PROJECT DESIGN DOCUMENT FORM
FOR CDM PROJECT ACTIVITIES (F-CDM-PDD)
Version 04.1

PROJECT DESIGN DOCUMENT (PDD)

Title of the project activity	**Dehydration and incineration of sewage sludge in Singapore**
Version number of the PDD	~~**06**~~ **07**
Completion date of the PDD	~~**9/09/2010**~~ **20 Sep 2013**
Project participant(s)	**ECO Special Waste Management Pte Ltd** **Sumitomo Mitsui Banking Corporation** **Kajima Corporation**
Host Party(ies)	**Singapore**
Sectoral scope and selected methodology(ies)	**Scope 1 – Energy industries (renewable / non-renewable resources)** **Scope 13 - Waste handling and disposal** **AM0025/version 11 - Avoided emission from organic waste through alternative waste treatment processes**
Estimated amount of annual average GHG emission reductions	~~**101,577**~~ **101,598 ton CO_2e**

SECTION A. Description of project activity

A.1. Purpose and general description of project activity

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The used water from both domestic and non-domestic sources in Singapore is collected through a comprehensive network of underground public sewers and treated by PUB (Public Utilities Board), a statutory board of the MEWR (Ministry of the Environment and Water Resources). The wastewater infrastructure of Singapore has rapidly developed to serve its increasing demand, and 100% of the population is served with modern sanitation which includes ~~6~~ 4 WRPs (Water Reclamation Plants). In all the WRPs, the sludge produced from the aerobic treatment process is collected, digested and dewatered anaerobically for energy recovery and to reduce the volume. Presently, 800 tons of digested and dewatered sewage sludge with water content of 72 – 85 % is produced in Singapore. Part of the dewatered sewage sludge goes through an additional drying process to reduce the total volume. The water content of the dry sewage sludge is approximately 10%. The dewatered sludge (500 ton/day) and dry sludge (139 ton/day) are transported to the sludge disposal site located at Changi East Area on a daily basis.

The sludge disposal process is well managed by PUB. Trenches are excavated and the sludge is mixed with soil in the trenches. The trenches are then covered with excavated earth. The disposed sewage sludge still contains significant amount of carbon that has the potential for methane production. Considering the DOC (Degradable Organic Carbon) content of the sewage sludge, management of the disposal site, and methane gas detected at the surface of the disposal site by actual measurement, there is methane gas emission from the site at the present status. This is the scenario existing prior to the start of the implementation of the proposed project activity, and also the baseline scenario.

The proposed project activity is the first project in Singapore that aims to dehydrate and incinerate the sewage sludge produced from the WRPs. In the project scenario, the sewage sludge will be incinerated in a vortex incinerator, and the heat produced from the combustion process will be used on-site for the dehydration process. The incineration process will reduce the volume of the sludge dramatically, and at the same time completely take away the potential for methane production at the sludge disposal site. Therefore, the baseline emission which is the methane gas emission from the sludge disposal site will be avoided through an alternative treatment method in the project scenario.

The proposed project activity will be carried out by ECO Special Waste Management Pte. Ltd. (herein after referred to as "ECO") under a BOO (Build-Own-Operate) scheme.

Environmental Sustainability

ECO received the "In-principle No Objection" clearance for the proposed project activity from NEA (National Environment Agency) on 1st Oct 2007 and subsequent approval dated 28th Apr 2008 after submission of Industrial Allocation Form.

The project activity adopts Japan's advanced technology to dehydrate and incinerate sewage sludge. It is a well-developed and reliable technology equipped with comprehensive pollution protection equipment capable of meeting all the local environmental protection requirements, standards, and regulations.

Presently, the sewage sludge is disposed of by landfill and there is methane emission at the landfill site. With the implementation of the project activity, significant reduction of methane generation and waste reduction will be achieved through its high combustion and destruction efficiency of the incinerator.

The innovative concept of the project activity is fully demonstrating its environmental sustainability. The project development will lead to the achievement of less utilization of high carbon-intensity fuel, promoting renewable energy, reduction in GHG emission, and prolong the life span of landfill site.

Economic Sustainability
The project activity comprises of five duplicate[1] trains in a single treatment plant to treat the sewage sludge generated from all WRPs (Water Reclamation Plants) in Singapore. The project participant believes that the project would be the largest single sewage sludge treatment plant in Southeast Asia.

The project utilizes more efficient technology through its innovative design. In-depth study of mass and heat balance allows the maximum utilization of sewage sludge as renewable resource to generate heat for sludge dehydration process which leads to the reduction in fossil fuel usage. Fossil fuel substitution by the renewable resource demonstrates the economic competitiveness and enhances the energy security through the mitigation of Singapore’s dependence on imported fossil fuel.

Transfer of Japanese technology to Singapore through the project activity allows wider accessibility and thus provides business opportunities for further technological developments from the project. This will lead to capacity building of the technology in GHG reduction in Singapore and become a valuable asset to be exported to regional market where there is a rapidly growing demand for the technology.

Social Sustainability
The project activity adopts a cleaner and greener concept to reduce GHG emission and contributes towards a cleaner air with less landfill waste which will markedly improve the quality of life in Singapore.

It also becomes a good educational showcase to local communities and at national level, it is a commitment of Singapore in reducing carbon-intensity per unit GDP. Employment opportunities will be created and a comprehensive training program will be provided. This will contribute to the enhancement of local expertise leading to the achievement of knowledge-based industry in Singapore.

PUB’s (Public Utilities Board) Waterhub is part of Singapore’s effort in sharing its expertise on water-related services and technologies in the region. By integrating the dehydration and incineration technology from the project activity, it will perfectly fit to value-add the water management in Singapore.

Partnership with local research institution to explore sludge ash utilization will build up the competencies of local research community which will benefit the society.

[1] In the actual operation, the volume of dry and wet sludge and their characteristics are significantly different compared to the results of the sampling during design stage of the plant. These variations resulted in sub-optimum operations of the plant. To address this issue and optimize the operations of the plant, additional train (Train No.6) was installed and its commercial operation commenced in May, 2012.

A.2. Location of project activity

A.2.1. Host Party(ies)

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Republic of Singapore

A.2.2. Region/State/Province etc.

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Tuas

A.2.3. City/Town/Community etc.

>>

23 Tuas View Circuit

A.2.4. Physical/Geographical location

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The project site (103˚38’E and 1˚19’N) is located in Tuas which is an industrial area at the western end of Singapore main island. The Changi reclaimed land where the sewage sludge is disposed of is located at the eastern end of Singapore main island (104˚00’E and 1˚19’N). The physical locations of the sites are as shown in Figure 1 and Figure 2.

Figure 1: Physical location of the project site and Changi Reclaimed Land

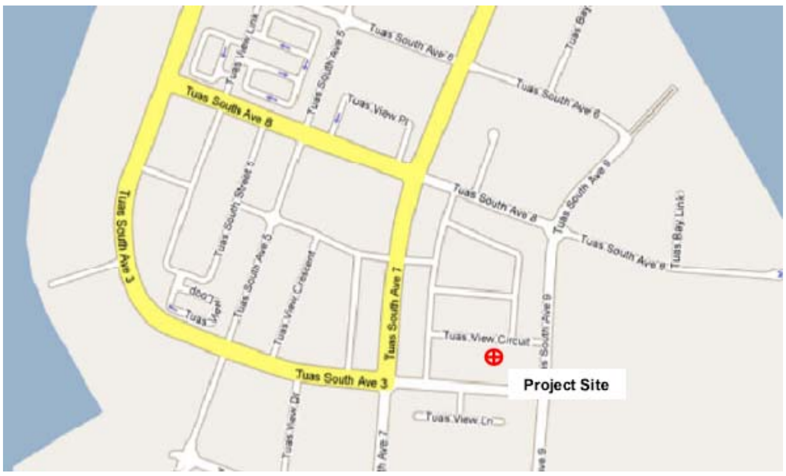

Figure 2: Physical location of the project site

A.3. Technologies and/or measures

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The 639 tons of sewage sludge (dewatered sludge: 500 ton/day dry sludge: 139 ton/day) produced from ~~6~~ 4 WRPs (Water Reclamation Plants) that treats 100% of Singapore’s used water is disposed at Changi Reclaimed Land. This is the scenario existing prior to the start of the project activity and it is also the baseline scenario. Figure-3 shows the scenario existing prior to the start of the project.

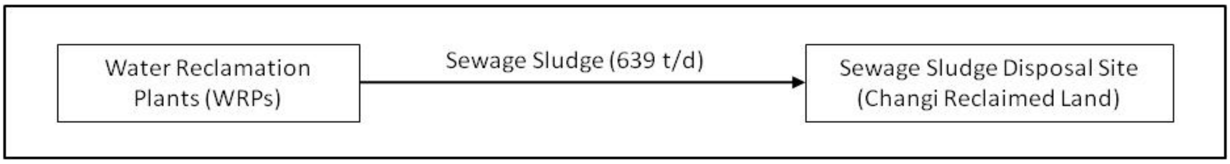

Figure-3 Scenario existing prior to the start of the project

In the project scenario, the 639 tons of sewage sludge produced daily from the WRPs will be treated by a sewage sludge dehydration and incineration plant. The ash produced will be disposed at Semakau landfill.

The plant will consume approximately 32.4 MWh and 3,620 m^3 of natural gas for the daily operation. The heat produced from the incineration will be used on-site for the dehydration process, exhaust gas will be treated by wet scrubber, and wastewater produced from the wet scrubber will be treated by a wastewater treatment facility. Figure-4 shows the project scenario.

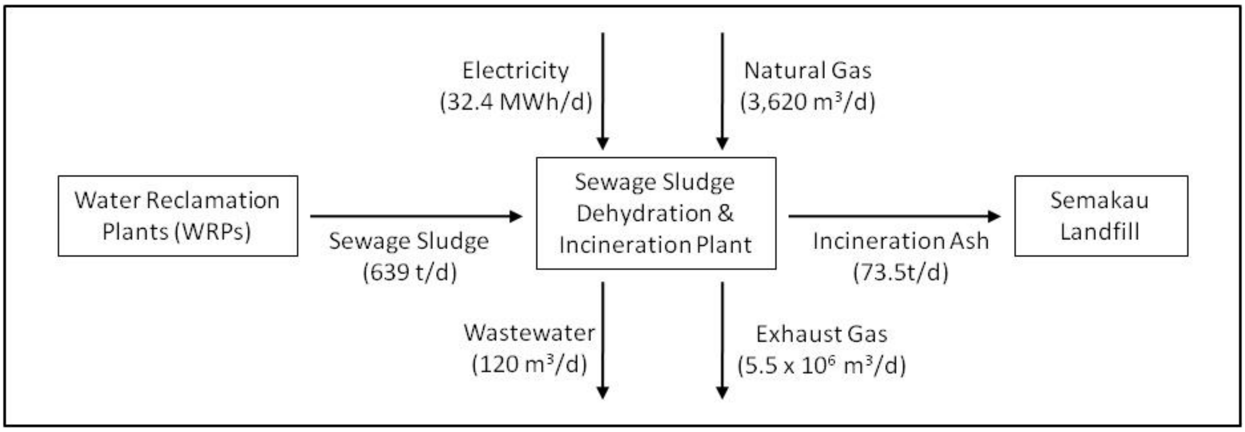

Figure-4 Project Scenario

Further detail of the plant is as shown in Figure-5.

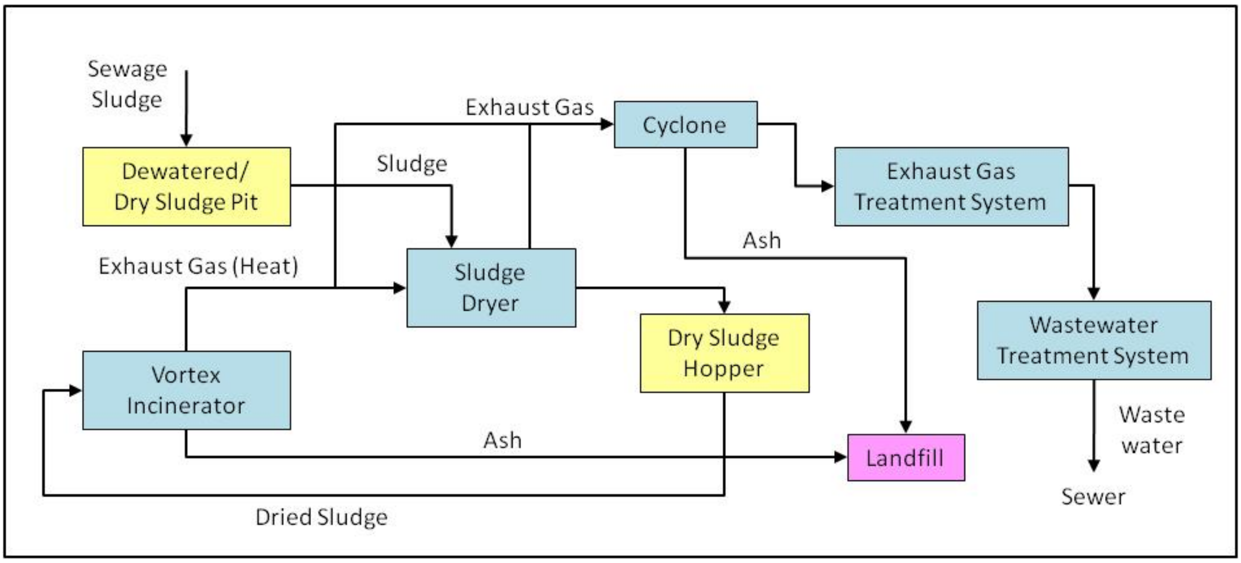

Figure-5 Schematic flow of the treatment

Sludge Dehydration
The sludge is put into the dryer to remove moisture to the self burning limit of combustible composition. The wet sludge that is put into the dryer is crushed into small pieces by the disintegrator blades at high speed. The crushed sludge falls to the bottom of the drum contacting with hot air and is raised again to the top by the lifter. The continuous process of crushing, drying and rotating inside the drum enlarge the surface area of sludge which produce the granulated dried sludge with high thermal efficiency.

Sludge Destruction
The dried sludge from the dryer will be fully destructed in the vortex incinerator. The vortex incinerator has rotating arms that mix the sludge and at the same time provide air for efficient equalized combustion. The air blown-out from the rotating arms creates a circulating flow inside the incinerator, thus keeping the temperature uniform for optimized combustion. Auxiliary burner fueled by natural gas is used to supplement the calorific value for stable operation.

Energy Recovery from Combustion
The exhaust heat of high temperature from the incinerator is utilized as heating source for the dehydration process of the sludge dryer.

Exhaust Gas Treatment
Negative pressure is kept in the enclosed sludge receiving room to ensure proper containment of unpleasant odor. The exhaust gas from the dryer and incinerator is further treated by secondary pollution protection equipment such as the wet scrubber system before final emission to the atmosphere.

Wastewater Treatment
Caustic medium is used to scrub acidic fume and produces scrubber wastewater that to be further treated by wastewater treatment plant. The plant is equipped with ash removal system with physical and chemical treatment prior to final pH adjustment and discharge into sewer.

Table- 1 Specification of main equipments

No	Equipment	Specification
1	Dewatered and Dry Sludge Pit	• Dewatered Sludge Pit (32.5m x 9m x 5m) with storage capacity up to 2 days • Dry Sludge Pit (24.5m x 9m x 5m) with storage capacity up to 3 days
2	Sludge Dryer	Rotating type model (KRD-330S) from Japanese manufacturer • Size of 8m length and 2.3m of shell internal diameter • Rotating speed (shell) of 2.32/min • Sludge dehydration capacity of 5,325 kg/hr (65% water)
3	Vortex Incinerator	Rotating arm type model (VI-200) from Japanese manufacturer • Size of 10.6m height and 5.8m in diameter • 6 rotating arms with 11 air nozzles per rotating arm • Sludge incineration capacity of 2,342 kg/hr (20% water)
4	Cyclone	Centrifugal multi-cyclone type dust collector • 3.6m height with upper chamber containing 25 cylinders (ö266mm) Centrifugal double-cyclone type dust collector • 6.4m height and coated with anti-corrosion paint
5	Exhaust Gas Treatment System	• SS mesh type media packing scrubber • 2 scrubber circulation pumps • 6 spray headers and 2 perforated plates • 18m height inclusive of chimney
6	Wastewater Treatment System	• Physical process – ash separation system comprising of ash settling tank, ash removal pump, ash filters and diffusers • Chemical process – process tank and chemical dosing pump • Cross-flow type cooling tower with capacity of 1.28 m^3/min

Photo-1 Sludge dryer

Photo-2 Vortex Incinerator

A.4. Parties and project participants

Party involved (host) indicates a host Party	Private and/or public entity(ies) project participants (as applicable)	Indicate if the Party involved wishes to be considered as project participant (Yes/No)
Singapore (host)	ECO Special Waste Management Pte. Ltd.	No
Japan	Sumitomo Mitsui Banking Corporation	No
Japan	Kajima Corporation	No

A.5. Public funding of project activity

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The financial plans for the project activity do not involve any public funding from any countries.

SECTION B. Application of selected approved baseline and monitoring methodology

B.1. Reference of methodology

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Approved baseline and monitoring methodology applied to the project activity is:

- "Avoided emissions from organic waste through alternative waste treatment processes" (AM0025 / version 11)
  http://cdm.unfccc.int/methodologies/DB/PIFTW0AFITR3JXAFH6MW7FM3IY2F70/view.html

Approved methodological tools applied to the project activity are:

- "Tool for the demonstration and assessment of additionality" (version 05.2)
  http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-01-v5.2.pdf
- "Tool to calculate the emission factor for an electricity system" (version 01.1)
  http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v1.1.pdf
- "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site"(version 04)
  http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-04-v4.pdf

B.2. Applicability of methodology

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As stated in the methodology, the methodology is applicable to scenarios which involve one or a combination of the following waste treatment options.

a) a composting process in aerobic conditions;
b) gasification to produce syngas and its use;
c) anaerobic digestion with biogas collection and flaring and/or its use;
d) mechanical/thermal treatment process to produce refuse-derived fuel (RDF)/stabilized biomass (SB) and its use. The thermal treatment process (dehydration) occurs under controlled conditions (up to 300 degrees Celsius). In case of thermal treatment process, the process shall generate a stabilized biomass that would be used as fuel or raw material in other industrial process. The physical and chemical properties of the produced RDF/SB shall be homogenous and constant over time;
e) incineration of fresh waste for energy generation, electricity and/or heat. The thermal energy generated is either consumed on-site and/or exported to a nearby facility. Electricity generated is either consumed on-site, exported to the grid or exported to a nearby facility. The incinerator is rotating fluidized bed or hearth or grate type.

The proposed project activity corresponds to e) incineration of fresh waste for energy generation, electricity and/or heat. The proposed project activity will generate heat from incineration of sewage sludge, the thermal energy generated will be used on-site for the dehydration process. The incinerator is a vortex incinerator which falls into the category of hearth type. In addition, the proposed project satisfies the following requirements shown in Table-2 of **Appendix 3**.

The proposed project activity satisfies all requirements listed in the methodology, and emissions of GHG from the sludge disposal site will be avoided through an alternative waste treatment process. Therefore, the methodology is applicable to the proposed project activity.

B.3. Project boundary

The spatial extent of the project boundary is the site of the project activity where the sewage sludge is incinerated. This includes the on-site electricity and natural gas consumption, and the emission of stack gas. The project boundary is as shown in Figure-6.

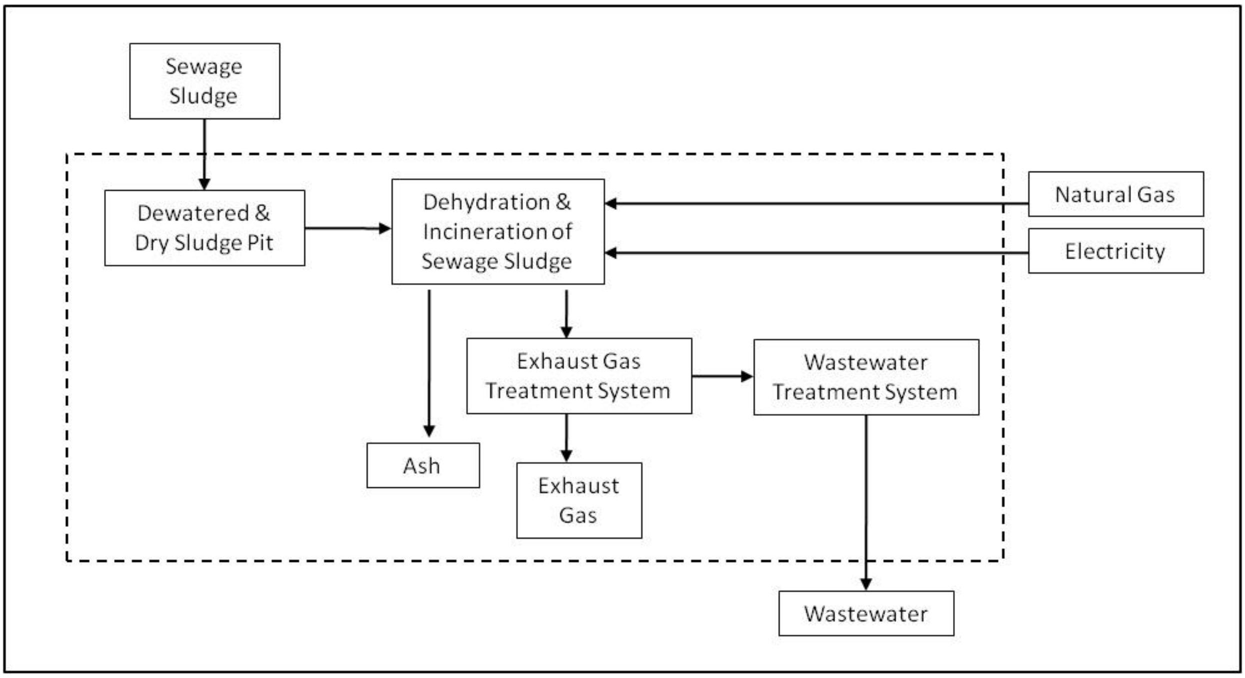

Figure-6 Project boundary

The greenhouse gases included in or excluded from the project boundary are shown in Table-3.

Table-3 The greenhouse gases included in or excluded from the project boundary

Source		Gas	Included?	Justification / Explanation
Baseline scenario	Emissions from decomposition of sewage sludge at the sludge disposal site	CH_4	Included	The major source of emissions in the baseline from the sludge disposal site.
		N_2O	Excluded	N_2O emissions are small compared to CH_4 emissions from the sludge disposal site. This is conservative.
		CO_2	Excluded	Not accounted for.

Source		Gas	Included?	Justification / Explanation
	Emissions from electricity consumption	CO_2	Excluded	There is no electricity consumption in the baseline scenario.
		CH_4	Excluded	Excluded for simplification. This is conservative.
		N_2O	Excluded	Excluded for simplification. This is conservative.
	Emissions from thermal Energy generation	CO_2	Excluded	There is no thermal energy generation in the baseline scenario.
		CH_4	Excluded	Excluded for simplification. This is conservative.
		N_2O	Excluded	Excluded for simplification. This is conservative.
Project scenario	On-site fossil fuel consumption due to the project activity	CO_2	Included	Auxiliary fuel consumption for the incineration process. (Natural Gas)
		CH_4	Excluded	Excluded for simplification. This emission source is assumed to be very small.
		N_2O	Excluded	Excluded for simplification. This emission source is assumed to be very small.
	On-site electricity use	CO_2	Included	Electricity from the national grid is consumed on-site for the operation of the plant.
		CH_4	Excluded	Excluded for simplification. This emission source is assumed to be very small.
		N_2O	Excluded	Excluded for simplification. This emission source is assumed to be very small.
	Direct emissions from the waste treatment process	CO_2	Excluded	The sewage sludge incinerated does not contain fossil based waste.
		N_2O	Included	The emission from stack gas will be monitored.
		CH_4	Included	The emission from stack gas will be monitored.
	Emissions from waste water treatment	CO_2	Excluded	The wastewater is from the wet scrubbers, which aim at removing fly ash and adjusting pH. Therefore, there are no organic matters in wastewater and thus CO_2 emissions are none.
		CH_4	Excluded	The wastewater is from the wet scrubbers, which aim at removing fly ash and adjusting pH. Therefore, there are no organic matters in wastewater and thus CH_4 emissions are none.
		N_2O	Excluded	Excluded for simplification. This emission source is assumed to be very small.

B.4. Establishment and description of baseline scenario
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The baseline scenario is identified using the “Tool for the demonstration and assessment of additionality” and the procedures specified in the methodology AM0025.

STEP 1: Identification of alternative scenarios.
The following alternative scenarios M1-M4 are defined as alternatives to the project activity.
M1. Sewage sludge dehydration and incineration not implemented as a CDM project;
M2. Composting of sewage sludge;
M3. Disposal of sewage sludge at a sludge disposal site where methane gas captured is flared;
M4. Disposal of sewage sludge at a sludge disposal site without the capture of methane gas.

The project activity does not involve electricity and thermal supply, hence the baseline scenarios for power and heat are not applicable.

In Singapore, there are no laws, regulations, or government policies that specify or restrict certain types of treatment methods for sewage sludge.
Therefore, all alternative scenarios are in compliance with mandatory applicable legal and regulatory requirements.

STEP 2: Identify the fuel for the baseline choice of energy source taking into account the national and/or sectoral policies as applicable.

Electricity generation in Singapore is mainly dependent on thermal power generation using natural gas and the electrification of the country is 100%. However, since the remaining credible alternatives considered in Step 1 are all waste management alternatives (M1 to M4) and these alternatives do not involve the use of fuel for energy generation, therefore this step is not applicable.

STEP 3: Investment Analysis

Since there are no mandatory laws or regulations that specify that the gases from the sludge disposal site must be captured and flared in Singapore, there will be no public funding, money grants, or any sort of incentive for the installation of gas collection and flaring equipments in Scenario M3. This scenario generates no income, and therefore, it can be stated clearly that Scenario M3 is economically unattractive, and shall be excluded from further consideration.

Composting can be one of an effective and economical treatment method for sewage sludge but the end use of the product is crucial for project implementation. In Singapore, there is no potential domestic demand for compost derived from sewage sludge as these are not allowed to be used in water catchment areas as well as for agriculture purposes. Therefore, Scenario M2 shall be excluded from further consideration.

Scenario M1, or the proposed project activity implemented without the CDM related income, generates financial benefits from sludge treatment fee of the sewage sludge received. The financial attractiveness of Scenario M1 will be determined by using the benchmark analysis. The financial indicator is the PIRR and the benchmark is the prime lending rate of Singapore[2].

The PIRR is calculated according to the following basic conditions as shown in Table-4.

Table-4 Basic conditions for calculating the project IRR

<table>
<tr><th colspan="2">Item</th><th>Description</th></tr>
<tr><td colspan="2">Project period</td><td>10 years</td></tr>
<tr><td colspan="2">Operation period</td><td>9 years</td></tr>
<tr><td colspan="2">Annual operation days</td><td>320 days</td></tr>
<tr><td rowspan="2">Sludge A (Dewatered sludge from Ulu Pandan and Kranji~~, Bedock, and Seletar~~ WRP)</td><td>Daily input of sewage sludge</td><td>312 t/d*</td></tr>
<tr><td>Sludge treatment fee</td><td>60 SGD/ton</td></tr>
<tr><td rowspan="2">Sludge B (Dewatered sludge from Jurong WRP)</td><td>Daily input of sewage sludge</td><td>188 t/d*</td></tr>
<tr><td>Sludge treatment fee</td><td>60 SGD/ton</td></tr>
</table>

[2] Sourced from website of Monetary Authority of Singapore (http://www.mas.gov.sg/index.html)

Sludge C (Dry sludge from Changi WRP)	Daily input of sewage sludge	139 t/d*
	Sludge treatment fee	58 SGD/ton
Inflation rate		2.0%[3]
Corporate tax		18.0%
Depreciation period		9 years
Residual value of plant**		0 SGD
Capital cost		30,800,000 SGD
Annual operational cost		7,835,000 SGD/yr (Average during 9 years)

* Rounded up figure
** Since the scrap value of the plant is less than the demolition cost, the residual value of the plant is set at 0 SGD conservatively.

The project period is defined as one hundred and twenty months (ten years) in the contract between PUB and ECO, which includes one-year construction period.

The expense and income of the project are as shown in Table-5.

Table-5 Expense and income of the project

Expense	Unit: SGD
Initial Investment	30,800,000
O&M Cost per year[4]	7,835,000
(1) Landfill Disposal Cost	1,762,000
(2) Electricity Cost	1,888,000
(3) Natural Gas Cost	1,267,000
(4) Others	2,918,000
Expense Total (10 years)	101,317,000
Income	
Sludge treatment fee (Sludge A) per year	6,000,000
Sludge treatment fee (Sludge B) per year	3,600,000
Sludge treatment fee (Sludge C) per year	2,578,000
Income Total (10 years)[5]	109,600,000
PIRR	4.36%

The inflation rates were decided for the landfill cost, labour cost and all other operational costs, considering three years historical data of the "Consumer Price Index[6]" sourced from Singapore Department of Statistics, the trend of the rise of petrol and material cost in 2007, the announcement of the Ministry of Environment on the landfill disposal cost, three years internal data of ECO on the labour cost and the data published by the Ministry of Manpower[7]. They are summarized in the table below.

cost item	reference	2004 (%)	2005 (%)	2006 (%)	average (%)	2007 (%)
Operational cost other than items below	Consumer price index	1.7	0.5	1.0	1.1	2.1

[3] Some of the items included in the O&M cost does not use the inflation rate of 2.0%. The inflation rate used for landfill disposal cost and labour cost is 1.0% and 4.0% accordingly.
[4] No O&M cost during the first year (construction period)
[5] No income during the first year (construction period)
[6] Sourced from website of Department of Statistics Singapore (http://www.singstat.gov.sg/stats/themes/economy/hist/cpi.html)
[7] Sourced from website of Ministry of Manpower (http://www.mom.gov.sg/publish/momportal/en/communities/others/mrsd/statistics/Earnings_and_Wages.html)

Labour cost	ECO's data	-	3.5	4.6	4.1	4.1
	Ministry of Manpower	3.6	4.3	4.5	4.1	5.9

cost item	reference	1999 (SGD)	-2002 (SGD)	-present (SGD)	Future (SGD)
Landfill disposal cost	Ministry of Environment	57	67	77	87

The average of the Consumer Price Index from 2004 to 2006 is 1.1%. Taking into account the rising prices of petrol and materials in 2007, the inflation rate was set at 2.0% for a conservative feasibility study (The consumer price index of 2007 which was published in 2008 was 2.1%). The inflation rate of 2.0% is used for all operational costs except for landfill disposal cost, and labour cost.

Since the landfill disposal cost for the Semakau landfill where the residual ash will be disposed is set by the government, the inflation rate of its cost is set differently. In April 1999 when Semakau landfill started its operation, the Ministry of Environment announced that it would increase the landfill disposal cost progressively from 57S$/ton to 87S$/ton to reflect the full cost of refuse disposal and encourage resource recycling to cut down waste production[8]. The current 77S$/ton was raised from 67S$/ton in May 2002. Because there is a chance of the landfill disposal cost to increase to 87S$/ton during the 10 years project period, 1.0% was used as the inflation rate for landfill disposal cost. The inflation rate is set at 4.0% for the labour cost based on past 3 years internal data of ECO (Average total wage change from 2004 to 2006 in Singapore is 4.13% according to the data publicized by the Ministry of Manpower).

The expenses for the project were fixed in January 2008 after several revisions of design and changes in operation expenses. The income for the project is a fixed amount stated in the contract between PUB and ECO. The assets will be depreciated during the project period according to the financial reporting standard of Singapore.

The benchmark that will be used is the prime lending rate of Singapore which is 5.33% published by Monetary Authority of Singapore. The PIRR calculated is 4.36%. Therefore, Scenario 1 (M1) is economically unattractive based on the conditions above.

Sensitivity analysis is conducted for further study of the economical attractiveness of Scenario 1 (M1). Below items are the major investment costs and revenue of the project.

1) Initial Investment (30% of total investment cost)
2) Landfill Disposal Cost (16% of total investment cost)
3) Electricity Cost (17% of total investment cost)
4) Natural Gas Cost (11% of total investment cost)
5) Sludge Treatment Fee (100% of total project revenue)

Among the items above, the initial investment, which was made in very short time from the final feasibility study (planed to be made in the first half of 2008), is estimated undoubtedly to increase due to the recent high price rise (6.9% rise by the Consumer Price Index averaged over first three quarters in 2008) Because the sensitivity analysis with the higher initial investment only produces less economical results, the initial investment is not considered as a parameter for the sensitivity analyses. In addition, the sludge treatment fee was already agreed at the fixed price between PUB and ECO, and it is not considered as a parameter for the sensitivity analyses.

Although no items in the operational cost constitutes more than 20% to the total investment cost, the items that constitutes more than 10% to the total investment cost were selected as parameters to examine its influence to the PIRR.

[8] Sourced from website of Singapore National Environment Agency (http://app.nea.gov.sg/cms/htdocs/article.asp?pid=1999)

The calculation results for the PIRR are as shown in Table-6.

Table-6 PIRR calculation results for the sensitivity analysis

	PIRR(%)								
	-10.0%	-7.5%	-5.0%	-2.5%	0%	+2.5%	+5.0%	+7.5%	+10.0%
Landfill Disposal	5.14	4.95	4.75	4.56	4.36	4.16	3.96	3.76	3.56
Electricity	5.19	4.99	4.78	4.57	4.36	4.15	3.94	3.72	3.51
Natural Gas	4.92	4.78	4.64	4.50	4.36	4.22	4.08	3.93	3.79

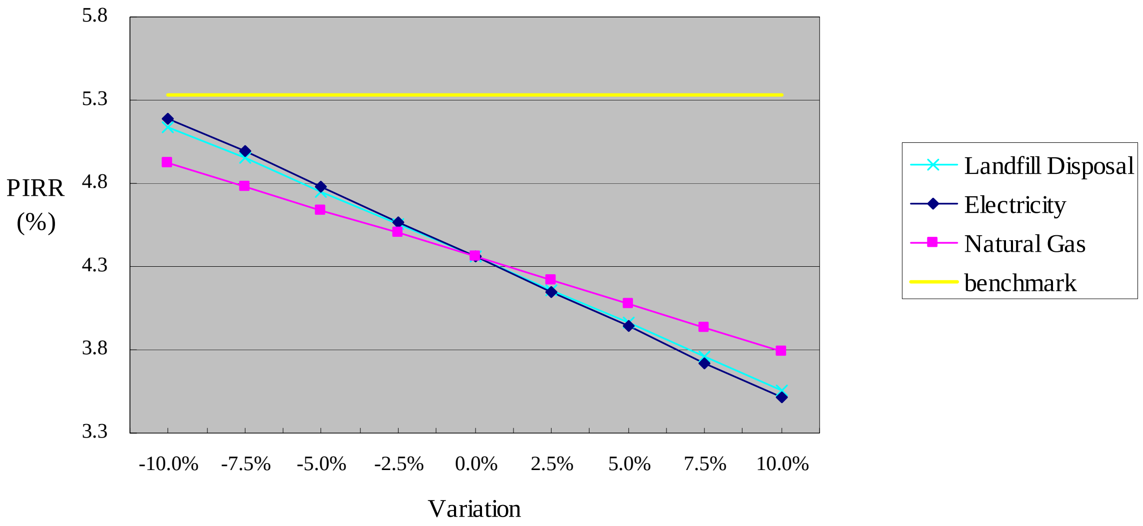

Figure-7 Result of sensitivity analysis

Figure-7 shows that the electricity price that constitutes 17% to the total investment cost has the biggest influence to the PIRR. The PIRR when the electricity price is reduced by 10% is 5.19% which is below the benchmark. The PIRR will hit the benchmark when the electricity price is reduced by 11.7%. However, the possibility of the occurrence of this scenario is very low considering the trend of the rise of electricity price that was observed at the time of the decision making for the project implementation (Average of 2004: 0.126S$/kWh, Average of 2005: 0.142S$/kWh, Average of 2006: 0.142S$/kWh, Average of 2007: 0.154S$/kWh)[9].

Figure-7 shows that the landfill disposal cost that constitutes 16% to the total investment cost also has a significant influence to the PIRR. The PIRR when the landfill disposal cost is reduced by 10% is 5.14% which is below the benchmark. The PIRR will hit the benchmark when the landfill disposal cost is reduced by 12.5%. However, the landfill disposal cost at Semakau landfill has increased since the start of its operation and it will continue to increase in the future according to the policy of the Ministry of the Environment. Therefore, it is very unlikely that the landfill disposal cost would decrease by 12.5%.

The influence of natural gas is relatively small compared to electricity and landfill disposal cost. The PIRR when the cost is reduced by 10% for natural gas is 4.92% which is below the benchmark. The PIRR will hit the benchmark when the natural gas cost is reduced by 17.4%. The possibility of the occurrence of this scenario can also be considered very low taking into account the prices have kept its increase during the past few years (Average of 2005: 17.3S$/mmBtu, Average of 2006: 19.3S$/mmBtu, Average of 2007: 20.5S$/mmBtu)[10].

[9] Sourced from historical data of electricity bill stored at ECO Special Waste Management Pte. Ltd.
[10] Sourced from historical data of natural gas price provided by the gas supplier

In all cases shown in Figure-7, the PIRR was below the benchmark. Therefore, Scenario M1 is economically unattractive, and shall be excluded from further consideration.
Scenario M4 represents the present status in Singapore where sewage sludge is disposed at a sludge disposal site without the capture of methane gas, and this has practiced since 2000. Therefore, this scenario is business as usual.

In case of this project, only one credible and plausible alternative remains through the process from STEP 1 to STEP 3, so STEP 4 is not applicable.

Through the assessment above, it is determined that the most plausible baseline scenario is Scenario M4 which is the disposal of sewage sludge at a sludge disposal site without the capture of methane gas.

B.5. Demonstration of additionality
>>
The additionality of the project activity is demonstrated and assessed using the "Tool for the demonstration and assessment of additionality" Version.05.2.

There is substantial evidence that the feasibility of the project with the incentive of CDM was seriously considered by the project participant. The project was affected by the decrease of revenue to design changes and increase of operational cost. ECO has studied thoroughly the amount of emission reduction and the possibility of registration with consultation from professional source before making the final decision to proceed with the project activity. The investment decision was made on 4th January 2008 when ECO had a board meeting and the final decision was made for the major investment of the project. ECO signed the contract with the major equipment supplier on 10th January 2008. Therefore, this date is when ECO had committed to expenditures and thus the starting date of the proposed project activity.

Table-7 shows the timeline of events and actions taken to achieve CDM registration.

Table-7 Timeline of events and actions taken to achieve CDM registration

Date	Description of Events	Description of Evidence
8th November 2007	Board meeting of ECO to discuss the outline of the project as a CDM after the meeting between ECO, SMBC, and JRI on 6th November 2007 (Prior consideration of CDM)	Minutes of meeting
14th November 2007	Internal meeting of ECO to discuss in detail the CER amount and the possibility of registration after the meeting with SMBC on the same day	Minutes of meeting
21st November 2007	Meeting between NEA, ECO, SMBC, and JRI to discuss about the necessary procedure for Singapore government approval	Minutes of meeting
4th January 2008	Final feasibility study result	Feasibility study report
4th January 2008	Board meeting of ECO when the final decision was made to proceed with the proposed project activity (Serious consideration of CDM)	Minutes of meeting

10th January 2008	Contract with major equipment supplier (Start date of the project)	Contract
1st April 2008	Start of construction of the plant	Contract
11th April 2008	Contract with installation contractor	Contract
7th May 2008	Contract with civil contractor	Contract
6th October 2008	Agreement on CDM Validation Services with DOE	Contract

Note: SMBC (Sumitomo Mitsui Banking Corporation)
JRI (Japan Research Institute)
NEA (National Environment Agency)

Step 1: Identification of alternatives to the project activity consistent with current laws and regulations

Sub-step 1a: Define alternatives to the project activity
The following scenarios M1-4 are defined as alternatives to the project activity.

M1. Sewage sludge dehydration and incineration not implemented as a CDM project;
M2. Composting of sewage sludge;
M3. Disposal of sewage sludge at a sludge disposal site where methane gas captured is flared;
M4. Disposal of sewage sludge at a sludge disposal site without the capture of methane gas.

Sub-step 1b: Consistency with mandatory laws and regulations:
In Singapore, there are no laws, regulations, or government policies that specify or restrict certain types of treatment methods for sewage sludge.
All alternative scenarios are in compliance with mandatory applicable legal and regulatory requirements.

Step 2: Investment Analysis

Sub-step 2a: Determine appropriate analysis method
The benchmark analysis is applied.

Sub-step 2b: Option III. Apply benchmark analysis
Scenario M1, or the proposed project activity implemented without the CDM related income, generates financial benefits from sludge treatment fee of the sewage sludge received. The financial attractiveness of Scenario M1 is as demonstrated in the previous section.

It can be concluded after applying the benchmark and sensitivity analysis that Scenario M1 is unlikely to be the most financially attractive scenario.

Step 4: Common practice analysis
The proposed project activity that dehydrates and incinerates sewage sludge is the first-of-its-kind to be implemented in Singapore. No similar project exists in Singapore or in the neighboring countries such as Malaysia or Indonesia. Therefore, this step will not be applied.

It is demonstrated through the assessment above that the proposed project is additional.

B.6. Emission reductions

B.6.1. Explanation of methodological choices
>>
Project Emissions

Project emissions are calculated using equation (1) provided in the methodology. $PE_{c,y}$, $PE_{a,y}$, $PE_{g,y}$, $PE_{r,y}$, $PE_{w,y}$, are excluded from the calculation since the proposed project activity involves only incineration.

$$PE_y = PE_{elec,y} + PE_{fuel,on-site,y} + PE_{i,y} \quad (1)$$

Where:

PE_y	is the project emissions during the year *y* (tCO_2e/yr)
$PE_{elec,y}$	is the emissions from electricity consumption due to the project activity during the year *y* (tCO_2/yr)
$PE_{fuel,on-site,y}$	is the emissions due to fuel consumption on-site in year *y* (tCO_2/yr)
$PE_{i,y}$	is the emissions during the waste incineration process in year *y* (tCO_2e/yr)

Emissions from electricity use ($PE_{elec,y}$)

The proposed project activity involves consumption of electricity. The emissions from electricity consumption are calculated using equation (2).

$$PE_{elec,y} = EG_{PJ,EF,y} \times CEF_{elec} \quad (2)$$

Where:

$PE_{elec,y}$	is the emissions from electricity consumption due to the project activity during the year *y* (tCO_2/yr)
$EG_{PJ,EF,y}$	is the amount of electricity generated in an on-site fossil fuel fired power plant or consumed from the grid in the project activity, measured using an electricity meter (MWh/yr)
CEF_{elec}	CO_2 emission factor for electricity generation in the project activity (tCO_2/MWh)

Electricity will be purchased from the grid. CEF_{elec} is provided by Singapore's DNA (Climate Change Unit, Resource Conservation Department, National Environment Agency).

Emissions from fuel use on-site ($PE_{fuel,on-site,y}$)

The proposed project activity involves on-site fossil fuel consumption. The emissions from fossil fuel consumption on-site are calculated using equation (3).

$$PE_{fuel,on-site,y} = F_{cons,y} \times NCV_{fuel} \times EF_{fuel} \quad (3)$$

Where:

$PE_{fuel,on-site,y}$	is the CO_2 emissions due to on-site fuel combustion in year *y* (tCO_2/yr)
$F_{cons,y}$	is the fuel consumption on site in year *y* (l/yr)
NCV_{fuel}	is the net calorific value of the fuel (MJ/l)
EF_{fuel}	is the CO_2 emission factor of the fuel (tCO_2/MJ)

Emissions from waste incineration process ($PE_{i,y}$)

The emissions from the waste incineration stacks are calculated using equation (4). $PE_{i,f,y}$ which is the CO_2 emissions from fossil-based waste incineration is excluded from the calculation since the proposed project activity aims to incinerate sewage sludge only, which does not contain fossil-based waste.

$$PE_{i,y} = PE_{i,s,y} \quad (4)$$

Where:

$PE_{i,y}$	is emissions during the waste incineration process in year y (tCO_2e/yr)
$PE_{i,s,y}$	is the N_2O and CH_4 emissions from the final stacks from waste incineration in year y (tCO_2e/yr)

Emissions of N_2O and CH_4 are estimated using equation (5) listed as Option 1 in the methodology.

Option 1:

$$PE_{i,s,y} = SG_{i,y} \times MC_{N2O,i,y} \times GWP_{N2O} + SG_{i,y} \times MC_{CH4,i,y} \times GWP_{CH4} \quad (5)$$

Where:

$PE_{i,s,y}$	is the total emissions of N_2O and CH_4 from waste incineration in year y (tCO_2e/yr)
$SG_{i,y}$	is the total volume of stack gas from waste incineration in year y (m^3/yr)
$MC_{N2O,i,y}$	is the monitored content of nitrous oxide in the stack gas from waste incineration in year y (tN_2O/m^3)
GWP_{N2O}	is the Global Warming Potential of nitrous oxide (tCO_2e/tN_2O)
$MC_{CH4,i,y}$	is the monitored content of methane in the stack gas from waste incineration in the year y (tCH_4/m^3)
GWP_{CH4}	is the Global Warming Potential of methane (tCO_2e/tCH_4)

Baseline Emissions

Baseline emissions are calculated using equation (6) provided in the methodology. $BE_{EN,y}$ is excluded from the equation since the proposed project activity does not displace energy that would have been consumed in the baseline scenario.

$$BE_y = MB_y - MD_{reg,y} \quad (6)$$

Where:

BE_y	is the baseline emissions in year y (tCO_2e/yr)
MB_y	is the methane produced at the sludge disposal site in the absence of the project activity in year y (tCO_2e/yr)
$MD_{reg,y}$	is the methane that would be destroyed in the absence of the project activity in year y (tCO_2e/yr)

Adjustment Factor (AF)

Since regulatory or contractual requirements do not specify $MD_{reg,y}$ in the proposed project activity, Adjustment Factor (AF) will be used to determine the methane that would be destroyed in the absence of the project activity.

$$MD_{reg,y} = MB_y \times AF \quad (7)$$

Where:

AF	is Adjustment Factor for MB_y (%)

Rate of Compliance

There are no laws, regulations, or government policies that specify or restrict certain types of treatment methods for sewage sludge in Singapore. Therefore, method for adjusting the baseline emissions by rate of compliance does not apply.

Methane generation from the landfill in the absence of the project activity (MB_y)

The amount of methane that is generated each year (MB_y) is calculated as per the "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site". Parameter *j* (waste type category) is excluded from the equation since the waste considered in the proposed project activity is only sewage sludge.

$$MB_y = BE_{CH4,SWDS,y} \tag{8}$$

$$BE_{CH4,SWDS,y} = \phi \cdot (1-f) \cdot GWP_{CH4} \cdot (1-OX) \cdot \frac{16}{12} \cdot F \cdot DOC_f \cdot MCF \cdot \sum_{x=1}^{y} W_{j,x} \cdot DOC_j \cdot e^{-kj \cdot (y-x)} \cdot \left(1-e^{-k,j}\right) \tag{9}$$

Where:

MB_y	is $BE_{CH4,SWDS,y}$ (tCO_2e/yr)
$BE_{CH4,SWDS,y}$	is the methane emissions avoided during the year *y* from preventing waste disposal at the solid waste disposal site (SWDS) during the period from the start of the project activity to the end of the year *y* (tCO_2e/yr)
ö	is the model correction factor to account for model uncertainties (0.9)
f	is the fraction of methane captured at the SWDS and flared, combusted or used in another manner
GWP_{CH4}	is the Global Warming Potential (GWP) of methane, valid for the relevant commitment period
OX	is the oxidation factor (reflecting the amount of methane from SWDS that is oxidised in the soil or other material covering the waste)
F	is the fraction of methane in the SWDS gas (volume fraction) (0.5)
DOC_f	is the fraction of degradable organic carbon (DOC) that can decompose
$W_{j,x}$	is the amount of waste type *j* prevented from disposal in the SWDS in the year *x* (tons)
MCF	is the methane correction factor
DOC_j	is the fraction of degradable organic carbon (by weight) in the waste type *j*
k_j	is the decay rate for the waste type *j*
x	is the year during the crediting period: *x* runs from the first year of the first crediting period (*x*=1) to year *y* for which avoided emissions are calculated (*x*=*y*)
y	is the year for which methane emissions are calculated

Baseline emissions from generation of electricity displaced by the project activity

This section is not applicable since the proposed project activity does not involve electricity generation.

Baseline emissions from electricity and heat cogeneration that is displaced by the project activity

Although heat recovered from the incineration process is used on-site, this section is not applicable since fossil fuel that would have been consumed in the absence of the proposed project activity does not exist.

<u>Leakage Emissions</u>

The leakage emissions of the proposed project activity are estimated using equation (10). $L_{r,y}$ (leakage emissions from the residual waste from the anaerobic digester, the gasifier, the processing/combustion of RDF/stabilized biomass, or compost in case it is disposed of in landfills in year *y*) and $L_{s,y}$ (leakage emissions from end use of stabilized biomass in year *y*) are excluded from the equation since the proposed project activity is incineration of sewage sludge.

$$L_y = L_{t,y} + L_{i,y} \quad (10)$$

Where:

L_y	is the leakage emissions during the year *y* (tCO_2e/yr)
$L_{t,y}$	is the leakage emissions from increased transport in year *y* (tCO_2e/yr)
$L_{i,y}$	is the leakage emissions from the residual waste from MSW incinerator in year *y* (tCO_2e/yr)

Emissions from increased transport

Sludge transportation from WRPs

$$L_{t,y} = NO_{vehicles,y} \times DT_y \times VF_{cons} \times NCV_{fuel,transport} \times D_{fuel} \times EF_{fuel,transport} \quad (11)$$

Where:

$L_{t,y}$	is the leakage emissions from increased transport in year *y* (tCO_2e/yr)
$NO_{vehicles,y}$	is the number of vehicles for transport
DT_y	is the additional distance travelled compared to baseline in year *y* (km)
VF_{cons}	is the vehicle fuel consumption in litres per kilometre (l/km)
$NCV_{fuel,transport}$	is the calorific value of the fuel (MJ/kg)
D_{fuel}	is the fuel density (kg/l)
$EF_{fuel,transport}$	is the emission factor of the fuel (tCO_2/MJ)

Ash transportation from project site to TMTS (Tuas Marine Transfer Station)

There will be additional transportation of incineration ash from the project site to TMTS where all of the MSW incineration ash and non-incinerable refuse produced in Singapore are collected before taken to Semakau landfill by barges. The amount of emission from ash transportation was calculated by using equation (11).

$$L_{t,y} = NO_{vehicles,y} \times DT_y \times VF_{cons} \times NCV_{fuel,transport} \times D_{fuel} \times EF_{fuel,transport} \quad (11)$$

Where:

$L_{t,y}$	is the leakage emissions from increased transport in year *y* (tCO_2e/yr)
$NO_{vehicles,y}$	is the number of vehicles for transport
DT_y	is the additional distance travelled compared to baseline in year *y* (km)
VF_{cons}	is the vehicle fuel consumption in litres per kilometre (l/km)
$NCV_{fuel,transport}$	is the calorific value of the fuel (MJ/kg)
D_{fuel}	is the fuel density (kg/l)
$EF_{fuel,transport}$	is the emission factor of the fuel (tCO_2/MJ)

Ash transportation from TMTS to Semakau landfill

The incineration ash from the project site will be taken to Semakau landfill by barges after it is collected at TMTS. According to NEA's (National Environment Agency) annual report 2007, over 2,000 tons of incineration ash and non-incinerables are transported to Semakau landfill daily. The amount of emission by the barge transportation was calculated by using equation (11).

$$L_{t,y} = NO_{vehicles,y} \times DT_y \times VF_{cons} \times NCV_{fuel,transport} \times D_{fuel} \times EF_{fuel,transport} \times C_{ashratio} \qquad (11)$$

Where:

$L_{t,y}$	is the leakage emissions from increased transport in year *y* (tCO_2e/yr)
$NO_{vehicles,y}$	is the number of vehicles (barges) for transport
DT_y	is the additional distance travelled compared to baseline in year *y* (km)
VF_{cons}	is the vehicle fuel consumption in litres per kilometre (l/km)
$NCV_{fuel,transport}$	is the calorific value of the fuel (MJ/kg)
D_{fuel}	is the fuel density (kg/l)
$EF_{fuel,transport}$	is the emission factor of the fuel (tCO_2/MJ)

Emissions from the residual waste from MSW incineration

The leakage emission from the residual waste of incinerator is accounted for using the following equation.

$$L_{i,y} = A_{residual} \times FC_{residual} \times \frac{44}{12} \qquad (12)$$

Where:

$L_{i,y}$	is the leakage emissions from the residual waste of the incinerator in year *y* (tCO_2e/yr)
$A_{residual}$	is the amount of residual waste from the incinerator (t/yr)
$FC_{residual}$	is the fraction of residual carbon contained in the residual waste (%)

<u>Emission Reduction</u>

The emission reductions are calculated by applying the following equation.

$$ER_y = BE_y - PE_y - L_y \qquad (13)$$

Where:

ER_y	is the emissions reductions in year *y* (tCO_2e)
BE_y	is the emissions in the baseline scenario in year *y* (tCO_2e)
PE_y	is the emissions in the project scenario in year *y* (tCO_2e)

B.6.2. Data and parameters fixed ex ante

Data / Parameter	***CEF_{elec}***
Unit	tCO_2/MWh
Description	The emission factor for electricity generation corresponding to electricity

	used in the project activity.
Source of data	Value provided by Singapore's DNA
Value(s) applied	0.4612
Choice of data or Measurement methods and procedures	The CEF is based on the 2007 data obtained from the power generators in Singapore. However, the Singapore's DNA (Climate Change Unit, Resource Conservation Department, National Environment Agency) confirmed that the data used to compile the emission factors are confidential data and the details of the calculations cannot be released to the public.
Purpose of data	**Project Emissions calculation**
Additional comment	-

Data / Parameter	EF_{fuel}
Unit	tCO_2/MJ
Description	Emission factor for natural gas
Source of data	IPCC 2006 Guidelines for National Greenhouse Gas Inventories (adopted from Volume 2, Table 1.4)
Value(s) applied	$64.2*10^{-6}$
Choice of data or Measurement methods and procedures	A default value recommended in the IPCC 2006 Guidelines for National Greenhouse Gas Inventories is used since the carbon content of the natural gas is not available in Singapore.
Purpose of data	**Project Emissions calculation**
Additional comment	-

Data / Parameter	GWP_{N2O}
Unit	-
Description	Global Warming Potential of nitrous oxide
Source of data	IPCC
Value(s) applied	310
Choice of data or Measurement methods and procedures	Valid for the First Commitment Period.
Purpose of data	**Project Emissions calculation**
Additional comment	-

Data / Parameter	GWP_{CH4}
Unit	-
Description	Global Warming Potential of methane
Source of data	IPCC
Value(s) applied	21
Choice of data or Measurement methods and procedures	Valid for the First Commitment Period.
Purpose of data	**Project Emissions calculation**
Additional comment	-

Data / Parameter	***AF***
Unit	%

Description	Adjustment factor for $MB_{reg,y}$
Source of data	Estimation
Value(s) applied	0
Choice of data or Measurement methods and procedures	There are no laws, regulations, or government policies that mandate the destruction of SWDS gas, and activity to collect or destruct SWDS gas is not expected at the Changi reclaimed land which is the only SWDS for sewage sludge in Singapore. Therefore, $MD_{reg,y}$ is expected to be 0 through out the crediting period.
Purpose of data	**Baseline Emissions calculation**
Additional comment	-

Data / Parameter	***ö***
Unit	-
Description	Model correction factor to account for model uncertainties of the "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site"
Source of data	"Tool to determine the methane emissions avoided from disposal of waste at a solid waste disposal site"
Value(s) applied	0.9
Choice of data or Measurement methods and procedures	A default value provided in the "Tool to determine methane emission avoided from disposal of waste at a solid waste disposal site".
Purpose of data	**Baseline Emissions calculation**
Additional comment	-

Data / Parameter	***f***
Unit	-
Description	Fraction of methane captured at the SWDS and flared, combusted or used in another manner
Source of data	"Tool to determine the methane emissions avoided from disposal of waste at a solid waste disposal site"
Value(s) applied	Already accounted for as AF (Adjustment Factor).
Choice of data or Measurement methods and procedures	
Purpose of data	**Baseline Emissions calculation**
Additional comment	-

Data / Parameter	***OX***
Unit	-
Description	Oxidation factor (reflecting the amount of methane from SWDS that is oxidized in the soil or other material covering the waste)
Source of data	"Tool to determine the methane emissions avoided from disposal of waste at a solid waste disposal site"
Value(s) applied	0.1
Choice of data or Measurement methods and procedures	The default value of 0.1 for "managed solid waste disposal sites that are covered with oxidation material such as soil or compost" was determined by site investigation.

Purpose of data	**Baseline Emissions calculation**
Additional comment	-

Data / Parameter	***F***
Unit	-
Description	Fraction of methane in the SWDS gas (volume fraction)
Source of data	"Tool to determine the methane emissions avoided from disposal of waste at a solid waste disposal site"
Value(s) applied	0.5
Choice of data or Measurement methods and procedures	A default value recommended in the IPCC 2006 Guidelines for National Greenhouse Gas Inventories.
Purpose of data	**Baseline Emissions calculation**
Additional comment	-

Data / Parameter	DOC_f
Unit	-
Description	Fraction of degradable organic carbon that can decompose
Source of data	"Tool to determine the methane emissions avoided from disposal of waste at a solid waste disposal site"
Value(s) applied	0.5
Choice of data or Measurement methods and procedures	A default value recommended in the IPCC 2006 Guidelines for National Greenhouse Gas Inventories.
Purpose of data	**Baseline Emissions calculation**
Additional comment	-

Data / Parameter	***MCF***
Unit	-
Description	Methane correction factor
Source of data	"Tool to determine the methane emissions avoided from disposal of waste at a solid waste disposal site".
Value(s) applied	1.0
Choice of data or Measurement methods and procedures	The default value of 1.0 for "anaerobic managed solid waste disposal sites" was determined by site investigation.
Purpose of data	**Baseline Emissions calculation**
Additional comment	-

Data / Parameter	DOC_j
Unit	-
Description	Fraction of degradable organic carbon (by weight) in the waste type *j*
Source of data	Laboratory analysis result
Value(s) applied	Dewatered Sludge: 7.4% Dry Sludge: 29.4%
Choice of data	Sludge samples from all WRPs were taken to determine the DOC values

or Measurement methods and procedures	for dewatered and dry sludge by laboratory analysis. Laboratory analysis was conducted at ICES (Institute of Chemical Engineering Sciences) which is a government research institute of Singapore under A Star (Agency for Science, Technology and Research).
Purpose of data	**Baseline Emissions calculation**
Additional comment	-

Data / Parameter	k_j
Unit	-
Description	Decay rate for the waste type *j*
Source of data	"Tool to determine the methane emissions avoided from disposal of waste at a solid waste disposal site",
Value(s) applied	Dewatered Sludge: 0.4 Dry Sludge: 0.4
Choice of data or Measurement methods and procedures	Value applied for the conditions below. >Rapidly degrading >Tropical (MAT>20^{o}C) >Wet (MAP>1000mm)
Purpose of data	**Baseline Emissions calculation**
Additional comment	Temperature and precipitation data sourced from Singapore NEA (National Environment Agency).

Data / Parameter	$EF_{fuel,transport}$
Unit	tCO_2/MJ
Description	Emission factor for ultra low sulphur diesel
Source of data	IPCC 2006 Guidelines for National Greenhouse Gas Inventories (adopted from Volume 2, Table 1.4)
Value(s) applied	$74.1*10^{-6}$
Choice of data or Measurement methods and procedures	A default value recommended in the IPCC 2006 Guidelines for National Greenhouse Gas Inventories is used since the carbon content of the diesel is not available in Singapore.
Purpose of data	**Project Emissions calculation**
Additional comment	A default value recommended in the IPCC 2006 Guidelines for National Greenhouse Gas Inventories is used since the carbon content of the diesel is not available in Singapore.

Data / Parameter	$DT_{i,y}$
Unit	km
Description	Average additional distance travelled compared to the baseline
Source of data	PUB (Public Utilities Board) documents

<table>
<tr><td>Value(s) applied</td><td>Sludge transportation:
<table>
<tr><th>WRP</th><th>Additional Distance (km)</th></tr>
<tr><td>Ulu Pandan</td><td>-16</td></tr>
<tr><td>Kranji</td><td>-13</td></tr>
<tr><td>Jurong</td><td>-35</td></tr>
<tr><td>~~Bedok~~</td><td>~~35~~</td></tr>
<tr><td>~~Seletar~~</td><td>~~15~~</td></tr>
<tr><td>Changi</td><td>50</td></tr>
</table>
Ash transportation: 5km</td></tr>
<tr><td>Choice of data or Measurement methods and procedures</td><td>Transportation route of the vehicles from the WRP to project site, and from project site to TMTS (Tuas Marine Transfer Station) which is stated in PUB’s document.</td></tr>
<tr><td>Purpose of data</td><td>Leakage Emissions calculation</td></tr>
<tr><td>Additional comment</td><td>At the time of implementation of the project and during this monitoring period, the WRPs in Bedok and Seletar have already been decommissioned by PUB.</td></tr>
</table>

B.6.3. Ex ante calculation of emission reductions

>>

Project Emissions

$$PE_y = PE_{elec,y} + PE_{fuel,on-site,y} + PE_{i,y} \quad (1)$$

Where:

PE_y	is the project emissions during the year y (tCO_2e/yr)
$PE_{elec,y}$	is the emissions from electricity consumption due to the project activity during the year y (tCO_2/yr)
$PE_{fuel,on\text{-}site,y}$	is the emissions on-site due to fuel consumption on-site in year y (tCO_2/yr)
$PE_{i,y}$	is the emissions during the incineration process in year y (tCO_2e/yr)

PE_y	$PE_{elec,y}$	$PE_{fuel,on\text{-}site,y}$	$PE_{i,y}$
tCO_2e/yr	tCO_2/yr	tCO_2/yr	tCO_2e/yr
7,687	4,782	2,905	0

Emissions from electricity use ($PE_{elec,y}$)

$$PE_{elec,y} = EG_{PJ,EF,y} \times CEF_{elec} \quad (2)$$

Where:

$PE_{elec,y}$	is the emissions from electricity consumption due to the project activity during the year y (tCO_2/yr)
$EG_{PJ,EF,y}$	is the amount of electricity generated in an on-site fossil fuel fired power plant or consumed from the grid in the project activity, measured using an electricity meter (MWh)
CEF_{elec}	CO_2 emission factor for electricity generation in the project activity (tCO_2/MWh)

$PE_{elec,y}$	$EG_{PJ,EF,y}$	CEF_{elec}

tCO_2/yr	MWh	tCO_2/MWh
4,782	10,368	0.4612

Emissions from fuel use on-site ($PE_{fuel,on-site,y}$)

$$PE_{fuel,on-site,y} = F_{cons,y} \times NCV_{fuel} \times EF_{fuel} \quad (3)$$

Where:

$PE_{fuel,on\text{-}site,y}$	is the CO_2 emissions due to on-site fuel combustion in year *y* (tCO_2/yr)
$F_{cons,y}$	is the fuel consumption on site in year *y* (ton/yr)
NCV_{fuel}	is the net calorific value of natural gas (MJ/ton)
EF_{fuel}	is the CO_2 emission factor of natural gas (tCO_2/MJ)

$PE_{fuel,on\text{-}site,y}$	$F_{cons,y}$	NCV_{fuel}	EF_{fuel}
tCO_2/yr	ton/yr	MJ/ton	tCO_2/MJ
2,905	718	63,017	$64.2*10^{-6}$

Emissions from waste incineration processes ($PE_{i,y}$)

$$PE_{i,s,y} = SG_{i,y} \times MC_{N2O,i,y} \times GWP_{N2O} + SG_{i,y} \times MC_{CH4,i,y} \times GWP_{CH4} \quad (5)$$

Where:

$PE_{i,s,y}$	is the total emissions of N_2O and CH_4 from waste incineration in year *y* (tCO_2e)
$SG_{i,y}$	is the total volume of stack gas from waste incineration in year *y* (m^3/yr)
$MC_{N2O,i,y}$	is the monitored content of nitrous oxide in the stack gas from waste incineration in year *y* (tN_2O/m^3)
GWP_{N2O}	is the Global Warming Potential of nitrous oxide (tCO_2e/tN_2O)
$MC_{CH4,i,y}$	is the monitored content of methane in the stack gas from waste incineration in the year *y* (tCH_4/m^3)
GWP_{CH4}	is the Global Warming Potential of methane (tCO_2e/tCH_4)

$PE_{i,y}$	$SG_{i,y}$	$MC_{N2O,i,y}$	GWP_{N2O}	$MC_{CH4,i,y}$	GWP_{CH4}
tCO_2/yr	m^3/yr	tN_2O/m^3	tCO_2e/tN_2O	tCH_4/m^3	tCO_2e/tCH_4
0	$1,766*10^6$	0	310	0	21

Baseline Emissions

$$BE_y = MB_y - MD_{reg,y} + BE_{EN,y} \quad (6)$$

Where:

BE_y	is the baseline emissions in year *y* (tCO_2/yr)
MB_y	is the methane produced in the landfill in the absence of the project activity in year *y* (tCO_2e/yr)
$MD_{reg,y}$	is the methane that would be destroyed in the absence of the project activity in year *y* (tCO_2e/yr)
$BE_{EN,y}$	Baseline emissions from generation of energy displaced by the project activity in year *y* (tCO_2/yr)

Year *y*	BE_y	MB_y	$MD_{reg,y}$	$BE_{EN,y}$
	tCO_2/yr	tCO_2e/yr	tCO_2e/yr	tCO_2/yr
2010	46,577	46,577	0	0

2011	77,799	77,799		
2012	98,727	98,727		
2013	112,756	112,756		
2014	122,160	122,160		
2015	128,463	128,463		
2016	132,689	132,689		
2017	135,521	135,521		
2018	137,420	137,420		

Adjustment Factor (AF)

$$MD_{reg,y} = MB_y \times AF \qquad (7)$$

Where:

AF is the Adjustment Factor for MB_y (%)

$MD_{reg,y}$	MB_y	AF
tCO_2e/yr	tCO_2e/yr	%
0	See table above	0

Methane generation from the landfill in the absence of the project activity (MB_y)

$$MB_y = BE_{CH4,SWDS,y} \qquad (8)$$

$$BE_{CH4,SWDS,y} = \phi \cdot (1-f) \cdot GWP_{CH4} \cdot (1-OX) \cdot \frac{16}{12} \cdot F \cdot DOC_f \cdot MCF \cdot \sum_{x=1}^{y} W_{j,x} \cdot DOC_j \cdot e^{-kj \cdot (y-x)} \cdot (1-e^{-kj}) \qquad (9)$$

Where:

MB_y	is $BE_{CH4,SWDS,y}$ (tCO_2e/yr)
$BE_{CH4,SWDS,y}$	is the methane emissions avoided during the year *y* from preventing waste disposal at the solid waste disposal site (SWDS) during the period from the start of the project activity to the end of the year *y* (tCO_2e/yr)
ö	is the model correction factor to account for model uncertainties (0.9)
f	is the fraction of methane captured at the SWDS and flared, combusted or used in another manner
GWP_{CH4}	is the Global Warming Potential (GWP) of methane, valid for the relevant commitment period
OX	is the oxidation factor (reflecting the amount of methane from SWDS that is oxidised in the soil or other material covering the waste)
F	is the fraction of methane in the SWDS gas (volume fraction) (0.5)
DOC_f	is the fraction of degradable organic carbon (DOC) that can decompose
$W_{j,x}$	is the amount of waste type *j* prevented from disposal in the SWDS in the year *x* (tons)
MCF	is the methane correction factor
DOC_j	is the fraction of degradable organic carbon (by weight) in the waste type *j*
k_j	is the decay rate for the waste type *j*
x	is the year during the crediting period: *x* runs from the first year of the first crediting period (*x*=1) to year *y* for which avoided emissions are calculated (*x*=*y*)
y	is the year for which methane emissions are calculated

Year *y*	MB_y	$BE_{CH4,SWDS,y}$
	tCO_2e/yr	tCO_2e/yr
2010	46,577	46,577
2011	77,799	77,799
2012	98,727	98,727
2013	112,756	112,756
2014	122,160	122,160
2015	128,463	128,463
2016	132,689	132,689
2017	135,521	135,521
2018	137,420	137,420

ö	*f*	GWP_{CH4}	*OX*	*F*	DOC_f	*MCF*
-	-	-	-	-	-	-
0.9	0	21	0.1	0.5	0.5	1.0

	$W_{j,x}$	DOC_j	k_j
	tons/yr	%	-
Dewatered Sludge	160,000	7.4	0.4
Dry Sludge	44,480	29.4	0.4

Baseline emissions from generation of electricity displaced by the project activity
This section is not applicable since the proposed project activity does not involve any electricity generation.

Baseline emissions from electricity and heat cogeneration that is displaced by the project activity
This section is not applicable since the proposed project activity does not involve electricity or heat cogeneration.

<u>Leakage Emissions</u>

$$L_y = L_{t,y} + L_{i,y} \quad (10)$$

Where:

L_y	is the leakage emissions during the year *y* (tCO_2e/yr)
$L_{t,y}$	is the leakage emissions from increased transport in year *y* (tCO_2e/yr)
$L_{i,y}$	is the leakage emissions from the residual waste from MSW incinerator in year *y* (tCO_2e/yr)

L_y	$L_{t,y}$	$L_{t,y}$	$L_{t,y}$	$L_{i,y}$
tCO_2e/yr	tCO_2/yr	tCO_2/yr	tCO_2e/yr	tCO_2e/yr
~~971~~ 950	~~68~~ 46	12	29	862

Emissions from increased transport

Sludge transportation from WRPs

$$L_{t,y} = NO_{vehicles,y} \times DT_y \times VF_{cons} \times NCV_{fuel,transport} \times D_{fuel} \times EF_{fuel,transport} \quad (11)$$

Where:

$L_{t,y}$	is the leakage emissions from increased transport in year *y* (tCO_2e/yr)
$NO_{vehicles,y}$	is the number of vehicles for transport
DT_y	is the additional distance travelled compared to baseline in year *y* (km)
VF_{cons}	is the vehicle fuel consumption in litres per kilometre (l/km)
$NCV_{fuel,transport}$	is the calorific value of the fuel (MJ/kg)
D_{fuel}	is the fuel density (kg/l)
$EF_{fuel,transport}$	is the emission factor of the fuel (tCO_2/MJ)

Water Reclamation Plant (WRP)	$NO_{vehicles,y}$	DT_y	VF_{cons}	$NCV_{fuel,transport}$	D_{fuel}	$EF_{fuel,transport}$	$L_{t,y}$
	-	km	l/km	MJ/kg	kg/l	tCO_2/MJ	tCO_2
Ulu Pandan	3,960	-16	0.45	43.0	0.85	$74.1{*}10^{-6}$	-77
Kranji	1,900	-13					-30
Jurong	3,460	-35					-148
~~Bedok~~	~~340~~	~~35~~					~~15~~
~~Seletar~~	~~340~~	~~15~~					~~6~~
Changi	4,942	50					301
						Total	~~68~~ 46

(note) *DT_y is estimated from the date below.*
The sewage sludge that is presently transported from the Water Reclamation Plants to the disposal site at Changi, will be transported to the project site at Tuas in the proposed project activity. The study result of the travel distance of vehicles in the baseline and project scenario is as shown in the table below.

Water Reclamation Plant (WRP)	Distance from WRP to Disposal Site (Changi)	Distance from WRP to Project Site (Tuas)	Additional Distance
	km	km	km
Ulu Pandan	42	26	-16
Kranji	44	31	-13
Jurong	48	13	-35
~~Bedok~~	~~16~~	~~51~~	~~35~~
~~Seletar~~	~~32~~	~~47~~	~~15~~
Changi	9	59	50
Total	~~191~~ 143	~~227~~ 129	~~36~~ -14

Ash transportation from project site to TMTS (Tuas Marine Transfer Station)

$$L_{t,y} = NO_{vehicles,y} \times DT_y \times VF_{cons} \times NCV_{fuel,transport} \times D_{fuel} \times EF_{fuel,transport} \quad (11)$$

Where:

$L_{t,y}$	is the leakage emissions from increased transport in year *y* (tCO_2e/yr)
$NO_{vehicles,y}$	is the number of vehicles for transport
DT_y	is the additional distance travelled compared to baseline in year *y* (km)
VF_{cons}	is the vehicle fuel consumption in litres per kilometre (l/km)
$NCV_{fuel,transport}$	is the calorific value of the fuel (MJ/kg)
D_{fuel}	is the fuel density (kg/l)

$EF_{fuel,transport}$ is the emission factor of the fuel (tCO_2/MJ)

$NO_{vehicles,y}$	DT_y	VF_{cons}	$NCV_{fuel,transport}$	D_{fuel}	$EF_{fuel,transport}$	$L_{t,y}$
-	km	l/km	MJ/kg	kg/l	tCO_2/MJ	tCO_2
1,470	5	0.59	43.0	0.85	$74.1*10^{-6}$	12

Ash transportation from TMTS to Semakau landfill

$$L_{t,y} = NO_{vehicles,y} \times DT_y \times VF_{cons} \times NCV_{fuel,transport} \times D_{fuel} \times EF_{fuel,transport} \times C_{ashratio} \quad (11)$$

Where:

$L_{t,y}$ is the leakage emissions from increased transport in year *y* (tCO_2e/yr)
$NO_{vehicles,y}$ is the number of vehicles (barges) for transport
DT_y is the additional distance travelled compared to baseline in year *y* (km)
VF_{cons} is the vehicle fuel consumption in litres per kilometre (l/km)
$NCV_{fuel,transport}$ is the calorific value of the fuel (MJ/kg)
D_{fuel} is the fuel density (kg/l)
$EF_{fuel,transport}$ is the emission factor of the fuel (tCO_2/MJ)

$NO_{vehicles,y}$	DT_y	VF_{cons}	$NCV_{fuel,transport}$	D_{fuel}	$EF_{fuel,transport}$	$L_{t,y}$
-	km	l/km	MJ/kg	kg/l	tCO_2/MJ	tCO_2
8	50	27	43.0	0.85	$74.1*10^{-6}$	29

Emissions from the residual waste from MSW incineration

$$L_{i,y} = A_{residual} \times FC_{residual} \times \frac{44}{12} \quad (12)$$

Where:

$L_{i,y}$ is the leakage emissions from the residual waste of the incinerator in year *y* (tCO_2e/yr)
$A_{residual}$ is the amount of residual waste from the incinerator (t/yr)
$FC_{residual}$ is the fraction of residual carbon contained in the residual waste (%)

$L_{i,y}$	$A_{residual}$	$FC_{residual}$
tCO_2e/yr	t/yr	%
862	23,520	1.0

The residual carbon content in the ash from similar type of incinerator was 0.63 – 0.80%. However, the residual carbon content is affected largely by the sludge properties and operation condition.

B.6.4. Summary of ex ante estimates of emission reductions

The ex-ante emission reductions throughout the crediting period are estimated as below:

Year	Baseline emissions (t CO_2e)	Project emissions (t CO_2e)	Leakage (t CO_2e)	Emission reductions (t CO_2e)
2010	46,577	7,687	950	~~37,919~~ 37,940
2011	77,799	7,687	~~971~~ 950	~~69,141~~ 69,162
2012	98,727	7,687	~~971~~ 950	~~90,069~~ 90,090
2013	112,756	7,687	~~971~~ 950	~~104,098~~ 104,119
2014	122,160	7,687	~~971~~ 950	~~113,502~~ 113,523
2015	128,463	7,687	~~971~~ 950	~~119,805~~ 119,826
2016	132,689	7,687	~~971~~ 950	~~124,031~~ 124,052
2017	135,521	7,687	~~971~~ 950	~~126,863~~ 126,884
2018	137,420	7,687	~~971~~ 950	~~128,762~~ 128,783
Total	992,112	69,183	~~8,739~~ 8,550	~~914,190~~ 914,379
Total number of crediting years	9			
Annual average over the crediting period	110,235	7,687	~~971~~ 950	~~101,577~~ 101,598

B.7. Monitoring plan
B.7.1. Data and parameters to be monitored

Data / Parameter	$EG_{PJ,EF,y}$
Unit	MWh/year
Description	The amount of electricity consumed from the grid in the project activity.
Source of data	ECO Special Waste Management Pte. Ltd.
Value(s) applied	10,368 MWh
Measurement methods and procedures	Electricity consumption will be measured by an electric meter of the dehydration incineration plant and aggregated annually.
Monitoring Frequency	Continuous
QA/QC procedures	Maintenance and calibration of meters will be carried out by a third party according to relevant local/international standards. Data will be cross checked by electricity bill.
Purpose of data	**Project Emissions calculation**
Additional comment	The electric meter of the plant has an accuracy class of 0.5s

Data / Parameter	$F_{cons,y}$
Unit	tons/year
Description	The natural gas consumption for the auxiliary burner of the incinerator
Source of data	ECO Special Waste Management Pte. Ltd.
Value(s) applied	718 tons

Measurement methods and procedures	Amount of natural gas consumption will be monitored by the original invoices from the natural gas supplier and flow meters that are installed for individual trains. Data will be aggregated annually.
Monitoring Frequency	Continuous
QA/QC procedures	Consistency between the invoice and accumulated data of the flow meter will be checked periodically. The flow meters that are installed for individual trains will be calibrated periodically by a third party.
Purpose of data	**Project Emissions calculation**
Additional comment	Accuracy level of the flow meter installed for individual trains is less than ± 1%

Data / Parameter	NCV_{fuel}
Unit	MJ/ton
Description	Net calorific value of natural gas
Source of data	Based on NCV value provided by the gas supplier
Value(s) applied	63,017
Measurement methods and procedures	NCV of natural gas is monitored daily by the gas supplier, and it is provided by the gas supplier. The monthly data of NCV will be used to calculate the project emission from natural gas consumption.
Monitoring Frequency	Monthly
QA/QC procedures	
Purpose of data	**Leakage Emissions calculation**
Additional comment	-

Data / Parameter	SG_y
Unit	m^3/year
Description	Stack gas volume flow rate
Source of data	ECO Special Waste Management Pte. Ltd.
Value(s) applied	1,766*10^6 m^3/y
Measurement methods and procedures	The flow rate of the stack gas will be monitored using a flow meter.
Monitoring Frequency	Continuous
QA/QC procedures	Maintenance and calibration of meters will be carried out by a third party according to relevant local/international standards.
Purpose of data	**Project Emissions calculation**
Additional comment	Accuracy level of flow meter is ±1% of reading +0.5% of full scale

Data / Parameter	$MC_{N2O,y}$
Unit	tN_2O/m^3
Description	Fraction of N_2O
Source of data	Outsourced

Value(s) applied	0
Measurement methods and procedures	Stack gas composition will be monitored by gas analyzer.
Monitoring Frequency	Quarterly
QA/QC procedures	Gas analyzing will be carried out by a third party according to relevant local/international standards.
Purpose of data	**Project Emissions calculation**
Additional comment	-

Data / Parameter	$MC_{CH4,y}$
Unit	tCH_4/m^3
Description	Fraction of CH_4
Source of data	Outsourced
Value(s) applied	0
Measurement methods and procedures	Stack gas composition will be monitored by gas analyzer.
Monitoring Frequency	Quarterly
QA/QC procedures	Gas analyzing will be carried out by a third party according to relevant local/international standards.
Purpose of data	**Project Emissions calculation**
Additional comment	-

Data / Parameter	W_j
Unit	tons
Description	Total amount of waste type *j* prevented from disposal in year *x*
Source of data	ECO Special Waste Management Pte. Ltd.
Value(s) applied	(see table below)
Measurement methods and procedures	The amount of incoming waste will be measured by a weighbridge on a continuous basis and aggregated annually. Data will be recorded in a manner that the quantity of dewatered sludge and dry sludge can be clearly distinguished.
Monitoring Frequency	Continuous

Year	$W_{dewatered}$	W_{dry}
2010	160,000	44,480
2011	160,000	44,480
2012	160,000	44,480
2013	160,000	44,480
2014	160,000	44,480
2015	160,000	44,480
2016	160,000	44,480
2017	160,000	44,480
2018	160,000	44,480

QA/QC procedures	The weighbridge will be subject to appropriate maintenance and periodic calibration by a third party.
Purpose of data	**Baseline Emissions calculation**
Additional comment	Accuracy level of weighbridge is ±10kg

Data / Parameter	$NO_{vehicles,y}$
Unit	-
Description	The number of vehicles for transport
Source of data	ECO Special Waste Management Pte. Ltd.
Value(s) applied	$NO_{vehicles,y}$ for sewage sludge transportation Water Reclamation Plant (WRP) / $NO_{vehicles,y}$ (-): Ulu Pandan: 3,960 Kranji: 1,900 Jurong: 3,460 ~~Bedok~~: ~~340~~ ~~Seletar~~: ~~340~~ Changi: 4,942 $NO_{vehicles,y}$ for ash transportation from project site to TMTS 1,470 $NO_{vehicles,y}$ for ash transportation from TMTS to Semakau Landfill 8
Measurement methods and procedures	Sewage sludge transportation ▪ Each load of sewage sludge delivery to ECO is attached with PUB's delivery order document with different colors indicating various sources of WRP. This information is recorded into weighbridge recording system and reported as Daily Loads Report. Ash transportation from project site to TMTS ▪ Each full load of ash delivery to TMTS by ECO's vehicle is recorded clearly into a log book which will be then recorded and computed. Ash transportation from TMTS to Semakau Landfill ▪ Number of vehicle (barge) is calculated by dividing the monitored ash amount with the fixed barge loading capacity.
Monitoring Frequency	Daily
QA/QC procedures	Appropriate maintenance of weighbridge recording system is required.
Purpose of data	**Leakage Emissions calculation**
Additional comment	-

<table>
<tr><td>Data / Parameter</td><td>$DT_{i,y}$</td></tr>
<tr><td>Unit</td><td>km</td></tr>
<tr><td>Description</td><td>Average additional distance travelled compared to the baseline</td></tr>
<tr><td>Source of data</td><td>PUB (Public Utilities Board) documents</td></tr>
<tr><td>Value(s) applied</td><td>Sludge transportation:
<table>
<tr><th>WRP</th><th>Additional Distance (km)</th></tr>
<tr><td>Ulu Pandan</td><td>-16</td></tr>
<tr><td>Kranji</td><td>-13</td></tr>
<tr><td>Jurong</td><td>-35</td></tr>
<tr><td>~~Bedok~~</td><td>~~35~~</td></tr>
<tr><td>~~Seletar~~</td><td>~~15~~</td></tr>
<tr><td>Changi</td><td>50</td></tr>
</table>
Ash transportation to TMTS: 5km
Ash transportation to Semakau Landfill: 50km</td></tr>
<tr><td>Measurement methods and procedures</td><td>-</td></tr>
<tr><td>Monitoring Frequency</td><td>Annually</td></tr>
<tr><td>QA/QC procedures</td><td>Nil</td></tr>
<tr><td>Purpose of data</td><td>Leakage Emissions calculation</td></tr>
<tr><td>Additional comment</td><td>-</td></tr>
</table>

Data / Parameter	***VF_{cons}***
Unit	l/km
Description	The vehicle fuel consumption in litres per kilometre
Source of data	The transporter ▪ Sewage sludge transportation (PUB's appointed tranporter) ▪ Ash transportation from project site to TMTS (ECO Special Waste Management Ptd. Ltd.) ▪ Ash transportation from TMTS to Semakau Landfill (NEA)
Value(s) applied	0.45 for sludge transportation from WRPs 0.59 for ash transportation from project site to TMTS 24.1 for ash transportation from TMTS to Semakau landfill
Measurement methods and procedures	The parameter will be requested via written correspondence to respective transporter by ECO Special Waste Management Pte. Ltd.
Monitoring Frequency	Quarterly
QA/QC procedures	Nil
Purpose of data	**Leakage Emissions calculation**
Additional comment	

Data / Parameter	***$NCV_{fuel,transport}$***
Unit	MJ/kg
Description	The calorific value of the fuel
Source of data	The fuel supplier

Value(s) applied	43.0 MJ/kg
Measurement methods and procedures	The parameter will be requested via written correspondence to respective fuel supplier by ECO Special Waste Management Pte. Ltd.
Monitoring Frequency	Quarterly
QA/QC procedures	Nil
Purpose of data	**Leakage Emissions calculation**
Additional comment	-

Data / Parameter	D_{fuel}
Unit	kg/l
Description	the fuel density (kg/l)
Source of data	The fuel supplier
Value(s) applied	0.85 kg/l
Measurement methods and procedures	The parameter will be requested via written correspondence to respective fuel supplier by ECO Special Waste Management Pte. Ltd.
Monitoring Frequency	Quarterly
QA/QC procedures	Nil
Purpose of data	**Leakage Emissions calculation**
Additional comment	-

Data / Parameter	$A_{residual}$
Unit	tons/year
Description	The amount of the residual waste from the incinerator
Source of data	ECO Special Waste Management Pte. Ltd.
Value(s) applied	23,520 tons
Measurement methods and procedures	The amount will be measured at the weighbridge.
Monitoring Frequency	Daily, aggregated annually.
QA/QC procedures	The weighbridge will be subject to appropriate maintenance and periodic calibration by a third party.
Purpose of data	**Leakage Emissions calculation**
Additional comment	Accuracy level of weighbridge is ±10kg

Data / Parameter	$FC_{residual}$
Unit	%
Description	Fraction of residual carbon in the residual waste of the incinerator
Source of data	Outsourced

Value(s) applied	1
Measurement methods and procedures	-
Monitoring Frequency	Sampling will be conducted to achieve maximum uncertainty range of 20% at a 95% confidence level. Sampling should be undertaken four times per year.
QA/QC procedures	Analyzing of the residual waste will be carried out by a third party according to relevant local/international standards.
Purpose of data	**Leakage Emissions calculation**
Additional comment	-

Data / Parameter	Energy generated by the auxiliary fossil fuel added in the incinerator
Unit	MJ
Description	Energy generated by the auxiliary fossil fuel added in the incinerator
Source of data	Project site
Value(s) applied	-
Measurement methods and procedures	The parameter will be calculated by multiplying the annual natural gas consumption to the average gross calorific value of natural gas.
Monitoring Frequency	Annually
QA/QC procedures	Natural gas consumption and gross heat value will be extracted from supplier's monthly bill.
Purpose of data	This parameter will be used to assess that the fraction of energy generated by fossil fuel is no more than 50% of the total energy generated in the incinerator. Energy generated by fossil fuel < 0.50 x (Q_y + $EG_{d,y}$)
Additional comment	-

Data / Parameter	$\boldsymbol{GWP_{CH4}}$
Unit	tCO_2e/tCH_4
Description	Global Warming Potential (GWP) of methane, valid for the relevant commitment period
Source of data	Decisions under UNFCCC and the Kyoto Protocol (a value of 21 is to be applied for the first commitment period of the Kyoto Protocol)
Value(s) applied	21
Measurement methods and procedures	Decisions under UNFCCC and the Kyoto Protocol (a value of 21 is to be applied for the first commitment period of the Kyoto Protocol)
Monitoring Frequency	Annually
QA/QC procedures	-
Purpose of data	**Baseline and Project Emissions calculation**
Additional comment	-

B.7.2. Sampling plan

>>

Not Applicable. AM0025 Ver 11 does not specify any requirement on sampling.

B.7.3. Other elements of monitoring plan

>>

ECO will collect and store relevant data in a systematic and reliable way, evaluate them regularly, generate reports, and ensure the availability of pertinent information for verification. An electronic spreadsheet file will be kept to accumulate all monitored variables, which will be presented to the DOE for verification.

Organization Structure and Monitoring Procedures

The basic organization structure as currently planned is described in Figure-8. Detail on monitoring and QA/QC procedures for each monitoring items will be put in to the Monitoring Manual which will be finalized before start of operation.

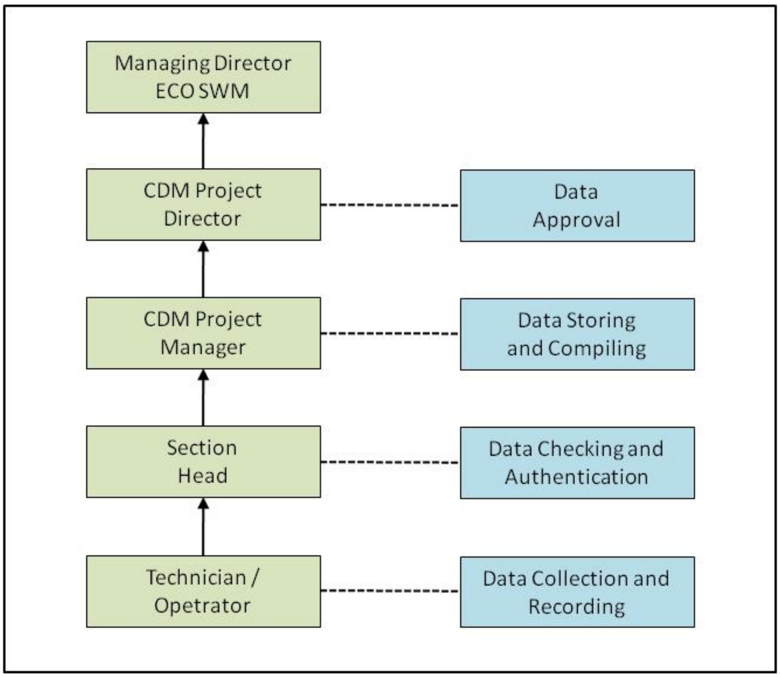

Figure-8 Basic organization structure

Data for the monitoring items will be collected and recorded by the Technicians or Operators at the project site. Then the collected and recorded data will be passed to the Section Head for checking and authentication. The CDM Manager will receive the authenticated data from the Section Head where the data will be cross checked with other sources such as invoices from suppliers. The data will be stored and compiled for calculation of the emission reduction and summarized for the monitoring report. The CDM Project Director will finally approve the data and will report to the Managing Director.

Calibration Certificates, Other Relevant Documents

Calibration of the monitoring equipment, meters, and weighbridges used will be done on a regular basis as recommended by the suppliers of the equipment or by the authorities. Records of the calibration certificates will be kept at the plant site and a duplicate will be stored at ECO. For parameters that will be

monitored by third parties, certification of the third parties will also be compiled and presented to the verifier if necessary.

Training
ECO will engage a CDM consultant for training of the CDM related staffs. The training may include but not be limited to the following;
- Importance of monitoring
- Detailed explanation on monitoring and QA/QC procedures
- Countermeasures for emergency situations and detail on incident reporting and corrective actions

SECTION C. Duration and crediting period
C.1. Duration of project activity
C.1.1. Start date of project activity
>>
10/01/2008
(Date when ECO signed the contract with the major equipment suppliers)

C.1.2. Expected operational lifetime of project activity
>>
10 years

C.2. Crediting period of project activity
C.2.1. Type of crediting period
>>
Fixed Crediting Period

C.2.2. Start date of crediting period
>>
01/01/2010 or the date of registration, whichever is later

C.2.3. Length of crediting period
>>
9 years

SECTION D. Environmental impacts
D.1. Analysis of environmental impacts
>>
The proposed project activity employs the advanced technology from Japan to dehydrate and incinerate sewage sludge. The system is well-equipped with pollution control equipment which is able to ensure all the anticipated environmental impacts are below the regulated values. Control measures will be implemented to ensure no significant environmental impact has been arisen from the project activity.

EIA & PCS Requirements
Through the communications between ECO and the relevant environment protection authorities in Singapore, it was confirmed by the relevant authorities on 8th April, 17th April, 9th July and 10th July 2008 that EIA was not requested for the proposed project activities. Further, NEA confirmed on 1st August 2008 that PCS (Pollution Control Study) was not insisted for the proposed project activities.

Air Pollution Impact
Exhaust gas is released to the atmosphere during the incineration of sewage sludge. The amount of air pollutants emitted to the air such as SO_x and NO_x are controlled by the cyclone and wet scrubber. The concentration level of air pollutants released, which are within the allowable limits for National Emission Standards for Air Pollutants in Code of Practice on Pollution Control (Appendix 19), is listed as follows:

Source	Air Pollutants	Concentration of Air Pollutants
Exhaust gas	SO_2	Max. 500mg/Nm^3
	NO_x	Max. 700mg/Nm^3
	Dust	Max. 100mg/Nm^3
	Dioxins and Furans	Max. 0.05ngTEQ/Nm^3
	CO	Less than 100mg/Nm^3
	Cu	Less than 1mg/ Nm^3
	HCl	Less than 200mg/Nm^3
	Smoke	Ringelmann No.1
	SO_3	Max. 100mg/Nm^3

Water Pollution Impact
The ash which is the end product from the incineration process will be disposed at Semakau landfill. The ash will be tested in accordance with the requirements of Leaching Test – Recommended Acceptance Criteria for Suitability of Industrial Wastes for Landfill Disposal, NEA.

The quantity of trade effluent (in m^3 per day) generated from the wet scrubber is approximately 120 and shall be treated to meet the Trade Effluent Discharge Limit.

The nature and characteristics of trade effluent, which are within the allowable limits for Trade Effluent Discharge in Code of Practice on Pollution Control (Appendix 9), are listed as follows:

Parameters	Quality Before Treatment	Quality after treatment
pH	4-7	6-9
BOD	Less than 100mg/l	Less than 100mg/l
COD	3,500mg/l	Less than 600mg/l
Suspended Solids	Less than 400mg/l	Less than 400mg/l
Total Dissolved Solids	Less than 40,000mg/l	Less than 3,000mg/l
Detergents	Nil	Nil
Oil & Grease	Nil	Nil
Fe	Less than 40mg/l	Less than 40mg/l
SO_4	30,000mg/l	Less than 1,000mg/l

Odour Impact
Odour nuisance may arise from the sludge receiving and handling building of the sludge treatment plant. With the proper containment within the sludge receiving building for dewatered and dry sludge, the odour is drawn through the vacuum ducts in the handling building and burned off in the incinerator before it is released to the atmosphere.

Noise Impact
The equipments which are installed in open surrounding operate at a very low noise level, except for the Circulation and Induced Fans whose noise level can reach as high as 90 decibels (dB). For these equipments, suitable acoustic enclosures are designed and constructed to contain the noise emitted by the equipments to locally acceptable level.

D.2. Environmental impact assessment
>>
The proposed project activity will meet all of the requirements and expect no significant environmental impacts.

SECTION E. Local stakeholder consultation

E.1. Solicitation of comments from local stakeholders
>>
Public consultation was undertaken as a part of the development of the Project activity. The public consultation was held at the Raffles Country Club (Raffles Lounge) on 4th September, 2008. The announcement of the meeting was made by invitation letter which was sent to neighboring companies, national authorities, NGO, academic institutions, and others during the third week of August 2008. A total of 29 people from 20 organizations participated in the meeting.
(Other than project participants)
Throughout the meeting, followings were presented to the participants.

- Purposes of the proposed project activity
- General description of the proposed project activity
- Environmental impact of the proposed project activity
- Benefits of the proposed project activity related to sustainable development
- Outline of CDM


Photo-3 Stakeholders' Meeting at Raffles Country Club


Photo-4 Q&A Session

E.2. Summary of comments received
>>
The Q&A session of the meeting was conducted by Mrs. Tam Li Phin (Director, School of Engineering Centre of Innovation Environmental & Water Technology, Ngee Ann Polytechnic) to ensure the meeting to be held in a proper and transparent manner.
The concerns raised by the stakeholders were answered clearly and thoroughly by the project participants. The stakeholders understood and were satisfied with the answers, and expressed their support for the implementation of the project.

E.3. Report on consideration of comments received
>>
There were no issues raised that required further explanations or interaction with the stakeholders.

SECTION F. Approval and authorization

>>

The project has been granted Letters of Approval (LoAs) both from The Republic of Singapore (8 Apr 2009) and Japan (24 June 2009).

- - - - -

Appendix 1: Contact information of project participants

Organization name	ECO Special Waste Management Pte. Ltd.
Street/P.O. Box	23 Tuas View Circuit
Building	-
City	-
State/Region	-
Postcode	637768
Country	Republic of Singapore
Telephone	(65) 6517 3600
Fax	(65) 6863 7809
E-mail	swmsales@eco.com.sg
Website	www.eco.com.sg
Contact person	-
Title	Senior Technical Manager
Salutation	Mr.
Last name	Boon Seng
Middle name	Tang
First name	Vincent
Department	-
Mobile	(65) 9230 1483
Direct fax	(65) 6862 0133
Direct tel.	(65) 6517 3642
Personal e-mail	bstang@eco.com.sg

Organization name	Sumitomo Mitsui Banking Corporation
Street/P.O. Box	1-2, Yurakucho 1-chome
Building	-
City	Chiyoda-ku
State/Region	Tokyo
Postcode	100-0006
Country	Japan
Telephone	-
Fax	-
E-mail	-
Website	http://www.smbc.co.jp/global/index.html
Contact person	-
Title	General Manager
Salutation	Ms.
Last name	Kudo
Middle name	-
First name	Teiko
Department	Environmental Products Department, Investment Banking Unit
Mobile	-
Direct fax	(81) 3 3501 8531
Direct tel.	(81) 3 3592 8238
Personal e-mail	Kudo_Teiko@yk.smbc.co.jp

Organization name	Kajima Corporation
Street/P.O. Box	3-1, Motoakasaka 1-chome,
Building	-
City	Minato-ku
State/Region	Tokyo
Postcode	107-8388
Country	Japan
Telephone	(81) 3 5544 1111
Fax	(81) 3 6438 2700
E-mail	-
Website	http://www.kajima.co.jp/welcome.html
Contact person	-
Title	General Manager
Salutation	Dr.
Last name	Bando
Middle name	-
First name	Kozo
Department	CDM/JI Group, Environmental Engineering Division
Mobile	(81) 90 4714 9778
Direct fax	(81) 3 5544 1736
Direct tel.	(81) 3 5544 0742
Personal e-mail	bandok@kajima.com

Appendix 2: Affirmation regarding public funding

The financial plans for the project activity do not involve any public funding from any countries

Appendix 3: Applicability of selected methodology

Table-2 Requirements described in the methodology

Requirement	Project Condition
In the case of incineration of the waste, the waste should not be stored longer than 10 days. The waste should not be stored in conditions that lead to anaerobic decomposition and, hence, generation of CH_4.	The plant is designed to treat 100% of the daily incoming sludge and the pit capacity is designed to store two days sludge volume. Therefore, the proposed project activity will not store the sewage sludge longer than 10 days and the sewage sludge will not be stored in conditions that may lead to anaerobic decomposition.
The proportions and characteristics of different types of organic waste processed in the project activity can be determined, in order to apply a multiphase landfill gas generation model to estimate the quantity of landfill gas that would have been generated in the absence of the project activity	Proportion and characteristics of dewatered and dry sludge can be determined since the sources are clearly specified, and only one type of waste (sewage sludge) will be treated in the proposed project activity.
The project activity may include electricity generation and/or thermal energy generation from the biogas, syngas captured, RDF/stabilized biomass produced, combustion heat generated in the incineration process, respectively, from the anaerobic digester, the gasifier, RDF/stabilized biomass combustor, and waste incinerator. The electricity can be exported to the grid and/or used internally at the project site. In case of RDF produced, the emission reductions can be claimed only for the cases where the RDF used for electricity and/or thermal energy generation can be monitored.	The project activity generates thermal energy from combustion heat generated in the incineration process. The thermal energy will be used on-site for the dehydration process of the sewage sludge. Emission reduction will not be claimed for the thermal energy generation, since it will not displace fossil fuel that would have been consumed in the absence of the project activity.
Waste handling in the baseline scenario shows a continuation of current practice of disposing waste in landfill despite environmental regulation that mandates the treatment of waste, if any, using any of the project activity mentioned above.	There are no laws, regulations, or government policies that restrict the disposal of sewage sludge. Therefore the baseline scenario shows that the current practice of disposing sewage sludge at the sludge disposal site will be continued.
The compliance rate of the environmental regulation during (part of) the crediting period is below 50%, if monitored compliance with the MSW rules exceeds 50%, the project activity shall receive no further credit, since the assumption that the policy is not enforced is no longer tenable.	There are no laws, regulations, or government policies that restrict the disposal of sewage sludge in Singapore. Therefore, the compliance rate does not need to be taken into account.

Requirement	Project Condition
The project activity does not involve thermal treatment process of neither industrial or hospital waste.	The proposed project activity handles sewage sludge from water reclamation plants. Neither industrial nor hospital waste is treated in the project activity.
In case of waste incineration, if auxiliary fossil fuel is added into the incinerator, the fraction of energy generated by auxiliary fossil fuel is no more than 50% of the total energy generated in the incinerator.	The energy generated from the auxiliary fuel (natural gas) is below 50% of the total energy generated in the incinerator.
This methodology is not applicable to project activities that involve capture and flaring of methane from existing waste in the landfill. This should be treated as a separate project activity due to the difference in waste characteristics of existing and fresh waste, which may have an implication on the baseline scenario determination.	The proposed project does not involve landfill gas capture or flaring.

Appendix 4: Further background information on ex ante calculation of emission reductions

BASELINE INFORMATION

1. Amount of Sewage Sludge

The amount of sewage sludge is calculated below.
ECO will receive sewage sludge from PUB for 9 years.

Dewatered Sludge	1,440,000 ton
Dry Sludge	400,000 ton

Therefore, the total amount per annum is 204,444 ton according to the calculation below.

(1,440,000 + 400,000)ton / 9years = 204,444 ton/year

The value applied to the PDD is calculated from the plant capacity and operation days per annum.

Dewatered Sludge	500 ton/day
Dry Sludge	139 ton/day

(500 + 139)ton * 320days = <u>204,480</u> ton/year

Since the capacity is a rounded figure, the total amount per annum is slightly different from 204,444 ton/year.

2. Baseline Emission

$$MB_y = BE_{CH4,SWDS,y}$$

$$BE_{CH4,SWDS,y} = \phi \cdot (1-f) \cdot (1-OX) \cdot \frac{16}{12} \cdot F \cdot DOC_f \cdot MCF \cdot \sum_{x=1}^{y} \sum_{j} W_{j,x} \cdot DOC_j \cdot e^{-kj \cdot (y-x)} \cdot (1-e^{-kj})$$

Parameters

1	ϕ	Model correstion factor to account for model uncertainties	0.9	-
2	f	Fraction of methane captured at the SWDS and flared, combusted or used in another	0	-
3	OX	Oxidation factor	0.1	-
4	F	Fraction of methane in the SWDS gas (volume fraction)	0.5	-
5	DOCf	Fraction of degradable organic carbon (DOC) that can decompose	0.5	-
6	MCF	Methane correction factor	1.0	-
7-1	$DOC_{dewatered}$	Fraction of degradable organic carbon (by weight) in the dewatered sludge	0.074	-
7-2	DOC_{dry}	Fraction of degradable organic carbon (by weight) in the dry sludge	0.294	-
8	k	Decay rate	0.4	-
9	W	Amount of waste prevented from disposal in the SWDS	204,480	ton

Gas Emission Computation

Year	Sludge Disposal	gas emission (tonCO_2/year)								
	t/year	2010	2011	2012	2013	2014	2015	2016	2017	2018
2018	204,480									46,577
2017	204,480								46,577	31,222
2016	204,480							46,577	31,222	20,928
2015	204,480						46,577	31,222	20,928	14,029
2014	204,480					46,577	31,222	20,928	14,029	9,404
2013	204,480				46,577	31,222	20,928	14,029	9,404	6,304
2012	204,480			46,577	31,222	20,928	14,029	9,404	6,304	4,225
2011	204,480		46,577	31,222	20,928	14,029	9,404	6,304	4,225	2,832
2010	204,480	46,577	31,222	20,928	14,029	9,404	6,304	4,225	2,832	1,899
total	1,840,320	46,577	77,799	98,727	112,756	122,160	128,463	132,689	135,521	137,420

Baseline Emission	**46,577**	**77,799**	**98,727**	**112,756**	**122,160**	**128,463**	**132,689**	**135,521**	**137,420**

3. DOC

The DOC value that was used for the previous version of the PDD was 6.8% which was derived from the proportion of domestic and industrial wastewater treated in Singapore, and the default value that is provided in the IPCC 2006 Guidelines for National Greenhouse Gas Inventories.

Domestic wastewater treated in Singapore: 55%
Industrial wastewater treated in Singapore: 45%

IPCC default value for domestic sludge: 5% (Assuming the dry matter content of 10%)
IPCC default value for industrial sludge: 9% (Assuming the dry matter content of 35%)

5% * 0.55 + 9% * 0.45 = 6.8%

However, there was a fundamental mistake when applying the IPCC default value. The dry matter content (or water content) was not taken into account. The dry matter content of the two types of sewage sludge that will be treated in the proposed project activity is 15 – 25% for dewatered sludge (500 ton/day), and 90% for dry sludge (139 ton/day) meaning the basis for setting the DOC value is completely different.

As readily surmised, DOC content of the sludge is likely to vary depending on the local conditions such as wastewater characteristics and treatment process. Considering these observations and the importance of the DOC value, this project uses the actual DOC value that is estimated by laboratory analysis for setting the DOC. The IPCC default value was used in the initial PDD, only because the laboratory analysis result was not available at the time of completion of the initial PDD.

In order to apply the most appropriate DOC values for the two types of sewage sludge, laboratory analysis was conducted at ICES (Institute of Chemical Engineering Sciences) which is a government research institute of Singapore under A Star (Agency for Science, Technology and Research). Samples from all operating WRPs were collected and analyzed to derive the DOC value. The DOC value for dewatered sludge is an average figure for the WRPs that produce dewatered sludge, and the DOC value for dry sludge represents Changi WRP which is the only WRP that produces dry sludge, as illustrated in the table below.

Dewatered sludge: 7.4% (Dry matter content of 15 – 25%)
Dry sludge: 29.4% (Dry matter content of 90%)

Table DOC values analyzed and averaged DOC values for the Project

	Dry matter content	DOC analysed	Average DOC to be used for Project
Dewatered sludge	15% – 25%	5.5% -9.3%	7.4%
Dry sludge	90%	29.4%	29.4%

When the above DOC value is converted so the dry matter content is 10% for all samples, the average equivalent DOC value is 3.9% which is lower than the IPCC default value for domestic sludge.

4. IRR Spread Sheet

(A) PIRR for basic scenario (5 Trains)

IRR 4.36%

	0	1	2	3	4	5	6	7	8	9
Capital Investment	(30,800,000)	0	0	0	0	0	0	0	0	0
Landfill Cost		1,692,499	1,709,424	1,726,518	1,743,784	1,761,221	1,778,834	1,796,622	1,814,588	1,832,734
Electricity Cost		1,741,824	1,776,660	1,812,194	1,848,438	1,885,406	1,923,114	1,961,577	2,000,808	2,040,824
Natural Gas		1,169,219	1,192,604	1,216,456	1,240,785	1,265,600	1,290,912	1,316,731	1,343,065	1,369,927
Others		2,666,373	2,725,276	2,785,847	2,848,139	2,912,206	2,978,105	3,045,895	3,115,637	3,187,392
Operation Cost Total		7,269,915	7,403,964	7,541,015	7,681,145	7,824,434	7,970,966	8,120,825	8,274,098	8,430,878
Revenue (Disposal fee)		12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778
Depreciation		3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222
Asset Value After Depreciation		27,377,778	23,955,556	20,533,333	17,111,111	13,688,889	10,266,667	6,844,444	3,422,222	0
Tax		267,415	243,286	218,617	193,394	167,602	141,226	114,252	86,662	58,442
Balance	(30,800,000)	4,640,447	4,530,527	4,418,145	4,303,239	4,185,742	4,065,586	3,942,702	3,817,017	3,688,458

(1) PIRR for landfill cost +10% scenario

IRR 3.56%

	0	1	2	3	4	5	6	7	8	9
Capital Investment	(30,800,000)	0	0	0	0	0	0	0	0	0
Landfill Cost		1,861,749	1,880,367	1,899,170	1,918,162	1,937,344	1,956,717	1,976,284	1,996,047	2,016,008
Electricity Cost		1,741,824	1,776,660	1,812,194	1,848,438	1,885,406	1,923,114	1,961,577	2,000,808	2,040,824
Natural Gas		1,169,219	1,192,604	1,216,456	1,240,785	1,265,600	1,290,912	1,316,731	1,343,065	1,369,927
Others		2,666,373	2,725,276	2,785,847	2,848,139	2,912,206	2,978,105	3,045,895	3,115,637	3,187,392
Operation Cost Total		7,439,165	7,574,907	7,713,667	7,855,523	8,000,556	8,148,849	8,300,487	8,455,557	8,614,151
Revenue (Disposal fee)		12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778
Depreciation		3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222
Asset Value After Depreciation		27,377,778	23,955,556	20,533,333	17,111,111	13,688,889	10,266,667	6,844,444	3,422,222	0
Tax		236,950	212,517	187,540	162,006	135,900	109,207	81,912	54,000	25,453
Balance	(30,800,000)	4,501,662	4,390,354	4,276,571	4,160,249	4,041,321	3,919,721	3,795,379	3,668,221	3,538,174

(2) PIRR for landfill cost -10% scenario

IRR 5.14%

	0	1	2	3	4	5	6	7	8	9
Capital Investment	(30,800,000)	0	0	0	0	0	0	0	0	0
Landfill Cost		1,523,249	1,538,482	1,553,867	1,569,405	1,585,099	1,600,950	1,616,960	1,633,129	1,649,461
Electricity Cost		1,741,824	1,776,660	1,812,194	1,848,438	1,885,406	1,923,114	1,961,577	2,000,808	2,040,824
Natural Gas		1,169,219	1,192,604	1,216,456	1,240,785	1,265,600	1,290,912	1,316,731	1,343,065	1,369,927
Others		2,666,373	2,725,276	2,785,847	2,848,139	2,912,206	2,978,105	3,045,895	3,115,637	3,187,392
Operation Cost Total		7,100,665	7,233,022	7,368,363	7,506,767	7,648,312	7,793,083	7,941,162	8,092,640	8,247,604
Revenue (Disposal fee)		12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778
Depreciation		3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222
Asset Value After Depreciation		27,377,778	23,955,556	20,533,333	17,111,111	13,688,889	10,266,667	6,844,444	3,422,222	0
Tax		297,880	274,056	249,695	224,782	199,304	173,245	146,591	119,325	91,431
Balance	(30,800,000)	4,779,232	4,670,700	4,559,720	4,446,229	4,330,162	4,211,450	4,090,025	3,965,813	3,838,742

(3) PIRR for electricity cost +10% scenario

IRR 3.51%

	0	1	2	3	4	5	6	7	8	9
Capital Investment	(30,800,000)	0	0	0	0	0	0	0	0	0
Landfill Cost		1,692,499	1,709,424	1,726,518	1,743,784	1,761,221	1,778,834	1,796,622	1,814,588	1,832,734
Electricity Cost		1,916,006	1,954,327	1,993,413	2,033,281	2,073,947	2,115,426	2,157,734	2,200,889	2,244,907
Natural Gas		1,169,219	1,192,604	1,216,456	1,240,785	1,265,600	1,290,912	1,316,731	1,343,065	1,369,927
Others		2,666,373	2,725,276	2,785,847	2,848,139	2,912,206	2,978,105	3,045,895	3,115,637	3,187,392
Operation Cost Total		7,444,097	7,581,630	7,722,234	7,865,989	8,012,975	8,163,277	8,316,982	8,474,179	8,634,960
Revenue (Disposal fee)		12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778
Depreciation		3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222
Asset Value After Depreciation		27,377,778	23,955,556	20,533,333	17,111,111	13,688,889	10,266,667	6,844,444	3,422,222	0
Tax		236,062	211,307	185,998	160,122	133,665	106,610	78,943	50,648	21,707
Balance	(30,800,000)	4,497,618	4,384,841	4,269,546	4,151,667	4,031,138	3,907,890	3,781,852	3,652,951	3,521,111

(4) PIRR for electricity cost -10% scenario

IRR 5.19%

	0	1	2	3	4	5	6	7	8	9
Capital Investment	(30,800,000)	0	0	0	0	0	0	0	0	0
Landfill Cost		1,692,499	1,709,424	1,726,518	1,743,784	1,761,221	1,778,834	1,796,622	1,814,588	1,832,734
Electricity Cost		1,567,642	1,598,994	1,630,974	1,663,594	1,696,866	1,730,803	1,765,419	1,800,727	1,836,742
Natural Gas		1,169,219	1,192,604	1,216,456	1,240,785	1,265,600	1,290,912	1,316,731	1,343,065	1,369,927
Others		2,666,373	2,725,276	2,785,847	2,848,139	2,912,206	2,978,105	3,045,895	3,115,637	3,187,392
Operation Cost Total		7,095,733	7,226,298	7,359,796	7,496,301	7,635,894	7,778,654	7,924,667	8,074,018	8,226,795
Revenue (Disposal fee)		12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778
Depreciation		3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222
Asset Value After Depreciation		27,377,778	23,955,556	20,533,333	17,111,111	13,688,889	10,266,667	6,844,444	3,422,222	0
Tax		298,768	275,266	251,237	226,666	201,539	175,842	149,560	122,677	95,177
Balance	(30,800,000)	4,783,277	4,676,213	4,566,745	4,454,811	4,340,345	4,223,281	4,103,551	3,981,083	3,855,806

(5) PIRR for natural gas cost +10% scenario

IRR 3.79%

	0	1	2	3	4	5	6	7	8	9
Capital Investment	(30,800,000)	0	0	0	0	0	0	0	0	0
Landfill Cost		1,692,499	1,709,424	1,726,518	1,743,784	1,761,221	1,778,834	1,796,622	1,814,588	1,832,734
Electricity Cost		1,741,824	1,776,660	1,812,194	1,848,438	1,885,406	1,923,114	1,961,577	2,000,808	2,040,824
Natural Gas		1,286,141	1,311,864	1,338,101	1,364,863	1,392,160	1,420,004	1,448,404	1,477,372	1,506,919
Others		2,666,373	2,725,276	2,785,847	2,848,139	2,912,206	2,978,105	3,045,895	3,115,637	3,187,392
Operation Cost Total		7,386,837	7,523,225	7,662,661	7,805,223	7,950,994	8,100,057	8,252,498	8,408,405	8,567,870
Revenue (Disposal fee)		12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778
Depreciation		3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222
Asset Value After Depreciation		27,377,778	23,955,556	20,533,333	17,111,111	13,688,889	10,266,667	6,844,444	3,422,222	0
Tax		246,369	221,820	196,721	171,060	144,821	117,990	90,550	62,487	33,783
Balance	(30,800,000)	4,544,571	4,432,733	4,318,396	4,201,495	4,081,962	3,959,731	3,834,730	3,706,886	3,576,124

(6) PIRR for natural gas cost -10% scenario

IRR 4.92%

	0	1	2	3	4	5	6	7	8	9
Capital Investment	(30,800,000)	0	0	0	0	0	0	0	0	0
Landfill Cost		1,692,499	1,709,424	1,726,518	1,743,784	1,761,221	1,778,834	1,796,622	1,814,588	1,832,734
Electricity Cost		1,741,824	1,776,660	1,812,194	1,848,438	1,885,406	1,923,114	1,961,577	2,000,808	2,040,824
Natural Gas		1,052,297	1,073,343	1,094,810	1,116,706	1,139,040	1,161,821	1,185,058	1,208,759	1,232,934
Others		2,666,373	2,725,276	2,785,847	2,848,139	2,912,206	2,978,105	3,045,895	3,115,637	3,187,392
Operation Cost Total		7,152,993	7,284,704	7,419,369	7,557,066	7,697,874	7,841,875	7,989,152	8,139,792	8,293,885
Revenue (Disposal fee)		12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778
Depreciation		3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222	3,422,222
Asset Value After Depreciation		27,377,778	23,955,556	20,533,333	17,111,111	13,688,889	10,266,667	6,844,444	3,422,222	0
Tax		288,461	264,753	240,513	215,728	190,383	164,463	137,953	110,837	83,101
Balance	(30,800,000)	4,736,323	4,628,320	4,517,895	4,404,983	4,289,521	4,171,441	4,050,673	3,927,148	3,800,792

(B) PIRR for basic scenario (6 Trains)

(1) PIRR for landfill cost -10% scenario

IRR 0.14%

	0	1	2	3	4	5	6	7	8	9
Capital Investment	(37,534,094)	0	0	0	0	0	0	0	0	0
Landfill Cost		752,655	760,182	767,783	775,461	783,216	791,048	798,958	806,948	815,017
Electricity Cost		1,324,085	1,350,567	1,377,578	1,405,130	1,433,232	1,461,897	1,491,135	1,520,957	1,551,377
Natural Gas		888,807	906,583	924,715	943,209	962,073	981,315	1,000,941	1,020,960	1,041,379
Maintenance Cost		1,126,023	1,148,543	1,171,514	1,194,944	1,218,843	1,243,220	1,268,085	1,293,446	1,319,315
Others		2,704,839	2,764,512	2,825,868	2,888,960	2,953,843	3,020,575	3,089,215	3,159,822	3,232,462
Operation Cost Total		5,670,386	5,781,843	5,895,944	6,012,760	6,132,365	6,254,835	6,380,249	6,508,688	6,640,235
Revenue (Disposal fee)		12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778
Depreciation		(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)
Asset Value After Depreciation		(33,363,639)	(29,193,184)	(25,022,729)	(20,852,274)	(16,681,819)	(12,511,365)	(8,340,910)	(4,170,455)	0
Tax		1,922,012	1,901,950	1,881,412	1,860,385	1,838,856	1,816,812	1,794,237	1,771,118	1,747,440
Balance	(37,534,094)	4,585,379	4,493,984	4,400,422	4,304,633	4,206,557	4,106,131	4,003,292	3,897,972	3,790,103

(2) PIRR for electricity cost -10% scenario

IRR 0.37%

	0	1	2	3	4	5	6	7	8	9
Capital Investment	(37,534,094)	0	0	0	0	0	0	0	0	0
Landfill Cost		836,283	844,646	853,093	861,623	870,240	878,942	887,732	896,609	905,575
Electricity Cost		1,191,676	1,215,510	1,239,820	1,264,617	1,289,909	1,315,707	1,342,021	1,368,862	1,396,239
Natural Gas		888,807	906,583	924,715	943,209	962,073	981,315	1,000,941	1,020,960	1,041,379
Maintenance Cost		1,126,023	1,148,543	1,171,514	1,194,944	1,218,843	1,243,220	1,268,085	1,293,446	1,319,315
Others		2,704,839	2,764,512	2,825,868	2,888,960	2,953,843	3,020,575	3,089,215	3,159,822	3,232,462
Operation Cost Total		5,621,606	5,731,251	5,843,495	5,958,409	6,076,065	6,196,539	6,319,909	6,446,253	6,575,655
Revenue (Disposal fee)		12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778
Depreciation		(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)
Asset Value After Depreciation		(33,363,639)	(29,193,184)	(25,022,729)	(20,852,274)	(16,681,819)	(12,511,365)	(8,340,910)	(4,170,455)	0
Tax		1,930,793	1,911,057	1,890,853	1,870,168	1,848,990	1,827,305	1,805,098	1,782,356	1,759,064
Balance	(37,534,094)	4,625,379	4,535,470	4,443,430	4,349,200	4,252,722	4,153,934	4,052,771	3,949,169	3,843,059

(3) PIRR for natural gas cost -10% scenario

IRR 0.18%

	0	1	2	3	4	5	6	7	8	9
Capital Investment	(37,534,094)	0	0	0	0	0	0	0	0	0
Landfill Cost		836,283	844,646	853,093	861,623	870,240	878,942	887,732	896,609	905,575
Electricity Cost		1,324,085	1,350,567	1,377,578	1,405,130	1,433,232	1,461,897	1,491,135	1,520,957	1,551,377
Natural Gas		799,926	815,925	832,243	848,888	865,866	883,183	900,847	918,864	937,241
Maintenance Cost		1,126,023	1,148,543	1,171,514	1,194,944	1,218,843	1,243,220	1,268,085	1,293,446	1,319,315
Others		2,704,839	2,764,512	2,825,868	2,888,960	2,953,843	3,020,575	3,089,215	3,159,822	3,232,462
Operation Cost Total		5,665,134	5,775,650	5,888,782	6,004,601	6,123,181	6,244,598	6,368,928	6,496,253	6,626,655
Revenue (Disposal fee)		12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778
Depreciation		(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)
Asset Value After Depreciation		(33,363,639)	(29,193,184)	(25,022,729)	(20,852,274)	(16,681,819)	(12,511,365)	(8,340,910)	(4,170,455)	0
Tax		1,922,958	1,903,065	1,882,701	1,861,854	1,840,509	1,818,654	1,796,275	1,773,356	1,749,884
Balance	(37,534,094)	4,589,686	4,499,063	4,406,295	4,311,323	4,214,087	4,114,526	4,012,575	3,908,169	3,801,239

(4) PIRR for maintenance cost -10% scenario

IRR 0.63%

	0	1	2	3	4	5	6	7	8	9
Capital Investment	(37,534,094)	0	0	0	0	0	0	0	0	0
Landfill Cost		836,283	844,646	853,093	861,623	870,240	878,942	887,732	896,609	905,575
Electricity Cost		1,324,085	1,350,567	1,377,578	1,405,130	1,433,232	1,461,897	1,491,135	1,520,957	1,551,377
Natural Gas		888,807	815,925	832,243	848,888	865,866	883,183	900,847	918,864	937,241
Maintenance Cost		1,013,421	1,033,689	1,054,363	1,075,450	1,096,959	1,118,898	1,141,276	1,164,102	1,187,384
Others		2,592,237	2,649,657	2,708,716	2,769,465	2,831,959	2,896,253	2,962,406	3,030,478	3,100,530
Operation Cost Total		5,641,412	5,660,795	5,771,630	5,885,107	6,001,297	6,120,276	6,242,119	6,366,908	6,494,723
Revenue (Disposal fee)		12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778	12,177,778
Depreciation		(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)
Asset Value After Depreciation		(33,363,639)	(29,193,184)	(25,022,729)	(20,852,274)	(16,681,819)	(12,511,365)	(8,340,910)	(4,170,455)	0
Tax		1,927,228	1,923,739	1,903,788	1,883,363	1,862,448	1,841,032	1,819,100	1,796,638	1,773,632
Balance	(37,534,094)	4,609,138	4,593,244	4,502,359	4,409,308	4,314,032	4,216,470	4,116,558	4,014,231	3,909,423

(5) PIRR for Sludge Revenue + 20% scenario

IRR 4.52%

	0	1	2	3	4	5	6	7	8	9
Capital Investment	(37,534,094)	0	0	0	0	0	0	0	0	0
Landfill Cost		1,100,124	1,111,126	1,122,237	1,133,459	1,144,794	1,156,242	1,167,804	1,179,482	1,191,277
Electricity Cost		1,741,824	1,776,660	1,812,194	1,848,438	1,885,406	1,923,114	1,961,577	2,000,808	2,040,824
Natural Gas		1,169,219	1,192,604	1,216,456	1,240,785	1,265,600	1,290,912	1,316,731	1,343,065	1,369,927
Maintenance Cost		1,126,023	1,148,543	1,171,514	1,194,944	1,218,843	1,243,220	1,268,085	1,293,446	1,319,315
Others		2,868,396	2,931,339	2,996,032	3,062,527	3,130,882	3,201,155	3,273,406	3,347,697	3,424,094
Operation Cost Total		6,879,563	7,011,729	7,146,918	7,285,209	7,426,683	7,571,424	7,719,517	7,871,053	8,026,123
Revenue (Disposal fee)		14,613,333	14,613,333	14,613,333	14,613,333	14,613,333	14,613,333	14,613,333	14,613,333	14,613,333
Depreciation		(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)	(4,170,455)
Asset Value After Depreciation		(33,363,639)	(29,193,184)	(25,022,729)	(20,852,274)	(16,681,819)	(12,511,365)	(8,340,910)	(4,170,455)	0
Tax		2,142,761	2,118,971	2,094,637	2,069,744	2,044,279	2,018,226	1,991,569	1,964,292	1,936,380
Balance	(37,534,094)	5,591,010	5,482,634	5,371,779	5,258,380	5,142,372	5,023,684	4,902,247	4,777,988	4,650,831

Appendix 5: Further background information on monitoring plan

Monitoring will be conducted in accordance with the monitoring plan. Figure-9 shows the position of where each monitoring items shall be monitored.

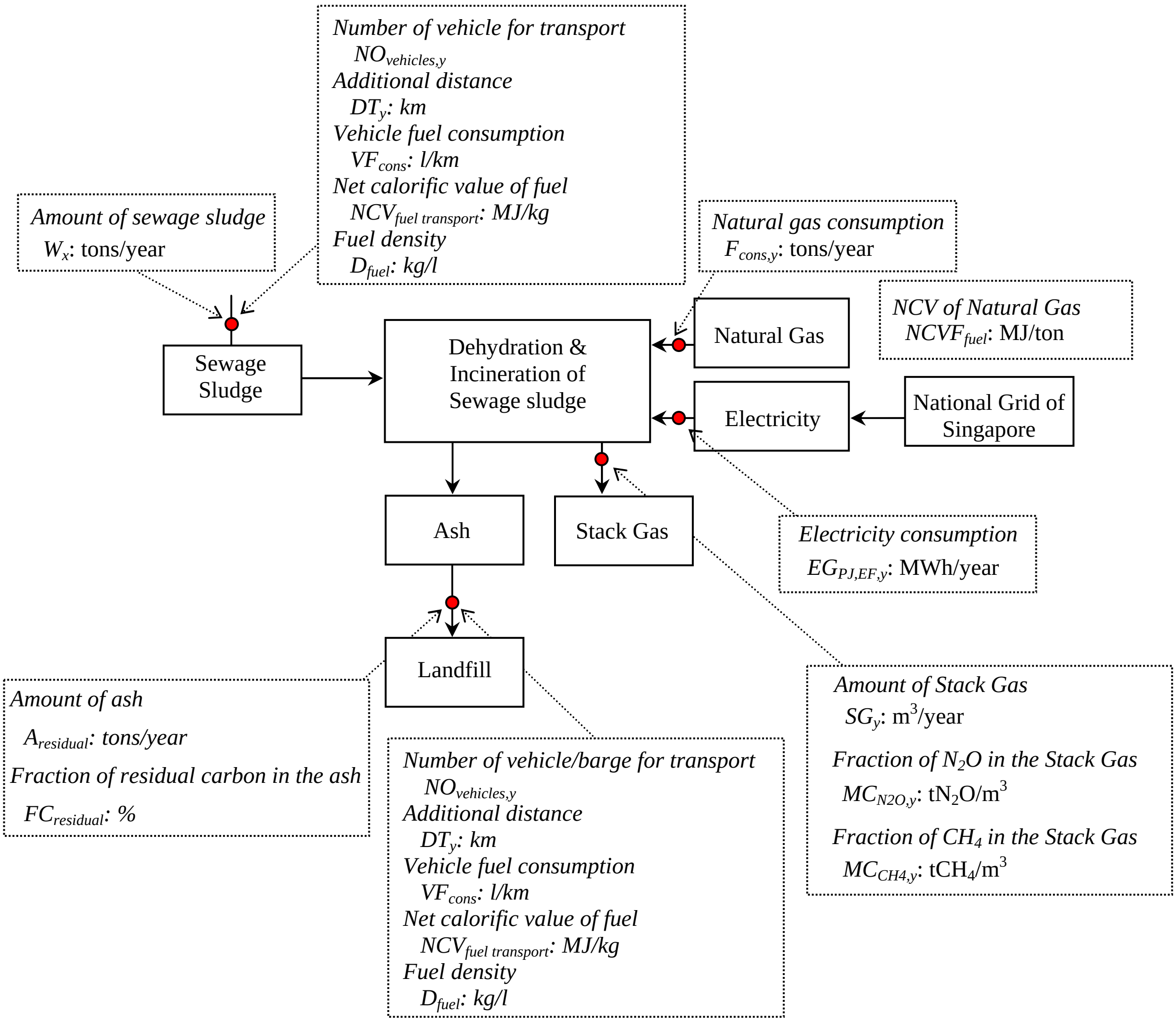

Figure-9 Position of where the monitoring items shall be monitored

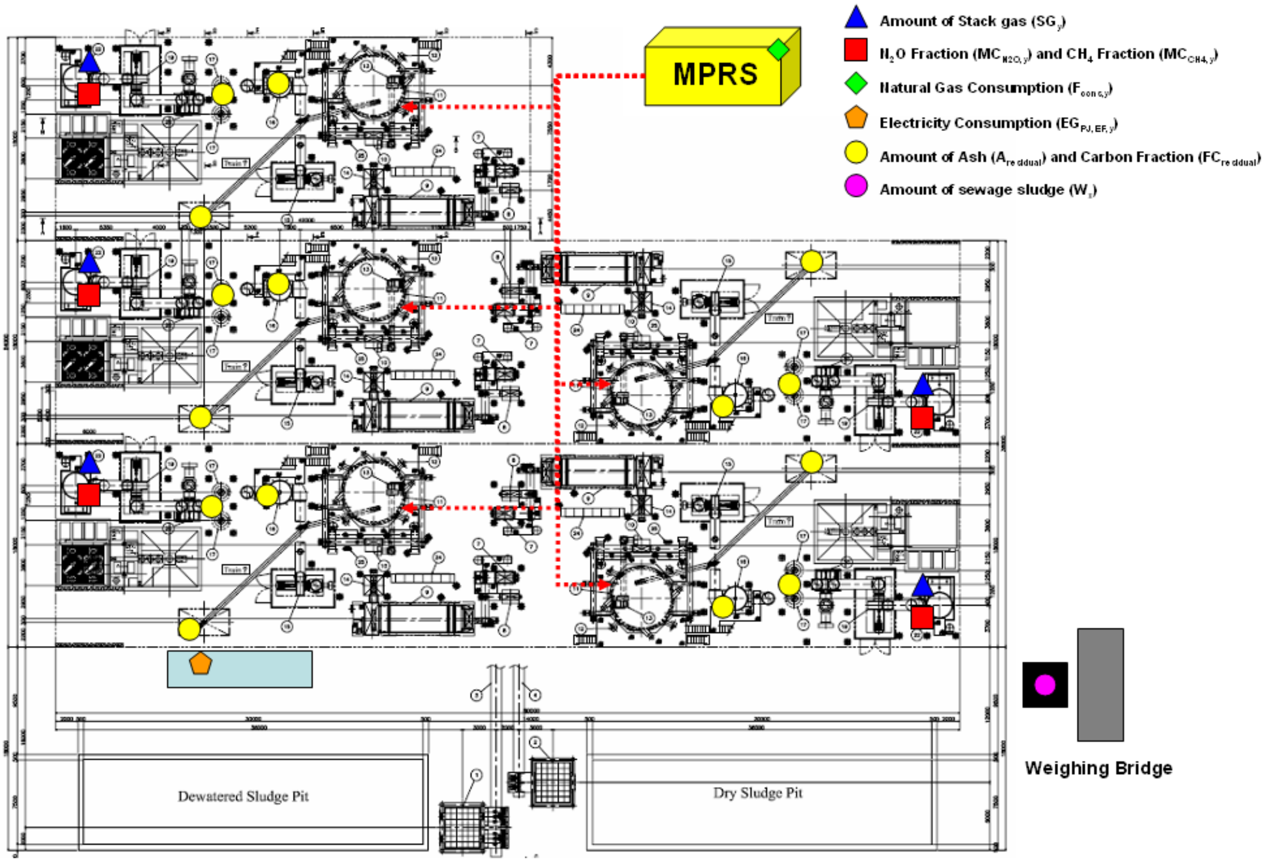

Figure-10 Monitoring points

Appendix 6: Summary of post registration changes

1. 2 WRPs (Bedok and Seletar) out of 6 WRPs were decommissioned by PUB.
   Ref. A.3, B.6.2, B.6.3 and B.7.1.
   Due to this change, the sludge transportation distance is reduced. However, sludge transportation is not under ECO-STP's scope. Hence the change has no impact on additionality of the project activity but leakage emission is reduced as described in B.6.3.

   WRP: Water Reclamation plant

2. Additional train (Train No.6) was installed and its commercial operation commenced in May, 2012.
   Ref. page 3 footnote.

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History of the document

Version	Date	Nature of revision
04.1	11 April 2012	Editorial revision to change version 02 line in history box from Annex 06 to Annex 06b.
04.0	EB 66 13 March 2012	Revision required to ensure consistency with the “Guidelines for completing the project design document form for CDM project activities” (EB 66, Annex 8).
03	EB 25, Annex 15 26 July 2006	
02	EB 14, Annex 06b 14 June 2004	
01	EB 05, Paragraph 12 03 August 2002	Initial adoption.
Decision Class: Regulatory **Document Type:** Form **Business Function:** Registration		