

BANDEIRANTES-SAO PAULO-BRAZIL”

**FOR
CASE STUDIES
OF
CDM - LANDFILL GAS PROJECTS**

**PRESENTED AT A
WORKSHOP
IN
THE WORLD BANK
19TH APRIL 2007**

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1. BACKGROUND

1.1. General background

Bandeirantes landfill is one of the biggest landfills in Brazil. This landfill is located in the metropolitan region of São Paulo, Brazil's biggest city and financial center of the country. With an estimated population of around 10 million citizens in 2000, São Paulo generates nearly 15.000 tons of waste daily. BLFGE's goal is to explore the gas produced in Bandeirantes landfill, using it to generate electricity.

Bandeirantes landfill is divided into 5 cells, named AS-1, AS-2, AS-3, AS-4 and AS-5. The former 3 are the oldest ones, which operated from 1978 until 1995. BLFGE has since its start been extracting gas from the newest cells, where there is still waste being disposed. Two main units can be detached: the degassing installations and the power plant.

The degassing installations are responsible for extracting the landfill gas from the landfill and transport it to the gas engines in the power plant. During the transportation, the gas goes through a treatment to allow its use as fuel for energy generation. Other functions of the degassing installations are: drying landfill gas by gas coolers; and measuring and analyzing the quantity and quality of the landfill gas for safety, process and operating purposes.

For electricity generation, a total of 24 Caterpillar engines, nominal capacity of 925 kW, model 3516 A were installed. They will burn the gas and generate energy, which is to be sent to Eletropaulo's – the electricity distributor supplying São Paulo metropolitan region – grid. This electricity will in fact not be commercialized directly; it will supply Unibanco's branches over São Paulo state.

2. SITE INFORMATION

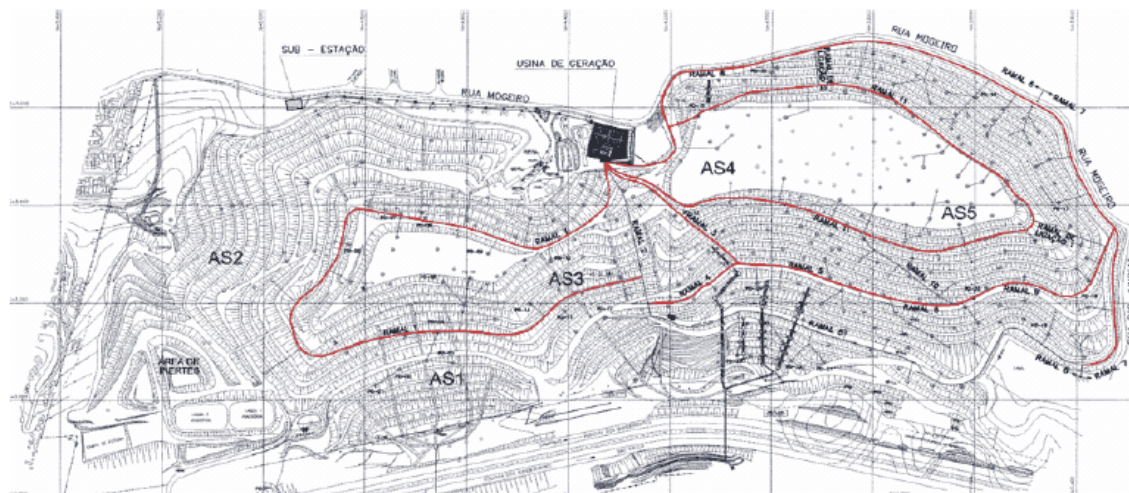
2.1. Data for Area

Please, fill out table 1 below. If necessary give a short description or comments to the site information.

City	São Paulo
Name of the landfills	Bandeirantes
Site geology (sand, clay, etc.)	Clay
Groundwater over/beneath bottom	beneath bottom
Precipitation (mm rain water) (data – 1996 to 2006)	Average: 34.20 (min – June) / 203,2 (max – January). Total average: 112,9
Normal range of temp. Win./Sum. (°C)	10/38

Table 1: Site area information

Place a plan drawing over the landfill if possible



Example on a plan drawing over a landfill

2.2. Landfill construction

Please, fill out table 2 below. If necessary give a short description or comments to the site information.

Start of landfill (Year)	1979
Closing of landfill (Year/year expected)	March, 2007
Area designated for landfilling (ha)	150
Site capacity at closure (Mio. tons)	30,000000
Area used in 2006 (ha)	150
Max./min. depth of landfill 2006 (m.)	5/90
Average depth of landfill 2006 (m.)	50
Waste in place 2006 (Mio. tons)	1973599
Gas extraction in 2006 from (tCO ₂ eq)	616683
Annual waste quantity (1,000 tons)	2,0000
Leachate drainage system (yes/no)	yes
Type of membrane in the bottom (if any)	PEAD

Table 2: Site construction data

2.3. Waste data

Please, describe the possibility for having good or bad historical information about the waste quantity and quality (we know this in many cases is difficult topic). Try to fill out table 3 as shown below with actual data and actual years for your landfill.

Year	MSW (ton)	Industrial/ commercial (ton)	Other (ton)	Total (ton)
1979	300000	-	90000	390000
1980	300000	-	90000	390000
1981	300000	-	90000	390000
1982	300000	-	90000	390000
1983	400000	-	120000	520000
1984	400000	-	120000	520000
1985	400000	-	120000	520000
1986	400000	-	120000	520000
1987	500000	-	150000	650000
1988	500000	-	150000	650000
1989	500000	-	150000	650000
1990	500000	-	150000	650000
1991	600000	-	180000	780000
1992	600000	-	180000	780000
1993	600000	-	180000	780000
1994	600000	-	180000	780000
1995	700000	-	210000	910000
1996	700000	-	210000	910000
1997	700000	-	210000	910000
1998	1585069	-	557256	2142325
1999	1339154	-	966309	2305464
2000	1396495	-	567929	1964424
2001	1348204	-	695412	2043617
2002	1295596	-	787259	2082855
2003	1213164	-	780207	1993371
2004	1224397	-	740949	1965347
2005	969796	-	624554	1594350
2006	1380842	-	592756	1973599
Total:	21052717	-	9102631	30155352

Table 3: Amount of waste disposed of. *Blue values is estimate and green values is real data.*

In table 3 the overall waste composition is divided. If more detail is available please, describe this by filling out table 4 below (with more or less breakdown, depending on the availability)

Type of waste	Waste composition (% by weight)
Domicilar Residue	67,18
street sweeping	3,32
paid residue	4,16
Rubbish	11,86
Silt	3,68
Free Fair	0,22
Pruning	0,63
Foods loosers	0,00
documents	0,00
Residue of the team	2,59
slag	0,97
reject	6,13
Total:	100
Total organic (if this is available)	60 %

Table 4: Waste composition

2.4. Landfill operation

Please, describe further information on landfill operation and fill out table 5. Explain very brief the leachate collection system.

Usage of compactor (yes/no)	Yes
Number of compactors	8
Is temporary cover used (yes/no)	Yes
Frequency of temporary cover	3 months
Existence of final cover (yes/no)	Yes
Type and thickness of final cover	Clay with 60 cm of thickness
Leachate collection from the bottom (yes/no)	Yes
Leachate collection from trenches (yes/no)	Yes

Table 5: Landfill operation

3. ESTIMATION OF LANDFILL GAS

3.1. Gas Model

The factors were determined from Van der Wiel Sortgas analysis of the landfill gas potential in Bandeirantes landfill. The Dutch firm has great experience in the field and has designed its own model for estimation. However, as ACM0001 requires the application of a publicly known model, Van der Wiel's analyses were adapted to **IPCC's first order decay model**, using the above factors under a conservative approach, i.e., which leads to a smaller emission reduction estimate

Key numbers used in the model: $Lo = 0,055$ (tCH₄/twaste) and $k = 0,105$

Data is used for input in the model:

- Year the waste site opened
- Year the waste site closed
- Amount of waste disposed in the site in a given year
- Methane generation rate constant (k)
- Methane generation potential (Lo)

3.2. LFG estimation

Please, inform about the result of the estimation by filling out table 6

Year	Estimation of LFG production (1.000 Nm ³ /year)	Estimation of LFG extraction (1.000 Nm ³ /year)	Estimation of LFG extraction (Nm ³ /hour)
1979	0	0	0
1980	500.498	300.299	34
1981	3.522.731	2.113.639	241
1982	6.342.605	3.805.563	434
1983	10.043.029	6.025.817	688
1984	13.568.167	8.140.900	929
1985	16.868.857	10.121.314	1.155
1986	21.027.263	12.616.358	1.440
1987	30.108.944	18.065.366	2.062
1988	41.380.839	24.828.503	2.834
1989	55.334.716	33.200.830	3.790
1990	64.118.653	38.471.192	4.392
1991	75.284.410	45.170.646	5.156
1992	85.826.045	51.495.627	5.878
1993	99.345.120	59.607.072	6.804
1994	110.057.752	66.034.651	7.538
1995	121.541.711	72.925.027	8.325
1996	136.496.492	81.897.903	9.349
1997	152.277.734	98.744.640	11.272
1998	167.114.169	114.530.816	13.074

1999	181.808.635	129.980.670	14.838
2000	193.669.638	142.742.056	16.295
2001	206.739.355	156.387.190	17.852
2002	220.133.545	170.151.869	19.424
2003	232.490.641	182.850.769	20.873
2004	243.890.946	194.566.411	22.211
2005	254.408.540	205.374.927	23.445
2006	264.111.773	215.346.556	24.583
2007	273.063.698	224.546.095	25.633
2008	251.920.766	207.159.812	23.648
2009	232.414.900	191.119.723	21.817
2010	214.419.346	176.321.596	20.128
2011	197.817.162	162.669.266	18.570
2012	182.500.462	150.074.017	17.132

Table 6: Estimation of LFG production and extraction

The total estimation for LFG extraction shown in a figure like figure 1 below

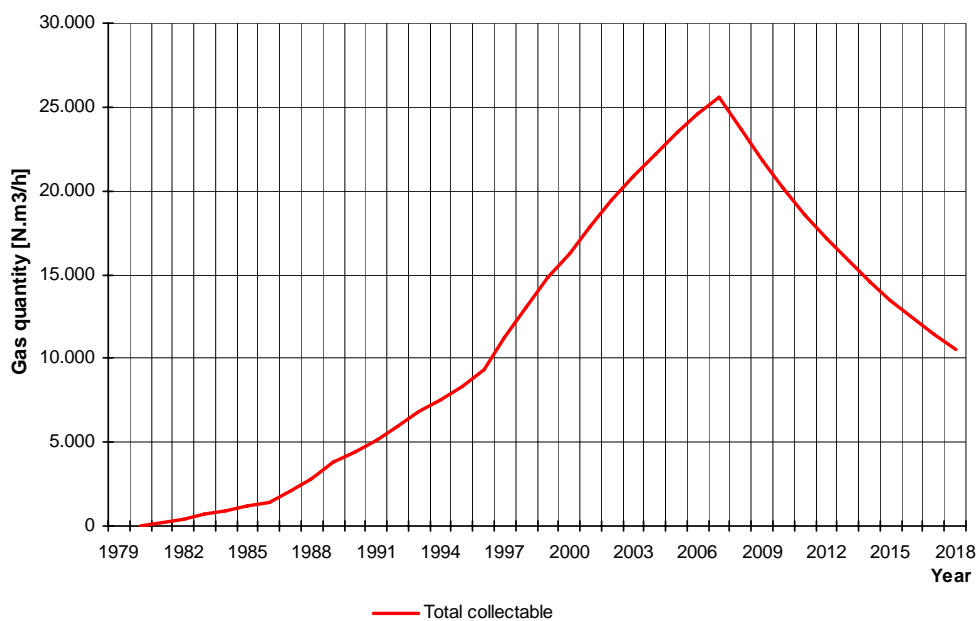


Figure 1: Estimation for gas extraction

4. TEST PUMPING

Pump capacity (m ³ /h)	300
Number of test wells	3
Duration of the test pumping	2 months

Well	Extracted average flow of biogas (Nm ³ /h)	Average flow of methane (Nm ³ /h)
PD 24	154,00	92,00
PD 22	133,00	81,00
PD 26	41,00	24,00

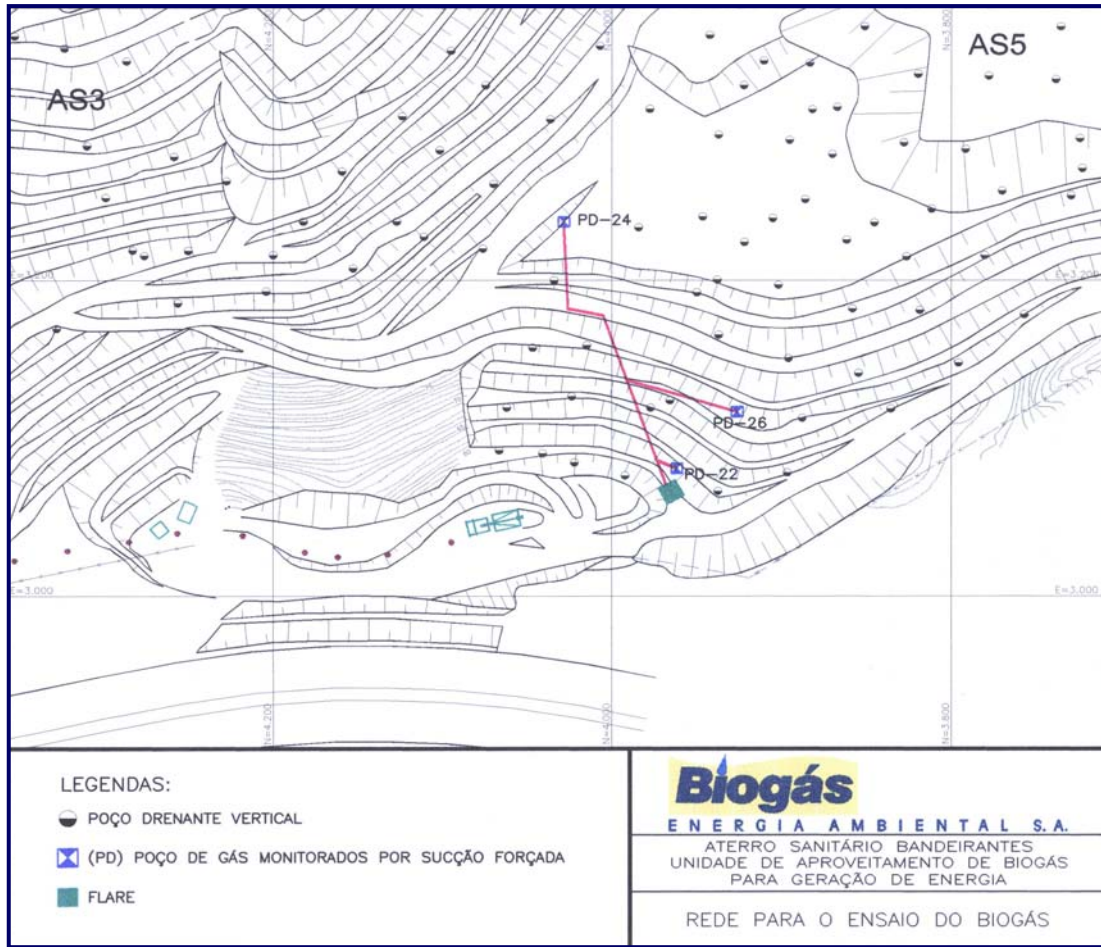
Table 7: Data and results from the test pumping

The available gas composition can be filled in to table 8 below

Well No	CH ₄ %
PD 24	60,00
PD 22	61,00
PD 26	58,00
Average	59,70

Table 8: LFG composition from test pumping

Plan drawing for the test wells at the landfill is available place it as the example below:



Example of plan drawing with test wells

The results from the test pumping valuable:

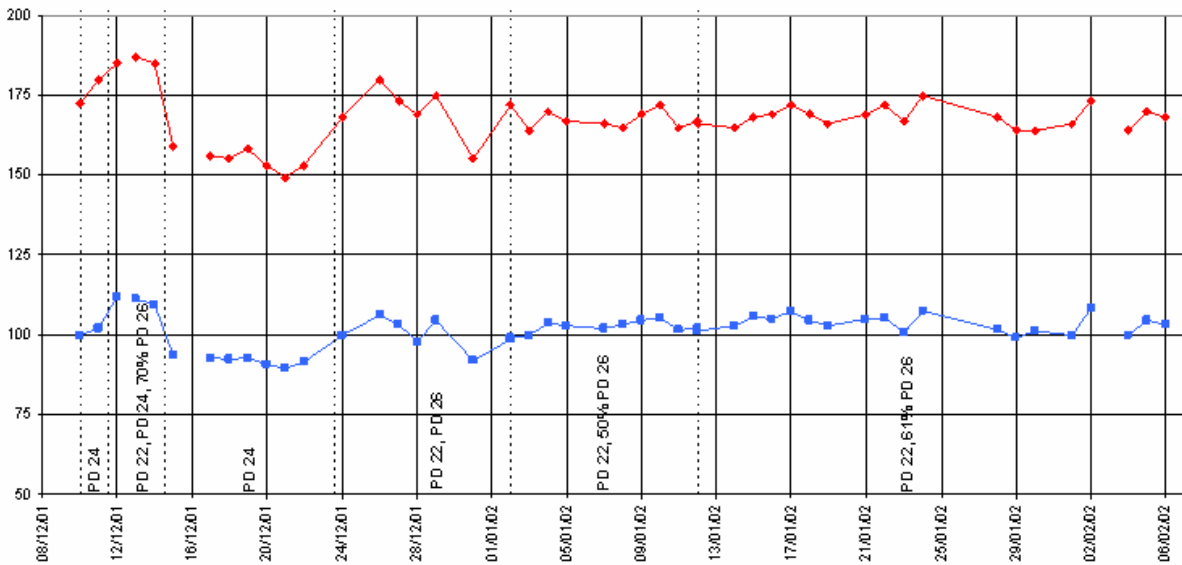


Figure - Flow (Nm³/h) of the wells. Red line is total flow (biogas measure) and blue line is methane flow (Nm³/h).

5. REAL LFG EXTRACTION

5.1. Estimated LFG extracted compared with real extracted

Compare the estimated gas extraction from table 6 with the real extraction in table 9 below:

Year	Estimation of LFG extraction (1.000 Nm ³ /year)	Real LFG extraction (1.000 Nm ³ /year)	Difference (+/- 1.000 Nm ³ /year)	Difference (+/- %)
2004	194566411	78046875	116519536	- 40
2005	205374927	89055907	116319020	- 43
2006	215346556	103161578	112184978	- 48

Table 9: Estimation of LFG production and extraction

5.2. Estimated LFG composition compared with real composition

General composition of the biogas:

LFG AVERAGE COMPOSITION	Values
Methane	53% V/V
CO ₂	37 V/V
Nitrogen	9,3% V/V
Oxygen	1,2% V/V
Acetaldeide	< 10 mg/m ³
Ammonia	70 mg/m ³
Carbon monoxide	< 0,01 %
Hydrogen sulfide	33 mg/m ³
Nitrogen oxides	89 mg/Nm ³
Nitric oxide	0.6 ppm
Sulphur oxides	< 5 mg/m ³
Sulphur (total)	0,74 mg/Nm ³
VOC's	< 5,0 mL/m ³
BTXE	< 5,0 mL/m ³
Moisture	10193 ppm
Oil	14 mg/m ³

Compare the estimated gas quality used in the original calculation with the real annual average quality in table 10 below:

Year	Estimated gas quality				Real gas quality			
	CH ₄ %	CO ₂ %	O ₂ %	N ₂ %	CH ₄ %	CO ₂ %	O ₂ %	N ₂ %
1979	50.00	-	-	-	-	-	-	-
1980	50.00	-	-	-	-	-	-	-
1981	50.00	-	-	-	-	-	-	-
1982	50.00	-	-	-	-	-	-	-
1983	50.00	-	-	-	-	-	-	-

1984	50.00	-	-	-	-	-	-	-
1985	50.00	-	-	-	-	-	-	-
1986	50.00	-	-	-	-	-	-	-
1987	50.00	-	-	-	-	-	-	-
1988	50.00	-	-	-	-	-	-	-
1989	50.00	-	-	-	-	-	-	-
1990	50.00	-	-	-	-	-	-	-
1991	50.00	-	-	-	-	-	-	-
1992	50.00	-	-	-	-	-	-	-
1993	50.00	-	-	-	-	-	-	-
1994	50.00	-	-	-	-	-	-	-
1995	50.00	-	-	-	-	-	-	-
1996	50.00	-	-	-	-	-	-	-
1997	50.00	-	-	-	-	-	-	-
1998	50.00	-	-	-	-	-	-	-
1999	50.00	-	-	-	-	-	-	-
2000	50.00	-	-	-	-	-	-	-
2001	50.00	-	-	-	-	-	-	-
2002	50.00	-	-	-	-	-	-	-
2003	50.00	-	-	-	-	-	-	-
2004	50.00	-	-	-	51.30	0.70	-	-
2005	50.00	-	-	-	52.48	0.88	-	-
2006	50.00	-	-	-	49.87	1.31	-	-
Actual		-	-	-	50.00	1.00	-	-

Table 10: Estimation of LFG production and extraction

6. LANDFILL GAS PLANT

6.1. LFG Collection System

Please, indicate the drilling system, how the wells are constructed and/or (if carried out) the horizontal collection system. Fill out table 11 below

Wells	
Number of wells	200
Depth of wells/average depth (m)	40
Diameter of well (mm)	600
Diameter of gas extraction pipe (mm)	315
Distance between wells (m)	40
Presence of water/condensate in wells (yes/no)	yes
Water/condensate pump in wells (yes/no)	no
Horizontal gas extraction pipes	
Horizontal gas extraction pipes (total m)	28000
Diameter of horizontal gas extraction pipe (mm)	110 – 250 - 315
Presence of water/condensate in pipes (yes/no)	yes
Water/condensate removal system for pipes	yes

(yes/no)	
Horizontal gas collection system (from wells to gas pump)	
Diameter of horizontal collection system (mm)	110
Condensate trap at low points (yes/no)	yes

Table 11: LFG Collection system

6.2. Gas Compressor/Pump System

In table 12 below

Type of gas compressor/pump	Blower
Capacity of gas compressor/pump (m ³ /hour)	4250
Suction pressure at the pump (mbar)	- 90
Suction pressure at the wells (mbar)	- 5

Table 12: Gas compressor/pump system

6.3. Utilization System

Please, inform very brief about the utilization system and fill in table 13 below

Flare	
Type of Flare (open or closed)	Closed
Number of flares	2
Total capacity of flares (m ³ /h)	2500
Actual gas used in flare (m ³ /h)	2000
Gas Engine/generator unit(s)	
Fabricate and type of gas engine	Caterpillar
Number of engines	24
Power production/generator (kW)	910
Actual total electricity production (kW)	18000
Boiler or other utilization system	
Total boiler capacity (kW)	-
Actual total heat production (kW)	-

Table 13: LFG utilization system

6.4. Energy Production

Please, fill in table 14 with the yearly energy production

Year	Electricity production (MWh/year)	Heat production (MW/year)
2004	77719.77	-
2005	100044.70	-
2006	152804.70	-

Table 14: Annual Energy production

6.5. Operation of the LFG Plant

Please, describe briefly the operation of the plant, especially the problems. If there is any automatic regulation for the gas extraction system, please describe that too. Then fill out table 14 below.

Is it possible to regulate the suction/flow from the individual wells and/or horizontal extraction pipes (yes/no)	Yes
Are there any automatic regulation for the gas extraction (yes/no)	No
Is water/condensate from gas wells and/or horizontal extraction pipes removed (yes/no)	Yes
Are there operation staff at the plant 24 hours/day	Yes
Do the alarm system call for attention 24 hours/day to the operator (yes/no)	Yes

What is the plant efficiency (working hours/year)	8580
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Table 15: Operation of the LFG Plant

6.6. Measuring and analyzing system

Please, inform briefly about the measuring and analyzing system and fill in table 16 below.

Are there stationary gas analyser in the plant (yes/no)	Yes
Which gases are analysed (CH ₄ , CO ₂ , O ₂ , H ₂ S, ?)	CH ₄ and O ₂
Type of portable gas analyser used	Geotechnical Instruments GA 94
Which gases are analysed (CH ₄ , CO ₂ , O ₂ , H ₂ S, ?)	CH ₄ , CO ₂ and O ₂
How often is the gas analysed from the individual wells (daily, weekly, or ?)	Weekly
Are pressure, temperature, etc. measured automatically or manual (a/m)	Automatic for the plant

Table 16: Measuring and analyzing system

6.7. Consultant, Contractor and O&M employees

Please, inform briefly about the establishment of the LFG plant, the commissioning, start-up and running-in; was it satisfactory? Was the training of the Operation and Maintenance (O&M) employees satisfactory? Fill in table 17 below

Consultant for implementation (good/poor)	Good
Did the consultant have good references and long experience in LFG plants (approx. years)	10
Contractor for implementation (good/poor)	Good
Did the contractor have good references and long experience in LFG plants (approx. number of plants)	3
Did the team for start-up and running-in have expertise (yes/no)	Yes
Good training of O&M employees (yes/no)	Yes
Good O&M manuals (yes/no)	Yes

Table 17: Consultant, contractors and O&M employees

6.8. Economy

Please, fill in to table 18 the investment costs and the annual income as well as the annual O&M costs

Year	Investment costs US\$	Annual income from energy US\$	Annual income from CO ₂ credit US\$	O&M costs US\$
2003	20,000,000	-	0	-
2004	1,000,000	6,500,000	5,000,000	2,000,000
2005	1,000,000	8,500,000	5,500,000	2,000,000
2006	1,000,000	13,000,000	5,500,000	2,000,000

Table 18: Economy

1* The incomes with sale of energy were dear in function of the generation and medium price of Market. The operation costs and maintenance don't involve fuel (CH₄)/Taxes.

2* The price of the carbon credit was considered 10 Euros/Ton.