{BOD,\ y} \times P_{BOD,\ y} \times B_0 \times MCF_p$

Where :

$Q_{BOD,\ y}$ = Amount of wastewater (m^3/year)

$P_{BOD,\ y}$ = Chemical Oxygen Demand (COD) of wastewater ($tCOD/m^3$) or Biochemical Oxygen Demand (BOD) of wastewater ($tBOD/m^3$)

B_0 = Maximum methane producing capacity = 0.60 ($kgCH_4/kgBOD$) = 0.25 ($kgCH_4/kgCOD$)

MCF_p = Methane conversion factor (fraction)

With the activity 1 :

Wastewater Treatment Process (Aerobic Treatment) + Sludge Disposal Process

PE_{with} =

Emissions of "With the activity" from electrical consumption in year y ($PE_{elec,\ y}$) +

Emissions of "With the activity" from fossil fuel consumption in year y ($PE_{fuel,\ on\text{-}site,\ y}$) +

Emissions of "With the activity" from wastewater treatment in year y ($PE_{CH4,\ w,\ y}$) +

Emissions of "With the activity" from sludge disposal process in year y ($PE_{s,\ y}$)

< Electrical Consumption >

$PE_{elec,\,y} = EC_{EL} \times EF_{EL\ elec}$

Where ;

EC_{EL} = Electrical consumption of sewage treatment facility (kWh/year)

EF_{EL} = CO_2 emission factor for electrical consumption ($kgCO_2$/kWh)

< Fossil Fuel Consumption >

$PE_{fuel,\,on\text{-}site,\,y} = EC_{FC} \times EF_{FF}$

Where ;

EC_{FC} = Energy consumption of sewage treatment facility (kJ or TOE/year)

EF_{FF} = CO_2 emission factor for fossil fuel consumption ($kgCO_2$/kJ)

< Aerobic Treatment Process for the Wastewater >

$PE_{CH4,\,w,\,y} = Q_{BOD,\,y} \times P_{BOD,\,y} \times B_0 \times MCF_p$

Where ;

$Q_{BOD,\,y}$ = Amount of wastewater (m^3/year)

$P_{BOD,\,y}$ = Chemical Oxygen Demand (COD) of wastewater ($tCOD/m^3$) or Biochemical Oxygen Demand (BOD) of wastewater ($tBOD/m^3$)

B_0 = Maximum methane producing capacity

= 0.60 ($kgCH_4$/kgBOD)

= 0.25 ($kgCH_4$/kgCOD)

MCF_p = Methane conversion factor (fraction) (= 0.0: Centralized, aerobic treatment plant must be well managed.)

< Sludge Disposal Process > (Aerobic process)

$PE_{s,\,y}=S_y \times DOC_{y,\,s} \times MCF_{ys} \times DOC_F \times F \times 16/12 \times GWP_{CH4}$

Where:

$PE_{s,\,y}$ = CH_4 emissions from the anaerobic decay of the final sludge generated in the wastewater system in the year y (tCO_2/year).

S_y = Amount of sludge generated by the wastewater treatment in the year y (ton/year).

$DOC_{y,\,s}$ = Degradable organic content of the sludge generated by the wastewater treatment in the year y (fraction).

IPDD default values = 0.05 (for domestic sludge; wet basis)

= 0.09 (for industrial sludge; wet basis)

MCF_s = CH_4 correction factor for the landfill that receives the final sludge.

DOC_F = Fraction of DOC dissimilated to biogas (IPCC default value is 0.5).

F = Fraction of CH_4 in landfill gas (IPCC default value is 0.5).

With the activity 2 :

Wastewater Treatment Process (Anaerobic Treatment) + Sludge Disposal Process

PE_{with} =

Emissions of "With the activity" from electrical consumption in year y ($PE_{elec, y}$) +

Emissions of "With the activity" from fossil fuel consumption in year y ($PE_{fuel, on\text{-}site, y}$) +

Emissions of "With the activity" from wastewater treatment in year y ($PE_{CH4, w, y}$) +

Emissions of "With the activity" from sludge disposal process in year y ($PE_{s, y}$)

< Electrical Consumption >

$PE_{elec, y} = EC_{EL} \times EF_{EL\ elec}$

Where ;

EC_{EL} = Electrical consumption of sewage treatment facility (kWh/year)

EF_{EL} = CO_2 emission factor for electrical consumption ($kgCO_2$/kWh)

< Fossil Fuel Consumption >

$PE_{fuel, on\text{-}site, y} = EC_{FC} \times EF_{FF}$

Where ;

EC_{FC} = Energy consumption of sewage treatment facility (kJ or TOE/year)

EF_{FF} = CO_2 emission factor for fossil fuel consumption ($kgCO_2$/kJ)

< Anaerobic Treatment Process of Wastewater >

$PE_{CH4, w, y} = Q_{BOD, y} \times P_{BOD, y} \times B_0 \times MCF_p$

Where ;

$Q_{BOD, y}$ = Amount of wastewater (m^3/year)

$P_{BOD, y}$ = Chemical Oxygen Demand (COD) of wastewater ($tCOD/m^3$) or Biochemical Oxygen Demand (BOD) of wastewater ($tBOD/m^3$)

B_0 = Maximum methane producing capacity

	= 0.60 ($kgCH_4/kgBOD$) = 0.25 ($kgCH_4/kgCOD$) MCF_p = Methane conversion factor (fraction) (= 0.8 : Anaerobic reactor.) <Anaerobic Digestion> $PE_{a,y} = P_l \times M_{a,y} + PE_{a,s,y}$ Where ; P_l = Physical leakage factor from a digester (fraction). It is assumed that the value of this parameter is zero. $M_{a,y}$ = Total quantity of methane produced by the digester in year y (tCO_2/year) (= $PE_{CH4,w,y}$) $PE_{a,s,y}$ = Total emissions of CH_4 and N_2O from the stacks of the anaerobic digestion process in year y (tCO_2/year). It is assumed that this parameter is ignored. < Sludge Disposal Process > (Aerobic process) $PE_{s,y}=S_y \times DOC_{y,s} \times MCF_{ys} \times DOC_F \times F \times 16/12 \times GWP_{CH4}$ Where: $PE_{s,y}$ = CH_4 emissions from the anaerobic decay of the final sludge generated in the wastewater system in the year y (tCO_2/year). S_y = Amount of sludge generated by the wastewater treatment in the year y (ton/year). $DOC_{y,s}$ = Degradable organic content of the sludge generated by the wastewater treatment in the year y (fraction). IPDD default values = 0.05 (for domestic sludge; wet basis) = 0.09 (for industrial sludge; wet basis) MCF_s = CH_4 correction factor of the landfill that receives the final sludge. DOC_F = Fraction of DOC dissimilated to biogas (IPCC default value is 0.5). F = Fraction of CH_4 in landfill gas (IPCC default value is 0.5). **GHG emission reductions** GHG emission reductions (ER) due to introduction of on-site units for primary wastewater treatment is determined using the following equation : ER = $BE_{without} - PE_{with}$
Required data and data source	(1) Data requiring field investigation

Data obtained through field investigation or reports are as indicated in Table 1. “Population using on-site units for primary wastewater treatment” is a parameter contributing directly to the amount of wastewater and amount of sludge.

Table 1 Data, source of data and data acquisition method

Data	Source of data	Data acquisition method
Concentration and amount of inflow water to on-site primary wastewater treatment units	Designing specification of the facilities.	Final report or the results values of the existing similar facility
Concentration and amount of outflow water from on-site primary wastewater treatment units		
Electrical consumption used for on-site units for primary wastewater treatment		
Fuel consumption used for on-site units for primary wastewater treatment		
Amount of sludge		
Population using on-site primary wastewater treatment units	Field investigation or statistics of the target country	Reports about the facility or on the web.

(2) Parameters to be selected from the existing parameters

For CH_4 conversion factor (MCF_p) choose an appropriate value from Table 2 of "Introduction of Sewerage Treatment Facility".

EF_{FF} : CO_2 emission factor of the fossil fuel consumption ($kgCO_2/kJ$)

Refer to ***Annex 2***.

EF_{EL} : CO_2 emission factor for electrical consumption ($kgCO_2/kWh$)

Refer to ***Annex 1***.

Preconditions

In the case of “Without the activity”, there is no electrical consumption used for wastewater treatment.

In the case of “Without the activity”, there is no fuel consumption used for wastewater treatment.

In the case where the "With the activity" is a form of aerobic wastewater treatment process, it is assumed that the management status is good and CH_4 conversion factor (MCF_p) is 0.

In the case where the "With the activity" is a form of anaerobic wastewater treatment process, it is assumed that there is no leak from the digester tank (P_l=0).

Special notes

Generally, in many cases, the electrical consumption and fuel consumption of on-site units for primary wastewater treatment are not measured.

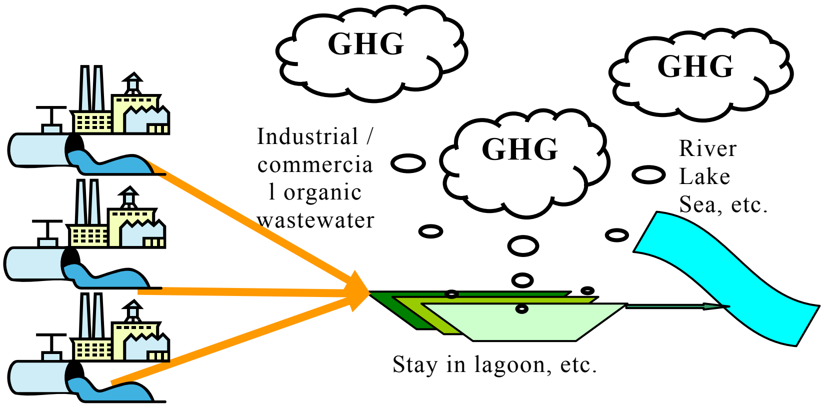
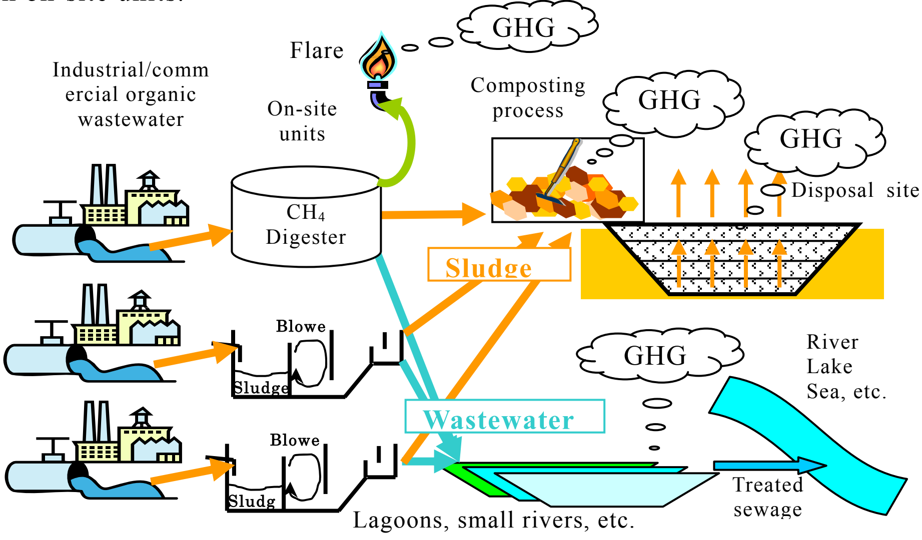
It is assumed that there are not many examples of JICA technical cooperation

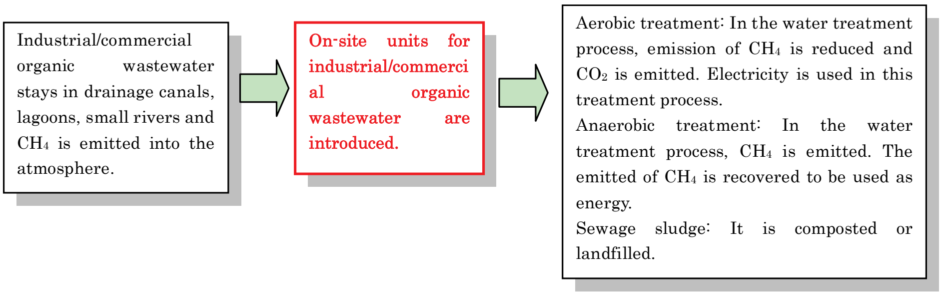
	projects involved in this activity. In the CDM methodology (ACM0014), the temperature effect of MCF (effect of varying the decomposition speed of organic matter by temperature) and the net COD treatment amounts relative to COD pollutant loads (in consideration of the difference between influent loads and effluent loads) are taken into account. However, this scenario is intended for construction of a simplified quantification method, and therefore, these factors are omitted to achieve that simplification.

Quantification Sheet

Activity: Water Pollution Control

(Introduction of On-Site Units for Industrial/Commercial Organic Wastewater)

Sector	Environmental Management
Sub-sector	Water Pollution Control (Measures regarding Industrial/Commercial Organic Wastewater)
GHG emission reduction activity	There is a factory emitting high concentration organic wastewater and sludge. In this factory, organic wastewater is discharged untreated into the system and is retained/detained in a lagoon, etc. In this factory, on-site units for organic wastewater are introduced. These facilities have CH_4 collection or aerobic processing. As a result, emissions of GHG (mainly, CH_4 and N_2O) are reduced.
GHG emission reduction impact	1: Activity will lead to GHG emission reduction 2: Activity will lead to GHG emission reduction subject to condition(s) 3: Activity will not lead to GHG emission reduction
GHG emission reduction scenarios (description of how GHG is reduced)	**<Without the activity>** There is the situation that industrial/commercial organic wastewater is discharged untreated into the system and is retained/detained in a lagoon, etc.  **<With the activity>** There is the situation that industrial/commercial organic wastewater is treated in on-site units. 

	[Schematics of GHG emission reduction process]  Industrial/commercial organic wastewater stays in drainage canals, lagoons, small rivers and CH_4 is emitted into the atmosphere. On-site units for industrial/commercial organic wastewater are introduced. Aerobic treatment: In the water treatment process, emission of CH_4 is reduced and CO_2 is emitted. Electricity is used in this treatment process. Anaerobic treatment: In the water treatment process, CH_4 is emitted. The emitted of CH_4 is recovered to be used as energy. Sewage sludge: It is composted or landfilled.
Calculation of GHG emission reduction	**[Calculation method]** GHG are emitted from the treatment process of wastewater (aerobic process, anaerobic process) and sludge disposal process. In addition, from these processes there are GHG emissions from electricity consumption and fuel consumption. Source of Equations: AMS-III.I “Avoidance of methane production in wastewater treatment through replacement of anaerobic lagoons by aerobic systems”, ACM0014 “Avoided methane emissions from wastewater treatment” and AM0025 ”Avoided emissions from organic waste thorough alternative waste treatment processes” **[Equations]** **Without the activity** There is the situation that industrial/commercial organic wastewater is discharged untreated into the system. $BE_{without}$ = Emissions of “Without the activity” from electrical consumption in year y ($BE_{elec, y}$) + Emissions of “Without the activity” from fossil fuel consumption in year y ($BE_{fuel, on-site, y}$) + Emissions of “Without the activity” from treatment of waste water in year y ($BE_{CH4, w, y}$) $BE_{without} = BE_{CH4, w, y} + BE_{elec, y} + BE_{fuel, on-site, y} + BE_{CH4, w, y}$ <Treatment of the Wastewater> $BE_{without} = BE_{CH4, w, y} = Q_{BOD, y} \times P_{BOD, y} \times B_0 \times MCF_p$ Where : $Q_{BOD, y}$ = Amount of wastewater (m^3/year) $P_{BOD, y}$ = Chemical Oxygen Demand (COD) of wastewater ($tCOD/m^3$) or Biochemical Oxygen Demand (BOD) of wastewater ($tBOD/m^3$) B_0 = Maximum methane producing capacity = 0.60 ($kgCH_4/kgBOD$)

= 0.25 ($kgCH_4/kgCOD$)

MCF_p = Methane conversion factor (fraction)

< Electrical Consumption >

$PE_{elec,\ y} = EC_{EL} \times EF_{EL\ elec}$

Where ;

EC_{EL} = Electrical consumption of the treatment facility for industrial/commercial organic wastewater (kWh/year)

EF_{EL} = CO_2 emission factor for electrical consumption ($kgCO_2/kWh$)

< Fossil Fuel Consumption >

$PE_{fuel,\ on\text{-}site,\ y} = EC_{FC} \times EF_{FF}$

Where ;

EC_{FC} = Energy consumption of the treatment facility for industrial/commercial organic wastewater (kJ or TOE/year)

EF_{FF} = CO_2 emission factor for fossil fuel consumption ($kgCO_2/kJ$)

<u>With the activity 1</u> :

Wastewater Treatment Process (Aerobic Treatment) + Sludge Disposal Process

PE_{with}=

Emissions of "With the activity" from electrical consumption in year y ($PE_{elec,\ y}$) +

Emissions of "With the activity" from fossil fuel consumption in year y ($PE_{fuel,\ on\text{-}site,\ y}$) +

Emissions of "With the activity" from wastewater treatment in year y ($PE_{CH4,\ w,\ y}$) +

Emissions of "With the activity" from sludge disposal process in year y ($PE_{s,\ y}$)

< Electrical Consumption >

$PE_{elec,\ y} = EC_{EL} \times EF_{EL\ elec}$

Where ;

EC_{EL} = Electrical consumption of the treatment facility for industrial/commercial organic wastewater (kWh/year)

EF_{EL} = CO_2 emission factor for electrical consumption ($kgCO_2/kWh$)

< Fossil Fuel Consumption >

$PE_{fuel,\ on\text{-}site,\ y} = EC_{FC} \times EF_{FF}$

Where ;

EC_{FC} = Energy consumption of the treatment facility for industrial/commercial organic wastewater (kJ or TOE/year)

EF_{FF} = CO_2 emission factor for fossil fuel consumption ($kgCO_2/kJ$)

< Aerobic Treatment Process of Wastewater >

$PE_{CH4,\,w,\,y} = Q_{BOD,\,y} \times P_{BOD,\,y} \times B_0 \times MCF_p$

Where ;

$Q_{BOD,\,y}$ = Amount of wastewater (m^3/year)

$P_{BOD,\,y}$ = Chemical Oxygen Demand (COD) of wastewater ($tCOD/m^3$) or Biochemical Oxygen Demand (BOD) of wastewater ($tBOD/m^3$)

B_0 = Maximum methane producing capacity
= 0.60 ($kgCH_4/kgBOD$)
= 0.25 ($kgCH_4/kgCOD$)

MCF_p = Methane conversion factor (fraction) (= 0.0 : Centralized, aerobic treatment plant must be well managed.)

< Sludge Disposal Process > (Aerobic process)

$PE_{s,\,y}=S_{\,y} \times DOC_{y,\,s} \times MCF_{ys} \times DOC_{\,F} \times F \times 16/12 \times GWP_{CH4}$

Where:

$PE_{s,\,y}$ = CH_4 emissions from the anaerobic decay of the final sludge generated in the wastewater system in the year y (tCO_2/year).

$S_{\,y}$ = Amount of sludge generated by the wastewater treatment in the year y (ton/year).

$DOC_{y,\,s}$ = Degradable organic content of the sludge generated by the wastewater treatment in the year y (fraction).
IPDD default values = 0.05 (for domestic sludge; wet basis)
= 0.09 (for industrial sludge; wet basis)

MCF_s = CH_4 correction factor of the landfill that receives the final sludge.

DOC_F = Fraction of DOC dissimilated to biogas (IPCC default value is 0.5).

F = Fraction of CH_4 in landfill gas (IPCC default value is 0.5).

With the activity 2 :

Wastewater Treatment Process (Anaerobic Treatment) + Sludge Disposal Process

PE_{with} =

Emissions of "With the activity" from electrical consumption in year y ($PE_{elec,\,y}$) +

Emissions of "With the activity" from fossil fuel consumption in year y ($PE_{fuel,\,on\text{-}site,\,y}$) +

Emissions of "With the activity" from wastewater treatment in year y ($PE_{CH4,\,w,\,y}$) +

Emissions of "With the activity" from sludge disposal process in year y ($PE_{s, y}$)

< Electrical Consumption >

$PE_{elec, y} = EC_{EL} \times EF_{EL\ elec}$

Where ;

EC_{EL} = Electrical consumption of the treatment facility for industrial/commercial organic wastewater (kWh/year)

EF_{EL} = CO_2 emission factor for electrical consumption ($kgCO_2/kWh$)

< Fossil Fuel Consumption >

$PE_{fuel, on\text{-}site, y} = EC_{FC} \times EF_{FF}$

Where ;

EC_{FC} = Energy consumption of the treatment facility for industrial/commercial organic wastewater (kJ or TOE/year)

EF_{FF} = CO_2 emission factor for fossil fuel consumption ($kgCO_2/kJ$)

< Anaerobic Treatment Process of Wastewater >

$PE_{CH4, w, y} = Q_{BOD, y} \times P_{BOD, y} \times B_0 \times MCF_p$

Where ;

$Q_{BOD, y}$ = Amount of wastewater (m^3/year)

$P_{BOD, y}$ = Chemical Oxygen Demand (COD) of wastewater ($tCOD/m^3$) or Biochemical Oxygen Demand (BOD) of wastewater ($tBOD/m^3$)

B_0 = Maximum methane producing capacity

= 0.60 ($kgCH_4/kgBOD$)

= 0.25 ($kgCH_4/kgCOD$)

MCF_p = Methane conversion factor (fraction) (= 0.8 : Anaerobic reactor.)

<Anaerobic Digestion>

$PE_{a, y} = P_l \times M_{a, y} + PE_{a ,s, y}$

Where ;

P_l = Physical leakage factor from a digester (fraction).
It is assumed that the value of this parameter is zero.

$M_{a, y}$ = Total quantity of methane produced by the digester in year y (tCO_2/year) (= $PE_{CH4, w, y}$)

$PE_{a ,s, y}$ = Total emissions of CH_4 and N_2O from the stacks of the anaerobic digestion process in year y (tCO_2/year).
It is assumed that this parameter is ignored.

< Sludge Disposal Process > (Aerobic process)

$PE_{s, y}=S_y \times DOC_{y, s} \times MCF_{ys} \times DOC_F \times F \times 16/12 \times GWP_{CH4}$

Where:

$PE_{s,\,y}$ = CH_4 emissions from the anaerobic decay of the final sludge generated in the wastewater system in the year y (tCO_2/year).

S_y = Amount of sludge generated by the wastewater treatment in the year y (ton/year).

$DOC_{y,\,s}$ = Degradable organic content of the sludge generated by the wastewater treatment in the year y (fraction).
IPDD default values = 0.05 (for domestic sludge; wet basis)
= 0.09 (for industrial sludge; wet basis)

MCF_s = CH_4 correction factor of the landfill that receives the final sludge.

DOC_F = Fraction of DOC dissimilated to biogas (IPCC default value is 0.5).

F = Fraction of CH_4 in landfill gas (IPCC default value is 0.5).

GHG emission reductions

GHG emission reductions (ER) due to introduction of on-site units for industrial/commercial organic wastewater is found using the following equation :

$ER = BE_{without} - PE_{with}$

Required data and data source

(1) Data requiring field investigation

Data obtained through field investigation or reports are as indicated in Table 1. "Amount of production of factory" is parameter contributing directly to the amount of wastewater and amount of sludge.

Table 1 Data, source of data and data acquisition method

Data	Source of data	Data acquisition method
Concentration and amount of inflow water to on-site industrial/commercial wastewater treatment units	Designing specification of the facilities.	Final report or the results values of the existing similar facilities
Concentration and amount of outflow water from on-site industrial/ commercial wastewater treatment units		
Electrical consumption for on-site industrial/commercial wastewater treatment units		
Fuel consumption for on-site units for industrial/ commercial wastewater		
Amount of sludge		
Amount of production of factory	Field investigation	Hearings about the factory.

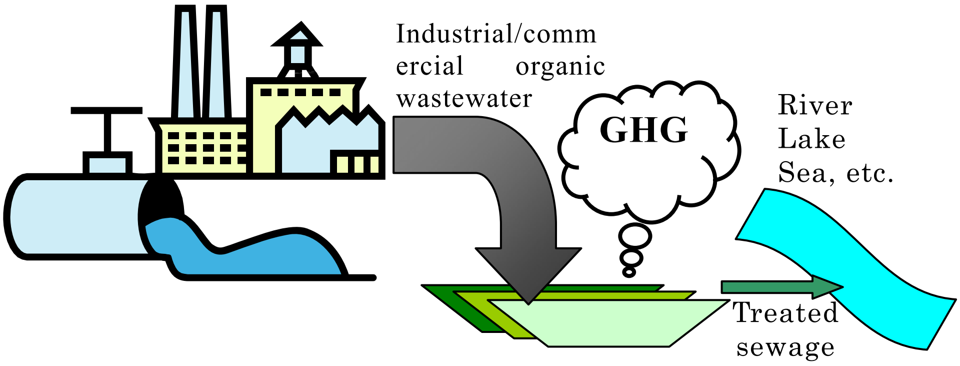
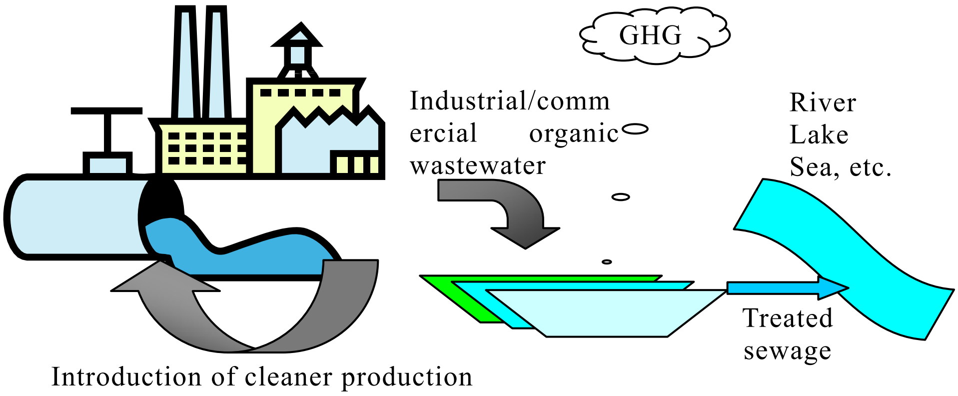
(2) Parameters to be selected from the existing parameters

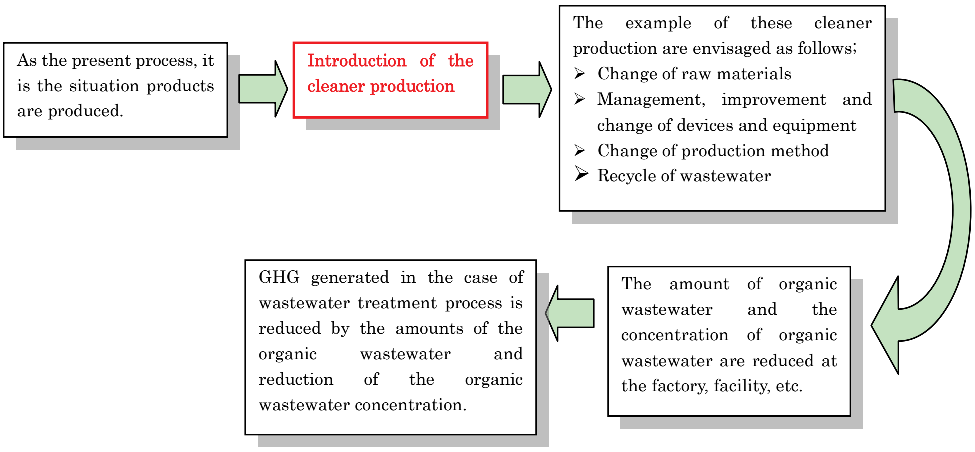
For CH_4 conversion factor (MCF_p) choose an appropriate value from Table 2 of "Introduction of Sewerage Treatment Facility".

	EF_{FF} : CO_2 emission factor for fossil fuel consumption ($kgCO_2/kJ$) Refer to ***Annex 2***. EF_{EL} : CO_2 emission factor for electrical consumption ($kgCO_2/kWh$) Refer to ***Annex 1***.
Preconditions	In the case that "With the activity" is a form of aerobic wastewater treatment process, it is assumed that the management status is good and CH_4 conversion factor (MCF_p) is 0. In the case that "With the activity" is a form of anaerobic wastewater treatment process, it is assumed that there is no leak from the digester tank (P_l=0).
Special notes	Generally, in many cases, the electrical consumption and fuel consumption of on-site units for industrial/commercial organic wastewater are not measured. In the CDM methodology (ACM0014), the temperature effect of MCF (effect of varying the decomposition speed of organic matter by temperature) and the net COD treatment amounts relative to COD pollutant loads (in consideration of the difference between influent loads and effluent loads) are taken into account. However, this scenario is intended for construction of a simplified quantification method, and therefore, these factors are omitted for said simplification.

Quantification Sheet

Activity: Water Pollution Control (Cleaner Production (Reduction of Wastewater))

Sector	Environmental Management
Sub-sector	Water Pollution Control (Measures regarding Industrial/ Commercial Organic Wastewater)
GHG emission reduction activity	Amounts and concentration of wastewater are reduced by the introduction of cleaner production. As a result, the GHG emissions from the wastewater treatment processes are reduced.
GHG emission reduction impact	1: Activity will lead to GHG emission reduction 2: Activity will lead to GHG emission reduction subject to condition(s) 3: Activity will not lead to GHG emission reduction
GHG emission reduction scenarios (description of how GHG is reduced)	**<Without the activity>** There is the situation that industrial/commercial organic wastewater is discharged in large amounts.  **<With the activity>** There is the situation that the amounts and concentration of wastewater from the factory are reduced. 

	[Schematics of GHG emission reduction process]  As the present process, it is the situation products are produced. Introduction of the cleaner production The example of these cleaner production are envisaged as follows; ➢ Change of raw materials ➢ Management, improvement and change of devices and equipment ➢ Change of production method ➢ Recycle of wastewater The amount of organic wastewater and the concentration of organic wastewater are reduced at the factory, facility, etc. GHG generated in the case of wastewater treatment process is reduced by the amounts of the organic wastewater and reduction of the organic wastewater concentration.
Calculation of GHG emission reduction	**[Calculation method]** Since amounts and concentration of wastewater are reduced, GHG emissions are reduced. Source of Equations: ACM0014 “Avoided methane emissions from wastewater treatment” **[Equations]** **Without the activity** $BE_{without} = Q_{BOD,\ without,\ y} \times P_{BOD,\ without,\ y} \times B_0 \times MCF_p$ Where : $Q_{BOD,\ without,\ y}$ = Amount of wastewater (m^3/year) $P_{BOD,\ without,\ y}$ = Chemical Oxygen Demand (COD) of wastewater ($tCOD/m^3$) or Biochemical Oxygen Demand (BOD) of wastewater ($tBOD/m^3$) B_0 = Maximum methane producing capacity = 0.60 ($kgCH_4/kgBOD$) = 0.25 ($kgCH_4/kgCOD$) MCF_p = Methane conversion factor (fraction) (MCF_p of without the activity = MCF_p of with the activity) **With the activity** $PE_{with} = Q_{BOD,\ with,\ y} \times P_{BOD,\ with,\ y} \times B_0 \times MCF_p$ Where : $Q_{BOD,\ with,\ y}$ = Amount of wastewater (m^3/year) $P_{BOD,\ with,\ y}$ = Chemical Oxygen Demand (COD) of wastewater ($tCOD/m^3$) or Biochemical Oxygen Demand (BOD) of wastewater ($tBOD/m^3$)

<table>
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B_0 = Maximum methane producing capacity
= 0.60 ($kgCH_4/kgBOD$)
= 0.25 ($kgCH_4/kgCOD$)
MCF_p = Methane conversion factor (fraction) (MCF_p of without the activity = MCF_p of with the activity)

<u>GHG emission reductions</u>
GHG emission reductions (ER) of cleaner production (reduction in the quantity of organic wastewater) is determined using the following equation :
$ER = BE_{without} - PE_{with}$
</td>
</tr>
<tr>
<td>Required data and data source</td>
<td>
(1) Data requiring field investigation
Data obtained through field investigation or reports are as indicated in Table 1. “Number of employees of factory or institutions” and “Amount of production of factory” are parameters contributing directly to the amount of wastewater.

Table 1 Data, source of data and data acquisition method
<table>
<tr><th>Data</th><th>Source of data</th><th>Data acquisition method</th></tr>
<tr><td>Concentration of wastewater before introduction of cleaner production</td><td rowspan="4">Designing specification of the facilities.</td><td rowspan="4">Final report or the values of existing similar facilities</td></tr>
<tr><td>Amount of wastewater before introduction of cleaner production</td></tr>
<tr><td>Concentration of wastewater after introduction of cleaner production</td></tr>
<tr><td>Amount of wastewater after introduction of cleaner production</td></tr>
<tr><td>Number of employees of factory or institutions, etc.</td><td rowspan="2">Field investigation</td><td rowspan="2">Reports about the factory.</td></tr>
<tr><td>Amount of production of factory</td></tr>
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<tr>
<td>Preconditions</td>
<td>
This quantification method is applied when cleaner production results in the amounts and concentration of wastewater being reduced. The examples of these cleaner production methods are envisaged as follows;
➢ Change of raw materials
➢ Management, improvement and change of devices and equipment
➢ Change of production methods
➢ Recycling of wastewater
</td>
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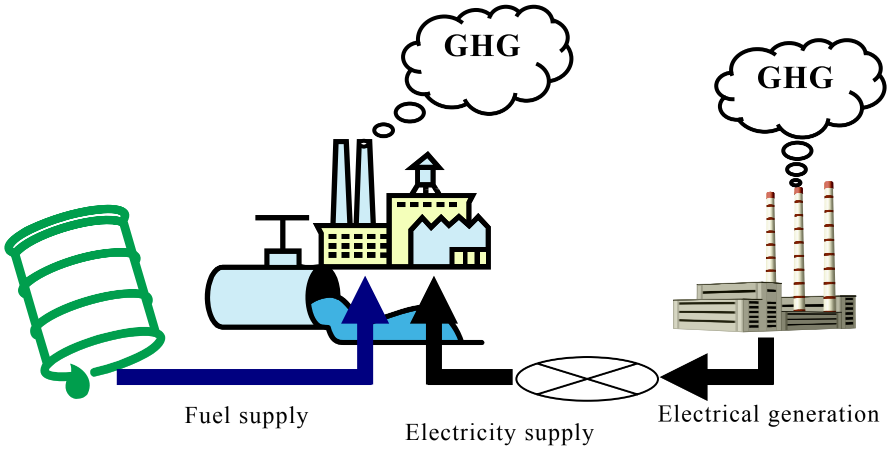
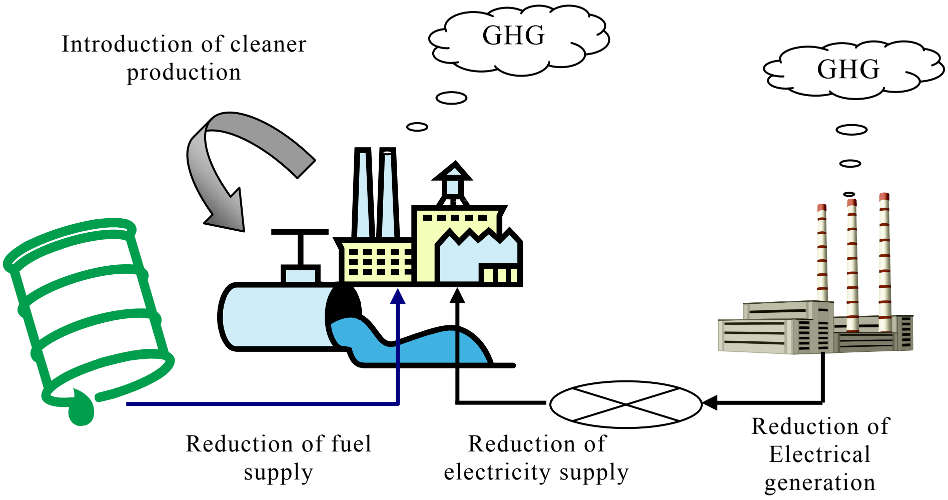
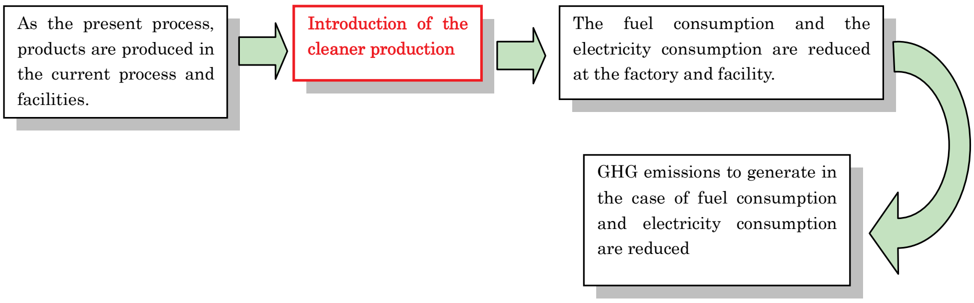
<tr>
<td>Special notes</td>
<td>In the introduction of cleaner production in the sector of water pollution control, it is assumed that it is difficult to grasp the amounts of wastewater reduction and concentration of wastewater concretely.</td>
</tr>
</table>

Quantification Sheet

Activity: Water Pollution Control or Air Pollution Control (Cleaner Production (Reductions of Electrical Consumption or Reductions of Fossil Fuel Consumption))

Sector	Environmental Management
Sub-sector	Water Pollution Control (Measures regarding Industrial/ Commercial Organic Wastewater) Air Pollution Control (Measures for a Stationary Emission Source)
GHG emission reduction activity	When cleaner production is carried out fuel consumption and electrical consumption are reduced thereby reducing GHG emissions.
GHG emission reduction impact	[✓ 1: Activity will lead to GHG emission reduction] 2: Activity will lead to GHG emission reduction subject to condition(s) 3: Activity will not lead to GHG emission reduction
GHG emission reduction scenarios (description of how GHG is reduced)	**<Without the activity>** There is a situation that the fuel consumption and the electrical consumption are large.  **<With the activity>** The fuel consumption and the electrical consumption are reduced by the introduction of cleaner production. 

	[Schematics of GHG emission reduction process] 
Calculation of GHG emission reduction	**[Calculation method]** Since the fuel consumption and the electrical consumption are reduced, GHG emissions from business activities are reduced. Source of Equations : Tool to calculate emissions of CDM ”Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion” Source of Equations : Tool to calculate emissions of CDM ”Tool to calculate baseline, project and/or leakage emissions from electricity consumption” **[Equations]** **Without the activity** $BE_{without} = EC_{FC} \times EF_{FF} + EC_{EL} \times EF_{EL}$ Where : EC_{FC} = Is the amount of fossil fuel consumption before the introduction of cleaner production in year y (kJ or TOE / year) EF_{FF} = Is the CO_2 emission factor of the fossil fuel ($kgCO_2/kJ$) EC_{EL} = Is the amount of electrical consumption from the grid before the introduction of cleaner production in the year y (kWh / year) EF_{EL} = Is the CO_2 emission factor for electricity generation in the year y ($kgCO_2/kWh$) **With the activity** $PE_{with} = EC_{FC} \times EF_{FF} + EC_{EL} \times EF_{EL}$ Where : EC_{FC} = Is the amount of fossil fuel consumption after the introduction of cleaner production in year y (kJ or TOE / year) EF_{FF} = Is the CO_2 emission factor of the fossil fuel ($kgCO_2/kJ$) EC_{EL} = Is the amount of electrical consumption from the grid after the introduction of cleaner production in the year y (kWh / year) EF_{EL} = Is the CO_2 emission factor for electricity generation in the year y ($kgCO_2/kWh$)

GHG emission reductions

GHG emission reductions (ER) of cleaner production (reduction of electrical consumption or reduction of fossil fuel consumption) are found using the following equation :

$ER = BE_{without} - PE_{with}$

Required data and data source

(1) Data requiring field investigation

Data obtained through field investigation or reports are as indicated in Table 1. “Number of employees of factory or institutions” and “Amount of production of factory” are parameters contributing directly to the amounts of fuel consumption and electrical consumption.

Table 1 Data, source of data and data acquisition method

Data	Source of data	Data acquisition method
Amount of fuel consumption before introduction of cleaner production	Designing specification of the facilities.	Final report or the values of the existing similar facilities
Amount of electrical consumption before introduction of cleaner production		
Amount of fuel consumption after introduction of cleaner production		
Amount of electrical consumption after introduction of cleaner production		
Number of employees of factory or institutions, etc.	Field investigation	Reports about the factory.
Amount of production of factory		

(2) Parameters to be selected from the existing parameters

EF_{FF} : CO_2 emission factor of the fossil fuel consumption ($kgCO_2/kJ$)

Refer to ***Annex 2***.

EF_{EL} : CO_2 emission factor for electrical consumption ($kgCO_2/kWh$)

Refer to ***Annex 1***.

Preconditions

When cleaner production is carried out so that fuel consumption is reduced, this quantification method can be applied.

Examples of cleaner production that could impact the water pollution control sector are as follows;

- Change of raw materials
- Management improvement and change of devices and equipment
- Change of production methods
- Recycling of wastewater

Examples of cleaner production that could impact the air pollution control sector are envisaged as follows;

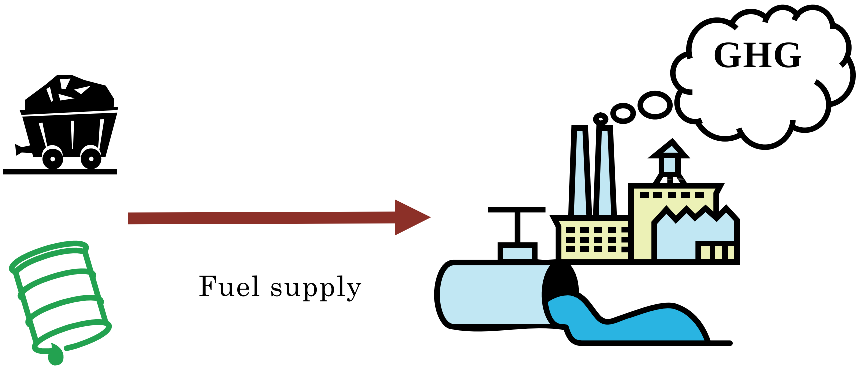
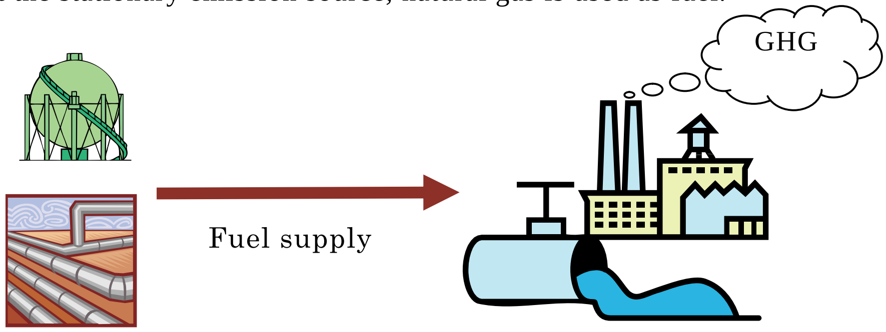
- NO_x Emission Reduction by Use of Low NO_x Burners
- Energy Efficiency Due to Improved Heavy Oil Burners

	➢ Introduction of Waste Heat Recovery ➢ Introduction of Energy saving process/equipment, etc.
Special notes	In introduction of cleaner production, it is assumed that it is difficult to grasp concrete amounts of fuel consumption reductions and amounts of electrical consumption reductions.

Quantification Sheet

Activity: Air Pollution Control

(Introduction of the Fuel Shift in the Stationary Emission Source)

Sector	Environmental Management
Sub-sector	Air Pollution Control (Measures for the Stationary Emission Source)
GHG emission reduction activity	At the stationary emission source, GHG emission reduction activity is the fuel shift from coal or heavy oil to natural gas.
GHG emission reduction impact	1: Activity will lead to GHG emission reduction 2: Activity will lead to GHG emission reduction subject to condition(s) 3: Activity will not lead to GHG emission reduction
GHG emission reduction scenarios (description of how GHG is reduced)	**<Without the activity>** At the stationary emission source, coal or heavy oil, etc. are used as fuel.  **<With the activity>** At the stationary emission source, natural gas is used as fuel.  **[Schematics of GHG emission reduction process]** At the stationary emission source such as boiler, coal or heavy oil are used. → At the stationary emission source such as boiler, natural gas is used. (fuel shift) → CO2 emissions per net calorific value are reduced. CO2 emissions are reduced even if the net calorific values (the activities) are the same.

<table>
<tr>
<td>Calculation of GHG emission reduction</td>
<td>

[Calculation method]

By the fuel shift (change from high-carbon fuel to low-carbon fuel), GHG emissions from business activities are reduced.

Source of Equations: ACM0009" Consolidated methodology for industrial fuel switching from coal or petroleum fuels to natural gas" and AMS-III.B. "Switching fossil fuels"

[Equations]

Without the activity

$BE_{without} = EC_{FC} \times EF_{FF}$

Where :

EC_{FC} = Is the fossil fuel consumption without the activity in year y (kJ or TOE / year)

EF_{FF} = Is the CO_2 emission factor of the fossil fuel ($kgCO_2/kJ$)

With the activity

$PE_{with} = EC_{FC} \times EF_{FF}$

Where :

EC_{FC} = Natural gas consumption with the activity in year y (kJ or TOE / year)

EF_{FF} = CO_2 emission factor of the natural gas ($kgCO_2/kJ$)

GHG emission reductions

GHG emission reductions (ER) of introduction of the fuel shift in the stationary emission source are determined using the following equation :

$ER = BE_{without} - PE_{with}$

</td>
</tr>
<tr>
<td>Required data and data source</td>
<td>

(1) Data requiring field investigation

Data obtained through field investigations or reports are as indicated in Table 1. "Number of employees of commerce and institutions" and "Amount of production of the factory" are parameters which contribute directly to the factory's energy consumption.

Table 1 Data, source of data and data acquisition method

<table>
<tr><th>Data</th><th>Source of data</th><th>Data acquisition method</th></tr>
<tr><td>Fuel consumption such as coal, heavy oil, natural gas and so on.</td><td>Designing specification of the facilities Field investigation</td><td>Final reports or the values of existing similar facilities</td></tr>
<tr><td>Number of employees of commerce and institutions</td><td rowspan="2">Field investigation</td><td rowspan="2">Reports and investigations regarding the institution</td></tr>
<tr><td>Amount of production of factory</td></tr>
</table>

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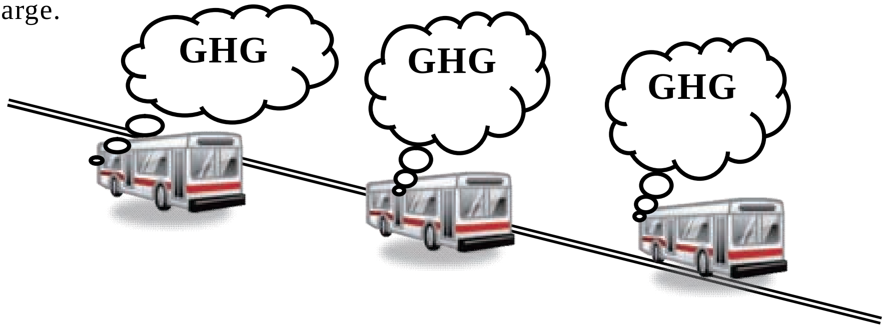
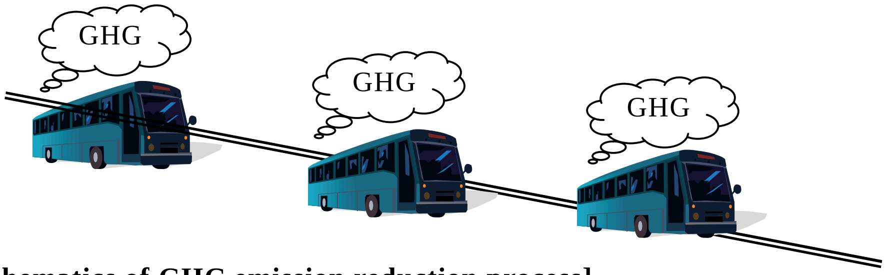
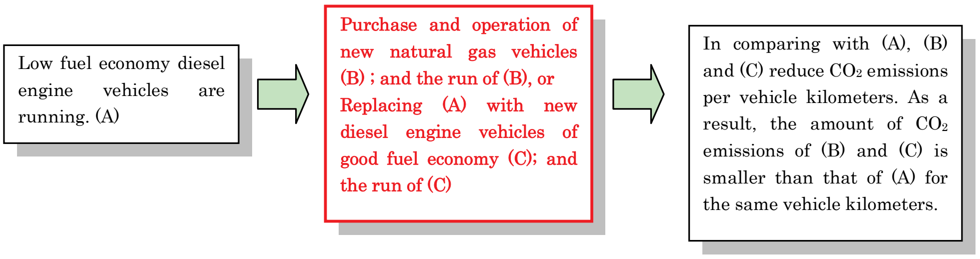
</table>

	(2) Parameters to be selected from the existing parameters EF_{FF} : CO_2 emission factor of the fossil fuel consumption ($kgCO_2/kJ$) Refer to ***Annex 2***.
Preconditions	The fuel consumptions on the basis of net calorific value (activity) of “Without the activity” and “With the activity” are the same. The fuel consumption of the net calorific value conversion of "Without the activity" and "With the activity" is equal. It is assumed that the net calorific value is a value specific to each project (specific to each country). However, the default value in 2006 IPCC Guideline for national greenhouse gas inventories is considered to be applicable. The GHG emission factors are the default value in 2006 IPCC Guideline for national greenhouse gas inventories.
Special notes	In the air pollution control sector, evaluation is based on the reduction of emissions of SO_2, NO_2, etc., and so it is necessary to calculate the fuel consumption in terms of the emission factors for SO_2, NO_2, etc.

Quantification Sheet

Activity: Air Pollution Control

(Purchase New NG Urban Buses or Replace old Urban Buses with New Diesel Buses)

Sector	Environmental Management
Sub-sector	Air Pollution Control (Measures regarding the mobile emission source)
GHG emission reduction activity	Fuel shift from old diesel engine vehicles of bad fuel economy to new natural gas vehicles Replacing old diesel engine vehicles of bad fuel economy with new diesel engine vehicles of good fuel economy
GHG emission reduction impact	[✓ 1: Activity will lead to GHG emission reduction] 2: Activity will lead to GHG emission reduction subject to condition(s) 3: Activity will not lead to GHG emission reduction
GHG emission reduction scenarios (description of how GHG is reduced)	**<Without the activity>** Diesel engines vehicles (buses) of old type are running. GHG emissions are large.  **<With the activity>** Natural gas vehicles (buses) or diesel engine vehicles (buses) with improved fuel efficiency are running. GHG emissions are small.  **[Schematics of GHG emission reduction process]**  Low fuel economy diesel engine vehicles are running. (A) Purchase and operation of new natural gas vehicles (B) ; and the run of (B), or Replacing (A) with new diesel engine vehicles of good fuel economy (C); and the run of (C) In comparing with (A), (B) and (C) reduce CO_2 emissions per vehicle kilometers. As a result, the amount of CO_2 emissions of (B) and (C) is smaller than that of (A) for the same vehicle kilometers.

Calculation of GHG emission reduction	**[Calculation method]** By the fuel shift in vehicles, GHG emissions from running the vehicles are reduced. Source of Equations: use the same equations as for the improvement of the road network in the transportation traffic sector (national level). Refer to ***Annex 3***. **[Equations]** **Without the activity** $BE_{without}$ = vehicle kilometres × fuel efficiency (A) × CO_2 emission factor (Diesel) (= the amount of fossil fuel consumption (a) × CO_2 emission factor (Diesel)) $BE_{without} = EC_{FC} \times EF_{FF}$ ・・・・equation-1 Where : EC_{FC} = amount of fossil fuel consumption of the object vehicle without the activity in year y (kJ or TOE / year) EF_{FF} = CO_2 emission factor of the fossil fuel (Diesel) ($kgCO_2/kJ$) **With the activity** PE_{with} = Vehicle kilometres × fuel efficiency (B) × CO_2 emission factor (Natural gas) (= the amount of fossil fuel consumption (b) × CO_2 emission factor (Natural gas)) $PE_{with} = EC_{FC} \times EF_{FF}$ ・・・・equation-2 Where : EC_{FC} = amount of fossil fuel (Natural Gas) consumption of the object vehicle with the activity in year y (kJ or TOE / year) EF_{FF} = CO_2 emission factor of the fossil fuel (Natural Gas) ($kgCO_2/kJ$) PE_{with} = Vehicle kilometres × fuel efficiency (C) × CO_2 emission factor (Diesel) (= the amount of fossil fuel consumption (c) × CO_2 emission factor (Diesel)) $PE_{with} = EC_{FC} \times EF_{FF}$ ・・・・equation-3

Where :

EC_{FC} = amount of fossil fuel (Diesel) consumption of the object vehicle with the activity in year y (kJ or TOE / year)

EF_{FF} = CO_2 emission factor of the fossil fuel (Diesel)($kgCO_2/kJ$)

GHG emission reductions

GHG emission reductions (ER) due to purchasing of new NG urban buses or replacing old urban buses with new diesel buses are determined using the following equation :

$ER = BE_{without} - PE_{with}$ = equation-1 - equation-2 (Purchase of new NG urban buses)

$ER = BE_{without} - PE_{with}$ = equation-1 - equation-3 (Replace old urban buses with new diesel buses)

Required data and data source

(1) Data requiring field investigation

Data obtained through field investigations or reports are as indicated in Table 1. The number of bus users is a parameter which contributes directly to the vehicle kilometres.

Table 1 Data, source of data and data acquisition method

Data	Source of data	Data acquisition method
Vehicle kilometres	Designing specification of the facilities.	Final report or the values of existing similar facilities
Fuel efficiency by fuel type, vehicle type, road type; Fuel efficiency (A), Fuel efficiency (B), Fuel efficiency (C)		
The amount of fuel consumption for the target vehicles; The amount of fuel consumption (a), The amount of fuel consumption (b), The amount of fuel consumption (c)		
The number of bus users	Field investigation or statistics of the target country	Reports about the facilities or on the web.

(2) Parameters to be selected from the existing parameters

EF_{FF} : CO_2 emission factor of the fossil fuel consumption ($kgCO_2/kJ$)

Refer to ***Annex 2***.

Fuel efficiency and vehicle kilometres travelled

Refer to ***Annex 3***.

Preconditions

Data of vehicle kilometres for "without the activity" and "with the activity" are the same. In addition, these data are original values for each project.

For the values such as fuel efficiency (A), fuel efficiency (B) and fuel efficiency (C), these values are assumed to be unique for each project, but the actual values in Japan are considered to be applicable. Especially, fuel

	efficiency (A) of "without the activity" is preferably a value specific to each project. The GHG emission factors are the default value in 2006 IPCC Guideline for national greenhouse gas inventories.
Special notes	In the air pollution control sector, evaluation is based on the reduction of emissions of SO_2, NO_2, etc., and so it is necessary to calculate the fuel consumption in terms of the emission factors for SO_2, NO_2, etc. The GHG emissions calculation is made using the same equation as used in the NO_x emissions and PM emissions for vehicles in the following manuals for air pollution control. Therefore, if NO_x emissions or PM emissions from vehicles are calculated, it is assumed that calculation of the GHG emissions will be relatively easy. Source of Equations: CO_2 emissions can be estimated by changing the NO_x emission factor in the equation for calculation of NO_x emissions from vehicles to the CO_2 emission factor on page 144 of "Manual of Total Emission of Nitrogen Oxides Regulations [Revised Edition] – Pollution Research and Measure Centre". Source of Equations: CO_2 emissions can also be estimated by changing the particulate matter emission factor in the equation for calculation of particulate matter emissions from vehicles to the CO_2 emission factor on page 116 of "The pollution prediction manual of SPM –Ministry of Environment, Environment Maintenance Bureau".
Calculation example	The GHG reduction effect of replacement of diesel busses with new natural gas vehicles (buses) in the "The acid deposition control strategy in the kingdom of Thailand" was estimated. In the Bangkok Metropolitan Region (BMR), the measure for SO_x and NO_x emission reduction through replacement of diesel buses with natural gas buses is presented. In this case, the GHG emission reduction can be calculated as follows: The scenario and action plan are as shown in Table 1.

Table 1 Scenario and Action Plan

	Scenario	Action Plan
NG1	New Natural Gas Urban Buses should be purchased instead of conventional diesel ones	17,500 diesel busses will be switched to natural gas buses from 2004 to 2011.
NG2	Over aged Urban Buses (over 10 years) should be replaced with New Natural Gas ones.	

According to the final report, the specific replacement schedule is as shown in Table 2. The numbers of busses replaced in each year is estimated from the replacement schedule are shown in Table 3.

Table 2 Replacement Schedule of Natural Gas Buses

	2004	2005	2006	2007	2008
NG1	300	600	900	700	900
NG2	500	600	800	1,000	1,200

	2009	2010	2011	Total
NG1	1,000	700	1,000	6,100
NG2	1,700	2,300	3,300	11,400

Source: Table 9.5.2.4 on page 9-42 of Main Report

Table 3 Secular change of the total number of introduced natural gas buses

	2004	2005	2006	2007
NG1	300	900	1,800	2,500
NG2	500	1,100	1,900	2,900

	2008	2009	2010	2011
NG1	3,400	4,400	5,100	6,100
NG2	4,100	5,800	8,100	11,400

Note: Calculation from the values of Table 2

The fuel consumption data is reported based on the operation status of bus sectors as shown in Table 4.

Table 4 Operation of Bangkok Metropolitan Transit Authority (BMTA) and Private Bus Companies

Items	Unit	Data	Source
Service	km/year	324,197,986	BMTA 2001 Annual Report
	km/day	888,762	ditto
	km/bus/day	259	ditto
Fuel Consumption	litre/year	153,073,668	ditto
	litre/day	419,380	ditto
	litre/bus/day	123	ditto
	km/litre	2.10	ditto
Natural Gas	litre/year	2,265,901	ditto
	litre/day	6,208	ditto
	litre/bus/day	178	ditto
	km/litre	1.58	ditto

Source: Table 7.1.1.3 on page 7-5 of Supporting Report

The emission factors are organized as shown in Table 5. Calculation of the emission factor for natural gas buses is on the basis of LNG (Liquefied Natural Gas). It is considered that many natural gas buses use CNG (Compressed Natural Gas). In the report, there is no description about it. Also, there is no description about emission factors. Therefore, the emission factors as shown in Table 5 are assumed.

If any similar project is implemented in the future, it is preferable that the contents and definitions of table 4 and table 5 are written clearly.

Table 5 Calculation data including emission factors

	Emission Factor	Net Calorific Value	Density
Diesel	74,100(kgCO_2/TJ)	43.0(TJ/kg)	0.8(kg/Nm^3)
Natural gas	56,100(kgCO_2/TJ)	48.0(TJ/kg)	0.456(kg/Nm^3)
Source	2006 IPCC Guideline for national greenhouse gas inventories		

Source of density; Diesel: page 183 of "New Technology and Law of the Control of Pollution 2006- Japan Environmental Management Association for Industry"

Source of density; Natural Gas: on the web-site of Tokyo Gas Co., Ltd. (Malaysian LNG)
http://www.tokyo-gas.co.jp/encyclopedia/article/article_01.php

The GHG emissions from the old diesel buses are shown in Table 6 ("Without the activity"), the GHG emissions from the introduced natural gas buses are shown in Table 7 ("With the activity") and the GHG emission reductions are shown in Table 8.

Emissions from old diesel buses: $BE_{without}$ = Total number of replaced buses × Fuel Consumption (litre/bus/day) × 365 (year/day) × 43.0 (MJ/kg) × 0.8 (kg/Nm^3) / 1,000,000(TJ/MJ) × 74,100(kgCO_2/TJ)/1,000(t/kg)

Table 6 Without the activity: GHG emissions from old diesel buses

Unit: (tCO_2/yr)

	2004	2005	2006	2007	2008
NG1	34,308	68,691	102,999	80,102	102,999
NG2	57,205	68,691	91,588	114,410	137,307
Total	91,513	137,382	194,587	194,512	240,306

	2009	2010	2011	Total
NG1	114,410	80,102	114,410	698,021
NG2	194,513	263,203	377,614	1,304,531
Total	308,923	343,305	492,024	2,002,552

Emissions from natural gas busses: PE_{with} = Total number of replaced buses × Natural Gas (litre/bus/day) × 365 (year/day) × 48.0 (MJ/kg) × 0.456 (kg/Nm^3) / 1,000,000 (TJ/MJ) × 56,100 (kgCO_2/TJ) / 1,000 (t/kg)

Table 7 With the activity: GHG emissions from introduced natural gas buses

Unit: (tCO_2/yr)

	2004	2005	2006	2007	2008
NG1	23,955	47,853	71,808	55,820	71,808
NG2	39,887	47,853	63,842	79,774	95,707
Total	63,842	95,706	135,650	135,594	167,515

	2009	2010	2011	Total
NG1	79,774	55,820	79,774	486,612
NG2	135,650	183,503	263,277	909,493
Total	215,424	239,323	343,051	1,396,105

Table 8 Calculation result of GHG emission reduction by introduction of natural gas buses

Unit: (tCO_2/yr)

	2004	2005	2006	2007	2008	2009	2010	2011	Total
NG1	10,353	20,838	31,191	24,282	31,191	34,636	24,282	34,636	211,409
NG2	17,318	20,838	27,746	34,636	41,600	58,863	79,700	114,337	395,038
Total	27,671	41,676	58,937	58,918	72,791	93,499	103,982	148,973	606,447

At a result, the GHG emission reductions from 2004 to 2011 will be **ER = 27,671 to 148,973 (tCO_2/year).** The total for 8 years is 606,447 (tCO_2/8year). After 2011, 17,500 diesel busses in total will be replaced with natural gas buses, and the GHG emissions can be expected to be reduced by **ER = 148,973(tCO_2/year)** each year.

3.3.5 Case Study

№	Project Title	Sector
5	The Study on Sewerage System Development in the Syrian Arab Republic	Environmental Management
6	The Study on Integrated Solid Waste Management Plan in Santo Domingo de Guzman, National District Dominican Republic	Environmental Management
7	The Acid Deposition Control Strategy in the Kingdom of Thailand	Environmental Management

Case study No.	5
Project title	The Study on Sewerage System Development in the Syrian Arab Republic
Sector	Environmental Management
Sub-sector	Water Pollution Control
Project summary	**[BACKGROUND]** A large percentage of the land of Syrian Arab Republic is comprised of desert plateaus with elevations ranging from 200 m to 1,000 m. Owing mainly to the small precipitation, water resources in the country are scarce. The situation is aggravated by industrialization and the rapid population inflow from rural areas resulting in water shortages in the urban areas. The development of a sewerage system has just been launched in the Syrian Republic. Presently, only the four major cities with large populations, Damascus, Aleppo, Homs and Hama, have sewage treatment facilities. Many other cities are not equipped with basic sewage treatment facilities, thereby causing aggravation in the daily living conditions of the populace, including the worsening state of sanitation and of the environment in the area. In addition, there is a marked deterioration of ground water and dam water for water supply, which resulted in the closing of wells and the suspension of intake from the dam water. The problem in groundwater quality is coupled with the decrease in groundwater storage volume as stated in the Main Report. This is caused by inefficient water usage, leakage from water supply pipes, illegal well construction and illegal water pipe connections. This situation demands that systematic pipe replacement planning and legal enforcement to illegal users be done immediately. Raw industrial wastewater generated in establishments such as the olive oil factories is discharged into the rivers nearby, contributing to the overall water quality deterioration. The absence, therefore, of sewerage systems and sewage treatment facilities has a direct link in accelerating even the water source shortage. The Syrian Government is tackling water environmental problem. Actions are mainly led by the Ministry of Housing and Construction (MHC) and the Ministry of Local Administration and Environment (MLAE). With achievement of nearly 100% of water supply service ratio, the Government is planning to develop sewerage systems and sewage treatment facilities aimed at water pollution control, effective utilization of water sources and cost recovery in sewerage works. **[OBJECTIVES]** The main objectives are as follows: 1) Review of existing development plans in national sewerage sectors 2) Formulate Governorate Master Plan for prioritized area aimed at water pollution control and public hygiene improvement 3) Conduct the feasibility Study in Rural Damascus Governorate in cooperation with Syrian counterpart officers 4) Execute the Technical Transfer to Syrian counterpart officers in course of the study The study is divided into three phases, which corresponds to a particular target study area as described below: Phase-I : Examination on the current status of sewerage sector and preparation of improvement plan for the entire area of Syria Phase-II : Establishment of a Master Plan for prioritized areas (four Areas in seven Governorates – Rural Damascus, Dar'aa, Tartous, Lattakia, Raqqa, Deir-Ez-zor, Hassakeh) Phase-III : Undertake the Feasibility Study as a plot project for the selected site in Rural Damascus Governorate

[The outline before the project enforcement]

The development of a sewerage system has just been launched in the Syrian Republic. Presently, only the four major cities with large populations, Damascus, Aleppo, Homs and Hama, have sewage treatment facilities. Many other cities are not equipped with basic sewage treatment facilities, thereby causing aggravation in the daily living conditions of the populace, including the worsening state of sanitation and of the environment in the area. In addition, there is a marked deterioration of ground water and dam water for water supply, which resulted in the closing of wells and the suspension of intake from the dam water. The problem in groundwater quality is coupled with the decrease in groundwater storage volume as stated in the Main Report. This is caused by inefficient water usage, leakage from water supply pipes, illegal well construction and illegal water pipe connections. This situation demands that systematic pipe replacement planning and legal enforcement to illegal users be done immediately.

Raw industrial wastewater generated in establishments such as the olive oil factories is discharged into the rivers nearby, contributing to the overall water quality deterioration. The absence, therefore, of sewerage systems and sewage treatment facilities has a direct link in accelerating even the water source shortage.

[The outline after the project enforcement]

Development of the Master plan and feasibility study were carried out by the JICA study team.

GHG emission reduction scenarios

There is the situation that wastewater of the sewered areas is untreated and discharged into lagoons, small rivers, etc.

Equations to calculate GHG emissions

Calculation formula list for GHG emissions is shown in Table 1.

Table 1 Calculation formula list for GHG emission

Component	Element	Note
Without the activity	Wastewater treatment	$PE_{CH4, w, y} = B_0 \times MCF_p \times Q_{COD, y} \times P_{COD, y}$ MCF_p: 0.5 (It is assumed that this is an "Untreated system")
Wastewater Treatment (Aerobic treatment process)	Electrical consumption	Electrical consumption × CO_2 emission factor
	Fossil fuel consumption	Fossil fuel consumption × CO_2 emission factor
	Wastewater treatment	$PE_{CH4, w, y} = B_0 \times MCF_p \times Q_{COD, y} \times P_{COD, y} = 0$ Since it is assumed that MCF_p is 0.0, so, $PE_{CH4, w, y}$ is 0.
Wastewater Treatment (Anaerobic treatment process)	Electrical consumption	Electrical consumption × CO_2 emission factor
	Fossil fuel consumption	Fossil fuel consumption × CO_2 emission factor
	Wastewater treatment	$PE_{CH4, w, y} = B_0 \times MCF_p \times Q_{COD, y} \times P_{COD, y} = M_{a, y}$: It is assumed that the total emission of CH_4 is collected. MCF_p: 0.8 (Assumption)
	Anaerobic digestion	Total emissions of CH_4 produced by the digester ($M_{a, y}$) × physical leakage factor Total emissions of CH_4 and N_2O from stacks
Sludge Disposal Treatment	Electrical consumption	Electrical consumption × CO_2 emission factor
	Fossil fuel consumption	Fossil fuel consumption × CO_2 emission factor
	Sludge disposal treatment	$PE_{s, y} = S_y \times DOC_{y, s} \times MCF_{ys} \times DOC_F \times F \times 16/12 \times GWP_{CH4}$ (=Amount of compost × GHG emission factor)

Applied data

According to the sewerage development plans of Thawra, data such as population and sewage flow are shown as Table2.

Table 2 Planning Parameters of Thawra

Item		Unit	2004	2010	2015	2020	2025
	Population	Person	69,425	80,300	90,700	102,400	115,600
Per capita wastewater	Daily average	LCD	129	135	142	148	155
	Daily max	LCD	150	157	165	172	180
	Peak hourly	L/capita /hour	250	262	275	287	300
Summer/Winter		%	100	100	100	100	100
Total wastewater Generated	Daily average	m^3/day	8,953	10,873	12,866	15,186	17,889
	Daily max	m^3/day	10,397	12,627	14,942	17,636	20,775
	Peak hourly	m^3/hour	17,328	21,045	24,903	29,393	34,625

Note: LCD = Litre per capita per day

Incoming sewage quality and effluent standards are shown as Table 3.

Table 3 Incoming Sewage Quality and Effluent Standards

	effluent stream	Influent quality and effluent standard					
		BOD	SS	NH_3-N	NO_3-N	T-N	T-P
Influent		310	360			74	24
Effluent Standard	Proposed effluent standard	40	30	5	50		

The conditions considered for Planning and specifications of proposed facilities are list in Table 4.

Table 4 Summary of Conditions and Proposed Facilities

Items	Contents
Population	115,600
Daily Average Sewage Flow (m^3/day)	17,889
Hourly Maximum Sewage Flow (m^3/day)	34,625
Sludge (kgDS/day)	2,361
Sludge (m^3/day)	5.9
Moisture content (%)	60
Treatment processes	Existing Wet-land + Primary Setting Tank + Drying Bed
Grit chamber (No. – w × D)	2 – 1.3m×7.5m
Main P (No. – D × power)	5 – ϕ250mm×11kW
Primary Settling Tank	4 –ϕ10
Drying Bed	20 – 15m×32m
Required land area (ha)	2.4

Calculation of GHG emissions

Without the activity

$BE_{without} = Q_{BOD,\,y} \times P_{BOD,\,y} \times B_0 \times MCF_p$ = 607 (tCH_4/year) = **12,752 (tCO_2/year)**

$Q_{BOD,\,y}$ = 17,889(m^3/day) × 365 = 6,529,485(m^3/year): Amounts of wastewater (Daily average sewage flow is used.)

$P_{BOD,\,y}$ = 310 (mg/l): BOD concentration (Influent quality is applied.)

B_0 = 0.60 (kgCH_4/kgBOD): Maximum CH_4 producing capacity

MCF_p = 0.5

With the activity

This project process is “Aerobic Wastewater Treatment + Drying Bed + Composting Process”.

Since the electrical consumption and the fossil fuel consumption of “Aerobic Wastewater Treatment + Drying Bed” are unknown, these items are not calculated.

$PE_{with} = PE_{with,\,w} + PE_{with,\,c}$(= wastewater treatment + composting process)

1) Wastewater treatment

$PE_{with,\,w} = B_0 \times MCF_p \times Q_{BOD,\,y} \times P_{BOD,\,y}$ = 364 (tCH_4/year) = **7,651 (tCO_2/year)**

$Q_{BOD,\,y}$ = 17,889(m^3/day) × 365 = 6,529,485(m^3/year): Amounts of wastewater (Daily average sewage flow is used.)

$P_{BOD,\,y}$ = 310 (mg/l): BOD concentration (Influent quality is applied.)

B_0 = 0.60 (kgCH_4/kgBOD): Maximum CH_4 producing capacity

MCF_p = 0.3 (Default value; it is assumed that this facility is not well managed and overloaded.)

< Sludge Disposal Process > (Aerobic process)

$PE_{s,\,y} = S_y \times DOC_{y,\,s} \times MCF_{ys} \times DOC_F \times F \times 16/12 \times GWP_{CH4}$

$= 861.8 \times 0.05 \times 0.8 \times 0.5 \times 0.5 \times 16/12 \times 21$ = **241 (tCO_2/year)**

Where:

$PE_{s,\,y}$ = CH_4 emissions from the anaerobic decay of the final sludge generated in the wastewater system in the year y (tCO_2/year).

S_y = Amount of sludge generated by the wastewater treatment in the year y (ton/year). = 2,361 (kgDS/day) × 365 (day/year) × 10^{-3} (ton/kg) = 861.8 (ton/year)

$DOC_{y,\,s}$ = Degradable organic content of the sludge generated by the wastewater treatment in the year y (fraction). IPDD default values = 0.05 (for domestic sludge; wet basis)

MCF_s = CH_4 correction factor of the landfill that receives the final sludge. = 0.8 (Unmanaged – deep (> 5m waste) and/or high waste table)

DOC_F = Fraction of DOC dissimilated to biogas (IPCC default value = 0.5).

F = Fraction of CH_4 in landfill gas (IPCC default value = 0.5).

GHG emission reductions

$ER = BE_{without} - PE_{with}$ = 12,752 – (7,651 + 241) = **4,860 (tCO_2/year)**

Preconditions	The electric consumption and fuel consumption in the “Aerobic Treatment (wastewater treatment) + Drying Bed (sludge disposal)” process are unknown and not estimated. If sludge is not composted but landfilled, the GHG emissions need to be estimated using the quantification method in “Solid Waste Management (Introduction of Semi-Aerobic Final disposal Sites)”.
Lessons learned from case study	The electrical consumption and fuel consumption of sewage treatment facilities needs to be determined. For the calculation of the CH_4 emissions, it is necessary that secular change of amount of sludge is determined. For the quantification of GHG emissions reduction, it is important to determine the value of MCFp "Without the activity". Therefore it is essential to do an investigation of the actual situation in order to grasp the wastewater treatment process "Without the activity".

Case study No.	6
Project title	The Study on Integrated Solid Waste Management Plan in Santo Domingo de Guzman, National District Dominican Republic
Sector	Environmental Management
Sub-sector	Solid Waste Management
Project summary	**[BACKGROUND]** The present situation of waste management in the Santo Domingo de Guzman, National District Dominican Republic is shown in Table-1.

Table 1 Present situation of Solid Waste Management

Solid Waste Management Component	Evaluation
Collection	Waste collection service is supposed to be provided in whole area of the city by the private contractor companies. However, the municipality by itself also operates its own service where the service seemed to be insufficient. A total of 31% of the citizens have to take their waste to a collection point because the collection trucks do not pass in front of their houses. The collection frequency is irregular. Although most of the city is covered with the collection service, it is not kept clean. Most of the citizens appreciate the current collection works. Improvement of the collection system should be given first priority among the issues regarding Solid Waste Management (SWM) in the National Direct.
Disposal	All waste collected in the National District is brought to the Duquesa landfill. Waste amount disposed is recorded by the weighbridge installed at the entrance of the landfill. The landfill does not have an impermeable liner and appropriate leachate treatment facility. The waste is covered with soil and gas extraction pipes are equipped. The contracted private company has a future operation plan. However, the indecisive situation regarding the airport and low tipping fee makes the company hesitate to invest. A consensus on the use or non-use of the Duquesa landfill among institutions concerned should be established in order to secure stable SWM in the future not only for the National District but also for other concerned municipalities.
Minimization	Official waste minimization activities have not been seen in the National District. The waste picking in the city causes waste scattering on the streets. The waste-pickers face to health risks. Environmental education regarding waste minimization is not widespread among the citizens so far.
Efficiency	Financial information of AND does not allow accurate estimating of the cost of the SWM. The collection works carried out by the private companies and the municipality overlap. The present data keeping system does not allow detailed diagnosis of efficiency of the SWM

[OBJECTIVES] The main objectives are as follows:

The objectives of study are shown in Table 2.

Table 2 Objectives of Study

To formulate an Integrated Solid Waste Management Plan setting 2015 as the target year, to understand, through the plan formulation process, the actual status of solid waste management conducted by ADN (National District Municipality), Dominican Republic, and to clarify the long-term measures for improvement of solid waste management.
To transfer technology and know-how on solid waste management to the counterpart personnel through joint work in the Master Plan formulation, so as to support the improvement of the ADN solid waste management capacity

[The outline after the project enforcement]

Development of Master plan and feasibility study were carried out by the JICA study team. The types of solid waste to be included in this Development Study are municipal waste and medical waste. Hazardous waste and construction debris will not be included in the Development Study but general recommendations will be made on the basis of existing information that can be collected. The following six strategies are recommended in order to attain the M/P Goals.

Table 3 Strategies and Action Plan

Strategies	Action Plan
1 : To establish legal infrastructure	Establishment of Basic Rule
2 : To strengthen the management organization	Strengthening of Coordination among Directorates of ADN Reform of the Urban Cleansing Department of EMUCD Establishment of Municipal Company
3 : To establish order in the collection service market	Categorization and Definition of Collection Services Design of Collection Services Structure Establishment of Collection Service Structure Establishment of Contract Auditing System Expansion of Collection Data Management Reform of AND Direct Operation Communication with Citizens
4 : To build a consensus among the municipalities in the Metropolitan Area	Improvement of the Current Disposal Operation Landfill Site Selection Construction and Operation of a New Transfer Station
5 : To begin the 3Rs and to apply the principle of Extended Producer Responsibility	Generation Control Discharge Control Resource Recovery
6 : To apply the Polluter Pay Principle, but to consider the poor	Increase of Income Reduction of Expenditures Subsidy to the Poor

The outline after the pilot project is shown in table 4.

Table 4 The outline after the pilot project

Solid Waste Management Component	Evaluation
Efficiency	97% of those interviewed said they feel very satisfied with the implementation of the plan to improve waste collection service. Generally 93% perceived that the quality of the collection service has improved. This has increased the tons collected by 11% with regard to the yields measured in time and movement. A Manual was elaborated for the Improvement of Collection. A Manual was elaborated for the Supervision of Service. Improvement of the sweeping service achieved covering of 100% of the considered area.
Environmental Education	The counterparts and the teachers fully understood the contents of the workshops. The trial lessons acquired a favourable reputation with the parents.

GHG emission reduction scenarios	**Without the activity** At final disposal sites, no sanitary management is conducted, and open dumping continues as it has been. (Some soil covering is applied and gas venting pipes are installed, but the degree of management is not clear, and it is assumed that they are nearly in a state of open dumping.) **With the activity** Final disposal sites will be Semi-aerobic and CH_4 emission will be reduced.
Equations to calculate GHG emissions	Emissions equation of "without the activity" and emissions equations of "with the activity" are as follows: $BE_{CH4,SWDS,y} = \varphi \times (1-f) \times GWP_{CH4} \times (1-OX) \times \frac{16}{12} \times F \times DOC_f \times MCF \times \sum_{x=1}^{y} \sum_{j}^{n} W_{j,x} \times DOC_j \times e^{-k_j(y-x)} \times (1-e^{-k_j})$ Where ; φ = Model correction factor to account for model uncertainties (=0.9) f = Fraction of methane captured as the SWDS and flared, combusted or used in another manner F = Fraction of methane in the SWDS gas (volume fraction) (=0.5) DOC_j = Fraction of degradable organic carbon (by weight) in the waste type j (This parameter needs investigation for each project. "2006 IPCC Guideline for National Greenhouse Gas Inventories" has a default value.) DOC_f = Fraction of degradable organic carbon (DOC) that can decompose (=0.5) MCF = Methane correction factor GWP_{CH4} = Global Warming Potential (GWP) of methane (=21) OX = Oxidation factor (reflecting the amount of methane from SWDS that is oxidized in the soil or other material covering the waste) $W_{j,x}$ = Amounts of organic waste type j prevented from disposal in the SWDS in the year x (ton) k_j = Decay rate for the waste type j j = Waste type category (index) x = Year during the crediting period: C runs from the first year of the first crediting period (x=1) to the year y for which avoided emissions are calculated (x=y) y = Year for which methane emissions are calculated The value used for calculations for of the each above parameters is summarized in table 5 and table 6. **[Equations]** **Without the activity** The amounts of CH_4 from the final disposal site "Without the activity" are as follows;

$$BE_{CH4,SWDS,y} = \varphi \times (1-f) \times GWP_{CH4} \times (1-OX) \times \frac{16}{12} \times F \times DOC_f$$
$$\times MCF \times \sum_{x=1}^{y}\sum_{j}^{n} W_{j,x} \times DOC_j \times e^{-k_j(y-x)} \times \left(1-e^{-k_j}\right)$$

Table 5 Parameters of “Without the activity“

Value of parameter	Notes
φ =0.9	Without the activity = With the activity
f = 0	Without the activity = With the activity
F= 0.5	Without the activity = With the activity
DOCj	Without the activity = With the activity
DOCf= 0.5	Without the activity = With the activity
MCF = 0.8	**Unmanaged – deep (> 5 m waste) (Because currently there is a great deal of accumulated waste)**
GWP_{CH4} = 21	Without the activity = With the activity
OX = 0.0	**Unmanaged and Uncategorised SWDS (Because Open Dumping is performed)**
Wj, x	Without the activity = With the activity
kj	Without the activity = With the activity
j	Without the activity = With the activity
x	Without the activity = With the activity
y	Without the activity = With the activity

With the activity

The amounts of CH_4 from the final disposal site “With the activity” are as follows;

$$PE_{CH4,SWDS,y} = \varphi \times (1-f) \times GWP_{CH4} \times (1-OX) \times \frac{16}{12} \times F \times DOC_f$$
$$\times MCF \times \sum_{x=1}^{y}\sum_{j}^{n} W_{j,x} \times DOC_j \times e^{-k_j(y-x)} \times \left(1-e^{-k_j}\right)$$

Table 6 Parameters of “With the activity”

Value of parameter	Notes
φ = 0.9	Without the activity = With the activity
f =0	Without the activity = With the activity
F=0.5	Without the activity = With the activity
DOC_j	Without the activity = With the activity
DOC_f= 0.5	Without the activity = With the activity
MCF = 0.5	**Managed – semi-aerobic**
GWP_{CH4} = 21	Without the activity = With the activity
OX = 0.1	**Managed covered with CH_4 Oxidising material**
Wj, x	Without the activity = With the activity
kj	Without the activity = With the activity
j	Without the activity = With the activity
x	Without the activity = With the activity
y	Without the activity = With the activity

GHG emission reductions

ER = BE – PE

Applied data

Master plan 1 supposes the continued use of the Duquesa final disposal site. Calculation results of this master plan 1 are shown below. The data of waste amount and physical composition were obtained from the final report.

Use Data

- ✓ Waste Amount of Plan

Table 7 Waste Amount of Master Plan 1 (unit: ton/year)

Service type	2007	2008	2009	2010	2011	2012	2013	2014	2015	total
Residential	438,320	451,381	450,505	456,071	461,646	460,936	456,224	453,677	449,383	4,078,142
Urban	315,590	324,994	324,364	328,371	332,385	331,874	328,481	326,647	323,555	2,936,262
Marginal	122,730	126,387	126,141	127,700	129,261	129,062	127,743	127,029	125,827	1,141,880
Big generators	26,337	27,122	27,069	27,403	27,738	27,696	27,413	27,260	27,002	245,039
Markets	32,733	33,708	33,643	34,059	34,475	34,422	34,070	33,880	33,559	304,548
Special service	3,762	3,875	3,867	3,915	3,963	3,957	3,916	3,894	3,857	35,006
Sweeping	30,099	30,996	30,936	31,318	31,701	31,652	31,329	31,154	30,859	280,044
Direct haulage	376	387	387	391	396	396	392	389	386	3,501
total	531,627	547,469	546,406	553,157	559,920	559,058	553,343	550,253	545,045	4,946,278

- ✓ Results of Physical Composition

Table 8 Physical Composition of Waste (Part 1)

Category	Low Income	Middle Income	High Income	Restaurant	Others
Kitchen Waste	51.2%	53.5%	45.7%	52.0%	7.7%
Paper	11.7%	16.9%	22.4%	25.3%	37.8%
Textile	3.0%	3.7%	5.4%	1.2%	17.4%
Grass/Wood/Bamboo	10.5%	5.9%	1.3%	2.3%	0.0%
Plastic	17.9%	8.4%	10.6%	10.3%	10.7%
Rubber/Leather	1.4%	0.0%	0.0%	0.1%	2.6%
Metal	1.9%	1.7%	3.1%	5.9%	9.8%
Bottle/Glass	2.4%	8.0%	8.3%	2.9%	10.7%
Soil/Store/Ceramics	0.0%	1.9%	3.2%	0.0%	3.3%
Others	0.0%	0.0%	0.0%	0.0%	0.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Table 9 Physical Composition of Waste (Part 2)

Category	Institutional	Market	Street Sweeping	Average (1)	Average (2)
Kitchen Waste	51.2%	53.5%	45.7%	37.0%	45.1%
Paper	11.7%	16.9%	22.4%	24.9%	20.6%
Textile	3.0%	3.7%	5.4%	7.2%	5.4%
Grass/Wood/Bamboo	10.5%	5.9%	1.3%	4.3%	4.7%
Plastic	17.9%	8.4%	10.6%	13.0%	11.9%
Rubber/Leather	1.4%	0.0%	0.0%	1.4%	0.7%
Metal	1.9%	1.7%	3.1%	5.9%	3.6%
Bottle/Glass	2.4%	8.0%	8.3%	5.3%	6.4%
Soil/Store/Ceramics	0.0%	1.9%	3.2%	1.1%	1.7%
Others	0.0%	0.0%	0.0%	0.0%	0.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Notes: The Average(1) is the average of “ Restaurant”, ” Others” and ” Institutional”.
The Average(2) is the average of all categories.

Furthermore, Table 10 shows per capita weighted average derived from the three types of income levels.

Table 10 Weighted Average per capita

Income Level	Population (%)	Generation Rate (g/person/day)	Weighted Average (g/person/day)	Weighted Average Rate (%)
High Income	10%	1,147.8	114.8	15%
Middle Income	30%	846.9	254.1	33%
Low Income	60%	681.2	408.7	53%
Total	-	-	777.6	

Calculation of GHG emissions

The physical composition of waste by service type was calculated as follows year by year.

The amounts of waste of "Residential (Urban)" and "Residential (Marginal)" of table 7 were allocated to "Weighted average per capita" of Table 10. This result is table 11.

Table 11 Secular change of waste amount by service type

Service type	2007	2008	2009	2010	2011	2012	2013	2014	2015	total
Urban High Income	46,592	47,980	47,887	48,479	49,071	48,996	48,495	48,224	47,768	433,491
Urban Middle Income	103,127	106,200	105,994	107,303	108,615	108,448	107,339	106,740	105,730	959,496
Urban Low Income	165,871	170,814	170,483	172,589	174,699	174,430	172,647	171,683	170,058	1,543,275
Marginal High Income	18,119	18,659	18,623	18,853	19,083	19,054	18,859	18,754	18,576	168,580
Marginal Middle Income	40,105	41,300	41,220	41,729	42,239	42,174	41,743	41,510	41,117	373,137
Marginal Low Income	64,506	66,428	66,299	67,118	67,938	67,834	67,141	66,765	66,134	600,162
Big generators	26,337	27,122	27,069	27,403	27,738	27,696	27,413	27,260	27,002	245,039
Markets	32,733	33,708	33,643	34,059	34,475	34,422	34,070	33,880	33,559	304,548
Special service	3,762	3,875	3,867	3,915	3,963	3,957	3,916	3,894	3,857	35,006
Sweeping	30,099	30,996	30,936	31,318	31,701	31,652	31,329	31,154	30,859	280,044
Direct haulage	376	387	387	391	396	396	392	389	386	3,501
total	531,627	547,469	546,406	553,157	559,920	559,058	553,343	550,253	545,045	4,946,278

With table 8, table 9 and table 11, the waste quantities by type are calculated for each generator category.

Table-12 - Table-14 show a breakdown of waste quantity and type according to the income level for years 2007-2015.

Table 12 Waste quantity and type for years 2007-2015 in the Low Income category

Low Income	2007	2008	2009	2010	2011	2012	2013	2014	2015	total
Kitchen Waste	117,953	121,468	121,232	122,730	124,230	124,039	122,771	122,085	120,930	1,097,438
Paper	26,954	27,757	27,703	28,046	28,389	28,345	28,055	27,898	27,634	250,781
Textile	6,911	7,117	7,103	7,191	7,279	7,268	7,194	7,153	7,086	64,302
Grass/Wood/Bamboo	24,190	24,910	24,862	25,169	25,477	25,438	25,178	25,037	24,800	225,061
Plastic	41,237	42,466	42,384	42,908	43,432	43,365	42,922	42,682	42,278	383,674
Rubber/Leather	3,225	3,321	3,315	3,356	3,397	3,392	3,357	3,338	3,307	30,008
Metal	4,377	4,508	4,499	4,554	4,610	4,603	4,556	4,531	4,488	40,726
Bottle/Glass	5,529	5,694	5,683	5,753	5,823	5,814	5,755	5,723	5,669	51,443
Soil/Store/Ceramics	0	0	0	0	0	0	0	0	0	0
Others	0	0	0	0	0	0	0	0	0	0
Total	230,376	237,241	236,781	239,707	242,637	242,264	239,788	238,447	236,192	2,143,433

Table 13 Waste quantity and type for years 2007-2015 in the Middle Income category

Middle Income	2007	2008	2009	2010	2011	2012	2013	2014	2015	total
Kitchen Waste	76,629	78,913	78,759	79,732	80,707	80,583	79,759	79,314	78,563	712,959
Paper	24,206	24,928	24,879	25,186	25,494	25,455	25,195	25,054	24,817	225,214
Textile	5,300	5,458	5,447	5,514	5,582	5,573	5,516	5,485	5,433	49,308
Grass/Wood/Bamboo	8,451	8,703	8,686	8,793	8,900	8,887	8,796	8,747	8,664	78,627
Plastic	12,031	12,390	12,366	12,519	12,672	12,652	12,523	12,453	12,335	111,941
Rubber/Leather	0	0	0	0	0	0	0	0	0	0
Metal	2,435	2,508	2,503	2,534	2,565	2,561	2,534	2,520	2,496	22,656
Bottle/Glass	11,459	11,800	11,777	11,923	12,068	12,050	11,927	11,860	11,748	106,612
Soil/Store/Ceramics	2,721	2,803	2,797	2,832	2,866	2,862	2,833	2,817	2,790	25,321
Others	0	0	0	0	0	0	0	0	0	0
Total	143,232	147,503	147,214	149,033	150,854	150,623	149,083	148,250	146,846	1,332,638

Table 14 Waste quantity and type for years 2007-2015 in the High Income category

High Income	2007	2008	2009	2010	2011	2012	2013	2014	2015	total
Kitchen Waste	29,573	30,454	30,395	30,771	31,146	31,099	30,781	30,609	30,319	275,147
Paper	14,495	14,927	14,898	15,082	15,266	15,243	15,087	15,003	14,861	134,862
Textile	3,494	3,599	3,592	3,636	3,680	3,675	3,637	3,617	3,583	32,513
Grass/Wood/Bamboo	841	866	865	875	886	885	876	871	862	7,827
Plastic	6,859	7,064	7,050	7,137	7,224	7,213	7,140	7,100	7,032	63,819
Rubber/Leather	0	0	0	0	0	0	0	0	0	0
Metal	2,006	2,066	2,062	2,087	2,113	2,110	2,088	2,076	2,057	18,665
Bottle/Glass	5,371	5,531	5,520	5,589	5,657	5,648	5,590	5,559	5,507	49,972
Soil/Store/Ceramics	2,071	2,132	2,128	2,155	2,181	2,178	2,155	2,143	2,123	19,266
Others	0	0	0	0	0	0	0	0	0	0
Total	64,710	66,639	66,510	67,332	68,153	68,051	67,354	66,978	66,344	602,071

Since there were not the data of the amount of waste corresponding to the big generators, Average (1) of table 9 is used.

Table 15 Waste quantity and type for years 2007-2015 in the Big Generator category

Big generators	2007	2008	2009	2010	2011	2012	2013	2014	2015	total
Kitchen Waste	9,737	10,027	10,007	10,131	10,255	10,239	10,135	10,078	9,983	90,592
Paper	6,566	6,762	6,748	6,832	6,915	6,905	6,834	6,796	6,732	61,090
Textile	1,896	1,953	1,949	1,973	1,997	1,994	1,974	1,963	1,944	17,643
Grass/Wood/Bamboo	1,125	1,158	1,156	1,170	1,184	1,183	1,171	1,164	1,153	10,464
Plastic	3,416	3,518	3,511	3,554	3,598	3,592	3,555	3,536	3,502	31,782
Rubber/Leather	361	372	371	375	380	379	376	373	370	3,357
Metal	1,546	1,592	1,589	1,609	1,628	1,626	1,609	1,600	1,585	14,384
Bottle/Glass	1,404	1,446	1,443	1,461	1,478	1,476	1,461	1,453	1,439	13,061
Soil/Store/Ceramics	290	298	298	301	305	305	302	300	297	2,696
Others	0	0	0	0	0	0	0	0	0	0
Total	26,341	27,126	27,072	27,406	27,740	27,699	27,417	27,263	27,005	245,069

Table 16 Waste quantity and type for years 2007-2015 in the Markets

Market	2007	2008	2009	2010	2011	2012	2013	2014	2015	total
Kitchen Waste	17,512	18,034	17,999	18,222	18,444	18,416	18,227	18,126	17,954	162,934
Paper	5,532	5,697	5,686	5,756	5,826	5,817	5,758	5,726	5,671	51,469
Textile	1,211	1,247	1,245	1,260	1,276	1,274	1,261	1,254	1,242	11,270
Grass/Wood/Bamboo	1,931	1,989	1,985	2,009	2,034	2,031	2,010	1,999	1,980	17,968
Plastic	2,750	2,831	2,826	2,861	2,896	2,891	2,862	2,846	2,819	25,582
Rubber/Leather	0	0	0	0	0	0	0	0	0	0
Metal	556	573	572	579	586	585	579	576	571	5,177
Bottle/Glass	2,619	2,697	2,691	2,725	2,758	2,754	2,726	2,710	2,685	24,365
Soil/Store/Ceramics	622	640	639	647	655	654	647	644	638	5,786
Others	0	0	0	0	0	0	0	0	0	0
Total	32,733	33,708	33,643	34,059	34,475	34,422	34,070	33,881	33,560	304,551

Table 17 Waste quantity and type for years 2007-2015 in the Street Sweeping category

Street Sweeping	2007	2008	2009	2010	2011	2012	2013	2014	2015	total
Kitchen Waste	13,755	14,165	14,138	14,312	14,487	14,465	14,317	14,237	14,103	127,979
Paper	6,742	6,943	6,930	7,015	7,101	7,090	7,018	6,978	6,912	62,729
Textile	1,625	1,674	1,671	1,691	1,712	1,709	1,692	1,682	1,666	15,122
Grass/Wood/Bamboo	391	403	402	407	412	411	407	405	401	3,639
Plastic	3,190	3,286	3,279	3,320	3,360	3,355	3,321	3,302	3,271	29,684
Rubber/Leather	0	0	0	0	0	0	0	0	0	0
Metal	933	961	959	971	983	981	971	966	957	8,682
Bottle/Glass	2,498	2,573	2,568	2,599	2,631	2,627	2,600	2,586	2,561	23,243
Soil/Store/Ceramics	963	992	990	1,002	1,014	1,013	1,003	997	987	8,961
Others	0	0	0	0	0	0	0	0	0	0
Total	30,097	30,997	30,937	31,317	31,700	31,651	31,329	31,153	30,858	280,039

Since special service targets waste generated by pruning activities, garden remains, construction debris, appliances and other devices, furniture generated from houses, it is considered that the waste type of this service is ”Grass/Wood/Bamboo”.

Table 18 Waste quantity and type for years 2007-2015 in the Special service category

Special service	2007	2008	2009	2010	2011	2012	2013	2014	2015	total
Kitchen Waste	0	0	0	0	0	0	0	0	0	0
Paper	0	0	0	0	0	0	0	0	0	0
Textile	0	0	0	0	0	0	0	0	0	0
Grass/Wood/Bamboo	3,762	3,875	3,867	3,915	3,963	3,957	3,916	3,894	3,857	35,006
Plastic	0	0	0	0	0	0	0	0	0	0
Rubber/Leather	0	0	0	0	0	0	0	0	0	0
Metal	0	0	0	0	0	0	0	0	0	0
Bottle/Glass	0	0	0	0	0	0	0	0	0	0
Soil/Store/Ceramics	0	0	0	0	0	0	0	0	0	0
Others	0	0	0	0	0	0	0	0	0	0
Total	3,762	3,875	3,867	3,915	3,963	3,957	3,916	3,894	3,857	35,006

According to the Direct haulage, Average(2) of Table 9 is used.

Table 19 Waste quantity and type for years 2007-2015 in the Direct haulage category

Direct haulage	2007	2008	2009	2010	2011	2012	2013	2014	2015	total
Kitchen Waste	169	174	174	176	178	178	177	175	174	1,575
Paper	78	80	80	81	82	82	81	80	80	724
Textile	20	21	21	21	21	21	21	21	21	188
Grass/Wood/Bamboo	18	18	18	18	19	19	18	18	18	164
Plastic	45	46	46	46	47	47	46	46	46	415
Rubber/Leather	3	3	3	3	3	3	3	3	3	27
Metal	14	14	14	14	14	14	14	14	14	126
Bottle/Glass	24	25	25	25	25	25	25	25	25	224
Soil/Store/Ceramics	6	7	7	7	7	7	7	7	7	62
Others	0	0	0	0	0	0	0	0	0	0
Total	377	388	388	391	396	396	392	389	388	3,505

Sum total of above Table are as follows;

Table 20 Total waste quantity and type for years 2007-2015 generated by all categories

Total	2007	2008	2009	2010	2011	2012	2013	2014	2015	total
Kitchen Waste	265,328	273,235	272,704	276,074	279,447	279,019	276,167	274,624	272,026	2,468,624
Paper	84,573	87,094	86,924	87,998	89,073	88,937	88,028	87,535	86,707	786,869
Textile	20,457	21,069	21,028	21,286	21,547	21,514	21,295	21,175	20,975	190,346
Grass/Wood/Bamboo	40,709	41,922	41,841	42,356	42,875	42,811	42,372	42,135	41,735	378,756
Plastic	69,528	71,601	71,462	72,345	73,229	73,115	72,369	71,965	71,283	646,897
Rubber/Leather	3,589	3,696	3,689	3,734	3,780	3,774	3,736	3,714	3,680	33,392
Metal	11,867	12,222	12,198	12,348	12,499	12,480	12,351	12,283	12,168	110,416
Bottle/Glass	28,904	29,766	29,707	30,075	30,440	30,394	30,084	29,916	29,634	268,920
Soil/Store/Ceramics	6,673	6,872	6,859	6,944	7,028	7,019	6,947	6,908	6,842	62,092
Others	0	0	0	0	0	0	0	0	0	0
Total	531,628	547,477	546,412	553,160	559,918	559,063	553,349	550,255	545,050	4,946,312

In order to introduce these results into the "First Order Model", table 20 is rearranged like table 21.

Table 21 Total waste quantity and type for years 2007-2015 generated by all categories (rearranged)

Waste type	2007	2008	2009	2010	2011	2012	2013	2014	2015	total
Wood and wood products (Woods, etc.)	40,709	41,922	41,841	42,356	42,875	42,811	42,372	42,135	41,735	378,756
Pulp, paper and cardboard (Paper, etc.)	84,573	87,094	86,924	87,998	89,073	88,937	88,028	87,535	86,707	786,869
Food, food waste, beverages and tobacco (Food, etc.)	265,328	273,235	272,704	276,074	279,447	279,019	276,167	274,624	272,026	2,468,624
Textiles	20,457	21,069	21,028	21,286	21,547	21,514	21,295	21,175	20,975	190,346
Garden, yard and park waste (Garden, etc.)	0	0	0	0	0	0	0	0	0	0
Glass, plastic, metal, other inert waste (Inert waste, etc.)	120,561	124,157	123,915	125,446	126,976	126,782	125,487	124,786	123,607	1,121,717
Total	531,628	547,477	546,412	553,160	559,918	559,063	553,349	550,255	545,050	4,946,312

(1) Calculation of “Without the activity”

It is assumed that GHG reduction occurred beginning in 2007 when semi-aerobic management started. The target of the case study is 2015 "Without the activity". As a result, **$BE_{Without}$ = 162,684 (tCO_2/year)** was obtained.

Results of the GHG emissions “Without the activity”

Without the activity

y	x		Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
			①	②				③		④	
2015	2007	Woods, etc.	40,709	0.43	8	0.020	-0.160	0.852144	0.9801987	0.019801	295.37
2015	2007	Paper, etc.	84,573	0.40	8	0.040	-0.320	0.726149	0.9607894	0.039211	963.21
2015	2007	Food, etc.	265,328	0.15	8	0.060	-0.480	0.618783	0.9417645	0.058235	1434.17
2015	2007	Textiles	20,457	0.24	8	0.040	-0.320	0.726149	0.9607894	0.039211	139.79
2015	2007	Garden, etc.	0	0.20	8	0.050	-0.400	0.670320	0.9512294	0.048771	0.00
2015	2007	Inert waste, etc.	120,561	0.00	8	0.000	0.000	1.000000	1	0	0.00
y	x		Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
2015	2008	Woods, etc.	41,922	0.43	7	0.020	-0.140	0.869358	0.9801987	0.019801	310.32
2015	2008	Paper, etc.	87,094	0.40	7	0.040	-0.280	0.755784	0.9607894	0.039211	1032.40
2015	2008	Food, etc.	273,235	0.15	7	0.060	-0.420	0.657047	0.9417645	0.058235	1568.24
2015	2008	Textiles	21,069	0.24	7	0.040	-0.280	0.755784	0.9607894	0.039211	149.85
2015	2008	Garden, etc.	0	0.20	7	0.050	-0.350	0.704688	0.9512294	0.048771	0.00
2015	2008	Inert waste, etc.	124,157	0.00	7	0.000	0.000	1.000000	1	0	0.00
y	x		Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
2015	2009	Woods, etc.	41,841	0.43	6	0.020	-0.120	0.886920	0.9801987	0.019801	315.97
2015	2009	Paper, etc.	86,924	0.40	6	0.040	-0.240	0.786628	0.9607894	0.039211	1072.44
2015	2009	Food, etc.	272,704	0.15	6	0.060	-0.360	0.697676	0.9417645	0.058235	1661.97
2015	2009	Textiles	21,028	0.24	6	0.040	-0.240	0.786628	0.9607894	0.039211	155.66
2015	2009	Garden, etc.	0	0.20	6	0.050	-0.300	0.740818	0.9512294	0.048771	0.00
2015	2009	Inert waste, etc.	123,915	0.00	6	0.000	0.000	1.000000	1	0	0.00
y	x		Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
2015	2010	Woods, etc.	42,356	0.43	5	0.020	-0.100	0.904837	0.9801987	0.019801	326.32
2015	2010	Paper, etc.	87,998	0.40	5	0.040	-0.200	0.818731	0.9607894	0.039211	1130.00
2015	2010	Food, etc.	276,074	0.15	5	0.060	-0.300	0.740818	0.9417645	0.058235	1786.55
2015	2010	Textiles	21,286	0.24	5	0.040	-0.200	0.818731	0.9607894	0.039211	164.00
2015	2010	Garden, etc.	0	0.20	5	0.050	-0.250	0.778801	0.9512294	0.048771	0.00
2015	2010	Inert waste, etc.	125,446	0.00	5	0.000	0.000	1.000000	1	0	0.00
y	x		Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
2015	2011	Woods, etc.	42,875	0.43	4	0.020	-0.080	0.923116	0.9801987	0.019801	336.99
2015	2011	Paper, etc.	89,073	0.40	4	0.040	-0.160	0.852144	0.9607894	0.039211	1190.48
2015	2011	Food, etc.	279,447	0.15	4	0.060	-0.240	0.786628	0.9417645	0.058235	1920.20
2015	2011	Textiles	21,547	0.24	4	0.040	-0.160	0.852144	0.9607894	0.039211	172.79
2015	2011	Garden, etc.	0	0.20	4	0.050	-0.200	0.818731	0.9512294	0.048771	0.00
2015	2011	Inert waste, etc.	126,976	0.00	4	0.000	0.000	1.000000	1	0	0.00
y	x		Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
2015	2012	Woods, etc.	42,811	0.43	3	0.020	-0.060	0.941765	0.9801987	0.019801	343.29
2015	2012	Paper, etc.	88,937	0.40	3	0.040	-0.120	0.886920	0.9607894	0.039211	1237.17
2015	2012	Food, etc.	279,019	0.15	3	0.060	-0.180	0.835270	0.9417645	0.058235	2035.82
2015	2012	Textiles	21,514	0.24	3	0.040	-0.120	0.886920	0.9607894	0.039211	179.56
2015	2012	Garden, etc.	0	0.20	3	0.050	-0.150	0.860708	0.9512294	0.048771	0.00
2015	2012	Inert waste, etc.	126,782	0.00	3	0.000	0.000	1.000000	1	0	0.00
y	x		Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
2015	2013	Woods, etc.	42,372	0.43	2	0.020	-0.040	0.960789	0.9801987	0.019801	346.63
2015	2013	Paper, etc.	88,028	0.40	2	0.040	-0.080	0.923116	0.9607894	0.039211	1274.50
2015	2013	Food, etc.	276,167	0.15	2	0.060	-0.120	0.886920	0.9417645	0.058235	2139.61
2015	2013	Textiles	21,295	0.24	2	0.040	-0.080	0.923116	0.9607894	0.039211	184.99
2015	2013	Garden, etc.	0	0.20	2	0.050	-0.100	0.904837	0.9512294	0.048771	0.00
2015	2013	Inert waste, etc.	125,487	0.00	2	0.000	0.000	1.000000	1	0	0.00
y	x		Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
2015	2014	Woods, etc.	42,135	0.43	1	0.020	-0.020	0.980199	0.9801987	0.019801	351.66
2015	2014	Paper, etc.	87,535	0.40	1	0.040	-0.040	0.960789	0.9607894	0.039211	1319.09
2015	2014	Food, etc.	274,624	0.15	1	0.060	-0.060	0.941765	0.9417645	0.058235	2259.23
2015	2014	Textiles	21,175	0.24	1	0.040	-0.040	0.960789	0.9607894	0.039211	191.45
2015	2014	Garden, etc.	0	0.20	1	0.050	-0.050	0.951229	0.9512294	0.048771	0.00
2015	2014	Inert waste, etc.	124,786	0.00	1	0.000	0.000	1.000000	1	0	0.00
y	x		Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
2015	2015	Woods, etc.	41,735	0.43	0	0.020	0.000	1.000000	0.9801987	0.019801	355.36
2015	2015	Paper, etc.	86,707	0.40	0	0.040	0.000	1.000000	0.9607894	0.039211	1359.93
2015	2015	Food, etc.	272,026	0.15	0	0.060	0.000	1.000000	0.9417645	0.058235	2376.23
2015	2015	Textiles	20,975	0.24	0	0.040	0.000	1.000000	0.9607894	0.039211	197.39
2015	2015	Garden, etc.	0	0.20	0	0.050	0.000	1.000000	0.9512294	0.048771	0.00
2015	2015	Inert waste, etc.	123,607	0.00	0	0.000	0.000	1.000000	1	0	0.00
										Σ	32278.65

φ	f	1-f	GWP	OX	1-OX	16/12	F	DOCf	MCF	⑤⑥⑦⑧⑨⑩⑪⑫
⑤		⑥	⑦		⑧	⑨	⑩	⑪	⑫	
0.9	0	1	21	0.00	1.00	1.333333	0.5	0.5	0.8	5.04
	No captured CH4			Unmanaged					Unmanaged - deep > 5m waste	

Without the activity	**CH4（tCOe）**	**162,684**

(2) Calculation of “With the activity”

It is assumed that GHG reduction began in 2007 when semi-aerobic management started. And the target of the case study is 2015 "With the activity". As a result, **PE_{With} = 91,510 (tCO_2/year)** was obtained.

Results of the GHG emissions “With the activity”

With the activity

y	x		Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
			①	②				③		④	
2015	2007	Woods, etc.	40,709	0.43	8	0.020	-0.160	0.852144	0.980199	0.019801	295.37
2015	2007	Paper, etc.	84,573	0.40	8	0.040	-0.320	0.726149	0.960789	0.039211	963.21
2015	2007	Food, etc.	265,328	0.15	8	0.060	-0.480	0.618783	0.941765	0.058235	1434.17
2015	2007	Textiles	20,457	0.24	8	0.040	-0.320	0.726149	0.960789	0.039211	139.79
2015	2007	Garden, etc.	0	0.20	8	0.050	-0.400	0.670320	0.951229	0.048771	0.00
2015	2007	Inert waste, etc.	120,561	0.00	8	0.000	0.000	1.000000	1	0	0.00
y	x		Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
2015	2008	Woods, etc.	41,922	0.43	7	0.020	-0.140	0.869358	0.980199	0.019801	310.32
2015	2008	Paper, etc.	87,094	0.40	7	0.040	-0.280	0.755784	0.960789	0.039211	1032.40
2015	2008	Food, etc.	273,235	0.15	7	0.060	-0.420	0.657047	0.941765	0.058235	1568.24
2015	2008	Textiles	21,069	0.24	7	0.040	-0.280	0.755784	0.960789	0.039211	149.85
2015	2008	Garden, etc.	0	0.20	7	0.050	-0.350	0.704688	0.951229	0.048771	0.00
2015	2008	Inert waste, etc.	124,157	0.00	7	0.000	0.000	1.000000	1	0	0.00
y	x		Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
2015	2009	Woods, etc.	41,841	0.43	6	0.020	-0.120	0.886920	0.980199	0.019801	315.97
2015	2009	Paper, etc.	86,924	0.40	6	0.040	-0.240	0.786628	0.960789	0.039211	1072.44
2015	2009	Food, etc.	272,704	0.15	6	0.060	-0.360	0.697676	0.941765	0.058235	1661.97
2015	2009	Textiles	21,028	0.24	6	0.040	-0.240	0.786628	0.960789	0.039211	155.66
2015	2009	Garden, etc.	0	0.20	6	0.050	-0.300	0.740818	0.951229	0.048771	0.00
2015	2009	Inert waste, etc.	123,915	0.00	6	0.000	0.000	1.000000	1	0	0.00
y	x		Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
2015	2010	Woods, etc.	42,356	0.43	5	0.020	-0.100	0.904837	0.980199	0.019801	326.32
2015	2010	Paper, etc.	87,998	0.40	5	0.040	-0.200	0.818731	0.960789	0.039211	1130.00
2015	2010	Food, etc.	276,074	0.15	5	0.060	-0.300	0.740818	0.941765	0.058235	1786.55
2015	2010	Textiles	21,286	0.24	5	0.040	-0.200	0.818731	0.960789	0.039211	164.00
2015	2010	Garden, etc.	0	0.20	5	0.050	-0.250	0.778801	0.951229	0.048771	0.00
2015	2010	Inert waste, etc.	125,446	0.00	5	0.000	0.000	1.000000	1	0	0.00
y	x		Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
2015	2011	Woods, etc.	42,875	0.43	4	0.020	-0.080	0.923116	0.980199	0.019801	336.99
2015	2011	Paper, etc.	89,073	0.40	4	0.040	-0.160	0.852144	0.960789	0.039211	1190.48
2015	2011	Food, etc.	279,447	0.15	4	0.060	-0.240	0.786628	0.941765	0.058235	1920.20
2015	2011	Textiles	21,547	0.24	4	0.040	-0.160	0.852144	0.960789	0.039211	172.79
2015	2011	Garden, etc.	0	0.20	4	0.050	-0.200	0.818731	0.951229	0.048771	0.00
2015	2011	Inert waste, etc.	126,976	0.00	4	0.000	0.000	1.000000	1	0	0.00
y	x		Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
2015	2012	Woods, etc.	42,811	0.43	3	0.020	-0.060	0.941765	0.980199	0.019801	343.29
2015	2012	Paper, etc.	88,937	0.40	3	0.040	-0.120	0.886920	0.960789	0.039211	1237.17
2015	2012	Food, etc.	279,019	0.15	3	0.060	-0.180	0.835270	0.941765	0.058235	2035.82
2015	2012	Textiles	21,514	0.24	3	0.040	-0.120	0.886920	0.960789	0.039211	179.56
2015	2012	Garden, etc.	0	0.20	3	0.050	-0.150	0.860708	0.951229	0.048771	0.00
2015	2012	Inert waste, etc.	126,782	0.00	3	0.000	0.000	1.000000	1	0	0.00
y	x		Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
2015	2013	Woods, etc.	42,372	0.43	2	0.020	-0.040	0.960789	0.980199	0.019801	346.63
2015	2013	Paper, etc.	88,028	0.40	2	0.040	-0.080	0.923116	0.960789	0.039211	1274.50
2015	2013	Food, etc.	276,167	0.15	2	0.060	-0.120	0.886920	0.941765	0.058235	2139.61
2015	2013	Textiles	21,295	0.24	2	0.040	-0.080	0.923116	0.960789	0.039211	184.99
2015	2013	Garden, etc.	0	0.20	2	0.050	-0.100	0.904837	0.951229	0.048771	0.00
2015	2013	Inert waste, etc.	125,487	0.00	2	0.000	0.000	1.000000	1	0	0.00
y	x		Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
2015	2014	Woods, etc.	42,135	0.43	1	0.020	-0.020	0.980199	0.980199	0.019801	351.66
2015	2014	Paper, etc.	87,535	0.40	1	0.040	-0.040	0.960789	0.960789	0.039211	1319.09
2015	2014	Food, etc.	274,624	0.15	1	0.060	-0.060	0.941765	0.941765	0.058235	2259.23
2015	2014	Textiles	21,175	0.24	1	0.040	-0.040	0.960789	0.960789	0.039211	191.45
2015	2014	Garden, etc.	0	0.20	1	0.050	-0.050	0.951229	0.951229	0.048771	0.00
2015	2014	Inert waste, etc.	124,786	0.00	1	0.000	0.000	1.000000	1	0	0.00
y	x		Wj,x	DOCj	y-x	kj	-k(y-x)	exp(-k(y-x))	exp(-kj)	1-exp(-kj)	①②③④
2015	2015	Woods, etc.	41,735	0.43	0	0.020	0.000	1.000000	0.980199	0.019801	355.36
2015	2015	Paper, etc.	86,707	0.40	0	0.040	0.000	1.000000	0.960789	0.039211	1359.93
2015	2015	Food, etc.	272,026	0.15	0	0.060	0.000	1.000000	0.941765	0.058235	2376.23
2015	2015	Textiles	20,975	0.24	0	0.040	0.000	1.000000	0.960789	0.039211	197.39
2015	2015	Garden, etc.	0	0.20	0	0.050	0.000	1.000000	0.951229	0.048771	0.00
2015	2015	Inert waste, etc.	123,607	0.00	0	0.000	0.000	1.000000	1	0	0.00
										Σ	32278.65

φ	f	1-f	GWP	OX	1-OX	16/12	F	DOCf	MCF	⑤⑥⑦⑧⑨⑩⑪⑫
⑤		⑥	⑦		⑧	⑨	⑩	⑪	⑫	
0.9	0	1	21	0.10	0.9	1.333333	0.5	0.5	0.5	2.835
	No captured CH4			Managed				Semi-Aerobic Final Disposal Sites		

With the activity	**CH4(tCOe)**	**91,510**
Without the activity	**CH4(tCOe)**	**162,684**
Amount of emission reductions	**CH4(tCOe)**	**71,174**

	(3) GHG emission reductions **ER = $BE_{Without}$ - PE_{With} = 162,684 - 91,510 = 71,174 (tCO_2/year)**
Preconditions	✓ At the final disposal site some soil covering is applied and gas venting pipes are installed, but the degree of management is not clear. It is assumed that they are nearly in a state of open dumping. ✓ Depth of wastes is unknown, but it is assumed to be 5m or deeper. ✓ After 2007, semi-aerobic control has been conducted.
Lessons learned from case study	If DOC_j (Fraction of degradable organic carbon) and MCF (CH_4 correction factor) are grasped, GHG emission reductions are comprehended. Data regarding DOCj needs to include information addressing change of waste quantity and waste type over time. In order to set each MCF of "without the activity" and "with the activity", it is necessary to comprehend the management situation of the final disposal site. Since these data have been examined by many existing investigations, it is comparatively easy to calculate the amount of GHG emission reduction.

Case study No.	7
Project title	The Acid Deposition Control Strategy in the Kingdom of Thailand
Sector	Environmental Management
Sub -sector	Air Pollution Control
Project summary	**[BACKGROUND]** Acid deposition is trans-boundary pollution in East Asia. It is necessary to tackle the pollution by respective nation and by whole countries of East Asia. For this end, a systematic approach for preparation of acid deposition control strategy was applied to Thailand. **[The outline after the project enforcement]** The systematic approach for preparation of acid deposition control strategy was applied to Thailand. The approach can be applied to other East Asian countries. After evaluation of the condition, the Study revealed that the current issues for mitigation were atmospheric pollution in the BMR. Components and methods of the Study are; 1. Investigation of current acid deposition and ambient air concentration of SO_2 and NO_2 - Collection of existing materials - Evaluation of collected data 2. Study for socio-economic conditions - Investigation into national and provincial conditions, collection and evaluation of future conditions - Analysis of energy growth elasticity to economic growth 3. Preparation of an emission inventory worthy of analysis of the current situation and projection for the future - Preparing an inventory of stationary and mobile sources for causing substances, i.e. sulfur oxides for the country, moreover nitrogen oxides for the MBR - Revision of the mobile source emission equation of nitrogen oxides 4. Simulation analysis of current and future status, based on current concentrations and the prepared inventory - Validity check by monitoring results - Sulfur simulations for the country - Sulfur dioxide and nitrogen oxides simulation for the BMR 5. Evaluation of conditions and prioritization of the problems to be tackled 6. Preparation of countermeasures and a management strategy - Technical, political, social, and financial feasibility study and preparation of countermeasures - Consideration for the enhancement of management 7. Technology transfer for the counterparts **[The outline after the project enforcement]** The JICA study team formulated the acid deposition control strategy and carried out technology transfer of air pollution control. First the monitoring results were collected and evaluated. Next, the inventory was

prepared. Based on monitoring results and the inventory, the simulation analysis of sulfur deposition of whole Thailand and SO_2 and NO_x concentrations in the BMR were another point of the study. According to the evaluation of monitoring and simulation results, atmospheric SO_2 and NO_2 concentrations in the BMR were current problems to tackle.

Countermeasures for the reduction of sulfur oxides and nitrogen oxides in the BMR were investigated. A draft control strategy, including countermeasures for pollutant reduction and enhancement of management, was prepared.

Technology transfer, especially for the preparation of inventories, the simulation by international model and investigation for policy, was implemented in the course of the Study.

GHG emission reduction scenarios

Without the activity

At the stationary emission sources in the BMR, use of heavy oil continues. It corresponds to BAU (Bussiness As Usual) case of this report.

Equations to calculate GHG emissions

Without the activity

$BE_{Without}$ = the fossil fuel consumption (coal, heavy oil, etc)×the CO_2 emission factor of the fossil fuel (coal, heavy oil, etc)

With the activity

PE_{With} = the fossil fuel consumption (natural gas)×the CO_2 emission factor of the fossil fuel (natural gas)

GHG emission reductions

$ER = BE_{Without} - PE_{With}$

Applied data

Table 1 shows the annual SO_x emission of "Without Case" in the BMR in 2011.

Table 1 Annual SO_x Emission in the BMR in 2011

(Unit:ton/yr)

	Point				Area					
	Power Pla	Refinery	Other	Sub-total	Agricultu	Mining	Construct	Resi.& Co	Sub-total	Total
Bangkok		822	23,213	24,035	47		894	116	1,057	25,092
Nonthaburi	19	0	4,253	4,272	10		67	18	94	4,366
Pathum Thani		0	20,220	20,220	15	0.1	33	13	61	20,281
Samut Prakan	91	0	30,421	30,512	67		52	20	139	30,651
Samut Sakhon		0	19,294	19,294	56	1	26	29	112	19,406
Nakhon Pathom		0	7,474	7,474	34	0.1	25	53	113	7,587
Total	110	822	104,875	105,807	229	1.2	1,097	249	1,576	107,383

Source : Table 3.3.7.1 of page 3-59 of Main Report

Provincial fuel consumption by manufacturing sector in the BMR in 2011 is shown in Table 2.

Table 2 Fuel Consumption by the Manufacturing sector in the BMR in 2011

	ULG91 (kL)	ULG95 (kL)	Kerosene (kL)	HSD (kL)
Bangkok	1,065	9,320	33,445	191,827
Nonthaburi	37	322	310	10,781
Pathum Thani	125	2,170	341	51,333
Samut Prakan	188	2,637	9,588	70,620
Samut Sakhon	78	1	1,031	62,724
Nakhon Pathom	124	147	265	28,706

	LSD (kL)	Fuel Oil (kL)	LPG (kL)	Coal (ton)	Lignite for industry (ton)	Natural Gas (MMscf)	Fuel Wood (kton)	Paddy Husk (kton)	Bagasse (kton)
Bangkok	6,182	1,035,203	301,120	36,023	9,197	545	949	1,154	7,957
Nonthaburi	104	54,635	14,523	0	0	0	46	56	384
Pathum Thani	638	334,805	59,395	7,236	1,847	1,005	187	228	1,569
Samut Prakan	2,571	762,530	64,507	12,210	70,151	28,627	203	247	1,704
Samut Sakhon	0	653,206	36,072	164,618	118,584	0	114	138	953
Nakhon Pathom	0	161,681	17,158	29,394	7,502	0	54	66	453
Total	9,496	3,002,060	492,773	249,481	207,281	30,177	1,553	1,888	13,021

Note : MMscf=10^6scf, scf = Standard cubic feet ≅ 28.32 Litre

Source : Table 3.3.4.4 of page 3-48 of Main Report

Table 3 shows the Emission factors of SO_2 used in the study.

Table 3 Emission Factors of SO_2

	ULG91	ULG95	Kerosene	HSD
Sulfur Content	0.0382	0.0382	0.15	0.0348
Unit	W %	W %	W %	W %
Density	0.7422	0.7422	0.7961	0.8358
Unit	kg/L(DEDP)	kg/L(DCR)	kg/L(DCR)	kg/L(DCR)
Emission Factor of SO_2	0.000567	0.000567	0.0023883	0.0005817
Unit	tSO_2/kL	tSO_2/kL	tSO_2/kL	tSO_2/kL

	LSD	Fuel Oil	LPG	Coal
Sulfur Content	0.458	1.7	0.343	0.5
Unit	W %	W %	g/m^3	W %
Density	0.8501	0.9402		
Unit	kg/L(DCR)	kg/L(DCR)		
Emission Factor of SO_2	0.0077869	0.0319668	0.0001715	0.0095
Unit	tSO_2/kL	tSO_2/kL	tSO_2/kL	tSO_2/ton

	Lignite for power	Lignite for industry	Natural Gas	Fuel Wood
Sulfur Content	3	2	0	
Unit	W %	W %	kg/M m3	
Density			9.5	
Unit			pm of H_2S	
Emission Factor of SO_2	0.045	0.03	0.02714	0.0375
Unit	tSO_2/ton	tSO_2/ton	$tSO_2/MMscf$	$tSO_2/kton$

	Paddy Husk	Bagasse
Sulfur Content		
Unit		
Density		
Unit		
Emission Factor of SO_2	0.0375	0.0375
Unit	$tSO_2/kton$	$tSO_2/kton$

Source : Table 3.2.3.1 of page 3-17 of Main Report and Table 3.2.3.2 of page 3-18 of Main Report

Calculation of GHG emissions

The most effective countermeasure is the SO_x reduction of 30% of the industrial SO_x emission in BMR. Since most of the fuel consumption of the industrial sector is fuel oil, the fuel shift assumes the scheme to change from fuel oil to natural gas. In this case GHG emission reduction is calculated as follows.

Step1 : SO_x Emission of the "Without Case"

Provincial fuel consumption such as fuel oil and natural gas

In the "Main Report", fuel consumption such as fuel oil and natural gas is reported. The consumption of fuel oil is 3,002,060(kL/yr) and the consumption of natural gas is 30,117(MMscf/yr). Furthermore, total annual emission of SO_x in the BMR in 2-11 is 107,384(tSO_2/yr). In addition, the SO_x emission factor for combustion facility is written down in the Main Report.

Table 4 SO_x emission of Without Case

Calculation item	Calculation results
Without Case : SO_x emissions of Fuel Oil	3,002,060(kL/yr) × 0.0319668(tSO_2/kL) = 95,966(tSO_2/yr)
Without Case : SO_x emissions of Natural Gas	30,117(MMscf/yr) × 0.02714(tSO_2/ MMscf) = 819(tSO_2/yr)
Without Case : SO_x emissions of other fuels	107,384 - 95,966 - 819 = 10,599(tSO_2/yr)

Note : MMscf = 10^6scf, scf = Standard cubic feet ≅ 28.32 Litre

Step2 : SO_x Emission of the "With the activity"

In "With the activity" it is assumed that Fuel Oil is reduced X (%) and Natural Gas is increased Y (MMscf/yr).

Table 4 SO_x emission of With the activity

Calculation item	Calculation results
With the activity : SO_x emissions of Fuel Oil	3,002,060(kL/yr)×0.0319668(tSO_2/kL) = 95,966(tSO_2/yr)
With the activity : SO_x emissions of Natural Gas	30,117(MMscf/yr)×0.02714(tSO_2/ MMscf) = 819(tSO_2/yr)
With the activity : SO_x emissions of other fuels	The SO_x emission of "With the activity" is 30% reduction of the SO_x emission of "Without Case".
A calculation equation for fuel shift	"Calorific value of Fuel Oil = Calorific value of Natural Gas ". 3,002,060 (kL/yr) × 10^3 × (100 - X(%))/100 × 39.77 (MJ/L) = (30,117 + Y) (MMscf/yr) × 10^6 × 1.02 (MJ/scf)
Calculation results of X and Y	X ≅ 34.4(%) Y ≅ 46,686(MMscf/yr)

Step3 : Calculation of Emission of GHG

The emission of GHG and emission reduction of GHG is calculated from the fuel consumption of Step 3 as follows.

Table 6 Calculation results of Emission of GHG

Calculation item	Calculation results
Without Case : GHG Emissions (only Fuel Oil)	3,002,060(kL/yr)×39.77(MJ/kL)×77,400(kgCO_2/TJ) ≅ 9,240,935(tCO_2/yr)
With the activity : GHG Emissions (Fuel Oil and Natural Gas)	Emission of GHG from Fuel Oil 3,002,060 (kL/yr) × 65.6 (%) × 39.77 (MJ/kL) × 77,400 (kgCO_2/TJ) ≅ 6,063,430 (tCO_2/yr) Emission of GHG from Natural Gas 46,686(MMscf/yr)×1.02×56,100(kgCO_2/ TJ) = 2,671,450(tCO_2/yr) Total ≅ 8,734,880(tCO_2/yr)
GHG Emission Reductions	9,240,935 - 8,734,880 ≅ **About 506,055(tCO_2/yr)**

Preconditions	The report describes "The effect of the most effective method, i.e. the shift to natural gas is estimated by Airviro simulation with a SO_x reduction of 30% of the industrial SO_x emission". However, the conversion rate to natural gas by specific fuel type is not indicated. On the other hand, much of the fuel consumed by the industrial sector in the capital area of Bangkok is heavy oil. Therefore, on the assumption that "SO_x emission is reduced by 30% through fuel conversion from heavy oil to natural gas", the GHG emission reductions are quantified.
Lessons learned from case study	If there are country original data such as net calorific value, fuel density and CO_2 emission factors, it is recommended that these data are investigated and described in the report. About the measures such as cleaner production, the specific amount of energy consumption reductions and electric consumption reductions of the institution should be figured out.