ASSESSMENT OF LANDFILL GAS RECOVERY AND UTILIZATION IN BULGARIA

RFP #EPA-OAR-CCD-09-03
Activities that Advance Methane Recovery and Use as a Clean Energy Source

FINAL TECHNICAL REPORT

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1. EXECUTIVE SUMMARY

This report is written for the U.S. Environmental Protection Agency (USEPA) under a grant from the Methane-to-Markets program. It presents a preliminary assessment of the potential for landfill gas (LFG) recovery and utilisation for Bulgarian landfills.

Questionnaires regarding the main characteristics of the landfills were sent to 10 municipalities. In some cases landfill operators were also contacted. The four largest municipalities (Sofia, Plovdiv, Varna and Burgas), four medium size municipalities (Dobritch, Blagoevgrad, Vidin and Smoljan) and two small size municipalities (Bansko and Berkovica) were assessed:

- Sofia – serviced by the Suhodol landfill, the biggest and best maintained landfill in Bulgaria;
- Plovdiv – serviced by the Tsalapitsa landfill that is comparatively new and very well maintained;
- Varna – the landfill is owned by the Aksakovo municipality and is in satisfactory condition;
- Burgas – serviced by the Bratovo landfill - is in satisfactory condition;
- Dobrich – information provided is not sufficient for a complete analysis;
- Blagoevgrad – preliminary data shows that the landfill is not well maintained;
- Vidin – preliminary data shows that the landfill is not well maintained;
- Smoljan – modernization is in progress – the potential can be assessed in the future;
- Bansko – not a well maintained landfill with a small potential for methane recovery;
- Berkovica – not well maintained landfill with a small potential for methane recovery.

Summarized data about the chosen landfills is given in Table 1.1

Table 1.1
Summarized Data for Selected Landfills

	Municipality									
	Sofia	***Plovdiv***	***Varna***	***Burgas***	***Dobrich****	***Blagoevgrad***	***Vidin***	***Smoljan***	***Bansko***	***Berkovica***
Questionnaire	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES
Year opened	1985	1999	2002	1982	1977	1977	1991		1973	1968
Year closure	2012	2010	2011	2012	2015	2012	2012	2035	2009	2009
Waste disposed in 2009, tons	400,000	170,000	138,000	88,000	46,000	45,000	29,000	33,668*	9,500	18,961**
Population, people	1,200,000	450,000	360,000	240,000	120,000	86,000	51,000	47,000	13,000	21,000
Total area, m2	300,000	232,000	97,000	120,000	100,000	106,000	25,000	120,000	33,538	32,000
Average depth, m	over 15	13	20	15 to 45	-	29.5	-		20	
Number of cells	5	12	3	1	1	1	1	5	1	1
Project volume, m3	4,500,000	2,200,000	1,800,000	3,600,000	-	1,452,000	-	526,511		240,000
Project for recultivation	YES	YES	YES	NO	-	YES	NO	YES	YES	YES
Gas collection wells	YES	YES (50%)	YES	NO	NO	NO	NO	YES	NO	NO
Data for morphological content	YES	NO	NO	YES	-	NO	NO	NO	NO	NO
Drainage system	YES	YES	YES	YES	-	NO	NO	YES	NO	YES

* Average for the old landfill
** Data for 2008

The location of the ten landfills is presented in Figure 1.1. The four landfills that were modelled using the EPA LandGem model (as modified for Ukraine), i.e., Sofia, Burgas, Plovdiv and Varna) are highlighted in red. The landfills highlighted in purple are considered to have some potential. The two landfills for which business plans were written are Plovdiv (Tsalapitsa landfill) and Varna (Aksakovo/Varna landfill).

Figure 1.1
Location of the Selected Landfills



Legend:

– Business plans; – Modeling; – Potential;

1 (Bansko), 2 (Berkovitca) – Considered with no potential

Summary of Morphological Content

The amount of methane gas depends mostly on the morphological content of the waste. There are very few detailed analyses of the morphological content of landfills in Bulgaria. Table 1.1 shows morphological content based on size of the population served. The source for this data is the Bulgarian Ministry of Environment and Water. This data can be used as an estimate of morphological content for landfills that do not have any specific measurements.

Table 1.1
Estimated Morphological Content for Bulgarian Landfills*

Population, inhabitants	less than 3,000	from 3,000 to 25,000	from 25,000 to 50,000	over 50,000
Content	%	%	%	%
Organic				
Food waste	4.86	12.56	20.85	28.80
Paper	3.87	6.55	10.45	11.10
Paperboard	1.30	0.70	1.63	9.70
Plastics	5.21	8.98	9.43	12.00
Textile	3.48	4.70	3.40	3.20
Rubber	1.15	0.45	1.10	0.60
Leather	1.36	1.35	2.10	0.70
Garden waste	14.12	14.00	5.53	6.80
Wood waste	2.14	2.28	1.58	1.30
Non-Organic				
Glass	8.85	3.4	8.78	9.9
Metals	2.88	1.3	2.83	1.7
Others				
Cinder, inert materials, sand, soil and other not indentified	50.78	43.73	32.35	14.2

** Source: Bulgarian Ministry of Environment and Water*

Table 1.2 is a summary comparison of the Ministry of Environment and Water estimate (for cities of over 50,000 population) and data from the most recent studies of the morphological content from the Sofia landfill. Varna and Burgas also provided some data about the morphological content (presented in Chapter 3 of the report). The models for Plovdiv and Varna are based on the data provided by the Bulgarian Ministry of Environment and Water, while the Burgas and Sofia models are based on the data provided by the municipalities.

Table 1.2
Comparison of Morphological Content in Percent:
General Estimate and Measured Content for Sofia Landfill

Components	Estimated* (Population: > 50,000)	Sofia (Population : 1,267,726**)
Food waste	28.8	19.5
Paper	11.1	14.4
Paperboard	9.7	14.7
Plastics	12	12.4
Textiles	3.2	4.6
Rubber	0.6	1.1
Leather	0.7	1.1
Yard Waste	6.8	7.7
Wood	1.3	3.8
Glass	9.9	8.2
Metals	1.7	2.2
Inert Materials	14.2	10
Hazardous Waste	1.17	0.3

* Source: Bulgarian Ministry of Environment and Water
** Only registred citizens, the actual number is over 1,500,000

Table 1.3 summarizes the output data of the landfill modelling for Sofia, Plovdiv, Asakovo/Varna and Burgas landfills.

Table 1.3
Comparison of Modelling Results

	Sofia			Plovdiv			Aksakovo/Varna			Burgas		
year	Predicted LFG Recovery m^3/h	Maximum Power Plant Capacity MW	Methane emission reduction estimates tCO_2eq/yr	Predicted LFG Recovery m^3/h	Maximum Power Plant Capacity MW	Methane emission reduction estimates tCO_2eq/yr	Predicted LFG Recovery m^3/h	Maximum Power Plant Capacity MW	Methane emission reduction estimates tCO_2eq/yr	Predicted LFG Recovery m^3/h	Maximum Power Plant Capacity MW	Methane emission reduction estimates tCO_2eq/yr
2010	821	1.36	54,068									
2011	1,267	2.10	83,469									
2012	1,834	3.03	120,761									
2013	1,723	2.85	113,444				472	0.78	31,085			
2014	1,622	2.68	106,831				436	0.72	28,744	387	0.64	25,477
2015	1,531	2.53	100,836	770	1.27	50,681	405	0.67	26,651	363	0.60	23,926
2016	1,448	2.40	95,386	711	1.18	46,819	376	0.62	24,777	342	0.57	22,514
2017	1,373	2.27	90,415	659	1.09	43,383	351	0.58	23,095	322	0.53	21,227
2018	1,304	2.16	85,868	612	1.01	40,319	328	0.54	21,583	304	0.50	20,049
2019	1,240	2.05	81,696	571	0.94	37,578	307	0.51	20,219	288	0.48	18,968
2020	1,182	1.96	77,856	533	0.88	35,121	288	0.48	18,987	273	0.45	17,975
2021	1,128	1.87	74,312	500	0.83	32,912	271	0.45	17,872	259	0.43	17,060
2022	1,079	1.78	71,031	469	0.78	30,920	256	0.42	16,858	246	0.41	16,214
2023	1,032	1.71	67,985	442	0.73	29,118	242	0.40	15,936	234	0.39	15,431
2024	989	1.64	65,149	417	0.69	27,484	229	0.38	15,094	223	0.37	14,704
2025	949	1.57	62,503	395	0.65	25,997	217	0.36	14,324	213	0.35	14,028
2026	911	1.51	60,026	374	0.62	24,640	207	0.34	13,617	203	0.34	13,397
2027	876	1.45	57,703	355	0.59	23,398	197	0.33	12,967	194	0.32	12,808
2028	843	1.39	55,518	338	0.56	22,258	188	0.31	12,367	186	0.31	12,257
2029	812	1.34	53,459	322	0.53	21,208	179	0.30	11,812	178	0.29	11,740
2030	782	1.29	51,515	307	0.51	20,238	172	0.28	11,298	171	0.28	11,254

Business Plans - Base Case and Variants

The project objective is to increase the capacity of municipalities to identify and implement LFG projects, through increased technical capability and access to private sector financial resources. Two municipal landfills were selected for the development of business cases for LFG recovery and use; the Plovdiv municipal landfill (Tsalapitsa landfill) and the Aksakovo/Varna municipal landfill. The business plans include a cost and financial analysis, risk assessment, and assessment of environmental issues and mitigation strategies. Two financing approaches were considered; one where the municipality assumes the project loan and owns and operates the landfill, and one where an energy service company (ESCo) invests in the project because the revenue from the sale of the energy products (electricity and heat) is sufficient to provide an acceptable return on their investment. The ESCo assumes the loan, leases the landfill from the municipality under a concession agreement, and operates it for a specified period of time. This second arrangement could be through a public-private partnership (PPP) with the ESCo if a suitable division of expenses and revenues can be agreed upon. The business plans have a section on project benefits that considers emission reduction of CO_2, NO_x, and SO_2 reduction as a result of displacement of natural gas and/or other fuels to generate the equivalent power and/or heat. Financing schemes include one where foreign investors provide a grant to finance the methane collection system in return for revenue from future carbon credits. The complete business plans are available as separate documents. Important details of each business plan are provided in Section 6. Summary results are presented in the following tables.

For each landfill, the business plans include a "Base Case I" where the municipality is the borrower (Table 1.4 and Table 1.7) and an investor has financed none of the methane collection system. Table 1.5 and Table 1.8 present results for "Base Case II" where an investor has financed 50% of the cost of the methane collection system. Table 1.6 and Table 1.9 present results for "Base Case III" where an investor has financed 100% of the cost of the methane collection system.

All three sets of tables show financial results for the following seven ESCo variants:

66,411: the ESCo pays the municipality EUR 66,411 as a concession fee.

100,000: the ESCo pays the municipality EUR 100,000 as a concession fee.

100,000 EU &20%: the ESCO pays the municipality EUR 100,000 as a concession fee and invests 20% of the loan amount as equity.

150,000: the ESCo pays the municipality EUR 150,000 as a concession fee.

150,000 EU &20%: the ESCO pays the municipality EUR 150,000 as a concession fee and invests 20% of the loan amount as equity.

200,000: the ESCo pays the municipality EUR 200,000 as a concession fee.

200,000 EU &20%: the ESCO pays the municipality EUR 200,000 as a concession fee and invests 20% of the loan amount as equity.

The tables also present results where the project is eligible for financing under the Bulgarian Energy Efficiency and Renewable Energy Credit Line (the EBRD BEERECL facility) whereby an incentive grant of 15% is awarded to the ESCo at the successful completion of the project as approved by an independent energy engineering inspector.

Summary of Plovdiv Business Plan

Table 1.4
Base Case I with ESCo Variants (Tslapitsa Landfill)

Parameters	Municipality	ESCO variants						
	Base case	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Loan amount	1,675,999	1,675,999	1,675,999	1,467,999	1,675,999	1,467,999	1,675,999	1,467,999
Loan term (months)	66	74	81	71	93	81	113	97
Equity	160,000	160,000	160,000	368,000	160,000	368,000	160,000	368,000
PBP	4.12	4.76	5.17	5.19	5.91	5.95	6.91	6.96
IRR	21.64%	17.71%	15.60%	15.52%	12.21%	12.12%	8.38%	8.26%
NPV	1,137,810	715,555	502,981	496,669	186,878	179,669	-127,094	-135,828
With Grant 15%								
PBP		4.10	4.45	4.56	5.09	5.22	5.94	6.11
IRR		20.75%	18.55%	18.08%	15.04%	14.57%	11.12%	10.63%
NPV		923,323	710,750	678,652	394,646	361,653	80,675	46,155
Municipality contract (concession tax for 15 years)		996,165	1,500,000	1,500,000	2,250,000	2,250,000	3,000,000	3,000,000

Parameters	Sensitivity Analysis							
	Municipality	ESCO variants						
	Base case	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Cost Overrun								
PBP	4.54	5.25	5.69	5.72	6.52	6.56	7.67	7.73
IRR	19.17%	15.45%	13.45%	13.38%	10.21%	10.13%	6.51%	6.41%
NPV	970,017	547,762	335,189	328,876	19,085	11,877	-294,886	-303,621
Start-Up Delay								
PBP	4.20	4.85	5.25	5.28	6.00	6.03	7.00	7.05
IRR	21.21%	17.36%	15.29%	15.21%	11.95%	11.86%	8.16%	8.05%
NPV	1,107,900	689,761	479,270	472,957	166,265	159,057	-145,323	-153,341
Savings								
PBP	4.57	5.27	5.72	5.75	6.54	6.58	7.70	7.76
IRR	19.02%	15.33%	13.34%	13.27%	10.13%	10.04%	6.43%	6.34%
NPV	865,697	485,953	294,881	288,568	10,783	3,575	-274,031	-280,688
Worse Case								
PBP	4.64	5.34	5.79	5.82	6.62	6.65	7.78	7.83
IRR	18.73%	15.10%	13.13%	13.06%	9.95%	9.86%	6.28%	6.19%
NPV	889,414	492,325	292,480	286,167	-4,677	-11,885	-301,452	-308,802

Table 1.5
Base Case II with ESCo Variants (Tslapitsa Landfill)

Parameters	Municipality	ESCO variants						
	Base case II	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Loan amount	1,416,374	1,416,374	1,416,374	1,261,100	1,416,374	1,261,100	1,416,374	1,261,100
Loan term (months)	56	64	68	62	78	70	93	82
Equity	160,000	160,000	160,000	315,275	160,000	315,275	160,000	315,275
PBP	3.56	4.12	4.47	4.49	5.13	5.15	6.00	6.04
IRR	25.80%	21.45%	19.11%	19.06%	15.42%	15.35%	11.29%	11.21%
NPV	1,358,051	935,490	721,725	718,038	404,655	400,199	88,805	83,286
With Grant 15%								
PBP		3.55	3.86	3.94	4.42	4.52	5.18	5.30
IRR		24.65%	22.22%	21.80%	18.38%	17.96%	14.14%	13.71%
NPV		1,111,073	897,309	874,373	580,239	556,533	264,388	239,621
Municipality contract (concession tax for 15 years)		996,165	1,500,000	1,500,000	2,250,000	2,250,000	3,000,000	3,000,000

Parameters	Sensitivity Analysis							
	Municipality	ESCO variants						
	Base case II	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Cost Overrun								
PBP	3.92	4.54	4.93	4.94	5.65	5.67	6.62	6.65
IRR	23.03%	18.94%	16.74%	16.69%	13.23%	13.17%	9.26%	9.19%
NPV	1,214,005	791,443	577,679	573,992	260,608	256,152	-55,242	-60,761
Start-Up Delay								
PBP	3.64	4.20	4.56	4.57	5.21	5.23	6.09	6.12
IRR	25.26%	21.01%	18.73%	18.67%	15.10%	15.03%	11.03%	10.95%
NPV	1,328,223	909,778	698,095	694,408	384,124	379,668	71,373	65,854
Savings								
PBP	3.95	4.56	4.95	4.97	5.68	5.70	6.64	6.68
IRR	22.85%	18.79%	16.61%	16.55%	13.12%	13.06%	9.18%	9.10%
NPV	1,085,939	705,888	513,625	509,938	228,561	224,104	-55,284	-60,802
Worse Case								
PBP	4.02	4.63	5.02	5.04	5.75	5.77	6.71	6.75
IRR	22.48%	18.50%	16.34%	16.29%	12.90%	12.84%	9.00%	8.92%
NPV	1,121,610	724,214	523,179	519,492	225,056	220,599	-71,848	-77,366

Table 1.6
Base Case III with ESCo Variants (Tslapitsa Landfill)

Parameters	Municipality	ESCO variants						
	Base case III	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Loan amount	1,146,250	1,146,250	1,146,250	1,045,000	1,146,250	1,045,000	1,146,250	1,045,000
Loan term (months)	46	52	55	51	62	58	73	67
Equity	160,000	160,000	160,000	261,250	160,000	261,250	160,000	261,250
PBP	2.96	3.43	3.73	3.74	4.28	4.29	5.03	5.04
IRR	31.76%	26.76%	24.12%	24.08%	19.96%	19.92%	15.40%	15.35%
NPV	1,592,292	1,168,803	954,591	952,517	636,313	634,136	318,951	316,148
With Grant 15%								
PBP		2.97	3.23	3.28	3.71	3.77	4.35	4.42
IRR		30.20%	27.43%	27.07%	23.10%	22.76%	18.39%	18.06%
NPV		1,310,900	1,096,688	1,082,062	778,410	763,681	461,048	445,693
Municipality contract (concession tax for 15 years)		996,165	1,500,000	1,500,000	2,250,000	2,250,000	3,000,000	3,000,000

Parameters	Sensitivity Analysis							
	Municipality	ESCO variants						
	Base case III	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Cost Overrun								
PBP	3.27	3.78	4.11	4.12	4.72	4.73	5.54	5.56
IRR	28.55%	23.89%	21.40%	21.37%	17.48%	17.44%	13.13%	13.08%
NPV	1,472,982	1,049,493	835,281	833,207	517,003	514,826	199,641	196,838
Start-Up Delay								
PBP	3.05	3.52	3.81	3.82	4.37	4.38	5.11	5.12
IRR	31.05%	26.19%	23.61%	23.57%	19.54%	19.50%	15.06%	15.01%
NPV	1,562,538	1,143,166	931,035	928,961	615,857	613,680	301,594	298,791
Savings								
PBP	3.29	3.80	4.13	4.14	4.74	4.76	5.56	5.58
IRR	28.33%	23.70%	21.23%	21.19%	17.34%	17.30%	13.02%	12.97%
NPV	1,320,179	939,202	746,491	744,416	460,219	458,042	174,863	172,060
Worse Case								
PBP	3.36	3.88	4.20	4.21	4.81	4.83	5.63	5.65
IRR	27.83%	23.30%	20.88%	20.85%	17.05%	17.01%	12.78%	12.73%
NPV	1,368,293	969,971	768,487	766,413	469,156	466,979	170,742	167,939

Summary of Aksakovo/Varna Business Plan

Table 1.7
Base Case I with ESCO Company (Aksakovo/Varna Landfill)

Parameters	Municipality	ESCO variants						
	Base case I	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Loan amount	1,249,398	1,249,398	1,249,398	1,088,518	1,249,398	1,088,518	1,249,398	1,088,518
Loan term (months)	63	75	84	73	106	90	over 180	124
Equity	111,250	111,250	111,250	272,130	111,250	272,130	111,250	272,130
PBP	3.94	4.77	5.33	5.36	6.47	6.51	8.57	8.70
IRR	22.87%	17.63%	14.76%	14.68%	10.00%	9.91%	4.15%	3.92%
NPV	941,114	523,330	312,681	307,559	158	-5,668	-311,500	-321,482
With Grant 15%								
PBP		4.10	4.58	4.70	5.56	5.71	7.12	7.37
IRR		20.73%	17.73%	17.23%	12.79%	12.30%	6.81%	6.21%
NPV		678,214	467,565	442,500	155,042	129,272	-156,616	-186,542
Municipality contract (concession tax for 15 years)		996,165	1,500,000	1,500,000	2,250,000	2,250,000	3,000,000	3,000,000

Parameters	Sensitivity Analysis							
	Municipality	ESCO variants						
	Base case I	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Cost Overrun								
PBP	4.34	5.25	5.87	5.91	7.16	7.21	9.96	10.22
IRR	20.32%	15.39%	12.66%	12.59%	8.11%	8.02%	2.43%	2.21%
NPV	817,730	399,946	189,297	184,175	-123,226	-129,052	-434,884	-444,866
Start-Up Delay								
PBP	4.04	4.87	5.44	5.47	6.59	6.63	8.74	8.88
IRR	22.31%	17.19%	14.38%	14.30%	9.68%	9.59%	3.89%	3.67%
NPV	913,136	499,469	290,901	285,780	-19,730	-25,213	-328,075	-337,926
Savings								
PBP	4.37	5.27	5.90	5.93	7.19	7.25	10.10	10.30
IRR	20.17%	15.27%	12.57%	12.49%	8.03%	7.94%	2.32%	2.14%
NPV	730,761	355,077	165,720	160,599	-116,905	-122,181	-401,206	-408,237
Worse Case								
PBP	4.45	5.37	5.99	6.02	7.31	7.36	10.30	10.54
IRR	19.77%	14.96%	12.29%	12.21%	7.79%	7.71%	2.16%	1.96%
NPV	747,644	354,821	156,796	151,675	-138,837	-144,320	-433,638	-442,046

Table 1.8
Base Case II with ESCO Company (Aksakovo/Varna Landfill)

Parameters	Municipality	ESCO variants						
	Base case II	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Loan amount	1,095,983	1,095,983	1,095,983	965,787	1,095,983	965,787	1,095,983	965,787
Loan term (months)	52	66	74	65	91	79	126	106
Equity	111,250	111,250	111,250	241,447	111,250	241,447	111,250	241,447
PBP	3.52	4.26	4.76	4.78	5.79	5.82	7.48	7.53
IRR	26.21%	20.52%	17.43%	17.35%	12.34%	12.26%	6.10%	6.00%
NPV	1,069,742	652,210	441,137	437,393	127,912	123,283	-186,266	-190,959
With Grant 15%								
PBP		3.67	4.10	4.20	4.98	5.11	6.37	6.53
IRR		23.78%	20.53%	20.06%	15.24%	14.78%	8.86%	8.40%
NPV		788,076	577,003	557,119	263,777	243,009	-50,400	-71,233
Municipality contract (concession tax for 15 years)		996,165	1,500,000	1,500,000	2,250,000	2,250,000	3,000,000	3,000,000

Parameters	Sensitivity Analysis							
	Municipality	ESCO variants						
	Base case II	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Cost Overrun								
PBP	3.88	4.69	5.25	5.27	6.38	6.42	8.46	8.54
IRR	23.42%	18.09%	15.16%	15.10%	10.31%	10.23%	4.27%	4.18%
NPV	960,324	542,792	331,719	327,975	18,493	13,865	-295,684	-300,377
Start-Up Delay								
PBP	3.62	4.36	4.87	4.89	5.90	5.93	7.62	7.68
IRR	25.54%	20.00%	16.97%	16.90%	11.98%	11.89%	5.80%	5.70%
NPV	1,041,813	628,398	419,406	415,663	109,053	104,652	-202,731	-207,423
Savings								
PBP	3.90	4.71	5.27	5.29	6.40	6.44	8.51	8.59
IRR	23.24%	17.95%	15.04%	14.97%	10.23%	10.15%	4.20%	4.09%
NPV	859,390	483,957	294,177	290,433	12,106	8,019	-272,346	-276,999
Worse Case								
PBP	3.99	4.80	5.36	5.39	6.51	6.54	8.66	8.74
IRR	22.76%	17.57%	14.71%	14.65%	9.95%	9.88%	3.98%	3.87%
NPV	883,305	490,733	292,284	288,540	-3,070	-6,828	-299,618	-304,311

Table 1.9
Base Case III with ESCO Company (Aksakovo/Varna Landfill)

Parameters	Municipality	ESCO variants						
	Base case III	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Loan amount	932,069	932,069	932,069	834,655	932,069	834,655	932,069	834,655
Loan term (months)	48	56	62	56	75	67	100	88
Equity	111,250	111,250	111,250	208,664	111,250	208,664	111,250	208,664
PBP	3.06	3.71	4.16	4.17	5.06	5.08	6.46	6.50
IRR	30.80%	24.44%	21.02%	20.97%	15.48%	15.42%	8.87%	8.79%
NPV	1,210,567	791,302	579,616	577,244	265,218	262,297	-47,838	-51,124
With Grant 15%								
PBP		3.21	3.59	3.66	4.37	4.46	5.58	5.70
IRR		27.89%	24.30%	23.87%	18.52%	18.11%	11.73%	11.33%
NPV		906,848	695,162	680,714	380,763	365,767	67,708	52,346
Municipality contract (concession tax for 15 years)		996,165	1,500,000	1,500,000	2,250,000	2,250,000	3,000,000	3,000,000

Parameters	Sensitivity Analysis							
	Municipality	ESCO variants						
	Base case III	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Cost Overrun								
PBP	3.37	4.09	4.58	4.59	5.57	5.60	7.16	7.20
IRR	27.67%	21.73%	18.52%	18.47%	13.26%	13.20%	6.89%	6.82%
NPV	1,116,069	696,804	485,118	482,746	170,719	167,799	-142,336	-145,622
Start-Up Delay								
PBP	3.16	3.81	4.26	4.28	5.17	5.19	6.59	6.62
IRR	29.96%	23.79%	20.46%	20.40%	15.03%	14.97%	8.50%	8.42%
NPV	1,182,691	767,543	557,938	555,567	246,639	243,719	-64,371	-67,582
Savings								
PBP	3.39	4.11	4.60	4.61	5.60	5.62	7.19	7.24
IRR	27.46%	21.57%	18.37%	18.32%	13.16%	13.09%	6.81%	6.73%
NPV	1,000,214	623,049	432,655	430,284	149,953	147,033	-132,657	-135,829
Worse Case								
PBP	3.48	4.20	4.69	4.71	5.70	5.72	7.32	7.36
IRR	26.85%	21.09%	17.96%	17.91%	12.82%	12.76%	6.53%	6.45%
NPV	1,031,642	637,338	438,276	435,905	142,670	139,749	-153,169	-156,380

SUMMARY OF CONCLUSIONS

Organized municipal waste collection covers about 80% of the population of the country. As part of the landfill data collection for this project, a comprehensive analysis of the waste accumulation rate in Bulgaria was completed (kilograms/capita annually) to verify the data submitted by the smaller municipalities that do not weigh disposal trucks at the entrance of their storage facilities. From these data, an average of 280 kilograms/capita annually was determined for landfills where incoming waste quantities were not accurately measured. Larger cities can be almost twice this amount. There is growing concern specifically about the availability of sufficient landfill capacity in the future, and in general about the need to implement sustainable solid waste management practices.

Despite recent attention to economic, social, and political impacts of municipal energy efficiency from the Bulgarian national and regional governments, the fact remains that more than 70% of total energy in Bulgaria is consumed at the municipal level. An indigenous energy source is available – municipal landfills in Bulgaria are generating about 234 million cubic meters (m^3) of landfill gas (LFG) annually, about 50% of which is methane (CH_4) – or an average of 1,642,000 tons of carbon dioxide (CO_2) equivalent

per year. Implementing LFG recovery and utilization projects at just the ten largest landfills in the country could produce up to 72 million m^3 of methane. This suggests a large potential for methane recovery projects in the country.

Two landfills were selected for development of a business plans for implementation of a methane recovery project based on the condition of the landfill and municipal support for the project, i.e., the Tsalapitsa landfill in Plovdiv (800 kW generation potential) and the Aksakovo/Varna landfill (500 kW generation potential).

The Tsalapitsa and Aksakovo/Varna landfills service the largest and most economically developed towns in Bulgaria thus containing the largest quantity of bio-degradable components. These landfills are also representative of the best waste storage facilities in Bulgaria. There are also preliminary plans for reclamation and construction of gas collection systems at each landfill. The business plans for methane recovery projects at these landfills analyzed two cases:

Case #1: Municipally-owned LFG Recovery Facility
The municipality of Plovdiv (the Tsalapitsa landfill) assumes the project loan of EUR 1,675,999 and invests EUR 160,000 as equity; assumes the costs for "interest during construction", management fees during construction", and "additional working capital"; and owns and operates the facility. The municipality receives revenue from the sale of electricity to NEK at the current preferential price. The possibility to receive revenue from the sale of heat was not included as there are no nearby consumers.

The municipality of Aksakovo (the Aksakovo/Varna landfill) assumes the project loan of EUR 1,249,398 and invests EUR 111,250 as equity; assumes the costs for "interest during construction", management fees during construction", and "additional working capital"; and owns and operates the facility. The municipality receives revenue from the sale of electricity to NEK at the current preferential price and the sale of heat at a greenhouse near the landfill.

Case #2: Municipal lease to an energy service company (ESCo)
The municipality enters into a long-term concession (a lease arrangement) with an ESCo that allows the ESCo to operate a LFG facility on the landfill for the project lifetime, i.e., 15 years. A contract is agreed to in which the ESCo assumes the EUR 1,675,999 loan (**Plovdiv**) or EUR 1,249,398 loan (**Aksakovo**) and invests some equity; assumes the costs for "interest during construction", management fees during construction", and "additional working capital"; and operates the facility. The ESCo is the beneficiary of a 15% "investment grant" if the loan is eligible for the BEERECL facility[1].

[1] The Bulgarian Energy Efficiency and Renewable Energy Credit Line (BEERECL) facility is a credit line established by the European Bank for Reconstruction and Development (EBRD) under which local banks provide loans at market rates to Bulgarian project developers. The developer is eligible for a cash incentive grant of 15% of the BEERECL loan upon project completion and acceptance by an independent energy company inspector.

A number of variants on this scheme are analyzed based on the amount of equity that the ESCo invests (zero to 20% of the total loan amount) and the price that the municipality charges for the concession (from EUR 66,411 to EUR 200,000 annually). The business plan considers the cost implications of future Green Certificates and/or other carbon trading schemes by analyzing cases where an investor provides a grant of 50% and 100% of the methane collection system cost in return for future revenues from the sale of carbon credits.

The cost and financial analyses uses current annual interest rates (i.e., 6.863%) and includes a risk sensitivity analysis resulting from a reasonable estimate of capital cost overrun, start-up delay, and operational delays that decrease net revenue generation. When the municipality assumes the loan, the payback period (PBP) ranges from 3.94 years to 3.08 years and the respective internal rate of return (IRR) ranges from 22.87% to 30.8% depending on how large the investor's grant for the methane collection system is. For the worse case risk sensitivity, the PBP is 4.45 years and the IRR is 19.77%.

The financial viability of the project for the ESCo cases is very dependent on the equity amount and the concession fee charged by the municipality. For the "best" variant where the ESCo pays EUR 66,411 for the concession fee and no equity, the PBP ranges from 3.71 years to 4.77 years and the respective IRR ranges from 24.44% to 17.63% depending on how much of the methane recovery system is paid for by an investor's grant. For the "worst" variant where the ESCo pays EUR 200,000 for the concession fee and 20% of the loan amount as equity, the PBP ranges from 8.7 years to 5.7 years and the respective IRR ranges from 3.92% to 11.33% depending on how much of the methane recovery system is paid for by an investor's grant. For the worse case risk sensitivity, the PBP is 10.54 years and the IRR is 1.98%.

On the basis of the developed Business Plans following conclusions could be done:

- The project are low risky. The offered technology and equipment have been implemented for long years all over the world.
- The financial parameters are very good – PB = 4.12 years, IRR = 21.64%, NPV = 1,137,810 Euros for Plovdiv and PB = 3.39 years; IRR = 26.25% and NPV = 1,095,998.for Aksakovo. They remain very good in the different scenarios presented in Risk Analysis as well.
- The projects are eligible for financing under the EBRD BEERECL facility in ESCO variants, whereby an incentive grant of 15% is awarded to the borrower.
- Additional cash-flow based on emissions trading can be generated, which is an opportunity to attract an investor, which will decrease the financial participation of the municipality and will improve the financial parameters.
- The projects provide additional benefits as clearer environment, opportunities for providing cheaper energy to public buildings and industrial enterprises.
- The structure and the staff of municipality posses sufficient capacity to organise and manage projects based on the utilisation of landfill gas and the re-cultivation of the landfill as well as with the implementation of different financing schemes including ESCO.

- The municipalities of Plovdiv and Aksakovo are ready to grant a concession to potential investors.
- Investors' interest was declared from potential users of gas and heat energy as well as by companies dealing in emissions trading.

Recommendations

Field tests at the Tsalapitsa and Aksakovo/Varna Landfills

The software modeling of the LFG resource and the methane recovery potential for this project is based on data provided by the Bulgarian municipalities or from estimates by engineers and physicists associated with Bulgarian landfills for many years. However, the accuracy of these data (waste volumes, morphological content, physical condition of the landfill, etc.) can vary considerably due to a lack of measured and/or recorded data. In addition, the software model used is the EPA LandGem model that was recently modified for Ukraine landfills. While every effort was made to match Ukraine input data with Bulgarian conditions, the effect of this estimation on the model results is unknown. A pump test and LFG resource recovery field test project at the Tsalapitsa and Aksakovo/Varna landfills should be conducted to (1) validate the use in Bulgaria of the Ukraine model (or identify necessary changes to the model for Bulgaria) and (2) to validate generator sizing and project lifetime used in the financial analysis in the business plans.

Municipal awareness and technology transfer throughout the Balkans

Proposed EU Directives require a reduction of anthropogenic methane emissions in countries that wish to join the EU. There is a desire, specifically in Serbia, the Federation of Bosnia and Hergezovina and Republika Srpska, and the Former Yugoslav Republic of Macedonia, to accede to the EU in the near future. This first Methane-to-Markets grant in Bulgaria presents the unique opportunity to disseminate "lessons learned" to other Balkan countries. Results support a project to:

- expand the capabilities of municipal networks in ***Bulgaria, Serbia, Macedonia, and Bosnia and Herzegovina***, to educate officials and address energy issues, and more specifically, to become aware of the benefits of LFG recovery through a "Regional Municipal LFG Project Development Network for the Balkans";
- survey and complete resource assessment through modeling at selected municipal landfills in ***Serbia and Bosnia and Herzegovina*** ; and
- develop up to two business plans per country (project design, cost and financial analysis, risk analysis, and emissions calculations) in ***Serbia and Bosnia and Herzegovina*** for project implementation at the best landfills with municipalities and/or Energy Service Companies (ESCOs);

The project would go a long way towards overcoming many of the existing barriers to the wide spread commercial implementation of municipal LFG projects in the Balkans, with specific objectives to help municipalities:

- Identify financing sources and sustainable financing mechanisms for LFG projects;

- Strengthen the institutional development and member participation in existing municipal networks, and focus their attention on the opportunities associated with LFG projects;
- Increase the level of funding available through well-designed LFG projects;
- Create broad-based public support among policy-makers, business leaders and the media for municipal LFG projects; and
- Increase the capacity of municipalities to identify and implement LFG projects, through increased technical capability and access to private sector financial resources.

2. GENERAL INFORMATION FOR THE SELECTED LANDFILLS

The following ten landfills were selected as representative of the range of municipal non-hazardous waste disposal facilities in Bulgaria:

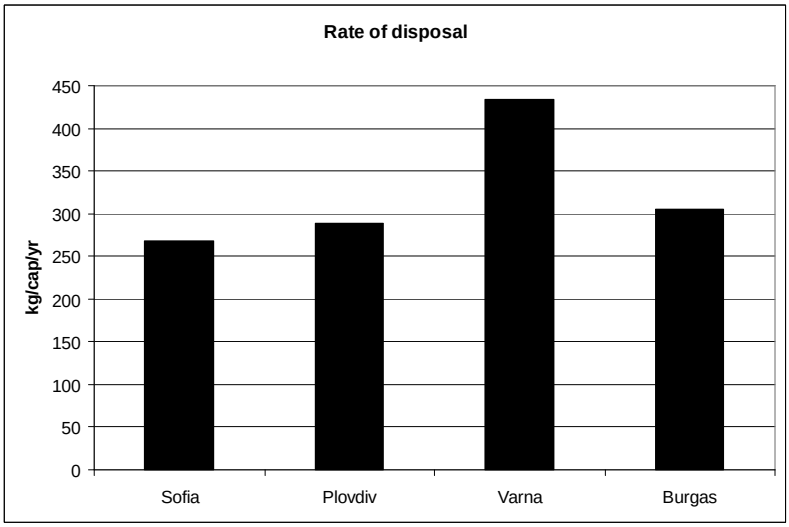
- Sofia - “Suhodol”
- Plovdiv - “Tsalapitsa”
- Varna and Aksakovo - “Vuglen”
- Burgas
- Dobrich
- Blagoevgrad
- Vidin
- Smolin
- Bansko
- Berkovitsa

Questionnaires were sent to the municipalities (Appendix A). In some cases, the landfill operators were also contacted. A preliminary assessment of the landfill gas recovery potential was completed for four of them. The amount of LFG generated was estimated using the USEPA LandGem model as modified for Ukraine. The most important criteria for this estimation includes:

- years of operation,
- amount of waste disposed annually,
- morphological content,
- management of waste disposal, and
- average precipitation in the region.

As part of the landfill data collection, a comprehensive analysis of the waste accumulation rate in Bulgaria was completed (kilograms/per capita/year) to verify the results submitted by the smaller municipalities that do not weigh disposal trucks at the entrance of their storage facilities. These municipalities usually calculate the incoming waste quantities based on the number of transported waste trucks or on the number of waste containers located in the town and the frequency of their collection. Data are shown in Figure 2.1 from the four largest municipal waste storage facilities where there is an electronic weight scale; Sofia, Plovdiv, Varna and Burgas.

Figure 2.1
Data from Landfills with Electronic Weight Scales



Sofia has the lowest acceptance rate (kilograms/per capita/year), because there is some sorting of oversized and construction waste that is then disposed in several different storage facilities. Higher results are received in Varna because there are two large resorts in the Varna municipality and in Burgas due to tourism during the summer. From these data, an average of 280 kilograms/per capita/year was used for the preliminary analysis of the landfills where incoming waste quantities were not accurately measured.

2.1. Sofia Municipality (Suhodol Landfill)

The disposal facility for solid domestic waste servicing the city of Sofia is located in the region of Stolichna Municipality, Ovtcha Kupel District, Suhodol Residential Area. It is situated on 338 decares (83.5 acres), about 2.5 kilometers (km) away from the ring-road of Sofia. A general view of the landfill is shown in Figure 2.2. There is a 20 kV electricity distribution line next to the landfill. A gas distribution network is located about 2 km away. There are potential consumers of heat energy located within 1.5 to 2 km of the landfill.

Figure 2.2
General View of Suhodol (Sofia) Landfill



The landfill is operated in three stages:

1st stage – exploitation started in 1985 and finished in 1990 (consists of one disposal cell);

2nd stage – exploitation started in 1997 and finished in 2005, then re-opened in 2007; the expected closure year is 2011 (consists of three disposal cells);

3rd stage – exploitation started in 2009 and the expected closure year is 2011 (new waste is deposited over the old waste of the 1st stage).

The 1st stage is located at the southern part of the landfill. The available operational data is not complete due to missing reports and a lack of supervisory control. The disposal area is 130 decares (32.1 acres) with a waste volume of about 750,000 m^3. The landfill had no bottom liner but is reclaimed and covered with a top insulation layer of soil.

A system for containing and processing the landfill gas was constructed in 2005. The system includes gas-capture (gas) wells, gas pipelines, a vacuum generating fan for extraction of the landfill gas, a cyclone filter for purification of the gas, and water and mechanical mixtures and burner (close-type torch) for flaring of the landfill gas. A system is installed that monitors the incoming parameters of the landfill gas to the burner. Burning parameters of the gas are: a temperature of 1000^0C and a gas holding time in the torch of 0.3 seconds.

A 2nd stage is located north of the 1st stage. The 2nd stage is split into three cells and constructed as a modern disposal facility with an outflow control and a bottom liner. A surface covering of soil seals the disposal facility for reclamation. A design for construction of gas wells has been completed as part of the reclamation. There is a system constructed for capture of the leachate and recirculation in the body of the landfill.

1st cell of 2nd stage: The area of this cell is 72 decares (17.8 acres) with a capacity of about 800,000 m^3. It was in operation from 1997 to 1999. The deposited quantity of solid domestic waste is about 705,000 tons. There is currently no remaining capacity available. Technical reclamation has been made. Gas wells and a gas pipeline are constructed. There is the possibility to connect the gas pipeline to the existing burner servicing the 1st stage.

2nd cell of the 2nd stage: The area of this cell is 59 decares (14.6 acres) with a capacity of about 600,000 m^3. It was in operation from 2000 to 2004. The disposed solid domestic waste is about 960,000 tons. Reclamation of a part of this cell has begun.

3rd cell of 2nd stage: The area of this cell is 69 decares (17.0 acres) with a capacity of about 857,000 m^3. It was in operation from 2002 – 2005 and from 2007-2009. The disposed solid domestic waste is about 1,490,000 tons.

There is a discrepancy between the capacity and quantity of the waste disposed in the different cells, because after the covering of the base of the storage facility it is difficult to specify the precise boundaries of the different cells. They overlap, because the body of the 2nd stage of the disposal facility is essentially one integral part. Currently, the 3rd stage is in operation on top of the initial 1st stage. Total capacity of this part of the disposal facility is about 600,000m^3, enough to provide for disposal of the waste of the Sofia municipality for about 2 years.

The depth of the disposed waste varies from 15 to 25 meters. The 1st stage does not have a bottom liner. The 2nd stage has a bottom liner. The landfill has a leachate capture system for return to the body of the disposal facility. This system is currently not operating efficiently, so the collected leachate is transported out of the site. A membrane coating was added during the reclamation of the disposal facility.

Operation of the disposal facility was relatively good. A compacting machine was used to increase the density of the disposed waste. Filling with soil was periodically done. According to the design, all cells of the landfill have gas capture and gas recovery systems. A system for use of part of the captured landfill gas is under construction.

Chistota Iskur EOOD, a 100% municipally owned company, is currently operating, maintaining and reclaiming the disposal facility. The company completes these activities under a public O&M procurement order (recompeted annually). The company has the equipment needed for this activity as regulated by the Waste Management Law (WML) and the Environmental Protection Act.

The Sofia landfill (the disposal facility in Suhodol) is the largest disposal facility in Bulgaria and therefore generates the largest landfill gas quantities in the country. Investigations should be made of the amount of recovered landfill gas to determine the capacity for extension of the system constructed for its use. The landfill has very good potential for further development of systems for generation of electricity from the landfill

gas, because there is a gas capture and distribution system and reclamation of the closed down sections is underway.

2.2. Plovdiv Municipality (Tsalapitsa Landfill)

The disposal facility for solid domestic waste servicing Plovdiv and neighbouring municipalities is located on 238 decares (58.8 acres) of land near the village of Tsalapitsa. The useful area is 180 decares (44.5 acres). The landfill is located 18 km west of Plovdiv alongside the road from Plovdiv to Pazardzhik and next to the Maritsa River at its southern bank, west from the mouth of the Vutcha River. A general view of the landfill is shown in Figure 2.3. There is a 20 kV electricity distribution line next to the disposal facility. There is no gas distribution network close to the site nor any potential heat energy consumers. Residual heat energy of an eventual co-generator could be offered for greenhouses, because the disposal facility is located in an agricultural field.

Figure 2.3
General View of Plovdiv Landfill



The design was for 12 cells that are already constructed. The depth permitted by the Ministry of Environment and Water (MEW) for waste disposal is 13 meters. After that, waste disposal is structured in the shape of a pyramid of 2 meters maximum height for shaping of the cell ridge. The calculated base loading capacity indicates that the depth of disposal could be 30 meters, so the maximum capacity could be 3,434,648 m^3 or about 3 million tons. For the current height of 13 meters, the useful capacity is about 2.0 to 2.2 million tons; about a 10-year operational lifetime for facility. There is a leachate collection system of two sewer-catcher basins. There is no leachate recirculation system. Old waste from the old landfill is about 1.5 million tons, which will be used for periodic covering of the new waste. There are current plans for increasing the volume, by increasing the height of the landfill. Permission for this activity is not granted yet.

The bottom of the cells is 1.80 meters in depth. At the lowest level, there is 50-60 cm of rammed clay in several layers. An insulating foil is placed on the waste and covered with sand and gravel. The foil is also used on the side walls, shaping the body of the disposal facility.

Solid domestic waste of Plovdiv, Stambolyiski and Rodopy municipalities is disposed in the landfill, thereby servicing 450,000 people. Future plans include use of the landfill by other neighbouring municipalities, i.e. Rakovski, Kaloyanovo etc., making the landfill a regional waste disposal facility. Since the other municipalities are far away, it is not clear exactly how this can be implemented. In addition, since 2006-2007, the landfill has accepted waste in bales from the Sofia municipality.

Two vertical gas capture wells are constructed at each cell. During the reclamation of the landfill, a gas pipeline system will be constructed. Filled in cells will be reclaimed and an insulation foil will be placed over them. When the waste reaches a depth of 3 meters, 30 cm of soil will be deposited on top as a cover.

Operation of the disposal facility started on 24 November 1999. The facility is equipped with a weigh scale so there is a precise accounting of the quantity of incoming waste. Since 2007, about 130,000 tons have been disposed annually. This has recently increased to about 150,000 tons annually due to the increased number of municipalities using the disposal facility. In addition, there are the packed bales of waste from Sofia. According to the design, the operation of the disposal facility was to continue to the end of 2009. However, the disposal facility is still in operation, because there is no new disposal facility available. Operation of the current disposal facility is comparatively good, but there is no special compacting equipment available. A bulldozer is used to level the waste. Land is available next to the disposal facility for construction of a system for use of recovered landfill gas. The disposal facility will be closed and reclaimed soon. Currently a legal procedure is being developed for assigning the rights for use of the landfill gas.

2.3. Varna and Aksakovo Municipalities (Aksakovo/Varna Landfill)

The disposal facility for solid domestic waste of the Aksakovo municipality is located on land with a total area of about 100 decares (24.7 acres). A general view of the landfill is shown in Figure 2.4. The depth of the landfill is 10 to 15 meters, but at some places it is up to 25 to 30 meters. The facility is located 11 km northern of the town of Varna, next to the village of Vuglen in the Aksakovo municipality. Solid domestic waste from the Varna and Aksakovo municipalities is disposed there, servicing about 370,000 people. The facility is also used by the Black Sea resorts located in the Varna municipality. A 20 kV electricity distribution line is located next to the landfill. There is no gas distribution network close to the site nor are there any potential heat energy consumers nearby. Residual heat energy could be used for greenhouses, because the disposal facility is located next to agricultural fields.

Figure 2.4
General View of Aksakovo Landfill



There are three cells - 1st cell, 2nd cell –1st stage and 2nd cell – 2nd stage. Design capacities are an approximate total of 1,748,850 m^3 as follows:

- 1st cell – 100,100 m^3
- 2nd cell – 1,648,750 m^3
  - 1st stage – 608,750 m^3
  - 2nd stage – 1,040,000 m^3

A leachate collection system is in place; a leachate recirculation system is planned. The bottom of the cells is made of insulation foil. The operation of the 2nd cell of the disposal facility has been extended so the capacity will not be reached until the middle of 2010. According to the design, the disposal facility has a very good gas capture system in place – 38 wells, each of 20 m radius of operation. There is a reclamation plan to place an insulation foil on the filled cells and to cover them with soil.

Waste is deposited with a 1.8 meter thickness; i.e., as 6 layers of 0.3 meter each. Cells are 20 x 30 meters - during the winter period the cells are extended to 25 x 35 meters because odors are not a noticeable in the colder weather. Each 0.3 meter layer of waste is compacted by a bulldozer until a density of 2.5 times the delivered waste is reached. The surrounding slope of the landfill is a ratio of 1:3. After the depth of 1.8 meters of waste is reached, a 15 centimeter layer of soil is placed on top as a cover.

Operation of the disposal facility started in December 2002 with a 6-year design lifetime. The former landfill, in operation for approximately 30 years, is located next to the current disposal facility. The facility is equipped with a weight scale, so there is a precise measurement of the quantity of incoming waste - about 170,000 tons/year. Operation of the disposal facility is comparatively good, there is no special compacting machine, and a bulldozer does all levelling of the waste. Land is available next to the disposal facility for construction of a system for use of recovered landfill gas. Currently, a private company

operates the disposal facility under a public procurement order pursuant to the Public Procurement Law. The relatively large disposal capacity that will be reached by mid-2010, and the subsequent closure of the landfill, make this landfill a good opportunity for recovering significant quantities of landfill gas.

2.4. Burgas Municipality

Burgas is serviced by the landfill for municipal solid waste located near the village of Bratovo, Burgas municipality. The landfill occupies a total area of 137 decares (33.8 acres) of which 120 decares (29.6 acres) are used. A general view of the landfill is shown in Figure 2.5. The depth of the landfill waste is 10 to 15 meters. The landfill is situated 18 km southwest of Burgas, next to the village of Bratovo. There is a 20 kV electricity distribution line close to the landfill. There are no potential heat energy consumers in the vicinity. The landfill is located near agricultural land and is about 10 km away from a petrochemical plant.

Figure 2.5
General View of Burgas Landfill



The landfill is regional and serves the municipalities of Burgas, Sredets, and Kameno. This is the first landfill for solid waste to be constructed following the standard, approved practice in developed countries. There is a bottom insulated foil and a drainage system for removal and purification of leachate. The leachate is returned to the body of the landfill.

The "Bratovo" landfill was built during the period 1979-1981 and waste disposal began in 1982. The useful volume is 3.6 million m^3. The lifetime of the landfill according to the design was for a period of 25 years, i.e., until 2006. The lifetime was extended until 2010 because a system for compressing the landfill waste was implemented.

During use of the landfill, numerous construction works were completed to provide proper and environmentally safe operation of the facility, e.g., repair of the barrier embankment slopes and ditch; building of a rebating facility at the landfill, etc. Operating procedures involve periodic covering of the waste with soil, i.e., every 2 meters of landfill waste is covered with 30 cm of soil. A problematic area is at the boundary of the landfill where there is a rather steep slope and less soil covering. This causes unfavourable conditions for the formation and retention of landfill gas.

A gas collection system is not currently planned. The landfill is not divided into cells. Since 1996, the landfill has used scales for precise measurement of the entering amount of waste; about 61,000 tons annually. The operation of the landfill is at a relatively good level. The adjacent terrain provides an area for the completion of a system for recovery of the landfill gas. Currently, a private company operates the landfill through a competitive contract in compliance with the Public Procurement Act. There is a project for construction of a new regional landfill, near this one.

2.5 Dobrich Municipality

The Dobrich landfill opened in 1977 near Bogdan village about 7 km away of the town of Dobrich. The landfill operation did not include soil covering and there was not enough compacting. In 1995, refurbishment of the old landfill and its expansion to extend its lifetime were completed. In recent years the amount of waste disposed is about 46,000 tons annually or about 410 kg per capita per year. Currently the total landfill area is approximately 100 decares (24.7 acres), 71.6 decares (17.7 acres) is owned by the Municipality of Dobrich, and 28.4 decares (7.0 acres) is owned by the town of Dobrich. The project for reconstruction of the site plans a separate area specifically for household waste of 46 decares (11.4 acres). The area for reclamation is 44 decares (10.9 acres). The newly built cell has an insulating bottom screen. It will be suitable for use for 5 to 5.5 years; there is an option to extend the lifetime to six years. Since the existing landfill does not solve the problem of long-term waste disposal, negotiations for the construction of a new regional landfill near Krupen are underway with the municipalities of Dobrich, Krushari, Balchik, Blagovo, Toshevo, Kavarna and Shabla.

2.6. Blagoevgrad Municipality

The Municipality of Blagoevgrad is serviced by the disposal facility in the village of Belo Pole. This landfill is typical for middle size municipalities in Bulgaria that are planned for closure. A general view is shown in Figure 2.6.

Figure 2.6
General View of Blagoevgrad Landfill



The landfill has been in operation since 1977 and is planned for closure in 2011. i.e., an operational lifetime of 32 years. After that, the waste will be disposed in the regional disposal facility in the town of Kocherinovo. The population using the current disposal facility is 82,000 citizens. According to municipal data, about 45,600 tons/year are disposed. According to other data, the actual quantity of the incoming waste is about 25,000 tons/year. For this disposal facility, as well as for most of the landfills in Bulgaria, no data has been collected of the morphological composition neither of the waste nor of the landfill gas emissions from it. There is a plan for the disposal facility to be in compliance with EU requirements. The facility is located in a plot of 106 decares (26.2 acres), 42 decares (10.4 acres) of which is the actual disposal facility. The waste depth is 29 meters. Since 1998, the disposal facility has been covered with 25 centimeters of soil. The facility has no power or water. It self-ignited in 2005 and again in 2008. Investigations indicate that the lack of a design for reclamation of the disposal facility means that use of the landfill gas generated by the facility will not be feasible for at least 2-3 years.

2.7. Vidin Municipality

The Vidin municipality has about 85,000 citizens. Currently, it is serviced by a disposal facility specifically for non-hazardous waste. The landfill is located 13 km from Vidin on the territory of Zheglitsa village in the Ramova Livada area. A general view of the landfill is presented in Figure 2.7. A new regional storage facility is planned near the village which will service the population from the neighbouring municipalities; a total of about 110,000 people and disposed waste of an estimated 35,000 tons/year. This regional disposal facility will have a 20-year operational lifetime and a depth of disposed waste of over 20 meters. The regional landfill will also contain re-deposited waste from small landfills in the region. This will increase the future gas production from the planned regional disposal facility.

Figure 2.7
General View of Vidin Landfill



The current Vidin landfill has been in operation since 1991. According to the Bulgarian Program for Management of Waste-related Activities of Vidin Municipality, the existing landfill is categorized as one of the "disposal facilities that do not meet the standard requirements". Access to the disposal facility is difficult because the concrete access road is in a very bad condition. There is no available water or power supply. The disposal facility was constructed without a liner and without provisions for recovering leachate or landfill gas. It does not comply with stated Bulgarian regulations for landfill construction. To avoid spreading of the waste and to protect the access roads, concrete support walls were initially constructed. Most of them are now destroyed, directly polluting an area of about 23 decares (5.68 acres).

In 2005, the municipality prepared a “compliance plan” that identified steps necessary for the disposal facility to be in conformity with Bulgarian regulations, i.e., Ordinance N8/2004 of the Ministry of Environment and Water (MEW) for the “conditions and requirements for construction and operation of disposal facilities and other facilities and installations for utilization and decontamination of the waste”. The plan was approved by the Regional Inspection of Environment and Waters in Decision N06-09-00/30.09.2005.

A schedule to close the existing Vidin municipal landfill has been developed based on the scope and requirements of the “compliance plan”, distances from the regional disposal facility, and legislative requirements for closure of the existing disposal facilities that do not comply with the normative requirements. The closure schedule complies with the time needed for commissioning of the new regional disposal facility. The current landfill should operate for one more year as the first cell of the new disposal facility is planned for commissioning by the middle of 2011. An area with a disposal waste height of 2.5 meters has been specified, i.e., the capacity for a one-year volume of domestic waste generated from the territory of the municipality. There are three separate zones:

- Area in the reclamation process with a network constructed for biogas extraction;
- Area prepared for reclamation - a temporary operation road constructed by reinforced panels passes through the area;
- Area for disposal of domestic waste.

An upper drainage cover consists of the following elements:

- Surface drainage for biogas consisting of a drainage mat of Enkandrain combined with drainage veins of trapezoidal cross-section and installed HDPE pipes perforated for biogas extraction. Drainage veins are intaken into the gas wells;
- Insulation of HDPE foil with a diameter of 1.5mm;
- Surface drainage for atmospheric waters - drainage mat of Enkadrain type.

After completion of the technical reclamation and commissioning of the new disposal facility, a design for containment of the landfill gas emitted by the current disposal facility and reclamation of the area should be completed.

2.8. Smolian Municipality

The landfill, situated 15 km away from Smolian, services the municipalities of Smolian, Chepelare, Banite and Laky. The landfill was designed in 1990 with the following parameters: Area of 120,000 m^2, volume 621,843 m^3, lifetime of 30 years at an annual disposal rate of 78,099 m^3/year. The landfill was designed before the national legislation requiring conformance with the EU requirements. There exists no insulation layer, no system for leachate collection and purification, no system for collection and burning of the landfill gas, and no service buildings. Reconstruction and modernization of the landfill was completed in 2005. The main goal was for the landfill to become regional and to comply with current legislation. The landfill is built in a gully with steep walls. The collected waste before reconstruction of the landfill is spread all over the bottom and there are 3 levels with a depth difference of about 4 to 5 meters. A drainage system was constructed under the waste. The leachate, directed by a concrete wall at the lower side of the landfill, flows down the gully. The reconstruction of the landfill was completed in 3 stages:

- 1st stage: volume of 167,361 m^3;
- 2nd stage: volume of 185,142 m^3;
- 3rd stage: volume of 174,008 m^3.

The landfill gas from the old waste will also be captured and led away. This will be done after compaction of the waste and implementation of a 25 cm drainage layer. Vertical wells will be dug; the depth will depend on the equipment used and the type of collected waste. The wells will be filled with gravel and insulated with concrete on the top. An HDPE pipe with a diameter of 110 mm will be installed and connected to the gas collection system of the new landfill. Gas wells will be connected to a pipeline and a system for disposal of landfill gas will be constructed.

2.9 Bansko Municipality

The landfill in Bansko conforms with local landfills for waste which are to be closed, as a new regional landfill is planned. The regional landfill has received a positive evaluation from the Assessment of the Environmental Impact early in 2010. The project decision for closure and reclamation of the old landfill has been made based on geological, hydrogeological and hydrological studies. The implementation of the following activities is envisaged:

- management of water infiltration through the capture of the infiltrate by drainage;
- surface water management through ditches;
- technical reclamation of the landfill sites including the following layers: a gas drainage layer of gravel, geotextile, soil layer, and humus;
- management of the gaseous emissions from the landfill body.

The landfill in Bansko has operated since 1973 and will be closed after the construction of a regional landfill in Razlog. The landfill services about 13,000 residents. About 9,500 tons of waste is deposited annually.

2.10 Berkovitsa Municipality

Berkovitsa is one of the small municipalities with no regulated landfills. Waste is deposited in uncontrolled municipal dumps. They do not comply with any normative requirements and they are subject to closure with waste re-directed to the regional disposal facilities. About 19,000 tons of waste are disposed annually by about 23,000 people, according to municipal data. More likely, according to expert opinion, the actual quantity of waste received by the disposal facility is about 7,000 tons/year. A general view of the landfill is shown in Figure 2.8.

Figure 2.8
General View of Berkovitsa Landfill



According to the National Program for Management of Waste Activities, all populated areas should be included in the system of organized collection and transportation of waste to a municipal disposal facility for solid domestic waste or to a regional disposal facility – in this case, Montana. Non-regulated landfills should be closed. Organized collection of domestic waste is made only in the town of Berkovitsa and the village of Burzia. In the remaining populated areas in the Berkovitsa municipality, there is no organized waste collection.

In Berkovitsa, waste disposal is in a separate, but not regulated, landfill located in the Rakovitsa area about 1.2 km from the town. The storage facility is an area of 32 decares (7.91 acres) on privately owned municipal land in the Berkovitsa protected area. There is a drainage system under the disposal facility. Borders of the disposal facility are not fenced, there is no access control and no weight scales. Some areas of the disposal facilities are covered with soil and compacted. Since June 2008, the Berkovitsa municipality has transported hazardous domestic waste to the regional disposal facility - Montana.

The current disposal facility is closed. There is a contract with a German consortium (CDM Consult GmbH./Fishtner GmbH&CoKG/C&E Consulting und Engineering GmbH) for preparation of detailed design, tender documentation and construction supervision of activities related to the landfill closure according to Measure 2000/BG/16/P/PE/002.

Due to the small quantity of the disposed waste, the condition of the disposal facility and the forthcoming procedure for its closure and reclamation, further consideration of this landfill for near-term gas recovery is not recommended.

2.11 Comparison based on provided information

Based on the assessment of received data from the ten landfills (Table 2.1), the Sofia, Plovdiv, Varna, and Burgas landfills were chosen for modelling using the EPA Ukrainian landfill gas model. Currently, an 800 kW co-generation unit is being installed at the Sofia landfill. It will begin operation before the end of 2010. Modeling results show that the 800 kW installed capacity is less than 50% of the total landfill capacity. The landfill was chosen because after the start up of the co-generation unit, it will be a good base point for comparison of the results received from the modelling of the other three landfills. The other three landfills (Plovdiv, Varna and Burgas) are owned by the largest and richest Bulgarian municipalities. This means they are well maintained, and operated. All of these landfills have reclamation projects planned. The Plovdiv and Varna landfills have started the construction of gas collection systems. The smaller municipalities are not operating the landfills well and gas potential is considered low. Landfills like Smoljan, Dobrich and the new regional landfill of Vidin can subsequently be examined. If they are operated and maintained to EU standards, they should have a significant potential for gas recovery and use.

Table 2.1
Summarized Data for Selected Landfills

	Municipality									
	Sofia	***Plovdiv***	***Varna***	***Burgas***	***Dobrich****	***Blagoevgrad***	***Vidin***	***Smoljan***	***Bansko***	***Berkovica***
Questionnaire	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES
Year opened	1985	1999	2002	1982	1977	1977	1991		1973	1968
Year closure	2012	2010	2011	2012	2015	2012	2012	2035	2009	2009
Waste disposed in 2009, tons	400,000	170,000	138,000	88,000	46,000	45,000	29,000	33,668*	9,500	18,961**
Population, people	1,200,000	450,000	360,000	240,000	120,000	86,000	51,000	47,000	13,000	21,000
Total area, m2	300,000	232,000	97,000	120,000	100,000	106,000	25,000	120,000	33,538	32,000
Average depth, m	over 15	13	20	15 to 45	-	29.5	-		20	
Number of cells	5	12	3	1	1	1	1	5	1	1
Project volume, m3	4,500,000	2,200,000	1,800,000	3,600,000	-	1,452,000	-	526,511		240,000
Project for recultivation	YES	YES	YES	NO	-	YES	NO	YES	YES	YES
Gas collection wells	YES	YES (50%)	YES	NO	NO	NO	NO	YES	NO	NO
Data for morphological content	YES	NO	NO	YES	-	NO	NO	NO	NO	NO
Drainage system	YES	YES	YES	YES	-	NO	NO	YES	NO	YES

* Average for the old landfill
** Data for 2008

3. MORPHOLOGICAL CONTENT

The amount of methane gas depends mostly on the morphological content of the waste. There are very few detailed analyses of the morphological content of landfills in Bulgaria. Table 3.1 shows morphological content based on size of the population served. The source for this data is the Bulgarian Ministry of Environment and Water. This data can be used as an estimate of morphological content for landfills that do not have any specific measurements.

Table 3.1
Estimated Morphological Content for Bulgarian Landfills*

Population, inhabitants	less than 3,000	from 3,000 to 25,000	from 25,000 to 50,000	over 50,000
Content	%	%	%	%
Organic				
Food waste	4.86	12.56	20.85	28.80
Paper	3.87	6.55	10.45	11.10
Paperboard	1.30	0.70	1.63	9.70
Plastics	5.21	8.98	9.43	12.00
Textile	3.48	4.70	3.40	3.20
Rubber	1.15	0.45	1.10	0.60
Leather	1.36	1.35	2.10	0.70
Garden waste	14.12	14.00	5.53	6.80
Wood waste	2.14	2.28	1.58	1.30
Non-Organic				
Glass	8.85	3.4	8.78	9.9
Metals	2.88	1.3	2.83	1.7
Others				
Cinder, inert materials, sand, soil and other not indentified	50.78	43.73	32.35	14.2

** Source: Bulgarian Ministry of Environment and Water*

Specific morphological content obtained for the Sofia (Suhodol), Burgas and Varna municipal landfills is shown in Table 3.2, Table 3.3 and Table 3.4 respectively. All the landfills service a population much greater than 50,000 people.

Table 3.2
Morphological Content of Sofia (Suhodol) Landfill

Components	Waste generated by the population	Waste from industrial and business objects	Total generated waste
Food waste	20.7%	15.6%	**19.5%**
Paper	14.0%	15.6%	**14.4%**
Paperboard	13.3%	18.8%	**14.7%**
Plastics	12.7%	11.5%	**12.4%**
Textiles	5.2%	2.8%	**4.6%**
Rubber	1.3%	0.6%	**1.1%**
Leather	1.1%	0.9%	**1.1%**
Yard waste	6.5%	11.3%	**7.7%**
Wood	4.4%	1.9%	**3.8%**
Glass	7.8%	9.3%	**8.2%**
Metals	2.3%	1.8%	**2.2%**
Inert materials	10.2%	9.6%	**10.0%**
Dangerous waste	0.3%	0.4%	**0.3%**

Since the Burgas landfill was the first to be constructed following the standard, approved practice in developed countries, it has been the subject of many studies. The main studies were conducted in 1995 by the Spanish company "COGRESA" SA and in 2006 by the U.S. government's "Ecolinks" program. This provides the opportunity for more complete and accurate data on the morphological composition of the waste. The yearly difference in the data is due to the natural changes in the generated waste, as well as to differences in classification.

The data presented for Aksakovo/Varna landfill is not considered reliable, so for the modelling the data presented by the Ministry is used.

Table 3.3
Morphological Content of Burgas Landfill

Components	1999	2006
Metals	1.9%	0.6%
Rubber, leather	1.2%	1.3%
Textiles	3.5%	n/a
Garden wastes	1.1%	18.3%
Inert materials	3.7%	8.2%
Glass	8.2%	3.3%
Paper	15.3%	16.7%
Plastics	17.6%	20.9%
Food wastes	13.9%	11.5%
Dangerous wastes	0.4%	1.6%
Others	33.2%	18.2%

Table 3.4
Morphological Content of Aksakovo/Varna Landfill

Components	
Paper and cardboard	12.3%
Plastics	12.9%
Glass	15.8%
Textile	8.2%
Metals	10.7%
Wood	2.0%
Rubber	2.7%
Kitchen waste	9.9%
Garden waste	11.1%
Construction waste	12.2%
Others	2.2%

Table 3.5 is a summary comparison of the Ministry of Environment and Water estimate (for cities of over 50,000 population) and data from the most recent studies of the morphological content from the Sofia landfills.

Table 3.5
Comparison of Morphological Content in Percent:
General Estimate and Measured Content for Sofia Landfill

Components	Estimated* (Population: > 50,000)	Sofia (Population : 1,267,726**)
Food waste	28.8	19.5
Paper	11.1	14.4
Paperboard	9.7	14.7
Plastics	12	12.4
Textiles	3.2	4.6
Rubber	0.6	1.1
Leather	0.7	1.1
Yard Waste	6.8	7.7
Wood	1.3	3.8
Glass	9.9	8.2
Metals	1.7	2.2
Inert Materials	14.2	10
Hazardous Waste	1.17	0.3

* Source: Bulgarian Ministry of Environment and Water
** Only registred citizens, the actual number is over 1,500,000

4. AMOUNT OF WASTE DISPOSED

The amount of landfill gas is directly related to the amount of waste stored in the landfill. Table 4.1 shows the annual disposed waste in the landfills analyzed in this report. The data covers the quantity deposited from the landfill opening to its closure or expected closure. Bansko and Berkovitca landfills are not included as site visits and information collected indicated that they were not in a satisfactory condition for implementation of a landfill gas recovery system.

Table 4.1
Annual Waste Deposited in Selected Municipal Landfills (metric tons)

	Sofia	Plovdiv	Burgas	Varna	Dobrich	Vidin	Blagoevgrad	Smolian
	metric tons							
from 1977					184,000		184,000	
1,981					46,000		46,000	
1,982			63,000		46,000		46,000	
1,983			63,000		46,000		46,000	
1,984			63,000		46,000		46,000	
1,985	125,000		63,000		46,000		46,000	
1,986	125,000		63,000		46,000		46,000	
1,987	125,000		63,000		46,000		46,000	
1,988	125,000		63,000		46,000		46,000	
1,989	125,000		63,000		46,000		46,000	
1,990	125,000		63,000		46,000		46,000	28,000
1,991			63,000		46,000	29,000	46,000	28,000
1,992			63,000		46,000	29,000	46,000	28,000
1,993			63,000		46,000	29,000	46,000	28,000
1,994			63,000		46,000	29,000	46,000	28,000
1,995			63,000		46,000	29,000	46,000	28,000
1,996			63,000		46,000	29,000	46,000	28,000
1,997	185,000		63,000		46,000	29,000	46,000	28,000
1,998	255,000		63,000		46,000	29,000	46,000	28,000
1,999	265,000	12,000	63,000		46,000	29,000	46,000	28,000
2,000	300,000	130,000	63,000		46,000	29,000	46,000	28,000
2,001	300,000	130,000	63,000		46,000	29,000	46,000	28,000
2,002	300,000	130,000	63,000	128,000	46,000	29,000	46,000	28,000
2,003	300,000	130,000	63,000	110,000	46,000	29,000	46,000	28,000
2,004	300,000	130,000	63,000	113,000	46,000	29,000	46,000	28,000
2,005	215,000	130,000	63,000	135,000	46,000	29,000	46,000	28,000
2,006		450,000	88,000	161,000	46,000	29,000	46,000	28,000
2,007	35,000	140,000	88,000	131,000	46,000	29,000	46,000	28,000
2,008	400,000	140,000	88,000	152,000	46,000	29,000	46,000	46,000
2,009	400,000	140,000	88,000	138,000	46,000	29,000	46,000	46,000
2,010	400,000	140,000	88,000	140,760	46,000	29,000	46,000	46,000
2,011	200,000	140,000	88,000	17,229	46,000	29,000		46,000
2,012		140,000	88,000		46,000	29,000		46,000
2,013		140,000			46,000			46,000
2,014					46,000			46,000
2,015					46,000			46,000
2,016					46,000			46,000
to 2035								x46000
Total	***4,605,000***	***2,222,000***	***2,128,000***	***1,225,989***	***1,840,000***	***638,000***	***1,564,000***	***1,838,000***

5. MODELING OF SELECTED MUNICIPAL LANDFILLS

Landfills that service the largest and most economically developed towns in Bulgaria contain the largest quantity of bio-degradable components. These landfills are also representative of the best waste storage facilities in Bulgaria. On the basis of the data received from municipalities and preliminary assessment of the landfill gas recovery potential, the largest four landfills were selected for modelling, i.e., Sofia, Burgas, Plovdiv, and Aksakovo/Varna. These landfills were built in compliance with current Bulgarian requirements for managed landfills that should be the same as EU requirements. There are also plans for reclamation and construction of gas collection systems at each landfill. Input/Output tables for the EPA LandGem model (as modified for Ukraine) and resulting graphs of projections of landfill gas generation and recovery are in Appendix B.

6. BUSINESS PLANS FOR DEVELOPMENT OF MUNICIPAL LANDFILLS

The project objective is to increase the capacity of municipalities to identify and implement LFG projects, through increased technical capability and access to private sector financial resources. Two municipal landfills were selected for the development of business cases for LFG recovery and use; the Plovdiv municipal landfill (Tsalapitsa landfill) and the Aksakovo/Varna municipal landfill. The business plans include a cost and financial analysis, risk assessment, and assessment of environmental issues and mitigation strategies. Two financing approaches were considered; one where the municipality assumes the project loan and owns and operates the landfill, and one where an ESCo assumes the loan, leases the landfill from the municipality, and operates it for a specified period of time. This second arrangement could be through a public-private partnership (PPP) with the ESCo if a suitable division of expenses and revenues can be agreed upon. The business plans have a section on project benefits that considers emission reduction of CO_2, NO_x, and SO_2 reduction as a result of displacement of natural gas and/or other fuels to generate the equivalent power. Financing schemes include one where foreign investors provide a grant to finance the methane collection system in return for revenue from future carbon credits.

6.1. Plovdiv Landfill (Tsalapitsa)

Plovdiv is the second-largest city in Bulgaria with a population of 380,683. Plovdiv is the administrative center of Plovdiv Province, Municipality of Plovdiv, Maritsa municipality and Rodopi municipality. The Mayor of the Municipality of Plovdiv, together with the six district mayors, represent the local executive authorities. The Municipal Council which consists of 51 municipal counselors, represents the legislative power and is elected according to the proportional system by parties' lists. The executive government of the Municipality of Plovdiv consists of a mayor who is elected by majority representation, five deputy mayors and one administrative secretary. All the deputy mayors and the secretary control their administrative structured units. According to the *Law for the Territorial Subdivision of the Capital Municipality and the Large Cities*, the territory of Plovdiv Municipality is subdivided into six district administrations, their mayors being appointed following approval by the Municipal Council. Plovdiv has one of the country's fastest growing economies with average GDP growth of 12-13%. As of 2005 the total revenues are 9.4 billion leva (approximately 4.8 billion euro), which is 88% more than in 2001. The profits for the same period rose 4.5 times. Unemployment is 6,5% which is lower than the national average.

The general approach to finance the Plovdiv landfill gas recovery project is through municipal ownership or a type of public-private-partnership (PPP). A formal definition of a PPP is *"a contractual arrangement between a public sector institution and a private party in which the private party performs an institutional function or uses public sector assets and assumes substantial financial, technical and operational risk in the design, financing, building and/or operation of the project, in return for a benefit*. For this project, the "private party" can be a "specialty company" established by the municipality

and the private sector partner to own and operate the LFG facility or an energy service company (ESCo). For this business plan, a simplified arrangement is used where the private sector company is an ESCo that leases the landfill from the municipality.
A detailed assessment is made of the project's suitability for development since the contract design is critical:

- risks should be clearly defined and distributed appropriately among the parties,
- innovation by the ESCo should be encouraged,
- the provisions governing transfer of public infrastructure to an ESCo (i.e., by means of a lease or license) and its reversion at the end of the concession period should be clear and transparent at the outset and over the lifetime of the project;
- the payment mechanism should be a clear procedure,
- reduction in costs over the life span of the contract should be encouraged by incentives to insure price-competitive quality public service, and
- adequate flexibility to encompass new and innovative ways of upgrading the quality of service is essential.

The roles and responsibilities of the municipality and the ESCo must be well defined. The ESCo may perform pump tests or other field data collection to verify assumptions in any business plan that were based on software modelling of the landfill. The municipal partner will provide the landfill, assist with permitting and licensing, ensure site security, and assist with required infrastructure (e.g., civil works).

Case #1: Municipally-owned LFG Recovery Facility
The municipality assumes the project loan and owns and operates the facility. The municipality puts in EUR 160,000 as it's "own contribution" ("equity"). The financial analysis shows:

- Included in the O&M cost is the salary of operating personnel.
- The municipality assumes the EUR 1,675,999 loan; the costs for "interest during construction", "management fees during construction", and "additional working capital"; and some "own contribution" ("equity").
- The municipality receives revenue from the sale of electricity to NEK at the current preferential price and may receive revenue from the sale of heat if an appropriate consumer is nearby.

Case #2: Municipal lease to an ESCo
The municipality enters into a long-term concession (a lease arrangement) with an ESCo that allows the ESCo to operate a LFG facility on the landfill for a specified period of time. A contract is agreed to in which:

- The municipality has no "own contribution", i.e. the "equity" is all from the ESCo.
- The ESCo assumes the EUR 1,675,999 loan; the costs for "interest during construction", management fees during construction", and "additional working capital"; and some "own contribution" ("equity").

- The ESCo is the beneficiary of the 15%-of-the-BEERECL-loan "investment grant" if the loan is eligible for the BEERECL facility[2].
- The ESCo enters into a long-term lease with the Municipality for use of the landfill.
- The ESCo is the beneficiary of revenue for electricity sold to NEK at the current preferential price and may receive revenue from the sale of heat if an appropriate consumer is nearby.

Base Project Costs

The project cost is estimated on the basis of estimations of quantities and their costs. Table 6.1 describes the project size, operational specifications, and expected revenues and savings.

Table 6.1
Project Specifications, Revenues and Savings

Implementation of gas generator at Tsalapitsa landfill

1. Expected condition	**Value**	**Unit**	**Sources**
Installed capacity	800	kW	Modelling
Working hours of the generator	6,000	h	Assessment
Annual electricity production	4,800	MWh/yr	Calculation
Electricity own needs	72	MWh/yr	1.5% Jebacker
Electricity sold to the grid	4,728	MWh/yr	Calculation
Electricity price	129	EUR/MWh	Decision No C-30
Income from sold electricity	611,599	EUR/yr	Calculation
2. Savings			
O&M costs	-138,356	EUR/yr	Jenbacker & Assessement
Annual revenues and savings	473,244	EUR/yr	Calculation

Table 6.2 presents the base project cost breakdown for design costs, equipment costs, construction works, commissioning tests, and contingency; VAT is excluded.

[2] The Bulgarian Energy Efficiency and Renewable Energy Credit Line (BEERECL) facility is a credit line established by the European Bank for Reconstruction and Development (EBRD) under which local banks provide loans at market rates to Bulgarian project developers. The developer is eligible for a cash incentive grant of 15% of the BEERECL loan upon project completion and acceptance by an independent energy company inspector.

Table 6.2
Base Project Costs Breakdown - Tsalapitsa Landfill Project

(EUR)	Design	Equipment	Construction Works	Commissioning test	Contingency	Total Project Cost
Implementation of gas generator at Tsalapitsa landfill	229,957	719,566	780,000	20,000	86,476	**1,835,999**
Total Project Costs	**229,957**	**719,566**	**780,000**	**20,000**	**86,476**	**1,835,999**

The general investment schedule from September 2013 through December 2014, used for the purposes of the cash flow analysis, is presented in Table 6.3.

Table 6.3
Funding Scheme – Tsalapitsa Landfill Project

(EUR)	2013						2014								
	September	November	December	January	March	April	May	June	July	August	September	November	December	Total	Share
Bank	34,320	14,160	48,711	180,000	215,870	37,619	43,174	135,991	537,340	88,019	239,957	28,000	72,838	**1,675,999**	**91.3%**
Plovdiv							70,000	42,000	28,000				20,000	**160,000**	**8.7%**
Total by	**34,320**	**14,160**	**48,711**	**180,000**	**215,870**	**37,619**	**113,174**	**177,991**	**565,340**	**88,019**	**239,957**	**28,000**	**92,838**	**1,835,999**	**100.0%**

The total base project cost is EUR 1,835,999 that includes costs for design, equipment, construction works, commissioning test and contingency (excluding VAT). The debt financing is EUR 1,675,999. The allocation of the equity and loan investments extended by the bank are shown in Table 6.4.

Table 6.4
Total Base Project Costs Provided by Equity and Debt Financing

(EUR)	Total		Project Total
	Plovdiv	Bank	
Implementation of gas generator at Tsalapitsa landfill			
Design			
Management		80,000	**80,000**
Design of gas collection system		23,600	**23,600**
Design of gas generator		71,957	**71,957**
Consultant, legal services and technical supervision		54,400	**54,400**
Total Design		**229,957**	**229,957**
Equipment			
Jenbacher gas generator (800 kW)		560,000	**560,000**
Interfacing and central process control		70,000	**70,000**
Flare		89,566	**89,566**
Total Equipment		**719,566**	**719,566**
Construction Works			
Gas collection system (fittings, pipes, etc.)		360,000	**360,000**
Gas generator set (monitoring, pumps, fans, filters, etc.)		112,000	**112,000**
Electrical integration		168,000	**168,000**
Foundations, office, civil works	140,000		**140,000**
Total Construction Works	**140,000**	**640,000**	**780,000**
Commissioning test			
72 hours trials and training ot the operational staff	20,000		**20,000**
Total commissioning tests	**20,000**		**20,000**
Contingency			
Contingency		86,476	**86,476**
Total Contingency		86,476	**86,476**
Total by Funding Source	**160,000**	**1,675,999**	**1,815,999**
Total Project cost	**1,835,999**		**1,835,999**

Project Cash Flow

Operational Costs

The operational costs for the project implementation are shown in Table 6.5. Training of the operation staff is included in the total price of the equipment. The total annual operational and maintenance cost is estimated as EUR 138,356.

Table 6.5
Operation and Maintenance Costs of the Tsalapitsa Landfill Project

(EUR)	
Operational and Maintenance Costs	
Cost for Salaries and Social Security of the Operational Staff	82,216
Cost for Maintenance of Equipment	15,339
Cost for Materials and External services	40,801
Total	**138,356**

The savings from implementation of the Tsalapitsa landfill project are achieved by the sale of 4,728 MWh of electricity to the national utility, NEK. Table 6.6 summarizes the basic scenario results from the implementation of the project for the project's life cycle from 2015 through 2030.

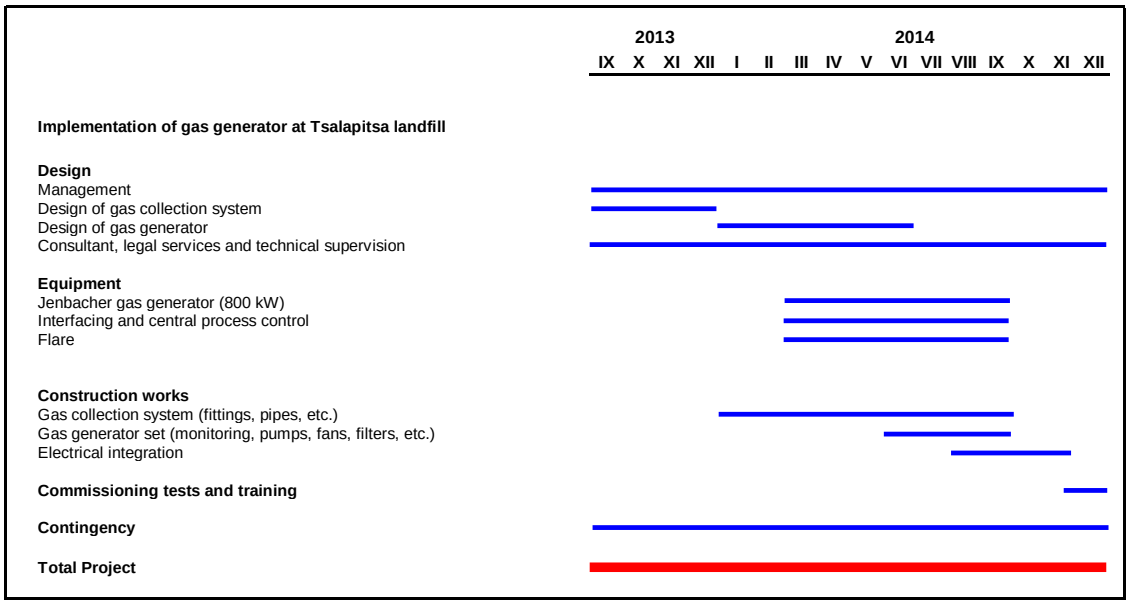
Table 6.6
Total Project Revenues and O&M Cost - Tsalapitsa Landfill Project

Sources of Cash Flow		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Implementation of gas generator at Tsalapitsa landfill																	
Electricity sold to NEC	MWh/yr	4,728	4,728	4,728	4,728	4,728	4,728	4,728	4,576	4,279	4,009	3,764	3,540	3,335	3,147	2,974	2,814
Operation and maintenance costs	EUR/yr	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356
Tariffs																	
Electricity produced by landfill gas	EUR/MWh	129.36	129.36	129.36	129.36	129.36	129.36	129.36	129.36	129.36	129.36	129.36	129.36	129.36	129.36	129.36	129.36
Cash Savings and Revenues																	
Electricity sold to NEC	EUR/yr	611,599	611,599	611,599	611,599	611,599	611,599	611,599	591,903	553,455	518,580	486,850	457,894	431,389	407,053	384,643	363,946
Operation and maintenance costs	EUR/yr	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356
Total Cash Flow	**EUR/yr**	**473,244**	**473,244**	**473,244**	**473,244**	**473,244**	**473,244**	**473,244**	**453,547**	**415,100**	**380,224**	**348,495**	**319,538**	**293,033**	**268,698**	**246,288**	**225,590**

Activity Based Schedule

Table 6.7 shows the activity based schedule for the Tsalapitsa landfill project. The schedule for project implementation is from September 2013 through December 2014.

Table 6.7
Activity Based Schedule – Tsalapitsa Landfill Project



Type and Amount of Requested Financing

The total base project cost amounts to EUR 1,835,999. The proposed financial scheme includes debt financing from the bank in the amount of EUR 1,675,999 and a contribution from the municipality of EUR 160,000. The debt equity ratio is 91.3% to 8.7%. The municipality will pay interest during construction in the amount of EUR 59,548 and management fees in the amount of EUR 32,512. (see Table 6.8).

Table 6.8
Project Cost and Proposed Financial Scheme

Project Cost	EUR	%
Total Base Project Cost	1,835,999	95.2%
Interest during Construction	59,548	3.1%
Management Fees during Construction	32,512	1.7%
Total Project Cost	**1,928,058**	100.0%
Base Capital Structure		
Debt	1,675,999	91.3%
Equity	160,000	8.7%
Total Investments	**1,835,999**	100.0%
Financial Scheme		
Requested Loan #1	1,675,999	86.9%
Project Sponsor Contribution		
Project Cost	160,000	8.3%
Interest during Construction	59,548	3.1%
Management Fees during Construction	32,512	1.7%
Total Project Sponsor Contribution	252,060	13.1%
Total Sources of Funding	**1,928,058**	100.0%

Proposed Financial Scheme Including the Municipal Contribution

The preliminary loan disbursement scheme including the borrower's own contribution is presented in Table 6.9. The scheme reflects the preliminary terms negotiated between the bank and the borrower. The final disbursement scheme is subject to negotiations between the bank and the borrower.

Table 6.9
Loan Disbursements and Own Contribution Scheme

EUR	2013 30-Sep	2013 30-Nov	2013 31-Dec	2014 30-Jan-14	2014 31-Mar-14	2014 30-Apr-14	2014 31-May-14	2014 30-Jun-14	2014 31-Jul-14	2014 31-Aug-14	2014 30-Sep-14	2014 30-Nov-14	2014 31-Dec-14	Total	Share
Tsalapitsa	€ -	€ -	€ -	€ -	€ -	€ -	€ 70,000	€ 42,000	€ 28,000	€ -	€ -	€ -	€ 20,000	**€ 160,000**	**8.7%**
BANK	€ 34,320	€ 14,160	€ 48,711	€180,000	€ 215,870	€ 37,619	€ 43,174	€ 135,991	€ 537,340	€ 88,019	€ 239,957	€ 28,000	€ 72,838	**€ 1,675,999**	**91.3%**
Total Sources of Funding	**34,320**	**€ 14,160**	**€ 48,711**	**€180,000**	**€ 215,870**	**€ 37,619**	**€ 113,174**	**€ 177,991**	**€ 565,340**	**€ 88,019**	**€ 239,957**	**€ 28,000**	**€ 92,838**	**€ 1,835,999**	**100%**

Proposed Terms and Conditions of Finance

For this business plan, it is assumed that preliminary negotiations between the borrower and the bank on the loan terms and conditions are for an interest rate that amounts to the 3-month EURIBOR plus a margin of 6.2%. Currently, the 3-Month EURIBOR is 0.6630%. For the purposes of the cash flow analysis, the interest is assumed to be 6.863% and to remain constant until the end of the loan period. The loan repayment starts in January 2015 - before that borrower pays monthly interest on the outstanding principal during the project construction period and during the 16-month grace period. The loan disbursement, loan repayment and the total monthly payments are presented in Table 6.10.

Table 6.10
Loan Parameters

Evaluation Period		
Construction Begins	(day/month/year)	01-Jan-14
Construction Ends	(day/month/year)	30-Nov-14
Operation Begins	(day/month/year)	01-Jan-15
Operation Ends	(day/month/year)	31-Dec-30
Loan Conditions		
Partner Bank Name		BANK
Loan Disbursement Begins	(day/month/year)	01-Sep-13
Loan Disbursement Ends	(day/month/year)	31-Dec-14
Grace Period	(Months)	16
Interest Rate		
Interest Payments Begin	(day/month/year)	31-Oct-13
3 Months EURIBOR	(%)	0.6630%
Margin	(%)	6.2000%
Total Interest Rate	(%)	6.863%
Loan Principal Payments		
Begin	(day/month/year)	01-Jan-15
End	(day/month/year)	28-Feb-19
Number of Payments per Year		12
Term	(Year)	4.17
Total Number of Payments		50
Total Loan Principal	(EUR)	1,675,999

Cash Flow Analysis and Project Financial Indicators

The project cash flow analysis indicates that the project's cash flow is sufficient to serve debt (pay loan interest and repay loan principal) within the loan terms negotiated with the bank. The following capital budgeting indicators result from the project cash flow projection and analysis (Table 6.11). The project payback period is 4.12 years, the IRR is 21.64%, and the NPV amounts to EUR 1,137,810 at fixed discount rate of 10%.

Table 6.11
Project Cash Flow Projection

Cash Flow Projection

(EUR)	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2030
Cash Flows From Operating Activity											
Electricity sold to NEC	0	0	611,599	611,599	611,599	611,599	611,599	611,599	611,599	591,903	363,946
O&M Costs	0	0	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356	-138,356
Management Fee BANK	-16,760	-15,752	-13,743	-9,721	-5,698	-1,676	0	0	0	0	0
Interest BANK	-670	-58,878	-102,371	-74,765	-47,160	-19,554	-575	0	0	0	0
Depreciation	0	0	-147,743	-147,743	-112,743	-112,743	-112,743	-108,743	-108,743	-108,743	-12,320
Income Tax	0	0	-20,939	-24,101	-30,764	-33,927	-35,993	-36,450	-36,450	-34,480	-21,327
Net Cash From Operating Activity	**-17,430**	**-74,630**	**336,191**	**364,656**	**389,621**	**418,087**	**436,676**	**436,794**	**436,794**	**419,067**	**204,263**
Cash Flow From Financing Activity											
Increase in Borrowing BANK	97,191	1,578,807	0	0	0	0	0	0	0	0	0
Net Increase in Borrowing	97,191	1,578,807	0	0	0	0	0	0	0	0	0
Project Sponsor's Contribution	0	160,000	0	0	0	0	0	0	0	0	0
Other Contributions - Insentive Grant	0	0	251,400	0	0	0	0	0	0	0	0
Principal Repayments to BANK	0	0	-402,240	-402,240	-402,240	-402,240	-67,040	0	0	0	0
Net Cash From Financing Activity	**97,191**	**1,738,807**	**-150,840**	**-402,240**	**-402,240**	**-402,240**	**-67,040**	**0**	**0**	**0**	**0**
Net Cash Flow From Investing Activity	**-97,191**	**-1,738,807**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Increase (Decrease) in Cash	-17,430	-74,630	185,351	-37,584	-12,618	15,847	369,636	436,794	436,794	419,067	204,263
Cash, Beginning of Year	0	-17,430	-92,060	93,291	55,707	43,089	58,936	428,572	865,365	1,302,159	3,809,106
Cash, End of Year	**-17,430**	**-92,060**	**93,291**	**55,707**	**43,089**	**58,936**	**428,572**	**865,365**	**1,302,159**	**1,721,226**	**4,013,369**

Cash Flow Analysis

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2030
Net Free Cash Flow	-97,191	-1,738,807	452,305	449,142	442,479	439,317	437,251	436,794	436,794	419,067	204,263
Discounted Net Free Cash Flow	-97,191	-1,580,734	373,806	337,447	302,219	272,781	246,817	224,144	203,767	177,725	40,412
Cumulative Cash Flow	-97,191	-1,835,999	-1,383,694	-934,552	-492,072	-52,756	384,495	821,289	1,258,083	1,677,150	3,969,292

Payback Period (Years)	**4.12**
IRR	**21.64%**
NPV	**1,137,810**

Base Case and Variants

The detailed cost and financial analysis above is for the "Base Case I" where the municipality is the borrower of the EUR 1,675,999 loan (Table 6.13) and an investor has financed none of the methane collection system. Table 6.14 presents results for "Base Case II" where an investor has financed 50% of the cost of the methane collection system. Table 6.15 presents results for "Base Case III" where an investor has financed 100% of the cost of the methane collection system. All three sets of tables show financial results for the following seven ESCo variants:

66,411: the ESCo pays the municipality EUR 66,411 as a concession fee.

100,000: the ESCo pays the municipality EUR 100,000 as a concession fee.

100,000 EU &20%: the ESCO pays the municipality EUR 100,000 as a concession fee and invests 20% of the loan amount as equity.

150,000: the ESCo pays the municipality EUR 150,000 as a concession fee.

150,000 EU &20%: the ESCO pays the municipality EUR 150,000 as a concession fee and invests 20% of the loan amount as equity.

200,000: the ESCo pays the municipality EUR 200,000 as a concession fee.

200,000 EU &20%: the ESCO pays the municipality EUR 200,000 as a concession fee and invests 20% of the loan amount as equity.

Table 6.13
Base Case I with ESCo Variants (Tsalapitsa Landfill)

Parameters	Municipality	ESCO variants						
	Base case	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Loan amount	1,675,999	1,675,999	1,675,999	1,467,999	1,675,999	1,467,999	1,675,999	1,467,999
Loan term (months)	66	74	81	71	93	81	113	97
Equity	160,000	160,000	160,000	368,000	160,000	368,000	160,000	368,000
PBP	4.12	4.76	5.17	5.19	5.91	5.95	6.91	6.96
IRR	21.64%	17.71%	15.60%	15.52%	12.21%	12.12%	8.38%	8.26%
NPV	1,137,810	715,555	502,981	496,669	186,878	179,669	-127,094	-135,828
With Grant 15%								
PBP		4.10	4.45	4.56	5.09	5.22	5.94	6.11
IRR		20.75%	18.55%	18.08%	15.04%	14.57%	11.12%	10.63%
NPV		923,323	710,750	678,652	394,646	361,653	80,675	46,155
Municipality contract (concession tax for 15 years)		996,165	1,500,000	1,500,000	2,250,000	2,250,000	3,000,000	3,000,000

Parameters	Sensitivity Analysis							
	Municipality	ESCO variants						
	Base case	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Cost Overrun								
PBP	4.54	5.25	5.69	5.72	6.52	6.56	7.67	7.73
IRR	19.17%	15.45%	13.45%	13.38%	10.21%	10.13%	6.51%	6.41%
NPV	970,017	547,762	335,189	328,876	19,085	11,877	-294,886	-303,621
Start-Up Delay								
PBP	4.20	4.85	5.25	5.28	6.00	6.03	7.00	7.05
IRR	21.21%	17.36%	15.29%	15.21%	11.95%	11.86%	8.16%	8.05%
NPV	1,107,900	689,761	479,270	472,957	166,265	159,057	-145,323	-153,341
Savings								
PBP	4.57	5.27	5.72	5.75	6.54	6.58	7.70	7.76
IRR	19.02%	15.33%	13.34%	13.27%	10.13%	10.04%	6.43%	6.34%
NPV	865,697	485,953	294,881	288,568	10,783	3,575	-274,031	-280,688
Worse Case								
PBP	4.64	5.34	5.79	5.82	6.62	6.65	7.78	7.83
IRR	18.73%	15.10%	13.13%	13.06%	9.95%	9.86%	6.28%	6.19%
NPV	889,414	492,325	292,480	286,167	-4,677	-11,885	-301,452	-308,802

Table 6.14
Base Case II with ESCo Variants (Tsalapitsa Landfill)

Parameters	Municipality	ESCO variants						
	Base case II	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Loan amount	1,416,374	1,416,374	1,416,374	1,261,100	1,416,374	1,261,100	1,416,374	1,261,100
Loan term (months)	56	64	68	62	78	70	93	82
Equity	160,000	160,000	160,000	315,275	160,000	315,275	160,000	315,275
PBP	3.56	4.12	4.47	4.49	5.13	5.15	6.00	6.04
IRR	25.80%	21.45%	19.11%	19.06%	15.42%	15.35%	11.29%	11.21%
NPV	1,358,051	935,490	721,725	718,038	404,655	400,199	88,805	83,286
With Grant 15%								
PBP		3.55	3.86	3.94	4.42	4.52	5.18	5.30
IRR		24.65%	22.22%	21.80%	18.38%	17.96%	14.14%	13.71%
NPV		1,111,073	897,309	874,373	580,239	556,533	264,388	239,621
Municipality contract (concession tax for 15 years)		996,165	1,500,000	1,500,000	2,250,000	2,250,000	3,000,000	3,000,000

Parameters	Sensitivity Analysis							
	Municipality	ESCO variants						
	Base case II	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Cost Overrun								
PBP	3.92	4.54	4.93	4.94	5.65	5.67	6.62	6.65
IRR	23.03%	18.94%	16.74%	16.69%	13.23%	13.17%	9.26%	9.19%
NPV	1,214,005	791,443	577,679	573,992	260,608	256,152	-55,242	-60,761
Start-Up Delay								
PBP	3.64	4.20	4.56	4.57	5.21	5.23	6.09	6.12
IRR	25.26%	21.01%	18.73%	18.67%	15.10%	15.03%	11.03%	10.95%
NPV	1,328,223	909,778	698,095	694,408	384,124	379,668	71,373	65,854
Savings								
PBP	3.95	4.56	4.95	4.97	5.68	5.70	6.64	6.68
IRR	22.85%	18.79%	16.61%	16.55%	13.12%	13.06%	9.18%	9.10%
NPV	1,085,939	705,888	513,625	509,938	228,561	224,104	-55,284	-60,802
Worse Case								
PBP	4.02	4.63	5.02	5.04	5.75	5.77	6.71	6.75
IRR	22.48%	18.50%	16.34%	16.29%	12.90%	12.84%	9.00%	8.92%
NPV	1,121,610	724,214	523,179	519,492	225,056	220,599	-71,848	-77,366

Table 6.15
Base Case III with ESCo Variants (Tsalapitsa Landfill)

Parameters	Municipality	ESCO variants						
	Base case III	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Loan amount	1,146,250	1,146,250	1,146,250	1,045,000	1,146,250	1,045,000	1,146,250	1,045,000
Loan term (months)	46	52	55	51	62	58	73	67
Equity	160,000	160,000	160,000	261,250	160,000	261,250	160,000	261,250
PBP	2.96	3.43	3.73	3.74	4.28	4.29	5.03	5.04
IRR	31.76%	26.76%	24.12%	24.08%	19.96%	19.92%	15.40%	15.35%
NPV	1,592,292	1,168,803	954,591	952,517	636,313	634,136	318,951	316,148
With Grant 15%								
PBP		2.97	3.23	3.28	3.71	3.77	4.35	4.42
IRR		30.20%	27.43%	27.07%	23.10%	22.76%	18.39%	18.06%
NPV		1,310,900	1,096,688	1,082,062	778,410	763,681	461,048	445,693
Municipality contract (concession tax for 15 years)		996,165	1,500,000	1,500,000	2,250,000	2,250,000	3,000,000	3,000,000

Parameters	Sensitivity Analysis							
	Municipality	ESCO variants						
	Base case III	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Cost Overrun								
PBP	3.27	3.78	4.11	4.12	4.72	4.73	5.54	5.56
IRR	28.55%	23.89%	21.40%	21.37%	17.48%	17.44%	13.13%	13.08%
NPV	1,472,982	1,049,493	835,281	833,207	517,003	514,826	199,641	196,838
Start-Up Delay								
PBP	3.05	3.52	3.81	3.82	4.37	4.38	5.11	5.12
IRR	31.05%	26.19%	23.61%	23.57%	19.54%	19.50%	15.06%	15.01%
NPV	1,562,538	1,143,166	931,035	928,961	615,857	613,680	301,594	298,791
Savings								
PBP	3.29	3.80	4.13	4.14	4.74	4.76	5.56	5.58
IRR	28.33%	23.70%	21.23%	21.19%	17.34%	17.30%	13.02%	12.97%
NPV	1,320,179	939,202	746,491	744,416	460,219	458,042	174,863	172,060
Worse Case								
PBP	3.36	3.88	4.20	4.21	4.81	4.83	5.63	5.65
IRR	27.83%	23.30%	20.88%	20.85%	17.05%	17.01%	12.78%	12.73%
NPV	1,368,293	969,971	768,487	766,413	469,156	466,979	170,742	167,939

6.2. Aksakovo/Varna Landfill

The Aksakovo/Varna landfill serves the municipalities of Akasakovo and Varna. **Aksakovo municipality is located in the northeast of Bulgaria and consists of 23 villages with a total area of 472 sq.km.** It is positioned in the eastern part of the Danube Plain, which renders the area its characteristic of hills and plateaus. The main part of the territory is occupied by the Dobrudja and Frangensko plateaus which are over 200 meters above the sea level. The large territory of Aksakovo municipality, its various relief forms, as well as the difference in its remoteness from the sea result in large climate differences; basically temperate-continental in the area of the plateaus. The climate is favorable for development of agriculture, especially for growing crops, vineyards, apricot-trees, etc. The rural character of the region could encourage the development of alternative rural, natural or ecological tourism. The Krumovo, Zasmyano, Liuben Karavelovo, Botevo and Osenovo dam lakes and the Batova, Osenovska and Suha rivers support the development of sport and fishing tourism. Aksakovo municipality is situated close to the town of Varna that has a key position in the trans-European nets and systems favoring transportation and communication links. **Varna is the largest city and seaside resort on**

the Bulgarian Black Sea Coast and in Northern Bulgaria, the third-largest city in Bulgaria after Sofia and Plovdiv, and the 92th-largest city in the European Union. Commonly referred to as the marine (or summer) capital of Bulgaria, Varna is a major tourist destination, business and university center, seaport, and headquarters of the Bulgarian Navy and merchant marine, as well as the center of Varna Province and Bulgaria's North-Eastern planning region (NUTS II), comprising also the provinces of Dobrich, Shumen, and Targovishte. In April 2008, Varna was designated seat of the Black Sea Euro-Region (a new regional organization, not to be confused with the Black Sea Euroregion) by the Council of Europe.

Demography	Aksakovo Municipality	Varna Municiplaity
Area Size (km^2)	472	237.5
Population	18,538	364,292 (503,999 metro area)
Total Towns and Cities	0	1
Total Villages	23	5
Center of Municipality	Village of Aksakovo	City of Varna

Aksakovo is a very small municipality with little economic influence. Economically, Varna is among the best-performing and fastest-growing Bulgarian cities; unemployment, at 2.34% (2007), is over 3 times lower than the nation's rate. In 2007, the median salary was the highest, on a par with Sofia and Burgas. Many Bulgarians regard Varna as a boom town and are relocating there. In September 2004, *FDI Magazine* (a *Financial Times* Business Ltd publication) proclaimed Varna *South-eastern Europe City of the Future* citing its strategic location, fast-growing economy, rich cultural heritage and higher education. In April 2007, rating agency Standard & Poor's announced that it had raised its long-term issue credit rating for Varna to BB+ from BB, declaring the city's outlook "stable" and praising its "improved operating performance". In December 2007 (and again in October 2008), Varna was voted "Best City in Bulgaria to Live In" by a national poll by *Darik Radio*, the *24 Chasa* daily and the information portal darik.news.

The general approach to finance the Aksakovo/Varna municipal landfill gas recovery project is through municipal ownership or a leasing agreement with an ESCo. As with the Plovdiv municipal landfill (Tsalapitsa landfill), two cases are considered:

Case #1: Municipally-owned LFG Recovery Facility

The municipality assumes the project loan and owns and operates the facility. The municipality puts in EUR 160,000 as it's "own contribution" ("equity"). The financial analysis shows:

- Included in the O&M cost is the salary of operating personnel.
- The municipality assumes the EUR 1,675,999 loan; the costs for "interest during construction", "management fees during construction", and "additional working capital"; and some "own contribution" ("equity").
- The municipality receives revenue from the sale of electricity to NEK at the current preferential price and revenue from the sale of heat to a nearby greenhouse.

Case #2: Municipal lease to an ESCo

The municipality enters into a long-term concession (a lease arrangement) with an ESCo that allows the ESCo to operate a LFG facility on the landfill for a specified period of time. A contract is agreed to in which:

- The municipality has no "own contribution", i.e. the "equity" is all from the ESCo.
- The ESCo assumes the EUR 1,675,999 loan; the costs for "interest during construction", management fees during construction", and "additional working capital"; and some "own contribution" ("equity").
- The ESCo is the beneficiary of the 15%-of-the-BEERECL-loan "investment grant" if the loan is eligible for the BEERECL facility.
- The ESCo enters into a long-term lease with the Municipality for use of the landfill.
- The ESCo is the beneficiary of revenue for electricity sold to NEK at the current preferential price and revenue from the sale of heat to a nearby greenhouse.

Base Project Costs

The project cost for the implementation of the energy efficiency measures is based on:

a) estimations of quantities and their costs;
b) preliminary conversations with Bulgarian companies;
c) specifications of the equipment and construction works.

Table 6.16 presents the base projects cost breakdown between design, equipment, construction works, commissioning tests and contingency (VAT is excluded).

Table 6.16
Base Project Cost Breakdown

(EUR)	Design	Equipment	Construction Works	Commissioning test	Contingency	Total Project Cost
Implementation of gas generator at Aksakovo landfill	188,801	591,778	496,229	20,000	63,840	**1,360,648**
Total Project Costs	**188,801**	**591,778**	**496,229**	**20,000**	**63,840**	**1,360,648**

The general investment schedule from October 2011 through January 2013, used for the purposes of the cash flow analysis, is presented in Table 6.17. The calculated own contribution of the municipality is (a) foundation for the generator; (b) offices for the operational staff; (c) civil works; and (d) commissioning tests and training.

Table 6.17
Funding Scheme – Aksakovo/Varna Landfill Project

(EUR)	2011						2012						2013		
	October	December	January	February	April	May	June	July	August	September	October	December	January	Total	Share
Bank	27,738	8,010	39,574	97,000	118,356	31,960	35,507	79,104	415,767	64,810	236,399	38,185	56,988	**1,249,398**	**91.8%**
Aksakovo							45,625	27,375	18,250				20,000	**111,250**	**8.2%**
Total by Funding Sources	**27,738**	**8,010**	**39,574**	**97,000**	**118,356**	**31,960**	**81,132**	**106,479**	**434,017**	**64,810**	**236,399**	**38,185**	**76,988**	**1,360,648**	**100.0%**

The total base project cost is EUR 1,360,648 that includes costs for design, equipment, construction works, commissioning test and contingency (excluding VAT). The debt financing is EUR 1,249,398. The allocation of the equity and loan investments extended by the bank is shown in Table 6.18.

Table 6.18
Total Base Project Costs Provided by Equity and Debt Financing

(EUR)	Total		Project
	Varna	Bank	Total
Implementation of gas generator at Aksakovo landfill			
Design			
Management		80,000	**80,000**
Design of gas collection system		13,350	**13,350**
Design of co-generation module		59,178	**59,178**
Consultant, legal services and technical supervision		36,273	**36,273**
Total Design		**188,801**	**188,801**
Equipment			
Jenbacher gas generator (500 kW)		365,000	**365,000**
Interfacing and central process control		45,625	**45,625**
Heat accumulator and boiler integration		109,500	**109,500**
Flare		71,653	**71,653**
Total Equipment		**591,778**	**591,778**
Construction Works			
Gas collection system (fittings, pipes, etc.)		194,000	**194,000**
Gas generator set (monitoring, pumps, fans, filters, etc.)		73,000	**73,000**
Electrical integration		109,500	**109,500**
Connection to the heat consumer (Greenhouse)		28,479	**28,479**
Foundations, office, civil works	91,250		**91,250**
Total Construction Works	**91,250**	**404,979**	**496,229**
Commissioning test			
72 hours trials and training ot the operational staff	20,000		**20,000**
Total commissioning tests	**20,000**		**20,000**
Contingency			
Contingency		63,840	**63,840**
Total Contingency		63,840	**63,840**
Total by Funding Source	**111,250**	**1,249,398**	**1,360,648**
Total Project cost	**1,360,648**		**1,360,648**

Project Cash Flow

Operational Costs

The operational costs for the project implementation are represented by the following components:

- salaries for the operational staff of the generator plant and social security costs for the operational staff of the facility (EUR 82,216);
- cost related to equipment maintenance and repair (EUR 9,587); and
- cost for materials (oil/filters, lubrication etc.) and external services (EUR 25,501).

Training of the operation staff is included in the total price of the equipment. The total annual operational and maintenance cost is estimated as EUR 117,303 (Table 6.19).

Table 6.19
Operation and Maintenance Costs of the Aksakovo/Varna Landfill Project

(EUR)	
Operational and Maintenance Costs	
Cost for Salaries and Social Security of the Operational Staff	82,216
Cost for Maintenance of Equipment	9,587
Cost for Materials and External services	25,501
Total	**117,303**

Revenues from Electricity Sales and Sale of Heat

The revenues from the implementation of the Aksakovo/Varna landfill project are achieved by the sale of 2,940 MWh of electricity to the national utility, NEK and 2,408 MWh of heat energy situated next to the landfill. Table 6.20 presents the project specifications and Table 6.21 summarizes the basic scenario results from the implementation of the project for the project's life cycle from 2013 through 2028.

Table 6.20
Project Specifications, Revenues and Savings

Implementation of gas generator at Aksakovo landfill

1. Expected condition	Value	Unit	Sources
Installed electrical capacity	500	kW	Modelling
Installed heat capacity	573	kW	Janbacker
Working hours of the generator	6,000	h	Assessment
Annual electricity production	3,000	MWh/yr	Calculation
Electricity own needs	60	MWh/yr	2% Jebacker
Electricity sold to the grid	2,940	MWh/yr	Calculation
Electricity price	135	EUR/MWh	Decision No C-30
Annual heat energy production	3,437	MWh/yr	Calculation
Heat energy price	33	EUR/MWh	Calculation
Heat energy needed in a greenhouse	2,406	MWh/yr	Assessment
Income from sold electricity	396,844	EUR/yr	Calculation
Income form sold heat energy	79,966	EUR/yr	Calculation
2. Savings			
O&M costs	-117,303	EUR/yr	Jenbacker & Assessement
Revenues and savings	359,507	EUR/yr	Calculation

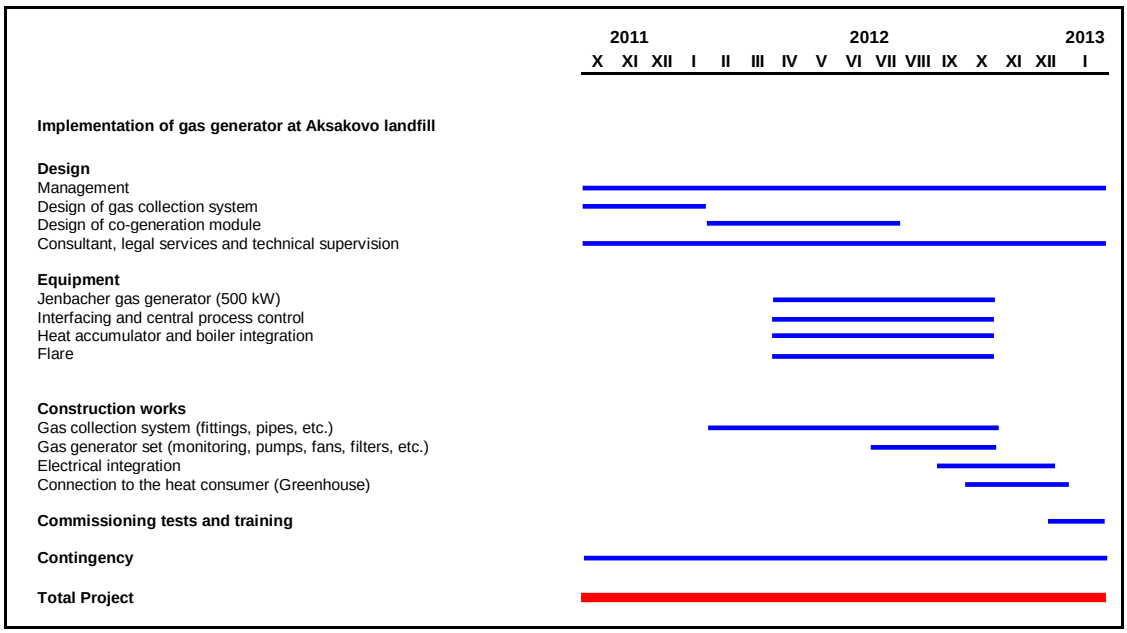
Table 6.21
Total Project Revenues and O&M Cost – Aksakovo/Varna Landfill Project

Sources of Cash Flow		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Implementation of gas generator at Aksakovo landfill																	
Electricity sold to NEC	MWh/yr	2,750	3,000	3,000	3,000	3,000	3,000	3,000	2,847	2,677	2,545	2,437	2,346	2,269	2,204	2,147	2,097
Heat energy	(MWh/yr.)	1,997	2,406	2,406	2,406	2,406	2,406	2,406	2,283	2,133	1,997	1,873	1,760	1,657	1,562	1,475	1,394
Operation and maintenance costs	EUR/yr	-107,528	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303
Concession tax																	
Tariffs																	
Electricity produced by landfill gas	EUR/MWh	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135
Heat energy	(EUR/MWh)	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Cash Savings and Revenues																	
Electricity sold to NEC	EUR/yr	371,198	404,943	404,943	404,943	404,943	404,943	404,943	384,273	361,390	343,541	328,882	316,670	306,327	297,459	289,772	283,045
Heat energy	(EUR/yr.)	66,367	79,966	79,966	79,966	79,966	79,966	79,966	75,884	70,902	66,379	62,261	58,502	55,063	51,907	49,004	46,326
Operation and maintenance costs	EUR/yr	-107,528	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303
Total Cash Flow	**EUR/yr**	**330,037**	**367,606**	**367,606**	**367,606**	**367,606**	**367,606**	**367,606**	**342,854**	**314,989**	**292,616**	**273,840**	**257,869**	**244,087**	**232,064**	**221,473**	**212,068**

Activity Based Schedule (ABS)

Table 6.22 shows the activity based schedule for the Aksakovo/Varna landfill project. The schedule for project implementation is from October 2011 through January 2013.

Table 6.22
Activity Based Schedule – Aksakovo/Varna Landfill Project



The design of the collection system, the management of the project and the legal services will start in October 2011, four months before the closure of the landfill. After landfill closure in January 2012, the construction of the gas collection system will start. Ordering and manufacturing of equipment (the gas generator and flare) is expected from April 2012 to October 2012. Electrical integration, commissioning tests and training will be performed in October 2012 and January 2013.

Type and Amount of Requested Financing

The total base project cost amounts to EUR 1,360,648. The proposed financial scheme includes debt financing from the bank in the amount of EUR 1,249,398 and a contribution from the municipality of EUR 111,250. The debt equity ratio is 91.8% to 8.2%. The municipality will pay interest during construction in the amount of EUR 41,130 and management fees in the amount of EUR 24,036. (see Table 6.23).

Table 6.23
Project Cost and Proposed Financial Scheme

Project Cost	**EUR**	**%**
Total Base Project Cost	1,360,648	95.4%
Interest during Construction	41,130	2.9%
Management Fees during Construction	24,036	1.7%
Total Project Cost	**1,425,814**	100.0%
Base Capital Structure		
Debt	1,249,398	91.8%
Equity	111,250	8.2%
Total Investments	**1,360,648**	100.0%
Financial Scheme		
Requested Loan #1	1,249,398	87.6%
Project Sponsor Contribution		
Project Cost	111,250	7.8%
Interest during Construction	41,130	2.9%
Management Fees during Construction	24,036	1.7%
Total Project Sponsor Contribution	176,416	12.4%
Total Sources of Funding	**1,425,814**	100.0%

Proposed Financial Scheme Including the Municipal Contribution

The preliminary loan disbursement scheme including the borrower's own contribution is presented in Table 6.24. The scheme reflects the preliminary terms negotiated between the bank and the borrower. The final disbursement scheme is subject to negotiations between the bank and the borrower.

Table 6.24
Loan Disbursements and Own Contribution Scheme

EUR	2011 31-Oct	2011 31-Dec	2012 30-Jan-12	2012 28-Feb-12	2012 30-Apr-12	2012 31-May-12	2012 30-Jun-12	2012 31-Jul-12	2012 31-Aug-12	2012 30-Sep-12	2012 31-Oct-12	2012 31-Dec-12	2013 30-Jan-13	Total	Share
Aksakovo	€ -	€ -	€ -	€ -	€ -	€ -	€ 45,625	€ 27,375	€ 18,250	€ -	€ -	€ -	€ 20,000	**€ 111,250**	**8.2%**
BANK	€ 27,738	€ 8,010	€ 39,574	€ 97,000	€ 118,356	€ 31,960	€ 35,507	€ 79,104	€ 415,767	€ 64,810	€ 236,399	€ 38,185	€ 56,988	**€ 1,249,398**	**91.8%**
Total Sources of Funding	**€ 27,738**	**€ 8,010**	**€ 39,574**	**€ 97,000**	**€ 118,356**	**€ 31,960**	**€ 81,132**	**€ 106,479**	**€ 434,017**	**€ 64,810**	**€ 236,399**	**€ 38,185**	**€ 76,988**	€ 1,360,648	100%

Proposed Terms and Conditions of Finance

For this business plan, it is assumed that preliminary negotiations between the borrower and the bank on the loan terms and conditions are for an interest rate that amounts to the 3-month EURIBOR plus a margin of 6.2%. Currently, the 3-Month EURIBOR is 0.6630%. For the purposes of the cash flow analysis, the interest is assumed to be 6.863% and to remain constant until the end of the loan period. The loan repayment starts in February 2013 - before that borrower pays monthly interest on the outstanding principal during the project construction period and during the 16-month grace period. The loan disbursement, loan repayment and the total monthly payments are presented in Table 6.25.

Table 6.25
Loan Parameters

Evaluation Period		
Construction Begins	(day/month/year)	01-Feb-12
Construction Ends	(day/month/year)	31-Dec-12
Operation Begins	(day/month/year)	01-Feb-13
Operation Ends	(day/month/year)	31-Dec-28
Loan Conditions		
Partner Bank Name		BANK
Loan Disbursement Begins	(day/month/year)	01-Oct-11
Loan Disbursement Ends	(day/month/year)	31-Jan-13
Grace Period	(Months)	16
Interest Rate		
Interest Payments Begin	(day/month/year)	30-Nov-11
3 Months EURIBOR	(%)	0.6630%
Margin	(%)	6.2000%
Total Interest Rate	(%)	6.863%
Loan Principal Payments		
Begin	(day/month/year)	01-Feb-13
End	(day/month/year)	31-Dec-16
Number of Payments per Year		12
Term	(Year)	3.92
Total Number of Payments		47
Total Loan Principal	(EUR)	1,249,398

Cash Flow Analysis and Project Financial Indicators

The project cash flow analysis indicates that the project's cash flow is sufficient to serve debt (pay loan interest and repay loan principal) within the loan terms negotiated with the bank. The following capital budgeting indicators result from the project cash flow projection and analysis. The project payback period is 3.94 years, the IRR is 22.87%, and the NPV amounts to EUR 941,114 at fixed discount rate of 10%.

Table 6.26
Project Cash Flow Projection

Cash Flow Projection

(EUR)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2028
Cash Flows From Operating Activity												
Electricity sold to NEC	0	0	371,198	404,943	404,943	404,943	404,943	404,943	404,943	384,273	361,390	283,045
Heat energy	0	0	66,367	79,966	79,966	79,966	79,966	79,966	79,966	75,884	70,902	46,326
O&M Costs	0	0	-107,528	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303	-117,303
Management Fee BANK	-12,494	-11,542	-10,102	-6,912	-3,722	-532	0	0	0	0	0	0
Interest BANK	-317	-33,993	-77,058	-55,644	-33,751	-11,859	0	0	0	0	0	0
Depreciation	0	0	-109,081	-118,997	-98,085	-96,184	-96,184	-79,455	-77,934	-77,934	-77,934	-7,002
Income Tax	0	0	-13,380	-18,605	-23,205	-25,903	-27,142	-28,815	-28,967	-26,492	-23,705	-20,507
Net Cash From Operating Activity	**-12,811**	**-45,535**	**229,498**	**286,445**	**306,928**	**329,312**	**340,463**	**338,791**	**338,638**	**316,362**	**291,283**	**191,561**
Cash Flow From Financing Activity												
Increase in Borrowing BANK	35,748	1,156,661	56,988	0	0	0	0	0	0	0	0	0
Net Increase in Borrowing	35,748	1,156,661	56,988	0	0	0	0	0	0	0	0	0
Project Sponsor's Contribution	0	91,250	20,000	0	0	0	0	0	0	0	0	0
Other Contributions -	0	0	187,410	0	0	0	0	0	0	0	0	0
Principal Repayments to BANK	0	0	-292,412	-318,995	-318,995	-318,995	0	0	0	0	0	0
Net Cash From Financing Activity	**35,748**	**1,247,911**	**-28,014**	**-318,995**	**-318,995**	**-318,995**	**0**	**0**	**0**	**0**	**0**	**0**
Net Cash Flow From Investing Activity	**-35,748**	**-1,247,911**	**-76,988**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Increase (Decrease) in Cash	-12,811	-45,535	124,495	-32,550	-12,067	10,317	340,463	338,791	338,638	316,362	291,283	191,561
Cash, Beginning of Year	0	-12,811	-58,347	66,149	33,598	21,531	31,848	372,312	711,102	1,049,741	1,366,103	3,047,048
Cash, End of Year	**-12,811**	**-58,347**	**66,149**	**33,598**	**21,531**	**31,848**	**372,312**	**711,102**	**1,049,741**	**1,366,103**	**1,657,386**	**3,238,610**

Cash Flow Analysis

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2028
Net Free Cash Flow	-35,748	-1,247,911	239,669	349,000	344,401	341,702	340,463	338,791	338,638	316,362	291,283	191,561
Discounted Net Free Cash Flow	-35,748	-1,134,465	198,074	262,209	235,230	212,170	192,183	173,853	157,977	134,168	112,302	37,899
Cumulative Cash Flow	-35,748	-1,283,659	-1,043,990	-694,990	-350,589	-8,887	331,577	670,367	1,009,006	1,325,368	1,616,651	3,197,875

Payback Period (Years)	**3.94**
IRR	**22.87%**
NPV	**941,114**

Base Case and Variants

The previous detailed cost and financial analysis is for the "Base Case I" where the municipality is the borrower of the EUR 1,249,398 loan (Table 6.28) and an investor has financed none of the cost of the methane collection system. Table 6.29 presents results for "Base Case II" where an investor has financed 50% of the cost of the methane collection system. Table 6.30 presents results for "Base Case III" where an investor has financed 100% of the methane collection system. All three sets of tables show financial results for the following seven ESCo variants:

66,411: the ESCo pays the municipality EUR 66,411 as a concession fee.

100,000: the ESCo pays the municipality EUR 100,000 as a concession fee.

100,000 EU &20%: the ESCO pays the municipality EUR 100,000 as a concession fee and invests 20% of the loan amount as equity.

150,000: the ESCo pays the municipality EUR 150,000 as a concession fee.

150,000 EU &20%: the ESCO pays the municipality EUR 150,000 as a concession fee and invests 20% of the loan amount as equity.

200,000: the ESCo pays the municipality EUR 200,000 as a concession fee.

200,000 EU &20%: the ESCO pays the municipality EUR 200,000 as a concession fee and invests 20% of the loan amount as equity.

Table 6.28
Base Case I with ESCO Company (Aksakovo/Varna Landfill)

Parameters	Municipality	ESCO variants						
	Base case I	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Loan amount	1,249,398	1,249,398	1,249,398	1,088,518	1,249,398	1,088,518	1,249,398	1,088,518
Loan term (months)	63	75	84	73	106	90	over 180	124
Equity	111,250	111,250	111,250	272,130	111,250	272,130	111,250	272,130
PBP	3.94	4.77	5.33	5.36	6.47	6.51	8.57	8.70
IRR	22.87%	17.63%	14.76%	14.68%	10.00%	9.91%	4.15%	3.92%
NPV	941,114	523,330	312,681	307,559	158	-5,668	-311,500	-321,482
With Grant 15%								
PBP		4.10	4.58	4.70	5.56	5.71	7.12	7.37
IRR		20.73%	17.73%	17.23%	12.79%	12.30%	6.81%	6.21%
NPV		678,214	467,565	442,500	155,042	129,272	-156,616	-186,542
Municipality contract (concession tax for 15 years)		996,165	1,500,000	1,500,000	2,250,000	2,250,000	3,000,000	3,000,000

Parameters	Sensitivity Analysis							
	Municipality	ESCO variants						
	Base case I	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Cost Overrun								
PBP	4.34	5.25	5.87	5.91	7.16	7.21	9.96	10.22
IRR	20.32%	15.39%	12.66%	12.59%	8.11%	8.02%	2.43%	2.21%
NPV	817,730	399,946	189,297	184,175	-123,226	-129,052	-434,884	-444,866
Start-Up Delay								
PBP	4.04	4.87	5.44	5.47	6.59	6.63	8.74	8.88
IRR	22.31%	17.19%	14.38%	14.30%	9.68%	9.59%	3.89%	3.67%
NPV	913,136	499,469	290,901	285,780	-19,730	-25,213	-328,075	-337,926
Savings								
PBP	4.37	5.27	5.90	5.93	7.19	7.25	10.10	10.30
IRR	20.17%	15.27%	12.57%	12.49%	8.03%	7.94%	2.32%	2.14%
NPV	730,761	355,077	165,720	160,599	-116,905	-122,181	-401,206	-408,237
Worse Case								
PBP	4.45	5.37	5.99	6.02	7.31	7.36	10.30	10.54
IRR	19.77%	14.96%	12.29%	12.21%	7.79%	7.71%	2.16%	1.96%
NPV	747,644	354,821	156,796	151,675	-138,837	-144,320	-433,638	-442,046

Table 6.29
Base Case II with ESCO Company (Aksakovo/Varna Landfill)

Parameters	Municipality	ESCO variants						
	Base case II	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Loan amount	1,095,983	1,095,983	1,095,983	965,787	1,095,983	965,787	1,095,983	965,787
Loan term (months)	52	66	74	65	91	79	126	106
Equity	111,250	111,250	111,250	241,447	111,250	241,447	111,250	241,447
PBP	3.52	4.26	4.76	4.78	5.79	5.82	7.48	7.53
IRR	26.21%	20.52%	17.43%	17.35%	12.34%	12.26%	6.10%	6.00%
NPV	1,069,742	652,210	441,137	437,393	127,912	123,283	-186,266	-190,959
With Grant 15%								
PBP		3.67	4.10	4.20	4.98	5.11	6.37	6.53
IRR		23.78%	20.53%	20.06%	15.24%	14.78%	8.86%	8.40%
NPV		788,076	577,003	557,119	263,777	243,009	-50,400	-71,233
Municipality contract (concession tax for 15 years)		996,165	1,500,000	1,500,000	2,250,000	2,250,000	3,000,000	3,000,000

Parameters	Sensitivity Analysis							
	Municipality	ESCO variants						
	Base case II	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Cost Overrun								
PBP	3.88	4.69	5.25	5.27	6.38	6.42	8.46	8.54
IRR	23.42%	18.09%	15.16%	15.10%	10.31%	10.23%	4.27%	4.18%
NPV	960,324	542,792	331,719	327,975	18,493	13,865	-295,684	-300,377
Start-Up Delay								
PBP	3.62	4.36	4.87	4.89	5.90	5.93	7.62	7.68
IRR	25.54%	20.00%	16.97%	16.90%	11.98%	11.89%	5.80%	5.70%
NPV	1,041,813	628,398	419,406	415,663	109,053	104,652	-202,731	-207,423
Savings								
PBP	3.90	4.71	5.27	5.29	6.40	6.44	8.51	8.59
IRR	23.24%	17.95%	15.04%	14.97%	10.23%	10.15%	4.20%	4.09%
NPV	859,390	483,957	294,177	290,433	12,106	8,019	-272,346	-276,999
Worse Case								
PBP	3.99	4.80	5.36	5.39	6.51	6.54	8.66	8.74
IRR	22.76%	17.57%	14.71%	14.65%	9.95%	9.88%	3.98%	3.87%
NPV	883,305	490,733	292,284	288,540	-3,070	-6,828	-299,618	-304,311

Table 6.30
Base Case III with ESCO Company (Aksakovo/Varna Landfill)

Parameters	Municipality	ESCO variants						
	Base case III	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Loan amount	932,069	932,069	932,069	834,655	932,069	834,655	932,069	834,655
Loan term (months)	48	56	62	56	75	67	100	88
Equity	111,250	111,250	111,250	208,664	111,250	208,664	111,250	208,664
PBP	3.06	3.71	4.16	4.17	5.06	5.08	6.46	6.50
IRR	30.80%	24.44%	21.02%	20.97%	15.48%	15.42%	8.87%	8.79%
NPV	1,210,567	791,302	579,616	577,244	265,218	262,297	-47,838	-51,124
With Grant 15%								
PBP		3.21	3.59	3.66	4.37	4.46	5.58	5.70
IRR		27.89%	24.30%	23.87%	18.52%	18.11%	11.73%	11.33%
NPV		906,848	695,162	680,714	380,763	365,767	67,708	52,346
Municipality contract (concession tax for 15 years)		996,165	1,500,000	1,500,000	2,250,000	2,250,000	3,000,000	3,000,000

Parameters	Sensitivity Analysis							
	Municipality	ESCO variants						
	Base case III	66,411	100,000	100,000 Eu&20%	150,000	150,000 Eu&20%	200,000	200,000 Eu&20%
Cost Overrun								
PBP	3.37	4.09	4.58	4.59	5.57	5.60	7.16	7.20
IRR	27.67%	21.73%	18.52%	18.47%	13.26%	13.20%	6.89%	6.82%
NPV	1,116,069	696,804	485,118	482,746	170,719	167,799	-142,336	-145,622
Start-Up Delay								
PBP	3.16	3.81	4.26	4.28	5.17	5.19	6.59	6.62
IRR	29.96%	23.79%	20.46%	20.40%	15.03%	14.97%	8.50%	8.42%
NPV	1,182,691	767,543	557,938	555,567	246,639	243,719	-64,371	-67,582
Savings								
PBP	3.39	4.11	4.60	4.61	5.60	5.62	7.19	7.24
IRR	27.46%	21.57%	18.37%	18.32%	13.16%	13.09%	6.81%	6.73%
NPV	1,000,214	623,049	432,655	430,284	149,953	147,033	-132,657	-135,829
Worse Case								
PBP	3.48	4.20	4.69	4.71	5.70	5.72	7.32	7.36
IRR	26.85%	21.09%	17.96%	17.91%	12.82%	12.76%	6.53%	6.45%
NPV	1,031,642	637,338	438,276	435,905	142,670	139,749	-153,169	-156,380

7. CONCLUSIONS

Globally, landfills are the third largest anthropogenic (human influenced) methane emission source. Countries in the European Union have seen a drop in anthropogenic methane emissions from landfills since 1990, because of the increase of collection, flaring of landfill gas, and in some cases, recovery of methane. However, in transition countries, such as the Balkan countries, anthropogenic methane from landfills has increased since 1990, and is expected to continue to increase. Proposed EU Directives have required a reduction of anthropogenic methane emissions in Bulgaria and will do so in the Balkan countries that wish to join the EU (i.e., Serbia, Albania, Bosnia and Herzegovina: Federation of Bosnia and Hergezovina and Republika Srpska, Croatia, the Former Yugoslav Republic of Macedonia, Kosovo, Montenegro). The implementation of LFG recovery projects will be required in those countries. These projects bring the added benefits of improved local air quality, reduced health risks, and improved energy independence. In light of the recent decision by the Bulgarian Parliament to improve the national economy that has suffered from the global economic downturn by cutting municipal budgets by 20%, LFG recovery projects provide an attractive rate of return from savings in natural gas and electricity purchases that generates needed revenue that municipalities can use to improve necessary infrastructure and provide required social services to its population.

Organized municipal waste collection covers about 80% of the population of Bulgaria. As part of the landfill data collection for this project, a comprehensive analysis of the waste accumulation rate in Bulgaria was completed (kilograms/capita annually) to verify the data submitted by the smaller municipalities that do not weigh disposal trucks at the entrance of their storage facilities. From these data, an average of 280 kilograms/capita annually was determined for landfills where incoming waste quantities were not accurately measured. This suggests a large potential for methane recovery projects. There is growing concern specifically about the availability of sufficient landfill capacity in the future, and in general about the need to implement sustainable solid waste management practices.

Despite recent attention to economic, social, and political impacts of municipal energy efficiency from the Bulgarian national and regional governments, the fact remains that more than 70% of total energy in Bulgaria is consumed at the municipal level. An indigenous energy source is available – municipal landfills in Bulgaria are generating about 234 million cubic meters (m^3) of landfill gas (LFG) annually, about 50% of which is methane (CH_4) – or an average of 1,642,000 tons of carbon dioxide (CO_2) equivalent per year. Implementing LFG recovery and utilization projects at just the ten largest landfills in the country could produce up to 72 million m^3 of methane.

Questionnaires regarding the main characteristics of the landfills were sent to 10 municipalities; the four largest municipalities (Sofia, Plovdiv, Varna and Burgas), four medium size municipalities (Dobritch, Blagoevgrad, Vidin and Smoljan) and two small size municipalities (Bansko and Berkovica). A preliminary assessment of the landfill gas recovery potential was completed for four of them using the USEPA LandGem model as modified for Ukraine. Two of these landfills were selected for development of a business plan for implementation of a methane recovery project based on the condition of the landfill and municipal support for the project, i.e., the Tsalapitsa Landfill in Plovdiv (800 kW generation potential) and the Aksakovo/Varna landfill (500 kW generation potential).

The Tsalapitsa and Aksakovo/Varna landfills service the largest and most economically developed towns in Bulgaria thus containing the largest quantity of bio-degradable components. These landfills are also representative of the best waste storage facilities in Bulgaria. There are also preliminary plans for reclamation and construction of gas collection systems at each landfill. The business plans for methane recovery projects at these landfills were developed:

The following conclusions were conveyed:

- The projects are low risky. The offered technology and equipment have been implemented for long years all over the world.

- The financial parameters are very good – PB = 4.12 years, IRR = 21.64%, NPV = 1,137,810 Euros for Plovdiv and PB = 3.39 years; IRR = 26.25% and NPV = 1,095,998.for Aksakovo. They remain very good in the different scenarios presented in Risk Analysis as well.

- The projects are eligible for financing under the EBRD BEERECL facility in ESCO variants, whereby an incentive grant of 15% is awarded to the borrower.

- Additional cash-flow based on emissions trading can be generated, which is an opportunity to attract an investor, which will decrease the financial participation of the municipality and will improve the financial parameters.

- The projects provide additional benefits as clearer environment, opportunities for providing cheaper energy to public buildings and industrial enterprises.

- The structure and the staff of municipality possess sufficient capacity to organize and manage projects based on the utilization of landfill gas and the re-cultivation of the landfill as well as with the implementation of different financing schemes including ESCO.

- Both municipalities are ready to grant a concession to potential investors.

- Investors have demonstrated considerable interest.

Recommendations

Field tests at the Tsalapitsa and Aksakovo/Varna Landfills

The software modeling of the LFG resource and the methane recovery potential for this project is based on data provided by the Bulgarian municipalities or from estimates by engineers and physicists associated with Bulgarian landfills for many years. However, the accuracy of these data (waste volumes, morphological content, physical condition of the landfill, etc.) can vary considerably due to a lack of measured and/or recorded data. In addition, the software model used is the EPA LandGem model that was recently modified for Ukraine landfills. While every effort was made to match Ukraine input data with Bulgarian conditions, the effect of this estimation on the model results is unknown. A pump test and LFG resource recovery field test project at the Tsalapitsa and Aksakovo/Varna landfills should be conducted to (1) validate the use in Bulgaria of the Ukraine model (or identify

necessary changes to the model for Bulgaria) and (2) to validate generator sizing and project lifetime used in the financial analysis in the business plans.

Municipal awareness and technology transfer throughout the Balkans

Proposed EU Directives require a reduction of anthropogenic methane emissions in countries that wish to join the EU. There is a desire, specifically in Serbia, the Federation of Bosnia and Hergezovina and Republika Srpska, and the Former Yugoslav Republic of Macedonia, to accede to the EU in the near future. This first Methane-to-Markets grant in Bulgaria presents the unique opportunity to disseminate "lessons learned" to other Balkan countries. Results support a project to:

- expand the capabilities of municipal networks in ***Bulgaria, Serbia, Macedonia, and Bosnia and Herzegovina***, to educate officials and address energy issues, and more specifically, to become aware of the benefits of LFG recovery through a "Regional Municipal LFG Project Development Network for the Balkans";
- survey and complete resource assessment through modeling at selected municipal landfills in ***Serbia and Bosnia and Herzegovina*** ; and
- develop up to two business plans per country (project design, cost and financial analysis, risk analysis, and emissions calculations) in ***Serbia and Bosnia and Herzegovina*** for project implementation at the best landfills with municipalities and/or Energy Service Companies (ESCOs);

The project would go a long way towards overcoming many of the existing barriers to the wide spread commercial implementation of municipal LFG projects in the Balkans, with specific objectives to help municipalities:

- Identify financing sources and sustainable financing mechanisms for LFG projects;
- Strengthen the institutional development and member participation in existing municipal networks, and focus their attention on the opportunities associated with LFG projects;
- Increase the level of funding available through well-designed LFG projects;
- Create broad-based public support among policy-makers, business leaders and the media for municipal LFG projects; and
- Increase the capacity of municipalities to identify and implement LFG projects, through increased technical capability and access to private sector financial resources.

APPENDIX A: QUESTIONNARIE

QUESTIONNARIE

For determination viability of a landfill methane recovery

Landfill name…….

1. Year opened ……. yr.

2. Years of exploitation ……. yr.

3. Projected or actual closure year ……. yr.

4. Annual disposal:

   - Annually ……. (metric tons)
   - Total ……. (metric tons)

5. Population served by the landfill ……. people.

6. Morphological content (if available):

   □Yes □ No

   …….
   …….
   …….
   …….
   …….

7. Evaluation of landfill gas □ Yes □ No

   Flow rate ……. m^3/yr.

   Content, %

   CH_4 ….. %
   CO_2 ….. %
   O_2 ….. %
   H_2S ….. pPM
   Water content ….. %
   Other ….. %
   Year of evaluation …….
   Evaluation prepared by ……
   Remarks: ……..

8. Landfill volume ……. m^3, or …… metric tons.

9. Landfill area …….. da.

10. Average landfill depth ……. m.

11. Number of cells ……..

12. Leachate collection system:

□Yes □ No

If existing, is it with recirculation?

□Yes □ No

13. Project for landfill recultivation:

□Yes □ No

14. Gas collection wells: □Yes □ No

If any:

Number …….
Distance between the wells ……. m
Data about the wells:

Cell 1 - …….. wells
Cell 2 - …….. wells
Cell 3 - …….. wells

…….
…….
…….
…….
…….

15. Data about:

- Evidence of surface or subsurface fires: □Yes □ No, year ……
- Landfill been flooded: □Yes □ No, year ……

APPENDIX B: LANDFILL MODELING

The quantity of recoverable methane was determined using the recently developed EPA Ukraine Landfill Gas Model (EPA, September 2009). The Model is currently considered as the most suitable for Bulgarian landfills. The model estimates the LFG generation rate in a given year using the following first-order exponential equation that was modified from the U.S. EPA's Landfill Gas Emissions Model (LandGEM), version 3.02 (EPA, 2005).

$$Q_{LFG} = \sum_{t=1}^{n} \sum_{j=0.1}^{1} 2kL_0 \left[\frac{M_i}{10} \right] \left(e^{-kt_{ij}} \right) (MCF)(F)$$

Where:
- Q_{LFG} = maximum expected LFG generation flow rate (m^3/yr),
- i = 1 year time increment,
- n = (year of calculation) – (initial year of waste acceptance),
- j = 0.1 year time increment,
- k = methane generation rate (1/yr),
- L_0 = potential methane generation capacity (m^3/Mg),
- M_i = mass of solid waste disposed in the i^{th} year (Mg),
- t_{ij} = age of the j^{th} section of waste mass M_i disposed in the i^{th} year (decimal years),
- MCF = methane correction factor,
- F = fire adjustment factor.

The above equation is used to estimate LFG generation for a given year from cumulative waste disposed up through that year. Multi-year projections are developed by varying the projection year, and then re-applying the equation. Total LFG generation is equal to two times the calculated methane generation[3]. The exponential decay function assumes that LFG generation is at its peak following a time lag representing the period prior to methane generation. The model assumes a six month time lag between placement of waste and LFG generation. For each unit of waste, after six months the model assumes that LFG generation decreases exponentially as the organic fraction of waste is consumed. The year of maximum LFG generation normally occurs in the closure year or the year following closure (depending on the disposal rate in the final years).

The model estimates LFG generation and recovery in cubic meters per hour (m^3/hr) and cubic feet per minute (cfm). It also estimates the energy content of generated and recovered LFG in megajoules per hour (MJ/hr), the system collection efficiency, the maximum power plant capacity that could be fueled by the collected LFG (MW), and the emission reductions in tonnes of CO_2 equivalent (CERs) achieved by the collection and combustion of the LFG.

The model can either calculate annual waste disposal rates and collection efficiency automatically using the information provided by the user in the "Inputs" worksheet, or the user can manually input annual waste disposal rates and collection efficiency estimates in the "Disposal & LFG Recovery" worksheet. The model automatically assigns values for k and L_0 based on climate and waste composition data. The k values vary depending on climate and waste group. The L_0 values vary depending on waste group. Climate is categorized into one of

[3] The composition of landfill gas is assumed by the model to consist of 50 percent methane (CH_4) and 50 percent other gases, including carbon dioxide (CO_2) and trace amounts of other compounds.

four climate regions within Ukraine based primarily on average annual precipitation[4]. Waste categories are assigned to one of five groups, including four organic waste groups based on waste decay rates, and one inorganic waste group. If site-specific waste composition data are available, the user can enter the waste composition data in the "Waste Composition" worksheet. Otherwise, the model will assign the default waste composition percentages for Ukraine, which are based on waste composition data gathered from cities throughout Ukraine. The annual waste disposal rates, k and L_0 values, methane correction and fire adjustment factors, and collection efficiency estimates are used to produce LFG generation and recovery estimates for landfills located in each province in Ukraine. Model results are displayed in the "Output-Table" and "Output-Graph" worksheets.

Sofia landfill modeling

A preliminary assessment of the potential for a landfill gas (LFG) recovery and utilization project has been prepared for the Sofia landfill, located in Suhodol, Bulgaria. The assessment was based on information provided by the landfill operator, and from observations made during the site visits in 5 May, 2010. The landfill began operation in 1985 and is projected to close in 2011 with a total final waste deposition of more than 4.0 millions tons.

The information and predictions contained within this report are based on the data provided by the landfill operator. EnEffect and EnCon Services cannot take responsibility for the accuracy of this data. Note that landfill conditions will vary with changes in waste input, management practices, engineering practices, and environmental conditions (particularly rainfall and temperature). Therefore, the quantity and quality of the landfill gas extracted from the landfill may vary from the values reported in this report.

The input data to the LFG recovery model was determined based on disposal rates, representative waste composition and climate data. EnEffect and EnCon Services gathered the following information for input to the model:

- Landfill management practices including site security, waste quantification method, landfill cover systems, waste disposal practices, and cover methods, among others;
- Historic waste disposal quantities, from 1985 to March 2010, average waste depth, disposal rate, disposal area (present and future).

A description of the landfill is presented in Chapter 2 of this Report. Table B.1 presents the average monthly precipitation in the area of Suhodol landfill[5]. This data was used to select the appropriate "Ukraine region" to use as input to the model.

[4] The appropriate zone for Bulgaria is selected based on comparable precipitation at the Bulgarian landfill being modeled.

[5] Precipitation data in this report is taken from the NASA Atmospheric Science Data Center if measured precipittion data is not available for the specific landfill site or for the nearby region.

Table B.1
Average Precipitation in Suhodol Landfill Region

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Annual**
						mm/day						
1.65	1.82	1.66	1.97	2.1	1.95	1.64	1.27	1.38	1.28	1.93	2.11	**1.72**
						mm/month						**mm/yr**
51.15	50.96	51.46	59.1	65.1	58.5	50.84	39.37	41.4	39.68	57.9	65.41	**630.87**

Table B.2
Model input table

PROJECTION OF LANDFILL GAS GENERATION AND RECOVERY INPUT WORKSHEET			
1	Landfill name:	Suhodol landfill	
2	City:	Sofia	
3	Province:	Poltava Oblast	4
4	Site-specific waste composition data?	Yes	
5	Year opened:	1985	
6	Annual disposal for latest year with data in tonnes per year (Mg/yr)	400,000	Mg
7	Year of annual disposal estimate	2009	
8	Waste in place estimate available in tonnes (Mg)?	Yes	
9	Waste in place estimate for end of 2008 or most recent year:	3,975,000	Mg
10	Estimated in-place waste density in Mg per m^3 (typical range: 0.5-1.0):	0.95	Mg/m^3
11	If waste in place estimate is in volume (m3), convert to Mg:	3,975,000	Mg
12	Year of waste in place estimate:	2009	
13	Projected or actual closure year:	2012	
14	Estimated growth in annual disposal:	0.0%	
15	Average landfill depth:	20	m
16	Site design and management practices:	2	
17a	Has site been impacted by fires?	No	
17b	If 13a answer is Yes, indicate % of landfill area impacted:	0%	
17c	If 13a answer is Yes, indicate the severity of fire impacts:	1	
18	Year of initial collection system start-up:	2010	
19	Percent of waste area with wells:	85%	
20	Percent of waste area with final cover:	100%	
21	Percent of waste area with intermediate cover:	0%	
22	Percent of waste area with daily cover:	0%	
23	Percent of waste area with no soil cover:	0%	
24	Percent of waste area with clay or synthetic liner:	100%	
25	Is waste compacted on a regular basis?	Yes	
26	Is waste delivered to a focused tipping area?	No	
27a	Does the landfill experience leachate surface seeps or surface ponding?	Yes	
27b	If 23a answer is yes, does this occur only after rainstorms?	Yes	
28	Collection efficiency estimate:	62%	

Table B.3
Model output table

PROJECTION OF LANDFILL GAS GENERATION AND RECOVERY
Suhodol landfill
Sofia, Bulgaria

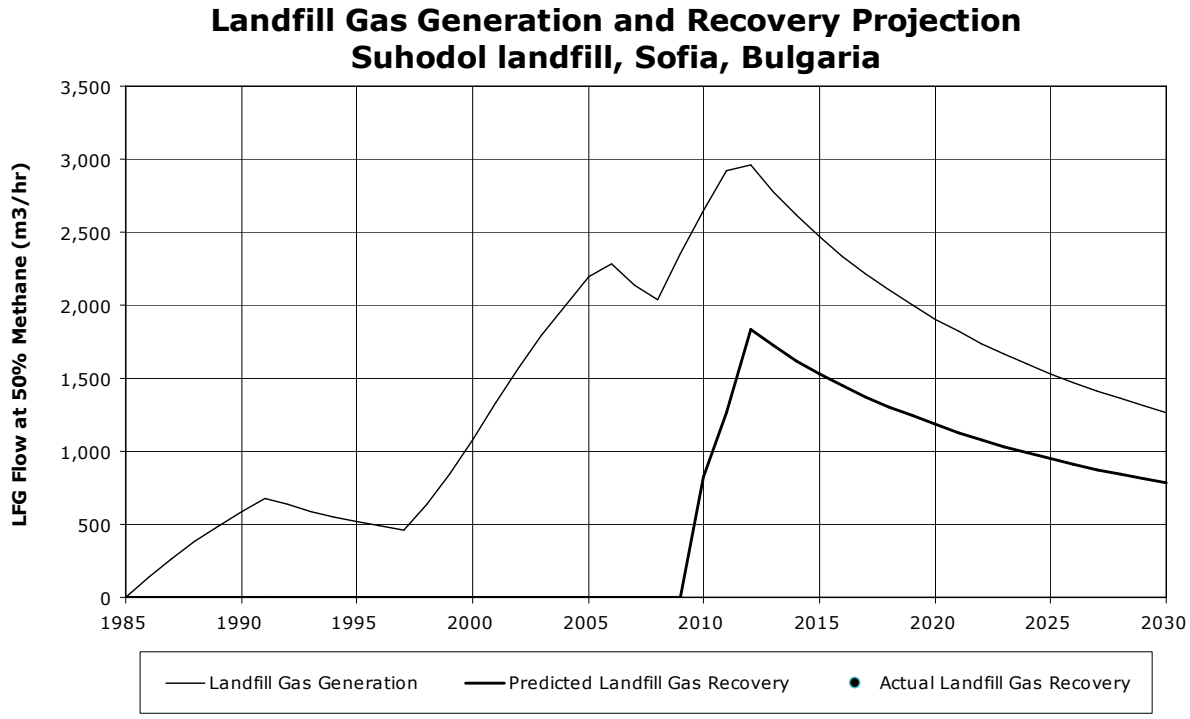
Year	Disposal (Mg/yr)	Refuse In-Place (Mg)	LFG Generation			Collection System Efficiency (%)	Predicted LFG Recovery			Maximum Power Plant Capacity* (MW)	Baseline LFG Flow (m3/hr)	Methane Emissions Reduction Estimates**	
			(m^3/hr)	(cfm)	(MJ/hr)		(m^3/hr)	(cfm)	(MJ/hr)			(tonnes CH_4/yr)	(tonnes CO_2eq/yr)
1985	125,000	125,000	0	0	0	0%	0	0	0	0.0	0	0	0
1986	125,000	250,000	136	80	2,564	0%	0	0	0	0.0	0	0	0
1987	125,000	375,000	261	154	4,931	0%	0	0	0	0.0	0	0	0
1988	125,000	500,000	378	222	7,125	0%	0	0	0	0.0	0	0	0
1989	125,000	625,000	486	286	9,163	0%	0	0	0	0.0	0	0	0
1990	125,000	750,000	586	345	11,062	0%	0	0	0	0.0	0	0	0
1991	0	750,000	680	400	12,837	0%	0	0	0	0.0	0	0	0
1992	0	750,000	633	372	11,937	0%	0	0	0	0.0	0	0	0
1993	0	750,000	590	347	11,131	0%	0	0	0	0.0	0	0	0
1994	0	750,000	552	325	10,408	0%	0	0	0	0.0	0	0	0
1995	0	750,000	517	304	9,758	0%	0	0	0	0.0	0	0	0
1996	0	750,000	486	286	9,172	0%	0	0	0	0.0	0	0	0
1997	185,000	935,000	458	270	8,641	0%	0	0	0	0.0	0	0	0
1998	225,000	1,160,000	633	373	11,954	0%	0	0	0	0.0	0	0	0
1999	265,000	1,425,000	839	494	15,841	0%	0	0	0	0.0	0	0	0
2000	300,000	1,725,000	1,074	632	20,265	0%	0	0	0	0.0	0	0	0
2001	300,000	2,025,000	1,330	783	25,093	0%	0	0	0	0.0	0	0	0
2002	300,000	2,325,000	1,568	923	29,585	0%	0	0	0	0.0	0	0	0
2003	300,000	2,625,000	1,790	1,054	33,776	0%	0	0	0	0.0	0	0	0
2004	300,000	2,925,000	1,998	1,176	37,697	0%	0	0	0	0.0	0	0	0
2005	215,000	3,140,000	2,193	1,291	41,376	0%	0	0	0	0.0	0	0	0
2006	0	3,140,000	2,284	1,344	43,092	0%	0	0	0	0.0	0	0	0
2007	35,000	3,175,000	2,137	1,258	40,334	0%	0	0	0	0.0	0	0	0
2008	400,000	3,575,000	2,044	1,203	38,569	0%	0	0	0	0.0	0	0	0
2009	400,000	3,975,000	2,357	1,387	44,476	0%	0	0	0	0.0	0	0	0
2010	400,000	4,375,000	2,648	1,559	49,974	31%	821	483	15,492	1.358	0	2,575	54,068
2011	200,000	4,575,000	2,920	1,719	55,106	43%	1,267	746	23,916	2.097	0	3,975	83,469
2012	0	4,575,000	2,958	1,741	55,809	62%	1,834	1,079	34,601	3.034	0	5,751	120,761
2013	0	4,575,000	2,778	1,635	52,427	62%	1,723	1,014	32,505	2.850	0	5,402	113,444
2014	0	4,575,000	2,616	1,540	49,371	62%	1,622	955	30,610	2.684	0	5,087	106,831
2015	0	4,575,000	2,470	1,454	46,601	62%	1,531	901	28,892	2.533	0	4,802	100,836
2016	0	4,575,000	2,336	1,375	44,082	62%	1,448	852	27,331	2.396	0	4,542	95,386
2017	0	4,575,000	2,214	1,303	41,784	62%	1,373	808	25,906	2.272	0	4,305	90,415
2018	0	4,575,000	2,103	1,238	39,683	62%	1,304	767	24,604	2.157	0	4,089	85,868
2019	0	4,575,000	2,001	1,178	37,755	62%	1,240	730	23,408	2.052	0	3,890	81,696
2020	0	4,575,000	1,907	1,122	35,981	62%	1,182	696	22,308	1.956	0	3,707	77,856
2021	0	4,575,000	1,820	1,071	34,343	62%	1,128	664	21,292	1.867	0	3,539	74,312
2022	0	4,575,000	1,740	1,024	32,826	62%	1,079	635	20,352	1.785	0	3,382	71,031
2023	0	4,575,000	1,665	980	31,419	62%	1,032	608	19,480	1.708	0	3,237	67,985
2024	0	4,575,000	1,596	939	30,108	62%	989	582	18,667	1.637	0	3,102	65,149
2025	0	4,575,000	1,531	901	28,885	62%	949	559	17,909	1.570	0	2,976	62,503
2026	0	4,575,000	1,470	865	27,741	62%	911	536	17,199	1.508	0	2,858	60,026
2027	0	4,575,000	1,413	832	26,667	62%	876	516	16,533	1.450	0	2,748	57,703
2028	0	4,575,000	1,360	800	25,657	62%	843	496	15,907	1.395	0	2,644	55,518
2029	0	4,575,000	1,309	771	24,706	62%	812	478	15,318	1.343	0	2,546	53,459
2030	0	4,575,000	1,262	743	23,807	62%	782	460	14,761	1.294	0	2,453	51,515

MODEL INPUT PARAMETERS
Assumed Methane Content of LFG: 50%
Methane Correction Factor (MCF): 1.0

Waste Category:	Fast Decay	Moderately Fast Decay	Moderately Slow Decay	Slow Decay
CH4 Generation Rate Constant (k):	0.150	0.075	0.030	0.015
CH4 Generation Potential (Lo) (m3/Mg):	69	126	214	201

NOTES
* Maximum power plant capacity assumes a net heat rate of 11.4 MJ per kW-hr (hhv).
**Emission reductions do not account for electricity generation or project emissions and are calculated using a methane density (at standard temperature and pressure) of 0.0007168 Mg/m3.

Figure B.1
Model output graph



Plovdiv landfill modeling

A preliminary assessment of the potential for a landfill gas (LFG) recovery and utilization project has been prepared for the Plovdiv landfill, located in Tsalapitsa, Bulgaria. The assessment was based on information provided by the landfill operator, and from observations made during the site visits. The landfill began operation in 1999 and is projected to close in 2013 with a total final waste deposition of more than 2.0 millions tons.

The information and predictions contained within this report are based on the data provided by the landfill operator. EnEffect and EnCon Services cannot take responsibility for the accuracy of this data. Note that landfill conditions will vary with changes in waste input, management practices, engineering practices, and environmental conditions (particularly rainfall and temperature). Therefore, the quantity and quality of the landfill gas extracted from the landfill may vary from the values reported in this report.

The input data to the LFG recovery model was determined based on disposal rates, representative waste composition and climate data. EnEffect and EnCon Services gathered the following information for input to the model:

- Landfill management practices including site security, waste quantification method, landfill cover systems, waste disposal practices, and cover methods, among others;
- Historic waste disposal quantities, from 1999 to March 2010, average waste depth, disposal rate, disposal area (present and future).

A description of the landfill is presented in Chapter 2 of this Report. Table B.4 presents the average monthly precipitation in the area of Tsalapitsa landfill. This data was used to select the appropriate "Ukraine region" to use as input to the model.

Table B.4
Average Precipitation in Tsalapitsa (Plovdiv) Landfill Region

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Annual**
						mm/day						
1.67	1.8	1.68	1.86	2	1.92	1.58	1.22	1.33	1.26	1.93	2.15	**1.69**
						mm/month						**mm/yr**
51.77	50.4	52.08	55.8	62	57.6	48.98	37.82	39.9	39.06	57.9	66.65	**619.96**

Table B.5
Model input table

PROJECTION OF LANDFILL GAS GENERATION AND RECOVERY INPUT WORKSHEET			
1	Landfill name:	Tsalapitsa landfill	
2	City:	Plovdiv	
3	Province:	Poltava Oblast	4
4	Site-specific waste composition data?	Yes	
5	Year opened:	1999	
6	Annual disposal for latest year with data in tonnes per year (Mg/yr)	170,000	Mg
7	Year of annual disposal estimate	2009	
8	Waste in place estimate available in tonnes (Mg)?	Yes	
9	Waste in place estimate for end of 2008 or most recent year:	1,662,000	Mg
10	Estimated in-place waste density in Mg per m^3 (typical range: 0.5-1.0):	0.70	Mg/m^3
11	If waste in place estimate is in volume (m3), convert to Mg:	1,662,000	Mg
12	Year of waste in place estimate:	2009	
13	Projected or actual closure year:	2013	
14	Estimated growth in annual disposal:	0.0%	
15	Average landfill depth:	15	m
16	Site design and management practices:	2	
17a	Has site been impacted by fires?	No	
17b	If 13a answer is Yes, indicate % of landfill area impacted:	0%	
17c	If 13a answer is Yes, indicate the severity of fire impacts:	1	
18	Year of initial collection system start-up:	2015	
19	Percent of waste area with wells:	80%	
20	Percent of waste area with final cover:	100%	
21	Percent of waste area with intermediate cover:	0%	
22	Percent of waste area with daily cover:	0%	
23	Percent of waste area with no soil cover:	0%	
24	Percent of waste area with clay or synthetic liner:	100%	
25	Is waste compacted on a regular basis?	Yes	
26	Is waste delivered to a focused tipping area?	No	
27a	Does the landfill experience leachate surface seeps or surface ponding?	Yes	
27b	If 23a answer is yes, does this occur only after rainstorms?	Yes	
28	Collection efficiency estimate:	58%	

Table B.6
Model output table

PROJECTION OF LANDFILL GAS GENERATION AND RECOVERY
Tsalapitsa landfill
Plovdiv, Bulgaria

Year	Disposal (Mg/yr)	Refuse In-Place (Mg)	LFG Generation			Collection System Efficiency (%)	Predicted LFG Recovery			Maximum Power Plant Capacity* (MW)	Baseline LFG Flow (m3/hr)	Methane Emissions Reduction Estimates**	
			(m^3/hr)	(cfm)	(MJ/hr)		(m^3/hr)	(cfm)	(MJ/hr)			(tonnes CH_4/yr)	(tonnes CO_2eq/yr)
1999	12,000	12,000	0	0	0	0%	0	0	0	0.0	0	0	0
2000	130,000	142,000	13	8	247	0%	0	0	0	0.0	0	0	0
2001	130,000	272,000	153	90	2,896	0%	0	0	0	0.0	0	0	0
2002	130,000	402,000	281	165	5,296	0%	0	0	0	0.0	0	0	0
2003	130,000	532,000	396	233	7,477	0%	0	0	0	0.0	0	0	0
2004	130,000	662,000	502	295	9,466	0%	0	0	0	0.0	0	0	0
2005	130,000	792,000	598	352	11,284	0%	0	0	0	0.0	0	0	0
2006	450,000	1,242,000	686	404	12,953	0%	0	0	0	0.0	0	0	0
2007	140,000	1,382,000	1,116	657	21,067	0%	0	0	0	0.0	0	0	0
2008	140,000	1,522,000	1,170	688	22,071	0%	0	0	0	0.0	0	0	0
2009	140,000	1,662,000	1,220	718	23,026	0%	0	0	0	0.0	0	0	0
2010	140,000	1,802,000	1,268	747	23,936	0%	0	0	0	0.0	0	0	0
2011	140,000	1,942,000	1,314	774	24,804	0%	0	0	0	0.0	0	0	0
2012	140,000	2,082,000	1,358	800	25,634	0%	0	0	0	0.0	0	0	0
2013	140,000	2,222,000	1,400	824	26,427	0%	0	0	0	0.0	0	0	0
2014	0	2,222,000	1,441	848	27,187	0%	0	0	0	0.0	0	0	0
2015	0	2,222,000	1,327	781	25,037	58%	770	453	14,522	1.273	0	2,413	50,681
2016	0	2,222,000	1,226	721	23,129	58%	711	418	13,415	1.176	0	2,229	46,819
2017	0	2,222,000	1,136	668	21,432	58%	659	388	12,430	1.090	0	2,066	43,383
2018	0	2,222,000	1,056	621	19,918	58%	612	360	11,552	1.013	0	1,920	40,319
2019	0	2,222,000	984	579	18,564	58%	571	336	10,767	0.944	0	1,789	37,578
2020	0	2,222,000	919	541	17,350	58%	533	314	10,063	0.882	0	1,672	35,121
2021	0	2,222,000	862	507	16,259	58%	500	294	9,430	0.827	0	1,567	32,912
2022	0	2,222,000	809	476	15,275	58%	469	276	8,859	0.777	0	1,472	30,920
2023	0	2,222,000	762	449	14,385	58%	442	260	8,343	0.732	0	1,387	29,118
2024	0	2,222,000	720	424	13,577	58%	417	246	7,875	0.690	0	1,309	27,484
2025	0	2,222,000	681	401	12,843	58%	395	232	7,449	0.653	0	1,238	25,997
2026	0	2,222,000	645	380	12,173	58%	374	220	7,060	0.619	0	1,173	24,640
2027	0	2,222,000	613	361	11,559	58%	355	209	6,704	0.588	0	1,114	23,398
2028	0	2,222,000	583	343	10,996	58%	338	199	6,378	0.559	0	1,060	22,258
2029	0	2,222,000	555	327	10,477	58%	322	190	6,077	0.533	0	1,010	21,208
2030	0	2,222,000	530	312	9,998	58%	307	181	5,799	0.508	0	964	20,238

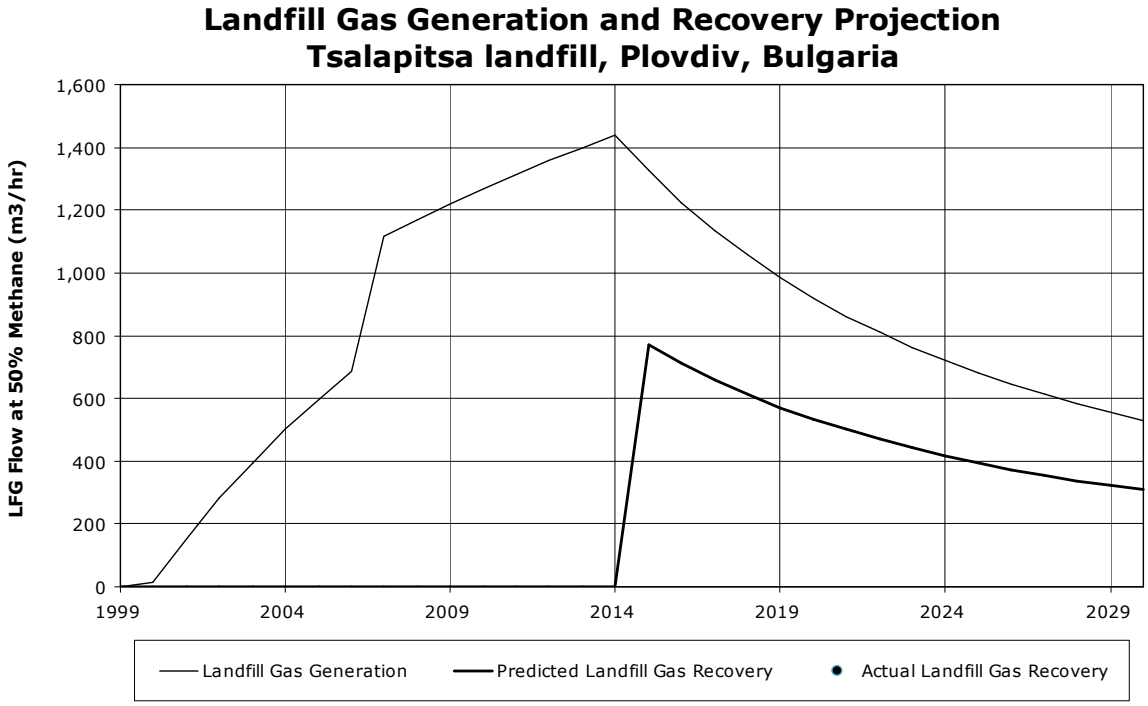
MODEL INPUT PARAMETERS

Assumed Methane Content of LFG:	50%
Methane Correction Factor (MCF):	1.0

Waste Category:	Fast Decay	Moderately Fast Decay	Moderately Slow Decay	Slow Decay
CH4 Generation Rate Constant (k):	0.150	0.075	0.030	0.015
CH4 Generation Potential (Lo) (m3/Mg):	69	126	214	201

NOTES
* Maximum power plant capacity assumes a net heat rate of 11.4 MJ per kW-hr (hhv).
**Emission reductions do not account for electricity generation or project emissions and are calculated using a methane density (at standard temperature and pressure) of 0.0007168 Mg/m3.

Figure B.2
Model output graph



Aksakovo/Varna landfill modeling

A preliminary assessment of the potential for a landfill gas (LFG) recovery and utilization project has been prepared for the Aksakovo landfill, located in Vaglen, Bulgaria. The assessment was based on information provided by the landfill operator, and from observations made during the site visits. The landfill began operation in 2002 and is projected to close in 2011 with a total final waste deposition of more than 1.0 million tons.

The information and predictions contained within this report are based on the data provided by the landfill operator. EnEffect and EnCon Services cannot take responsibility for the accuracy of this data. Note that landfill conditions will vary with changes in waste input, management practices, engineering practices, and environmental conditions (particularly rainfall and temperature). Therefore, the quantity and quality of the landfill gas extracted from the landfill may vary from the values reported in this report.

The input data to the LFG recovery model was determined based on disposal rates, representative waste composition and climate data. EnEffect and EnCon Services gathered the following information for input to the model:

- Landfill management practices including site security, waste quantification method, landfill cover systems, waste disposal practices, and cover methods, among others;
- Historic waste disposal quantities, from 2002 to March 2010, average waste depth, disposal rate, disposal area (present and future).

A description of the landfill is presented in Chapter 2 of this Report. Table B.7 presents the average monthly precipitation in the area of Aksakovo landfill. This data was used to select the appropriate "Ukraine region" to use as input to the model.

Table B.7
Average Precipitation in Aksakovo Landfill Region

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Annual**
						mm/day						
1.62	1.53	1.61	1.6	1.63	2.04	1.6	1.29	1.62	1.4	1.88	1.91	**1.64**
						mm/month						**mm/yr**
50.22	42.84	49.91	48	50.53	61.2	49.6	39.99	48.6	43.4	56.4	59.21	**599.90**

Table B.8
Model input table

PROJECTION OF LANDFILL GAS GENERATION AND RECOVERY INPUT WORKSHEET			
1	Landfill name:	Vaglen	
2	City:	Varna	
3	Province:	Kiev	3
4	Site-specific waste composition data?	Yes	
5	Year opened:	2002	
6	Annual disposal for latest year with data in tonnes per year (Mg/yr)	138,000	Mg
7	Year of annual disposal estimate	2009	
8	Waste in place estimate available in tonnes (Mg)?	Yes	
9	Waste in place estimate for end of 2008 or most recent year:	1,068,000	Mg
10	Estimated in-place waste density in Mg per m^3 (typical range: 0.5-1.0):	0.80	Mg/m^3
11	If waste in place estimate is in volume (m3), convert to Mg:	1,068,000	Mg
12	Year of waste in place estimate:	2009	
13	Projected or actual closure year:	2010	
14	Estimated growth in annual disposal:	0.0%	
15	Average landfill depth:	20	m
16	Site design and management practices:	2	
17a	Has site been impacted by fires?	No	
17b	If 13a answer is Yes, indicate % of landfill area impacted:	0%	
17c	If 13a answer is Yes, indicate the severity of fire impacts:	1	
18	Year of initial collection system start-up:	2013	
19	Percent of waste area with wells:	80%	
20	Percent of waste area with final cover:	100%	
21	Percent of waste area with intermediate cover:	0%	
22	Percent of waste area with daily cover:	0%	
23	Percent of waste area with no soil cover:	0%	
24	Percent of waste area with clay or synthetic liner:	100%	
25	Is waste compacted on a regular basis?	Yes	
26	Is waste delivered to a focused tipping area?	No	
27a	Does the landfill experience leachate surface seeps or surface ponding?	Yes	
27b	If 23a answer is yes, does this occur only after rainstorms?	Yes	
28	Collection efficiency estimate:	60%	

Table B.9
Model output table

PROJECTION OF LANDFILL GAS GENERATION AND RECOVERY
Vaglen
Varna, Bulgaria

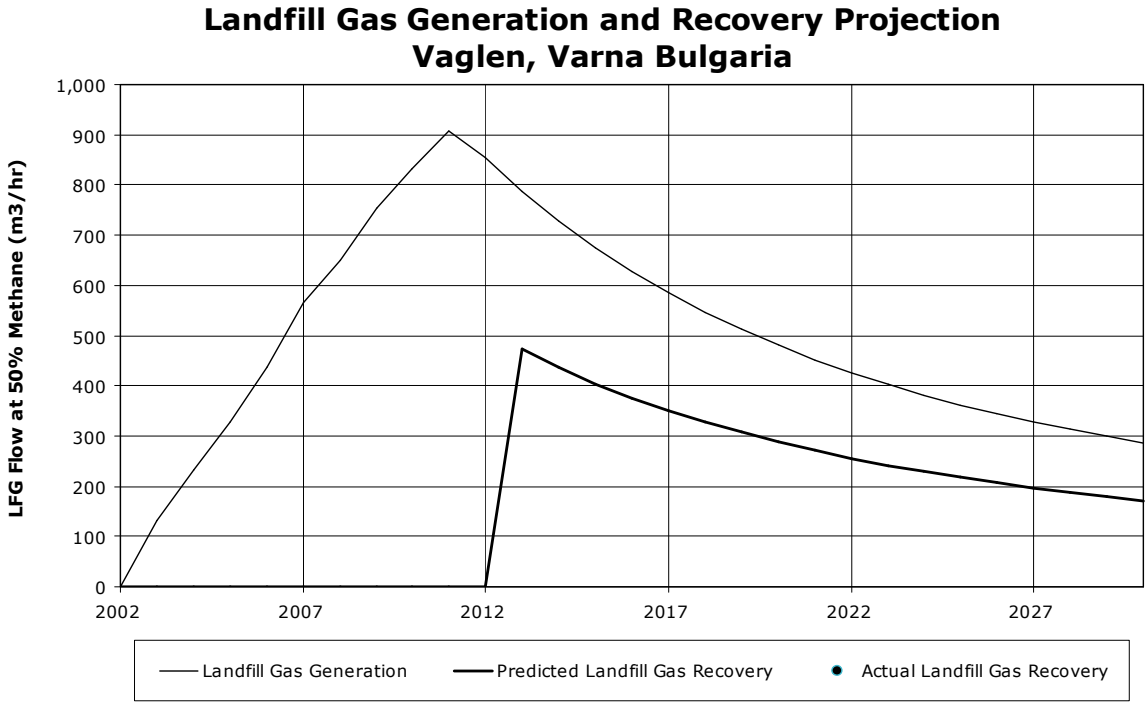
Year	Disposal (Mg/yr)	Refuse In-Place (Mg)	LFG Generation			Collection System Efficiency (%)	Predicted LFG Recovery			Maximum Power Plant Capacity* (MW)	Baseline LFG Flow (m3/hr)	Methane Emi Reduction Estir	
			(m^3/hr)	(cfm)	(MJ/hr)		(m^3/hr)	(cfm)	(MJ/hr)			(tonnes CH_4/yr)	C
2002	128,000	128,000	0	0	0	0%	0	0	0	0.0	0	0	
2003	110,000	238,000	131	77	2,471	0%	0	0	0	0.0	0	0	
2004	113,000	351,000	232	137	4,376	0%	0	0	0	0.0	0	0	
2005	135,000	486,000	327	193	6,176	0%	0	0	0	0.0	0	0	
2006	161,000	647,000	437	257	8,251	0%	0	0	0	0.0	0	0	
2007	131,000	778,000	565	332	10,657	0%	0	0	0	0.0	0	0	
2008	152,000	930,000	651	383	12,288	0%	0	0	0	0.0	0	0	
2009	138,000	1,068,000	753	443	14,201	0%	0	0	0	0.0	0	0	
2010	140,760	1,208,760	832	490	15,697	0%	0	0	0	0.0	0	0	
2011	17,229	1,225,989	908	535	17,141	0%	0	0	0	0.0	0	0	
2012	0	1,225,989	853	502	16,098	0%	0	0	0	0.000	0	0	
2013	0	1,225,989	787	463	14,845	60%	472	278	8,907	0.781	0	1,480	
2014	0	1,225,989	727	428	13,726	60%	436	257	8,236	0.722	0	1,369	
2015	0	1,225,989	674	397	12,727	60%	405	238	7,636	0.670	0	1,269	
2016	0	1,225,989	627	369	11,832	60%	376	221	7,099	0.622	0	1,180	
2017	0	1,225,989	584	344	11,029	60%	351	206	6,617	0.580	0	1,100	
2018	0	1,225,989	546	321	10,307	60%	328	193	6,184	0.542	0	1,028	
2019	0	1,225,989	512	301	9,656	60%	307	181	5,793	0.508	0	963	
2020	0	1,225,989	481	283	9,067	60%	288	170	5,440	0.477	0	904	
2021	0	1,225,989	452	266	8,535	60%	271	160	5,121	0.449	0	851	
2022	0	1,225,989	427	251	8,051	60%	256	151	4,830	0.424	0	803	
2023	0	1,225,989	403	237	7,610	60%	242	142	4,566	0.400	0	759	
2024	0	1,225,989	382	225	7,208	60%	229	135	4,325	0.379	0	719	
2025	0	1,225,989	362	213	6,840	60%	217	128	4,104	0.360	0	682	
2026	0	1,225,989	345	203	6,503	60%	207	122	3,902	0.342	0	648	
2027	0	1,225,989	328	193	6,192	60%	197	116	3,715	0.326	0	617	
2028	0	1,225,989	313	184	5,906	60%	188	111	3,543	0.311	0	589	
2029	0	1,225,989	299	176	5,641	60%	179	106	3,385	0.297	0	562	
2030	0	1,225,989	286	168	5,395	60%	172	101	3,237	0.284	0	538	

MODEL INPUT PARAMETERS
Assumed Methane Content of LFG: 50%
Methane Correction Factor (MCF): 1.0

Waste Category:	Fast Decay	Moderately Fast Decay	Moderately Slow Decay	Slow Decay
CH4 Generation Rate Constant (k):	0.140	0.070	0.028	0.014
CH4 Generation Potential (Lo) (m3/Mg):	69	126	214	201

NOTES
* Maximum power plant capacity assumes a net heat rate of 11.4 MJ per kW-hr (hhv)
**Emission reductions do not account for electricity generation or project emissions ar
calculated using a methane density (at standard temperature and pressure) of 0.0007
Mg/m3.

Figure B.3
Model output graph



Burgas landfill modeling

A preliminary assessment of the potential for a landfill gas (LFG) recovery and utilization project has been prepared for the Burgas landfill, located in Bratovo, Bulgaria. The assessment was based on information provided by the landfill operator, and from observations made during the site visits. The landfill began operation in 1982 and is projected to close in 2012 with a total final waste deposition of more than 2.0 million tons.

The information and predictions contained within this report are based on the data provided by the landfill operator. EnEffect and EnCon Services cannot take responsibility for the accuracy of this data. Note that landfill conditions will vary with changes in waste input, management practices, engineering practices, and environmental conditions (particularly rainfall and temperature). Therefore, the quantity and quality of the landfill gas extracted from the landfill may vary from the values reported in this report.

The input data to the LFG recovery model was determined based on disposal rates, representative waste composition and climate data. EnEffect and EnCon Services gathered the following information for input to the model:

- Landfill management practices including site security, waste quantification method, landfill cover systems, waste disposal practices, and cover methods, among others;
- Historic waste disposal quantities, from 1982 to March 2010, average waste depth, disposal rate, disposal area (present and future).

A description of the landfill is presented in Chapter 2 of this Report. Table B.10 presents the average monthly precipitation in the area of Burgas landfill. This data was used to select the appropriate "Ukraine region" to use as input to the model.

Table B.10
Average Precipitation in Burgas Landfill Region

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Annual**
						mm/day						
1.96	1.9	1.84	1.69	1.57	1.72	1.31	1.09	1.44	1.64	2.31	2.45	**1.74**
						mm/month						**mm/yr**
60.76	53.2	57.04	50.7	48.67	51.6	40.61	33.79	43.2	50.84	69.3	75.95	**635.66**

Table B.11
Model input table

PROJECTION OF LANDFILL GAS GENERATION AND RECOVERY INPUT WORKSHEET			
1	Landfill name:	Bratovo landfill	
2	City:	Burgas	
3	Province:	Poltava Oblast	4
4	Site-specific waste composition data?	Yes	
5	Year opened:	1982	
6	Annual disposal for latest year with data in tonnes per year (Mg/yr)	88,000	Mg
7	Year of annual disposal estimate	2009	
8	Waste in place estimate available in tonnes (Mg)?	Yes	
9	Waste in place estimate for end of 2008 or most recent year:	1,864,000	Mg
10	Estimated in-place waste density in Mg per m^3 (typical range: 0.5-1.0):	0.60	Mg/m^3
11	If waste in place estimate is in volume (m3), convert to Mg:	1,864,000	Mg
12	Year of waste in place estimate:	2009	
13	Projected or actual closure year:	2012	
14	Estimated growth in annual disposal:	0.0%	
15	Average landfill depth:	20	m
16	Site design and management practices:	2	
17a	Has site been impacted by fires?	No	
17b	If 13a answer is Yes, indicate % of landfill area impacted:	0%	
17c	If 13a answer is Yes, indicate the severity of fire impacts:	1	
18	Year of initial collection system start-up:	2014	
19	Percent of waste area with wells:	80%	
20	Percent of waste area with final cover:	100%	
21	Percent of waste area with intermediate cover:	0%	
22	Percent of waste area with daily cover:	0%	
23	Percent of waste area with no soil cover:	0%	
24	Percent of waste area with clay or synthetic liner:	100%	
25	Is waste compacted on a regular basis?	Yes	
26	Is waste delivered to a focused tipping area?	No	
27a	Does the landfill experience leachate surface seeps or surface ponding?	Yes	
27b	If 23a answer is yes, does this occur only after rainstorms?	Yes	
28	Collection efficiency estimate:	58%	

Table B.12
Model output table

PROJECTION OF LANDFILL GAS GENERATION AND RECOVERY
Bratovo landfill
Burgas, Bulgaria

Year	Disposal (Mg/yr)	Refuse In-Place (Mg)	LFG Generation			Collection System Efficiency (%)	Predicted LFG Recovery			Maximum Power Plant Capacity* (MW)	Baseline LFG Flow (m3/hr)	Methane Emissions Reduction Estimates**	
			(m^3/hr)	(cfm)	(MJ/hr)		(m^3/hr)	(cfm)	(MJ/hr)			(tonnes CH_4/yr)	(tonnes CO_2eq/yr)
1982	63,000	63,000	0	0	0	0%	0	0	0	0.0	0	0	0
1983	63,000	126,000	45	27	854	0%	0	0	0	0.0	0	0	0
1984	63,000	189,000	87	51	1,640	0%	0	0	0	0.0	0	0	0
1985	63,000	252,000	125	74	2,363	0%	0	0	0	0.0	0	0	0
1986	63,000	315,000	161	95	3,032	0%	0	0	0	0.0	0	0	0
1987	63,000	378,000	194	114	3,652	0%	0	0	0	0.0	0	0	0
1988	63,000	441,000	224	132	4,227	0%	0	0	0	0.0	0	0	0
1989	63,000	504,000	252	149	4,763	0%	0	0	0	0.0	0	0	0
1990	63,000	567,000	279	164	5,263	0%	0	0	0	0.0	0	0	0
1991	63,000	630,000	304	179	5,730	0%	0	0	0	0.0	0	0	0
1992	63,000	693,000	327	192	6,168	0%	0	0	0	0.0	0	0	0
1993	63,000	756,000	349	205	6,579	0%	0	0	0	0.0	0	0	0
1994	63,000	819,000	369	217	6,966	0%	0	0	0	0.0	0	0	0
1995	63,000	882,000	388	229	7,331	0%	0	0	0	0.0	0	0	0
1996	63,000	945,000	407	239	7,675	0%	0	0	0	0.0	0	0	0
1997	63,000	1,008,000	424	250	8,001	0%	0	0	0	0.0	0	0	0
1998	63,000	1,071,000	440	259	8,309	0%	0	0	0	0.0	0	0	0
1999	63,000	1,134,000	456	268	8,602	0%	0	0	0	0.0	0	0	0
2000	63,000	1,197,000	471	277	8,880	0%	0	0	0	0.0	0	0	0
2001	63,000	1,260,000	485	285	9,145	0%	0	0	0	0.0	0	0	0
2002	63,000	1,323,000	498	293	9,397	0%	0	0	0	0.0	0	0	0
2003	63,000	1,386,000	511	301	9,637	0%	0	0	0	0.0	0	0	0
2004	63,000	1,449,000	523	308	9,867	0%	0	0	0	0.0	0	0	0
2005	63,000	1,512,000	534	315	10,086	0%	0	0	0	0.0	0	0	0
2006	88,000	1,600,000	546	321	10,296	0%	0	0	0	0.0	0	0	0
2007	88,000	1,688,000	574	338	10,835	0%	0	0	0	0.0	0	0	0
2008	88,000	1,776,000	601	354	11,339	0%	0	0	0	0.0	0	0	0
2009	88,000	1,864,000	626	368	11,811	0%	0	0	0	0.0	0	0	0
2010	88,000	1,952,000	649	382	12,253	0%	0	0	0	0.0	0	0	0
2011	88,000	2,040,000	671	395	12,669	0%	0	0	0	0.0	0	0	0
2012	88,000	2,128,000	692	407	13,061	0%	0	0	0	0.0	0	0	0
2013	0	2,128,000	712	419	13,430	0%	0	0	0	0.0	0	0	0
2014	0	2,128,000	667	393	12,586	58%	387	228	7,300	0.640	0	1,213	25,477
2015	0	2,128,000	626	369	11,820	58%	363	214	6,855	0.601	0	1,139	23,926
2016	0	2,128,000	589	347	11,122	58%	342	201	6,451	0.566	0	1,072	22,514
2017	0	2,128,000	556	327	10,486	58%	322	190	6,082	0.533	0	1,011	21,227
2018	0	2,128,000	525	309	9,904	58%	304	179	5,745	0.504	0	955	20,049
2019	0	2,128,000	497	292	9,371	58%	288	170	5,435	0.477	0	903	18,968
2020	0	2,128,000	471	277	8,880	58%	273	161	5,150	0.452	0	856	17,975
2021	0	2,128,000	447	263	8,428	58%	259	152	4,888	0.429	0	812	17,060
2022	0	2,128,000	424	250	8,010	58%	246	145	4,646	0.407	0	772	16,214
2023	0	2,128,000	404	238	7,623	58%	234	138	4,421	0.388	0	735	15,431
2024	0	2,128,000	385	227	7,264	58%	223	131	4,213	0.369	0	700	14,704
2025	0	2,128,000	367	216	6,930	58%	213	125	4,019	0.352	0	668	14,028
2026	0	2,128,000	351	206	6,619	58%	203	120	3,839	0.337	0	638	13,397
2027	0	2,128,000	335	197	6,328	58%	194	114	3,670	0.322	0	610	12,808
2028	0	2,128,000	321	189	6,055	58%	186	110	3,512	0.308	0	584	12,257
2029	0	2,128,000	307	181	5,800	58%	178	105	3,364	0.295	0	559	11,740
2030	0	2,128,000	295	173	5,560	58%	171	101	3,225	0.283	0	536	11,254

MODEL INPUT PARAMETERS
Assumed Methane Content of LFG: 50%
Methane Correction Factor (MCF): 1.0

Waste Category:	Fast Decay	Moderately Fast Decay	Moderately Slow Decay	Slow Decay
CH4 Generation Rate Constant (k):	0.150	0.075	0.030	0.015
CH4 Generation Potential (Lo) (m3/Mg):	69	126	214	201

NOTES
* Maximum power plant capacity assumes a net heat rate of 11.4 MJ per kW-hr (hhv).
**Emission reductions do not account for electricity generation or project emissions and are calculated using a methane density (at standard temperature and pressure) of 0.0007168 Mg/m3.

Figure B.4
Model output graph

