LANDFILL GAS RECOVERY AND USE THROUGH SOUTH EAST EUROPE

RFP #EPA-OAR-CCD-10-12
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 Global Methane Initiative program. This project is a follow-up of the initial grant for work completed by EnEffect in the first ever M2M grant for landfills in Bulgaria (completed in August 2010) and presents an assessment of the potential for landfill gas (LFG) recovery and utilisation in middle size Bulgarian landfills.

Based on the available by Eurostat data the amount of municipal waste disposed in Bulgarian landfills was 94% of the generated amount in 2011. Despite the trend of increasing the percentage of recycled organic waste, it can be stated that in Bulgaria high percentage of the organic waste is still disposed in landfills. Considering the above it is highly recommended to use this resource by implementing landfill gas utilisation (LFG) projects.

In order to assess the potential for LFG in Bulgaria, Suhodil landfill (as the biggest Bularian landfill, serving Sofia city) and 5 medium size landfills, servicing the municipalities of Gabrovo, Vratsa, Montana, Silistra, and Sevlievo were visited. Questionnaires regarding the main characteristics of the landfills were filled in during meetings with the landfill operators and/or municipality's representatives.

- Gabrovo – preliminary data shows that the existing landfill is not well maintained. A new cell is under construction and it is expected that it will be designed and maintained better and in accordance with the EU legislation.
- Vratsa – well maintained landfill. The first cell will be closed down soon and a new one will start operation in 2013.
- Montana – well maintained landfill. Relatively new.
- Silistra – well maintained landfill. Very low waste acceptance rate, considered as insufficient for gas recovery project.
- Sevlievo – well maintained landfill. Relatively new. Disposed waste is not enough for gas recovery project.
- Sofia – serviced by the Suhodol landfill, the biggest and best maintained landfill in Bulgaria. Investigated in the report from 2010.

The annual reports of the landfill operators concerning the condition of the facilities were also analyzed. Such reports are submitted annually by the operators to maintain the required for their activities Complex Permission.

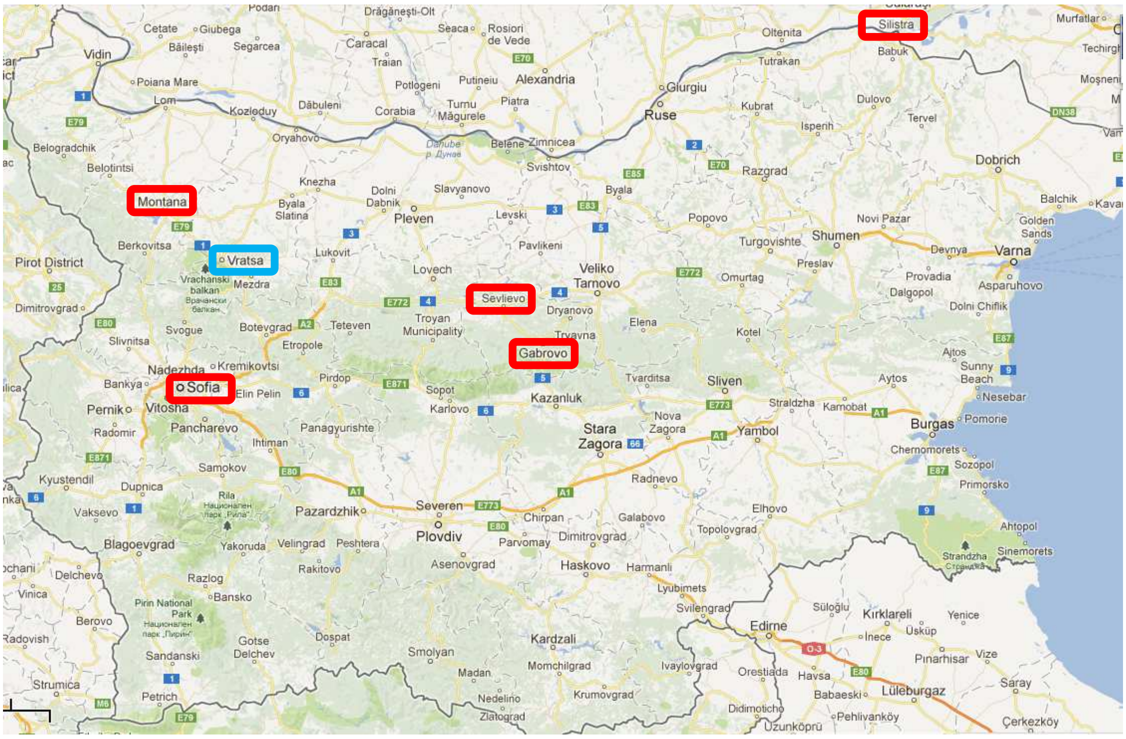
Summarized data about the chosen landfills is given in Table 1.1

Table 1.1 Summarized Data for Selected Landfills

	Municipality					
	Gabrovo	Vratsa	Montana	Silistra	Sofia	Sevlievo
Year opened	1984 - existing 2015 - new part	2000	2006	2006	1985	2007
Expected closure year	2015 - existing 2045 - new	First cell - end of 2012 Second cell - 2027	2027	2032	2012	First cell - 2032
Designed site capacity (tons)	447,000 - existing 397,428 - new	491,491	911,400	1,011,416	5,000,000	1,600,000
Waste in place (tons)	407,315	208,403	241,190	314,690	5,070,178	104,992
Average depth (meters)	15	11	10	16	20	12
Gas collection wells	NO - will be drilled before closure	YES	YES	YES	YES	YES
Drainage system	NO - existing YES - new part	YES	YES	YES	YES	YES
Measurement of the accepted waste	NO - calculation based on number of inhabitants	Yes - scale at the enterance	Yes - scale at the enterance	Yes - scale at the enterance	Yes - scale at the enterance	Yes - scale at the enterance
Evidances of fire	YES	NO	NO	NO	NO	NO

The location of the six landfills is presented in Figure 1.1. Vratsa town is highlighted in blue where modelling of the landfill with EPA LandGem model (as modified for Ukraine), was performed. The other five landfill locations are highlighted in red.

Figure 1.1 Location of the Selected Landfills



Morphology

One of the main factors determining the amount of methane gas generated in a landfill is the morphological content of the waste. The most detailed analyses of the morphological content are made for the Sofia landfill, but it cannot be considered relevant for smaller municipalities where the percentage of people living in smaller settlements is much higher. People there live mainly in single family houses usually have domestic animals and use wood stoves for heating. This leads to much lower percentage of food waste while paper is usually used for kindling, but the percentage of inert materials is much higher.

In 2012 a methodology for determination of waste morphological content was issued[1]. In the document an example for analyzed morphological content of a municipality with population of about 157,000 inhabitants (146,000 inhabitants living in town and 11,323 inhabitants in villages) was presented. Table 3.1 presents the final results of the analyses.

Table 3.1 Estimated Morphological Content of the waste in a Bulgarian Municipality

Type of waste	Town	Villages	Average for the municipality
Food waste	14.6%	12.9%	14.5%
Paper and paperboard	20.4%	12.9%	20.0%
Plastics	20.9%	16.2%	20.8%
Textile	4.0%	8.0%	4.2%
Rubber	0.2%	1.0%	0.3%
Leather	0.1%	0.4%	0.1%
Garden waste	10.8%	9.6%	10.7%
Wood	0.5%	1.4%	0.6%
Glass	6.9%	5.5%	6.8%
Metals	4.5%	1.7%	4.3%
Inert materials	16.9%	30.1%	17.5%
Dangerous wastes	0.2%	0.3%	0.2%
Total	**100.0%**	**100.0%**	**100.0%**

The results presented in the table above can be considered as the most relevant data about the morphological content of the waste generated in the Bulgarian municipalities.

[1] Prepared by Enviro Consult Ltd. (http://www.enviroconsult-bg.com), under the Operational Programme Environment 2007–2013.

Modeling

Vratsa landfill was considered with the best potential and modeling with EPA LandGem (as modified for Ukraine), was performed. The cell that is currently under closure procedures and the new cell that starts operation in 2013 were investigated. The modeling results are presented in Table 1.3 and Table 1.4.

Table 1.3 Modelling Results (Cell 1)

Year	Disposal (Mg/yr)	Refuse In-Place (Mg)	Predicted LFG Recovery m^3/yr	Maximum Power Plant Capacity (MW)	Methane Emissions Reduction Estimates (tCO_2eq/yr)
2000	2 368	2 368	0	0	0
2001	11 419	13 787	0	0	0
2002	12 918	26 705	0	0	0
2003	13 696	40 401	0	0	0
2004	17 591	57 992	0	0	0
2005	19 093	77 085	0	0	0
2006	20 699	97 784	0	0	0
2007	20 110	117 894	0	0	0
2008	21 676	139 570	0	0	0
2009	22 979	162 549	0	0	0
2010	23 095	185 644	0	0	0
2011	22 760	208 404	0	0	0
2012	23 000	231 404	0	0	0
2013	0	231 404	0	0	0
2014	0	231 404	63	0.105	4 168
2015	0	231 404	57	0.094	3 748
2016	0	231 404	51	0.085	3 380
2017	0	231 404	46	0.077	3 056
2018	0	231 404	42	0.070	2 772
2019	0	231 404	38	0.063	2 522
2020	0	231 404	35	0.058	2 301
2021	0	231 404	32	0.053	2 107
2022	0	231 404	29	0.049	1 935
2023	0	231 404	27	0.045	1 782
2024	0	231 404	25	0.041	1 647
2025	0	231 404	23	0.038	1 527
2026	0	231 404	22	0.036	1 420
2027	0	231 404	20	0.033	1 325
2028	0	231 404	19	0.031	1 240

Table 1.4 Modelling Results (Cell 1)[2]

Year	Disposal (Mg/yr)	Refuse In-Place (Mg)	Predicted LFG Recovery m^3/yr	Maximum Power Plant Capacity (MW)	Methane Emissions Reduction Estimates (tCO_2eq/yr)
2013	23 000	23 000	0	0	0
2014	23 000	46 000	0	0	0
2015	23 000	69 000	0	0	0
2016	23 000	92 000	0	0	0
2017	23 000	115 000	0	0	0
2018	23 000	138 000	0	0	0
2019	23 000	161 000	0	0	0
2020	23 000	184 000	0	0	0
2021	11 500	195 500	0	0	0
2022	0	195 500	59	0.098	3 891
2023	0	195 500	53	0.088	3 487
2024	0	195 500	48	0.079	3 134
2025	0	195 500	43	0.071	2 824
2026	0	195 500	39	0.064	2 552
2027	0	195 500	35	0.058	2 313
2028	0	195 500	33	0.055	2 204

As Cell 2 will be still in operation in the year 2020 it is highly recommended to partly close the cell and build the gas collection system of the closed part. In such case it will be possible to operate the gas generator at nominal capacity after the decrease of LFG recovery in Cell 1. This will lead to additional investments but the financial analyses made, show that this action is profitable.

Business Plan

The project objective is to increase the capacity of municipalities to identify and implement LFG projects through increased technical capability. The landfill servicing Vratsa and Mezdra municipalities was selected for development of business case for LFG recovery and use. The business plan includes a cost and financial analysis, risk assessment, and assessment of environmental issues and mitigation strategies. Three approaches were considered in the analyses: a) the municipality gets a loan without support from the Operational programmes; b) the municipality gets a loan and participates in the Operational programmes receiving 50% grant after the project completion; c) the municipality gets a loan and participates in the Operational programmes receiving 75% grant after the project completion. Comparison of the final results for the investigated cases is presented in Table 1.5.

[2] It is assumed that Cell 2 will be partly capped in 2021 and its gas collection system connected to the CHP module.

Table 1.5 Comparison of the results

Parameter	Case 1	Case 2	Case 3
Incentive	0%	50%	75%
Payback Period (yr)	4.64	2.67	1.34
IRR	19%	31%	48%
NPV	171,607	213,092	262,904

The complete business plan is available as a separate document. The main items of the business plan are presented in Section 6 of this report. Summary results for the three investigated scenarios, including the capital budgeting indicators, resulting from the project cash flow projection, are presented in Table 1.6, 1.7, and 1.8.

Table 1.6 Project Cash Flow – Case 1

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Cash Flow Sources																	
Revenues																	
Produced electricity	MWh/yr.		255	511	511	511	485	461	438	416	511	511	511	511	511	511	511
Electricity feed-in-tariff	EUR/MWh		124.46	124.46	124.46	124.46	124.46	124.46	124.46	124.46	124.46	124.46	124.46	124.46	124.46	124.46	124.46
Income from sold electricity	EUR/yr.		31,778	63,556	63,556	63,556	60,378	57,359	54,491	51,767	63,556	63,556	63,556	63,556	63,556	63,556	63,556
Expenses																	
Operational & Maintenance Costs	EUR/yr.		-8363	-16725	-16725	-16725	-16725	-16725	-16725	-6725	-16725	-16725	-16725	-16725	-16725	-16725	-16725
Investments																	
Investments Loan	EUR/yr.	40,910	118,985														
Municipality Contribution	EUR/yr.	-53,299								-25000							
Loan servicing																	
Payments to EE Fund	EUR/yr.	-773	-25,563	-44,767	-44,767	-44,767	-22,384										
Cash																	
Cash (beginning of year)		0	-54,072	-56,219	-54,155	-52,091	-50,027	-28,758	11,877	49,643	69,685	116,516	163,347	210,178	257,009	303,840	350,670
Cash (end of year)		-54,072	-56,219	-54,155	-52,091	-50,027	-28,758	11,877	49,643	69,685	116,516	163,347	210,178	257,009	303,840	350,670	397,501
Cash Flow Analysis																	
Net Free Cash Flow		-94,209	-95,570	46,831	46,831	46,831	43,653	40,634	37,766	20,042	46,831	46,831	46,831	46,831	46,831	46,831	46,831
Discounted Free Cash Flow		-94,209	-89,318	40,904	38,228	35,727	31,124	27,076	23,519	11,664	25,473	23,806	22,249	20,794	19,433	18,162	16,974
Cumulative Cash Flow		-94,209	-189,779	-142,948	-96,117	-49,286	-5,632	35,002	72,768	92,810	139,641	186,472	233,303	280,134	326,965	373,796	420,627
Payback Period (yr)	4.64																
IRR	19%																
NPV	171,607																

Table 1.7 Project Cash Flow – Case 2

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Cash Flow Sources																	
Revenues																	
Produced electricity	MWh/yr.		255	511	511	511	485	461	438	416	511	511	511	511	511	511	511
Electricity feed-in-tariff	EUR/MWh		111	111	111	111	111	111	111	111	111	111	111	111	111	111	111
Income from sold electricity	EUR/yr.		28,294	56,588	56,588	56,588	53,758	51,070	48,517	46,091	56,588	56,588	56,588	56,588	56,588	56,588	56,588
Expenses																	
Operational & Maintenance Costs	EUR/yr.		-8,363	-16,725	-16,725	-16,725	-16,725	-16,725	-16,725	-6,725	-16,725	-16,725	-16,725	-16,725	-16,725	-16,725	-16,725
Investments																	
Investments Loan	EUR/yr.	40,910	118,985														
Municipality Contribution	EUR/yr.	-53,299								-25,000							
Incentive payment	EUR		106,597														
Loan servicing																	
Payments to EE Fund	EUR/yr.	-773	-12,766	-19,172	-19,172	-9,586											
Cash																	
Cash (beginning of year)		0	-54,072	59,691	80,382	101,072	131,349	168,382	202,727	234,519	248,885	288,748	328,610	368,473	408,335	448,198	488,061
Cash (end of year)		-54,072	59,691	80,382	101,072	131,349	168,382	202,727	234,519	248,885	288,748	328,610	368,473	408,335	448,198	488,061	527,923
Cash Flow Analysis																	
Net Free Cash Flow (including grant)		-94,209	7,543	39,863	39,863	39,863	37,033	34,345	31,792	14,366	39,863	39,863	39,863	39,863	39,863	39,863	39,863
Discounted Free Cash Flow		-94,209	7,050	34,818	32,540	30,411	26,404	22,886	19,798	8,361	21,683	20,264	18,938	17,699	16,542	15,459	14,448
Cumulative Cash Flow		-94,209	-86,666	-46,803	-6,941	32,922	69,955	104,301	136,092	150,458	190,321	230,183	270,046	309,909	349,771	389,634	429,496
Payback Period (yr)	2.67																
IRR	31%																
NPV	213,092																

Table 1.8 Project Cash Flow – Case 3

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Cash Flow Sources																	
Revenues																	
Produced electricity	MWh/yr.		255	511	511	511	485	461	438	416	511	511	511	511	511	511	511
Electricity feed-in-tariff	EUR/MWh		111	111	111	111	111	111	111	111	111	111	111	111	111	111	111
Income from sold electricity	EUR/yr.		28,294	56,588	56,588	56,588	53,758	51,070	48,517	46,091	56,588	56,588	56,588	56,588	56,588	56,588	56,588
Expenses																	
Operational & Maintenance Costs	EUR/yr.		-8,363	-16,725	-16,725	-16,725	-16,725	-16,725	-16,725	-6,725	-16,725	-16,725	-16,725	-16,725	-16,725	-16,725	-16,725
Investments																	
Investments Loan	EUR/yr.	40,910	118,985														
Municipality Contribution	EUR/yr.	-53,299								-25,000							
Incentive payment	EUR		159,896														
Loan servicing																	
Payments to EE Fund	EUR/yr.	-773	-3,180														
Cash																	
Cash (beginning of year)		0	-54,072	122,576	162,438	202,301	242,163	279,197	313,542	345,334	359,699	399,562	439,425	479,287	519,150	559,012	598,875
Cash (end of year)		-54,072	122,576	162,438	202,301	242,163	279,197	313,542	345,334	359,699	399,562	439,425	479,287	519,150	559,012	598,875	638,738
Cash Flow Analysis																	
Net Free Cash Flow (including grant)		-94,209	60,841	39,863	39,863	39,863	37,033	34,345	31,792	14,366	39,863	39,863	39,863	39,863	39,863	39,863	39,863
Discounted Free Cash Flow		-94,209	56,861	34,818	32,540	30,411	26,404	22,886	19,798	8,361	21,683	20,264	18,938	17,699	16,542	15,459	14,448
Cumulative Cash Flow		-94,209	-33,367	6,495	46,358	86,221	123,254	157,599	189,391	203,757	243,619	283,482	323,344	363,207	403,070	442,932	482,795
Payback Period (yr)	1.34																
IRR	48%																
NPV	262,904																

Summary of conclusions

There will be a huge potential for LFG recovery projects in Bulgaria and the neighbour countries in C&E Europe (like Serbia, Former Yugoslav Republic of Macedonia, Bosnia and Herzegovina), in the next few years. These projects should not be considered just as economically feasible business investments, but also as a way to follow EU directives, improve the local air quality, reduce the health risks, and improve the energy independence.

However the implementation of LFG projects is currently restricted by lack of knowledge of benefits, limited funding sources, and restrictive lending practices. Many organizations (potential project developers and municipal governments) do not have enough capacity to develop bankable project proposals. Considering the above the current project has four basic elements:

- Research and assessment.
- Business case development.
- Software development.
- Public awareness.

The software was developed by SCS Engineers, based on the data provided by the local partners. EnEffect was the organization responsible for Bulgaria.

During the first months of the project investigation and assessment of 5 middle size Bulgarian landfills and the Sofia landfill (as the biggest and best maintained in the country) was performed. During the site visits interviews with municipal and landfill operators' representatives were held. Based on these interviews a standard data collection form was filled in. Summarized data about the chosen landfills is presented in Section 2 of this report.

The municipal landfill of Vratsa (Mezdra) was chosen for more detailed assessment due to the fact that Cell 1 will be capped in 2013 and its gas collection system will be attached to the existing flare. The assessment results can be confirmed or rejected after the start up of the flare expected in the second half of 2013. For these preliminary assessments of the LFG recovery potential the USEPA LandGem model, as modified for Ukraine, was used. The landfill is built in compliance with the current Bulgarian and EU requirements for managed landfills. Input/output tables of the EPA LandGem model and the resulting graphs illustrating the landfill gas generation and recovery are in Appendix B. The calculation of the landfill potential show that 80 kW generator can be implemented.

The Vratsa landfill services both Vratsa and Mezdra municipalities and can be considered as typical Bulgarian landfill of average size.

This business plan includes a cost and financial analysis and a risk sensitivity assessment. It is considered that the municipality gets a loan and owns and operates the landfill. Three variants on this scheme are analyzed based on different amounts of incentive payments:

Case I: No incentive payment is expected.
Case II: Incentive payment in the amount of 50 % (106,597 EUR) is expected after the project completion.
Case III: Incentive payment in the amount of 75% (159,896 EUR) is expected after the project completion.

In summary, the financial viability of the project depends on the amount of the incentive payment. For the three investigated cases the Payback Period (PBP) ranges from 4.64 to 1.34 years and the respective Internal Rate of Return (IRR) ranges from 19% to 48%.

Based on the developed Business Plan, the following conclusions were done:

- Low risk project – the technology and equipment have been implemented all over the world. The modelling results can be confirmed with none or minor investments.
- Good financial parameters – PBP = 4.64 years, IRR = 19%, NPV = 171,607 EUR in Case 1 without incentive payment. For the worse case risk sensitivity the PBP is 5.72 years and the IRR is 15%.
- Environmental benefits – reduction of the greenhouse gas emissions is expected after the project implementation.

During the first year of the project, the database with information about the landfills in Bulgaria, Serbia, Poland, and Ukraine was updated. Having into consideration this new data the development of a new version of the software for estimation of methane resources in these countries' landfills has begun. During the submission of the current report Beta version of the software, as well as User's manual, are available for testing.

Three workshops and one training, concerning issues related to LFG recovery and landfill maintenance were organised. The following subjects were discussed and recommendations were given to the participants:

- Landfill design – what should be considered before the landfill build up.
- Landfill maintenance – exploitation practices as important factor for the amount of LFG captured and pollution reduction.
- Modelling – Ukrainian and C&E Europe LandGem models and how to use them.
- LFG utilization – what is LFG-to-energy project and how to implement such type of projects.

- Business plan – the results of the developed business plan (key technical and financial conclusions) were presented.

Information about the project was periodically published in the Bulgarian Municipal Energy Efficiency Network bulletin.

Recommendations

Although responsible for the control and monitoring of the facility are the landfill operators the municipality and/or external experts should supervise the main activities and systems periodically. The main factors influencing the reduction of greenhouse gas emissions and the increase of the amount of LFG utilized are regular compacting, daily cover, cells isolation, and drainage and gas capture systems.

The main objective standing in front of Bulgaria and the neighbouring countries, potential new members of EU, is to decrease the disposal of biodegradable municipal waste. To achieve this goal adequate morphological research of the composition of the waste is required. Funds for such investigations should be foreseen during the next budget period in the framework of the Environment Operational Programme.

A LFG project has already been implemented in Sofia landfill. However this landfill cannot be considered relevant to the middle sized Bulgarian landfills, where the amount of waste disposed and the percentage of biodegradable waste are both lower. An implemented LFG project in a middle size landfill can provide the cost-effectiveness and feasibility of LFG utilization. The implementation of Vratsa (Mezdra) LFG project can become a relevant and good example for middles size municipal landfills like those in Silistra, Montana, Rouse, etc.

During the next EU programming period 2014-2020 funding not only for reduction of biodegradable waste disposed in the landfills, but also funding for LFG utilization projects in existing landfills should be foreseen. It becomes obvious from the developed business plan that incentive payment can significantly improve the financial parameters of such types of projects, despite the lower feed-in-tariff in the case of subsidies used for the project implementation. Therefore, it is highly recommendable that funds for the LFG projects implementation are foreseen for the next budget period in the framework of the Environment Operational Programme.

In case Vratsa municipality is interested to implement the proposed business model it is advisable to make publicly known the amount of captured LFG, as wells as the amount of generated electricity. During the project implementation information about the main problems and the project development should be spread through newspapers, local cable televisions, internet sites and radios in order to reach the largest audience possible.

2. GENERAL INFORMATION FOR THE SELECTED LANDFILLS

The landfills of Gabrovo, Vratsa, Montana, SIlistra, and Sevlievo were selected as representative of the range of middle size municipal non-hazardous waste disposal facilities in Bulgaria.

Suhodol landfill was included in this report as considered the biggest and best maintained landfill in Bulgaria. Furthermore there is a CHP module installed already on site. It can be a good example for the small municipalities how to maintain their landfills and develop such types of projects.

Questionnaires were filled in by representatives of the landfill operators and/or representatives of the municipalities (Appendix A). A preliminary assessment of the landfill gas recovery potential was completed for the Vratsa landfill. The amount of LFG generated was estimated using the USEPA LandGem model as modified for Ukraine. The most important criteria for this estimation are:

- Years of operation.
- Amount of waste disposed annually.
- Morphological content.
- Management of waste disposal, and
- Average precipitation in the region.

The most recent data about the waste accumulation rates in Bulgaria is presented in Table 2.1.

Table 2.1 Waste accumulation rates

Population number of inhabitants	Accumulation rate kilograms/per capita/year
over 150 000	410.3
50 000 - 150 000	349.6
25 000 - 50 000	334.9
3 000 - 25 000	295.5
under 3 000	241.7

However the acceptance rate of the landfill depends also on other factors like: a) type of housing (multifamily or single family); b) type of heating (district heating or local heating with wood, gas, etc.); c) cost-of-living allowance; d) tourism; e) universities, etc.

2.1. Gabrovo Municipality

The disposal facility for solid domestic waste servicing Gabrovo municipality is located on 3.4 ha near the town of Gabrovo. The average depth is 10 to 12 meters and the designed site capacity is 407,315 tons. Currently a new cell is designed and is expected to start operation in 2015. A general view of the landfill is shown on Figure 2.1.

Figure 2.1 General View of Gabrovo Landfill

The landfill was put into operation in 1984 but actual data about the accepted waste until the year 2005 is missing. There is no bottom linear and daily cover and compacting was not performed during this period. There are evidences of fire in the summer months. The facility is not well secured as at some parts the fence is missing. It is expected that reclamation of the landfill will be performed in 2015 and 9 gas wells will be built and connected with horizontal pipes. Considering the size (volume) of the landfill and its current condition it is not advisable to invest in electricity generation units as the methane content is expected to be low.

In 2010 research for construction of a new landfill next to the existing one was performed. The new landfill will serve the municipalities of Gabrovo and Tryavna. It is expected to start operation in 2015 and close in 2045. The total area will be 1.84 ha and the total volume – 397,428 m^3. The new landfill will be built in accordance with all European Union (EU) standards i.e. bottom linear, drainage system, gas capture system, etc. It is recommendable to operate it in such way that capping of parts of the landfill could be possible after 10 years of operation. This will provide an opportunity for installation of small gas engine in the future. There is no gas distribution network close to the site or any potential heat energy consumers. Residual heat energy of an eventual co-generator could be offered to greenhouses, because the disposal facility is located in an agricultural area.

2.2. Vratsa Municipality

The disposal facility for solid domestic waste servicing Vratsa and Mezdra municipalities is located on 13.2 ha, 4 km away from the town of Vratsa. The oldest part that operated until the year 2000 is 3.3 ha is closed and reclamation was performed. Due to lack of data and missing bottom linear this part is not taken into consideration for the current analysis. Cell 1 that was put in operation in the year 2000 is with total area of 1.95 ha. Currently a project for reclamation of Cell 1 is under preparation. Cell 2 with total area of 2 ha will be put into operation in 2013 and a third cell (Cell 3) with total area of 2 ha will be designed thereafter. The average depth of the landfill is 12 meters and the designed site capacity is 491,481 tons. A general view of the landfill is shown in Figure 2.2.

Figure 2.2 General View of Vratsa Landfill

The generated leachate is captured and through a pump and pusher stations is lead to a treatment plant. All cells are designed in accordance with all EU requirements and bottom linear, drainage layer, gas collection system are or will be built. Soil cover and compacting in Cell 1 are performed weekly. 98 % of the disposed waste is municipal and only 2% comes from nearby industrial facilities. A scale at the entrance measures the disposed waste. There are no evidences of fire in Cell 1. The landfill is considered well secured.

Close to the site (at about 2 km) is situated Himko AD, the largest producer and trader of urea on the Balkan Peninsula. The company produces also fertilizers (NPK), potash, liquid fertilizers and soil improvers. Currently the factory is not working at full capacity but in the future can be investigated as possible consumer of heat energy generated by a CHP module installed in the landfill.

It is expected that Cell 1 will be capped in 2013 and its gas collection system will be attached to the existing flare. The model of Cell 1 of Vratsa landfill was performed as the start up of the flare and will actually show the accuracy of the software. The results are expected in the second half of 2013 and can be compared not only with the results from the Ukrainian version of LanfGEM, but also with the results generated by the new version of LandGEM, especially modified for C&E Europe.

On the base of the data generated by the Ukrainian version of LandGEM, technical and financial analyses were made and the results are presented in Section 6 of this report.

2.3. Montana municipality

The disposal facility for solid domestic waste servicing Montana and the neighbour municipalities of Krivodol, Boichinovci, Berkovitsa, Lom, Chiprovtsi, Georgi Damyanovo, Brusartsi, Medkovets, Varshets, Yakimovo, and Valchedram is located on 18.5 ha, about 4 km away from the town of Montana. The oldest part that operated until the year 2006 is closed down but the methane generated is insufficient for electricity generation and even the existing flare that is connected to the gas collection system of this part can be started incidentally. The new part of the landfill is 7.3 ha and consists of four cells. The cells will be operated consecutively. After the disposed waste in Cell 1 reaches a certain level Cell 1 and Cell 2 will be operated simultaneously. Cell 3 will start operation after Cell 1 and Cell 2 reach the maximum designed volume. During the exploitation of Cell 3, Cell 1 and Cell 2 will be capped with final cover. There are 6 wells in Cell 1 and Cell 2 that will be connected to the flare after the cells reclamation. Only then the actual LFG generation can be measured and a project for electricity generation foreseen. A general view of the landfill is shown in Figure 2.3.

Figure 2.3 General View of Montana Landfill

The generated leachate is captured and through a pump station is lead to a treatment plant. All cells are designed in accordance with all EU requirements and bottom linear, drainage layer, gas collection system are or will be built. Soil cover and compacting during the current exploitation of Cell 1 and Cell 2 are performed. 86.5% of the disposed waste is municipal and only 13.5% comes from nearby industrial facilities. A scale at the entrance measures the disposed waste. There are no evidences of fire in Cell 1 and Cell 2. The landfill is considered well secured.

2.4. Silistra municipality

After the closure of the old municipal landfill in 2006, a new regional one was put into operation in October 2006. The new landfill services the municipalities of Silistra, Kainardza, Sitovo, Dulovo, Alfatar, Glavinitsa. The landfill is situated at about 8 km from Silistra town. The total area of the landfill is 12 ha and it is designed to accept 1,011,416 tons of waste. In June 2012 the amount of disposed waste was 314,690 tons but in 2008 and 2009 about 170,000 tons from Sofia were delivered and disposed. The current annual acceptance rate is about 30,000 to 35,000 tons. The landfill consists of four cells and currently Cell 1 and Cell 2 are in operation. A general view of the landfill is shown in Figure 2.4.

Figure 2.4 General View of Silistra Landfill

The landfill is built in accordance with the EU legislation. It is considered as well maintained and well secured landfill. Possible project for implementation of CHP module can be considered in the future. There is no gas distribution network close to the site or 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 area.

2.5 Sevlievo Municipality

The disposal facility for solid domestic waste servicing the municipalities of Sevlievo, Dryanovo, and Suhindol is located on 6 ha (the old part that operated before 2007 not included), about 3 km away from the town of Sevlievo. The old cell that operated until the year 2007 is closed but the methane generated is insufficient for electricity generation and even the existing flare that is connected to the gas collection system of this part can be started incidentally. The new landfill consist of 3 cells of about 2 ha each. Two of them are built and the first one is in operation. The third one will be build after the first two reach their maximum capacity. Individual small concrete cells for hazardous waste are also built on the landfill. A general view of the landfill is shown in Figure 2.5.

Figure 2.5 General View of Sevlievo Landfill

The landfill is built in accordance with the EU legislation. It is considered as well maintained and well secured landfill. Compacting and soil cover are performed daily. However the acceptance rate is considered very low and the implementation of electricity generation unit is considered unprofitable. In 2011 the landfill accepted about 18,000 tons of Sofia's waste.

2.6. 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 33.8 ha, about 2.5 kilometers away from the ring-road of Sofia. The facility is the largest in Bulgaria and therefore generates the largest landfill gas quantities in the country.

A general view of the landfill is shown in Figure 2.6. 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 the heat energy located within 1.5 to 2 km of the landfill.

Figure 2.6 General View of Suhodol (Sofia) Landfill

Although the landfill was investigated in the previous report another visit to the site was maid and a new questionnaire was filled. Shortly after the first report completion a CHP unit was commissioned and in February 2011 put into operation. During the visit of the landfill on 16/06/2012 the module was put in operation for 3,779 hours and produced 1,424 MWh electricity. When EnEffect's expert visited the facility the unit was running with capacity of 335 kW and the methane content in the LFG was 40.2 %. The gas flow was not measured but the estimations show that it is about 210 m^3/h. Since the landfill is not completely closed yet, gas is extracted only from *1^{st} stage A* and *Cell 1 of 2^{nd} stage* (see below for details).

The landfill is operated in three stages:

1^{st} stage A – exploitation started in 1985 and ended in 1990 (consists of one disposal cell);

2^{nd} stage – exploitation started in 1997 and ended in 2005, then re-opened in 2007; the expected closure year is 2013 (consists of three disposal cells);

1st stage B – exploitation started in 2009 and the expected closure year is 2013 (new waste is deposited over the old waste of the 1st stage A).

The 1st stage A is located at the southern part of the landfill. The available operational data is not complete due to missing reports and lack of supervisory control. The disposal area is 10 ha and the estimated amount of waste is about 750,000 tons. The landfill has 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 built 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 for monitoring the income parameters of the landfill gas to the burner was installed. The burning parameters of the gas are: temperature of 1,000°C and gas holding time in the torch - 0.3 seconds. In 2011 the gas pipelines were connected to the CHP module.

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

1st cell of 2nd stage: The area of this cell is 7.2 ha. It was in operation from 1997 till 1999. The deposited quantity of solid domestic waste is about 736,245 tons. Currently no more capacity is available. Technical reclamation has been made. Gas wells and a gas pipeline are built and connected to the CHP module.

2nd cell of the 2nd stage: The area of this cell is 5.9 ha. It was in operation from 2000 till 2004. The disposed solid domestic waste is about 1,058,261 tons. Reclamation of part of this cell has begun.

3rd cell of 2nd stage: The area of this cell is 6.9 ha. It was in operation from 2002 till 2005 and from 2007 till 2009. The disposed solid domestic waste is about 1,645,150 tons. Reclamation of this area started in 2013.

The 1st stage B is situated over the 2nd stage A, as mentioned above. The operational area is 10 ha and the amount of disposed waste is expected to reach 880,520 tons when closed in February 2013.

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.

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 that the collected leachate is transported out of the site. A membrane coating was added during the reclamation.

The operation of the disposal facility is relatively good. A compacting machine is used to increase the density of the disposed waste. Filling with soil is periodically done. According to the design, all cells of the landfill have gas capture and gas recovery systems.

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. It possesses the equipment needed for these activities as regulated by the Waste Management Law (WML) and the Environmental Protection Act.

Based on the Ukrainian version of LandGEM and the data from the site visit on 16/06/2012 the actual efficiency of the existing gas collection system was determined at 25%. The low value is due to the poor exploitation practices in 1st Stage A where bottom linear is missing. It can also be stated that the gas collection system is not designed and built properly. Currently over this area 1st stage B is situated and new waste is disposed above the old one.

The annual electricity generated by the current configuration is about 1,000 MWh/yr. The installation operates about 50 % of the time at the minimum possible load. It is expected that after the full reclamation of the landfill it will operate at nominal power and additional unit can be installed. However it is strongly recommended to make a revision of the current projects for gas collection systems of *2nd cell of the 2nd stage*, *3rd cell of 2nd stage*, and *1st stage B* in order to achieve maximum efficiency. Calculations show that additional CHP module can be implemented after the full closure of the landfill.

2.7. Comparison based on provided information

Based on the assessment of the collected data from the six landfills (Table 2.1), the Vratsa (Mezdra) landfill was chosen for modelling using the EPA Ukrainian landfill gas model. The main reason for the selection is the forthcoming reclamation of Cell 1 and the available flare already installed on the facility. According to the EU legislation after the reclamation of Cell 1 the built gas collection system should be connected to this flare. In this case field tests can be performed without additional investments and the modelling data can be approved or denied. If an economically feasible project is implemented in Vratsa (Mezdra) landfill, other well maintained middle size Bulgarian landfills like Montana and Silistra will be interested and may consider the implementation of CHP units on their sites.

Table 2.1 Summarized Data for Investigated Landfills

	Municipality					
	Gabrovo	Vratsa	Montana	Silistra	Sofia	Sevlievo
Year opened	1984 - existing 2015 - new part	2000	2006	2006	1985	2007
Expected closure year	2015 - existing 2045 - new	First cell - end of 2012 Second cell - 2027	2027	2032	2012	First cell - 2032
Designed site capacity (tons)	447,000 - existing 397,428 - new	491,491	911,400	1,011,416	5,000,000	1,600,000
Waste in place (tons)	407,315	208,403	241,190	314,690	5,070,178	104,992
Average depth (meters)	15	11	10	16	20	12
Gas collection wells	NO - will be drilled before closure	YES	YES	YES	YES	YES
Drainage system	NO - existing YES - new part	YES	YES	YES	YES	YES
Measurement of the accepted waste	NO - calculation based on number of inhabitants	Yes - scale at the enterance	Yes - scale at the enterance	Yes - scale at the enterance	Yes - scale at the enterance	Yes - scale at the enterance
Evidances of fire	YES	NO	NO	NO	NO	NO

3. MORPHOLOGICAL CONTENT

One of the main factors determining the amount of methane gas generated in a landfill is the morphological content of the waste. The most detailed analyses of the morphological content are made for Sofia, but it cannot be considered relevant for smaller municipalities where the percentage of people living in smaller settlements is much higher. Such people live in single family houses, usually have domestic animals and heat themselves with wood stoves. This leads to much lower percentage of food waste and paper that is usually used for kindling, while the percentage of inert materials is much higher.

Data about the morphological content of the disposed waste in Bulgaria (Table 3.1) is available on the website of the Bulgarian Ministry of Environment and Water. The data is based on the analyses made for the waste generated in Sofia town and theoretical estimations.

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*

In 2012 a methodology for determination of waste morphological content was issued. In the document an example for analyzed morphological content of a municipality with population of about 157,000 inhabitants (146,000 inhabitants living in town and 11,323 inhabitants in villages) was presented. Table 3.2 presents the final results of the analyses.

Table 3.2 Estimated Morphological Content of the waste in a Bulgarian Municipality

Type of waste	Town	Villages	Average for the municipality
Food waste	14.6%	12.9%	14.5%
Paper and paperboard	20.4%	12.9%	20.0%
Plastics	20.9%	16.2%	20.8%
Textile	4.0%	8.0%	4.2%
Rubber	0.2%	1.0%	0.3%
Leather	0.1%	0.4%	0.1%
Garden waste	10.8%	9.6%	10.7%
Wood	0.5%	1.4%	0.6%
Glass	6.9%	5.5%	6.8%
Metals	4.5%	1.7%	4.3%
Inert materials	16.9%	30.1%	17.5%
Dangerous wastes	0.2%	0.3%	0.2%
Total	**100.0%**	**100.0%**	**100.0%**

The results presented in the table above can be considered as the most relevant data about the morphological content of the waste generated in the Bulgarian municipalities.

Although during the site visits of the selected landfills data about the morphological content was presented this data is not considered reliable. That's why for the modelling of Vratsa landfill a pessimistic approach (based on the information shown in Table 3.2) was used.

4. AMOUNT OF WASTE DISPOSED

The amount of disposed waste in the landfill directly reflects the amount of LFG generated. Table 4.1 presents the annual disposed waste in the analyzed landfills, as well as the expected amounts until 2020 (if the landfill is not closing sooner).

Table 4.1 Annual Waste Deposited in Selected Municipal Landfills

Year	Municipality					
	Gabrovo	Vratza	Montana	Silistra	Sofia	Sevlievo
	tons					
1985					125,000	
1986					125,000	
1987					125,000	
1988					125,000	
1989					125,000	
1990					125,000	
1991					0	
1992					0	
1993					0	
1994					0	
1995					0	
1996					0	
1997					185,088	
1998					254,894	
1999					296,263	
2000		2,368			323,864	
2001		11,419			321,494	
2002		12,918			352,377	
2003		13,696			348,850	
2004		17,591			361,702	
2005		19,093			275,685	
2006	36,680	20,699	30,000	3,357	0	
2007	35,400	20,110	34,000	26,389	25,508	15,927
2008	35,400	21,676	38,000	57,177	393,931	15,110
2009	35,348	22,979	44,000	172,854	354,820	17,702
2010	35,645	23,095	47,000	33,186	319,426	18,712
2011	35,020	22,760	48,000	37,005	256,276	37,540
2012	35,000	23,000	48,000	14,722	250,000	19,000
2013	35,000	23,000	48,000	15,000		19,000
2014	35,000	23,000	48,000	15,000		19,000
2015	17,000	23,000	48,000	15,000		19,000
2016	17,000	23,000	48,000	15,000		19,000
2017	17,000	23,000	48,000	15,000		19,000
2018	17,000	23,000	48,000	15,000		19,000
2019	17,000	23,000	48,000	15,000		19,000
2020	17,000	23,000	48,000	15,000		19,000

5. MODELING

The specific goal of the current project is to investigate the LFG potential of the middle size landfills in Bulgaria. Vratsa landfill was chosen among the other observed landfills, due to the forthcoming reclamation of Cell 1 and the expected connection of the gas collection system of this cell to the existing flare. Furthermore the landfill is built in compliance with the current Bulgarian and EU requirements for managed landfills. After the cell is finally capped and connected to the flare, the modelling results can be compared to the real data. Input/output tables of the EPA LandGem model (as modified for Ukraine) and resulting graphs, illustrating the landfill gas generation and recovery, are available in Appendix B.

6. BUSINESS PLAN FOR DEVELOPMENT OF VRATSA LANDFILL

The project objective is to increase the capacity of the middle-sized municipalities to identify and implement LFG projects, through increased technical capability. The business plan developed under the framework of this project includes a cost and financial analysis and assessment of environmental issues and mitigation strategies. The investments for the final reclamation of the landfill or a single cell are not included in the project cost considering the obligations of the municipality to close the landfill in compliance with the regulatory requirements.

It was considered that the municipality gets a loan and for the project implementation and owns and operates the landfill. The loan is provided by the Bulgarian Energy Efficiency and Renewable Sources Fund (EERSF) as the most economically feasible option. In accordance with the EERSF politics, the minimum equity contribution is 25 %. The main advantage is that there are no additional credit conditions (taxes) and the repayment schedule is structured according to the needs of the project developer (Vratsa Municipality). The annual interests are lower in comparison with the interests offered by the commercial banks in Bulgaria, and vary between 5% and 9%.

Three approaches were considered in the analyses: a) the municipality gets a loan without support from the Operational programmes; b) the municipality gets a loan and participates in the Operational programmes receiving 50% grant after the project completion; c) the municipality gets a loan and participates in the Operational programmes receiving 75% grant after the project completion.

The responsibilities of the municipality for the implementation of the project must be clearly defined. Analyses of the LFG potential should be made with the start-up of the existing flare, after the closure of Cell 1, to verify the assumptions based on the software modelling of the landfill. Only then, the expenses for the project management, permissions and licensing, CHP module, civil works, etc., should be considered.

The financial analyses of the three cases show:

- O&M costs, including salaries of the operating personal, spare parts and supply of the equipment.
- Total project costs; debt to equity ratio; costs for interest; distribution of expenses.
- Expected revenues from the sale of electricity to the National Electric Company EAD (NEK) at the current preferential price.

6.1. General Information about the Landfill

The regional landfill has been operating since October 2000 and is designed to serve both Vratsa and Mezdra municipalities.

The municipality of Vratsa consist of 23 settlements (Vratsa town and 22 villages) and the total population is 72,877 (59,700 in the town and 13,177 in the villages). The municipality of Mezdra consist of 28 settlements (Mezdra town and 26 villages) and the total population is 21,436 (10,789 in the town and 10,647 in the villages). The municipalities are situated in the North West part of Bulgaria at about 110 kms from Sofia.

The landfill is well secured with fence and guards. An electronic scale is installed at the entrance. There are administrative building, garages, workshop, water treatment plant, leachate pump station, monitoring wells for underground waters, and gas wells in the facility.

The facility is divided into three cells and Cell 1 consists of two areas 1-1 and 1-2. Currently reclamation of Cell 1 is performed and Cell 2 is under exploitation. The total amount of waste in Cell 1 is 231,404 tons. Due to the regular compacting the waste density is reported to be 0.75 t/m^3. The cells are insulated with clay, 2 mm of foil and geotextile. There is a drainage system for the leachate and devices for environmental monitoring.

For construction and operation of the landfill a contract between Vratsa and Mezdra municipalities was signed. The share of Vratsa municipality for construction and operation of the landfill is 75%, and respectively the share of Mezdra municipality is 25%. The facility is operated by the Ecoproect Ltd., registered in both Vratsa and Mezdra municipalities. The company was granted with complex permission No KP 5 in 2004, issued by the Ministry of Environment and Water.

The general approach to finance the Vratsa landfill gas recovery project is through municipal ownership as currently the municipal owned company Ecoproect Ltd. manages to operate the landfill with good success. The investments are considered within the reach of the municipality budget.

6.2 Base Project Costs

The project cost for the implementation of the CHP unit is based on preliminary investigation of the costs of the equipment and construction works needed (Table 6.1).

Table 6.1 Base Project Costs

Acticity/Equipment	*EUR*
Project management	12,676
Legal services, consultant	10,372
Electrical integration	17,286
CHP unit	115,240
Gas generator set (pumps, fans, etc.)	23,048
Substructure, civil works	28,810
Contingency	5,762
Capping and gas collection system Cell 2	25,000
Total cost	**238,194**

The capping and the gas collection system for Cell 2 is expected to be done in the year 2021, when the generated LFG in Cell 1 will be insufficient for the operation of the CHP unit at nominal load. Only half of the cell can be capped and its collection system connected to the unit. This should be taken into consideration during the first years of exploitation of the cell to make it technically possible in the future. Therefore the actual investment cost in the first two years of the project is in the amount of EUR 213,194.

The investment schedule suggested and used for the cash flow analyses, as well as the debt-equity, are presented in Table 6.2.

Table 6.2 Funding scheme, debt-equity

Expenses	*2013*		*2014*		*2021*	***Total***	
	Vratsa	*EE Fund*	*Vratsa*	*EE Fund*	*Vratsa*	***Vratsa***	***EE Fund***
Project management	6,338			6,338		**6,338**	**6,338**
Legal services, consultant	5,186			5,186		**5,186**	**5,186**
Electrical integration	4,322			12,965		**4,322**	**12,965**
CHP unit	13,829	32,267		69,144		**13,829**	**101,411**
Gas generator set (pumps, fans, etc.)	9,219			13,829		**9,219**	**13,829**
Substructure, civil works	14,405	8,643		5,762		**14,405**	**14,405**
Contingency				5,762			**5,762**
Capping and gas collection system Cell 2					25,000	**25,000**	
Total by funding source	**53,299**	**40,910**	**0**	**118,985**	**25,000**	**78,299**	**159,896**
Total by year	**94,209**		**118,985**		**25,000**	**238,194**	

The minimum equity contribution from the project developer that is required by the EERSF is at least 25%. The calculated investments needed in the first two years amount to EUR 213,194. The debt financing is calculated at EUR 159,896.

6.3 Project Cash Flow

The operational and maintenance costs after the project implementation include:

- Cost for salaries and social security payments of the operational staff amount to 14,725 EUR per year.
- Costs for materials (oil/filters, lubrication, etc.) and equipment maintenance amount to 2,000 EUR per year.

The total annual operational and maintenance cost is estimated to EUR 16,725, including the salaries of three additional employees that will be responsible for the proper system operation. The implemented CHP unit will be fully automatic and regular manual control will not be required.

The revenues from the project implementation are achieved by the sale of 510.64 MWh of electricity to NEK annually. Table 6.3 presents the project specifications for the three investigated cases. According to the current Decision No 018/28.06.2012 of the State Energy and Water Regulatory Commission, the feed-in-tariffs for electricity generated by LFG vary, depending on the incentive payment granted to the project. Table 6.4 summarizes the three scenario results from the implementation of the project from 2014 through 2028.

Table 6.3 Project Specifications, Revenues and Savings

Implementation of CHP module at Vratsa landfill				
		no grant	***50% grant***	***75% grant***
Revenues				
	Dimension	Value		
Installed capacity	kW	80	80	80
Working hours	h/yr	6,500	6,500	6,500
Produced electricity	kWh/yr	520,000	520,000	520,000
Electricity for auxiliary needs	%	1.8	1.8	1.8
Electricity for auxiliary needs	kWh/yr	9,360	9,360	9,360
Electricity sold to the grid	kWh/yr	510,640	510,640	510,640
Electricity price	EUR/MWh	124.46	110.82	101.73
Annual income from sold electricity	EUR/yr	63,556	56,588	51,946
Operational & Maintenance costs	EUR/yr	16,725	16,725	16,725
Total annual income	**EUR/yr**	**46,831**	**39,863**	**35,220**
Investment costs				
Project management	EUR	12,676	12,676	12,676
Legal services, consultant	EUR	10,372	10,372	10,372
Electrical integration	EUR	17,286	17,286	17,286
CHP unit	EUR	115,240	115,240	115,240
Gas generator set (pumps, fans, etc.)	EUR	23,048	23,048	23,048
Substructure, civil works	EUR	28,810	28,810	28,810
Contingency	EUR	5,762	5,762	5,762
Grant	EUR	0	106,597	159,896
Total investments	**EUR**	**213,194**	**213,194**	**213,194**
Payback	**yr**	**4.6**	**2.7**	**1.5**

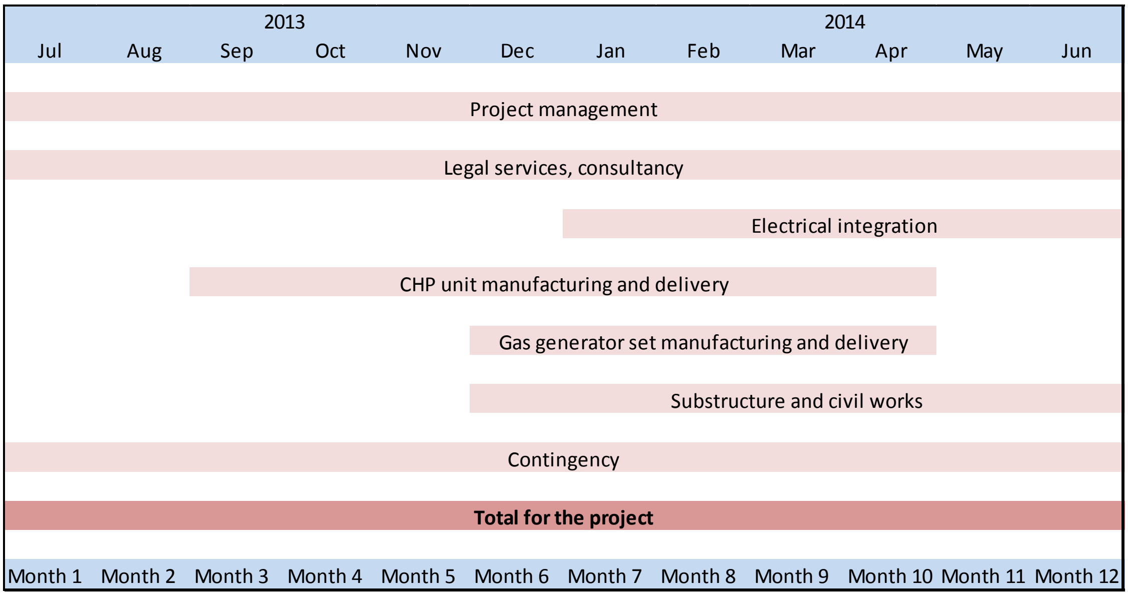
Table 6.4 Total Project Revenues and O&M Cost

Case 1 (No Grant)		2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Revenues																
Produced electricity	MWh/yr.	511	511	511	511	485	461	438	511	511	511	511	511	511	511	511
Electricity feed-in-tariff	EUR/MWh	124	124	124	124	124	124	124	124	124	124	124	124	124	124	124
Income from sold electricity	EUR/yr.	63,556	63,556	63,556	63,556	60,378	57,359	54,491	63,556	63,556	63,556	63,556	63,556	63,556	63,556	63,556
Expenses																
Operational & Maintenance Costs	EUR/yr.	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725
Total project revenues	EUR/yr.	46,831	46,831	46,831	46,831	43,653	40,634	37,766	46,831	46,831	46,831	46,831	46,831	46,831	46,831	46,831
Case 2 (50% Grant)		2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Revenues																
Produced electricity	MWh/yr.	511	511	511	511	485	461	438	511	511	511	511	511	511	511	511
Electricity feed-in-tariff	EUR/MWh	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111
Income from sold electricity	EUR/yr.	56,588	56,588	56,588	56,588	53,758	51,070	48,517	56,588	56,588	56,588	56,588	56,588	56,588	56,588	56,588
Expenses																
Operational & Maintenance Costs	EUR/yr.	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725
Total project revenues	EUR/yr.	39,863	39,863	39,863	39,863	37,033	34,345	31,792	39,863	39,863	39,863	39,863	39,863	39,863	39,863	39,863
Case 3 (75% Grant)		2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Revenues																
Produced electricity	MWh/yr.	511	511	511	511	485	461	438	511	511	511	511	511	511	511	511
Electricity feed-in-tariff	EUR/MWh	102	102	102	102	102	102	102	102	102	102	102	102	102	102	102
Income from sold electricity	EUR/yr.	51,946	51,946	51,946	51,946	49,348	46,881	44,537	51,946	51,946	51,946	51,946	51,946	51,946	51,946	51,946
Expenses																
Operational & Maintenance Costs	EUR/yr.	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725	16,725
Total project revenues	EUR/yr.	35,220	35,220	35,220	35,220	32,623	30,156	27,812	35,220	35,220	35,220	35,220	35,220	35,220	35,220	35,220

6.4 Project Implementation schedule

Table 6.5 shows the implementation schedule for the Vratsa landfill project.

Table 6.5 Project Implementation Schedule



The project starts in July 2013 with advance payments for management, legal services, consultancy and part of the equipment. The CHP unit and the auxiliary equipment will be delivered in April 2014. The start up of the installation is expected in June 2014.

6.5. Type and Amount of Requested Financing

The total base project cost amounts to EUR 213,194 (the expenses for partly capping Cell 2 and connecting its gas collection system to the installed CHP unit will be done in the year 2021 and the financing will be provided by the project revenues). The proposed financial scheme includes the debt financing from the EERSF in the amount of EUR 159,896 and the contribution of the municipality in the amount of EUR 53,299. The debt equity ratio is 75% to 25%. The municipality will pay interest during the construction in the amount of EUR 3,953. The proposed financial scheme is presented in Table 6.6.

Table 6.6 Project Cost and Proposed Financial Scheme

Expenses	EUR	%
Base Projcet Cost	213,194	98.2%
Interest during construction	3,953	1.8%
Total Project Cost	**217,147**	**100.0%**
Capital Structure	EUR	%
Debt	159,896	75.0%
Equity	53,299	25.0%
Total Investments	**213,194**	**100.0%**
Financial Scheme	EUR	%
Loan amount	159,896	73.6%
Municipal contribution		
Own investments	*53,299*	*24.5%*
Interest during construction	*3,953*	*1.8%*
Total contribution of the municiplaity	57,251	26.4%
Total	**217,147**	**100.0%**

The preliminary loan disbursement scheme, including the borrower's own contribution, is presented in Table 6.7 and in Appendix A, with breakdown of the investments. However the final disbursement scheme is subject to negotiations between the bank and the borrower.

Table 6.7 Loan Disbursements and Own Contribution Scheme

EUR	2013		2014			
	Jul	Oct	Feb	Jun	**Total**	**Share**
EERSF	32,267	8,643	83,549	35,436	**159,896**	**75%**
Municipality	47,537	5,762			**53,299**	**25%**
Total	**79,804**	**14,405**	**83,549**	**35,436**	**213,194**	**100%**

The conditions of financing suggested in Table 6.8 are based on preliminary conversations with the financial expert of EERSF. The interest rate is assumed at 7%, although a lower interest rate can be negotiated between the municipality and the Fund. The loan repayment starts on 30th of July 2014, after the project completion; before that the borrower pays only monthly interest on the outstanding principal, during the project construction period.

Table 6.8 Loan Parameters

Project	
Construction begins	01 July 2013
Construction ends	30 June 2014
Operations begins	01 July 2014
Operation ends	31 December 2028
Loan	
Total loan amount	159,896 €
Interest Rate	7%
Loan disbursment begins	31 July 2013
Loan disbursment ends	30 June 2014
Grace period	12 months
Interest payment begins	30 August 2013
Loan principal payments begin	30 July 2014
Loan principal payments end	30 July 2018
Number of payments per year	12

In case the municipality participates in an Operational programme and incentive payment is negotiated, the loan repayment period will be shorter as the incentive will be used for payment of the outstanding principle, immediately after the project completion.

6.6 Project Cash Flow Analysis and Financial Indicators

Three approaches were considered in the analyses: a) the municipality gets a loan without participating in an Operational programme; b) the municipality gets a loan and participates in an Operational programme receiving 50% grand after the project completion; c) the municipality gets a loan and participates in an Operational programme receiving 75% grand after the project completion. The three cases are as follow:

Case #1: The municipality gets a loan and does not participate in an Operational Programme (grant is not expected)

The municipality puts in EUR 53,299 as its equity contribution and gets EUR 159,896 as a loan from the EERSF. The Fund provides low interest rate loans to municipalities without any additional credit conditions (taxes) and a payment schedule structured in accordance with the municipality needs. The price of the produced electricity sold to the NEK will be 124.46 EUR/MWh in accordance with Decision No 018/28.06.2012 of the State Energy and Water Regulatory Commission.

Case #2: The municipality gets a loan and participates in an Operational Programme (50% grant is expected)

The same conditions (equity contribution/loan) as in Case #1, but the municipality participates in an Operational Programme and gets 50% incentive payments (EUR 106,597) after the project completion. The price of the produced electricity sold to the NEK will be 110.86 EUR/MWh in accordance with Decision No – 018/28.06.2012 of the State Energy and Water Regulatory Commission. The incentives will be used to partly cover the loan repayment.

Case #3: The municipality gets a loan and participates in an Operational Programme (75% grant is expected)

The same conditions (equity contribution/loan) as in Case #1, but the municipality participates in an Operational Programme and gets 75% incentive payments (EUR 159,896) after the project completion. The price of the produced electricity sold to the NEK will be 101.73 EUR/MWh in accordance with Decision No 018/28.06.2012 of the State Energy and Water Regulatory Commission. The incentive will be used to cover the loan and only interest will be paid by the municipality.

The capital budget indicators, resulting from the project cash flow projection and analysis, are presented in Tables 6.9, 6.10, and 6.11.

Table 6.9 Project Cash Flow – Case 1

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Cash Flow Sources																	
Revenues																	
Produced electricity	MWh/yr.		255	511	511	511	485	461	438	416	511	511	511	511	511	511	511
Electricity feed-in-tariff	EUR/MWh		124.46	124.46	124.46	124.46	124.46	124.46	124.46	124.46	124.46	124.46	124.46	124.46	124.46	124.46	124.46
Income from sold electricity	EUR/yr.		31,778	63,556	63,556	63,556	60,378	57,359	54,491	51,767	63,556	63,556	63,556	63,556	63,556	63,556	63,556
Expenses																	
Operational & Maintenance Costs	EUR/yr.		-8363	-16725	-16725	-16725	-16725	-16725	-16725	-6725	-16725	-16725	-16725	-16725	-16725	-16725	-16725
Investments																	
Investments Loan	EUR/yr.	40,910	118,985														
Municipality Contribution	EUR/yr.	-53,299								-25000							
Loan servicing																	
Payments to EE Fund	EUR/yr.	-773	-25,563	-44,767	-44,767	-44,767	-22,384										
Cash																	
Cash (beginning of year)		0	-54,072	-56,219	-54,155	-52,091	-50,027	-28,758	11,877	49,643	69,685	116,516	163,347	210,178	257,009	303,840	350,670
Cash (end of year)		-54,072	-56,219	-54,155	-52,091	-50,027	-28,758	11,877	49,643	69,685	116,516	163,347	210,178	257,009	303,840	350,670	397,501
Cash Flow Analysis																	
Net Free Cash Flow		-94,209	-95,570	46,831	46,831	46,831	43,653	40,634	37,766	20,042	46,831	46,831	46,831	46,831	46,831	46,831	46,831
Discounted Free Cash Flow		-94,209	-89,318	40,904	38,228	35,727	31,124	27,076	23,519	11,664	25,473	23,806	22,249	20,794	19,433	18,162	16,974
Cumulative Cash Flow		-94,209	-189,779	-142,948	-96,117	-49,286	-5,632	35,002	72,768	92,810	139,641	186,472	233,303	280,134	326,965	373,796	420,627
Payback Period (yr)	4.64																
IRR	19%																
NPV	171,607																

Table 6.10 Project Cash Flow – Case 2

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Cash Flow Sources																	
Revenues																	
Produced electricity	MWh/yr.		255	511	511	511	485	461	438	416	511	511	511	511	511	511	511
Electricity feed-in-tariff	EUR/MWh		111	111	111	111	111	111	111	111	111	111	111	111	111	111	111
Income from sold electricity	EUR/yr.		28,294	56,588	56,588	56,588	53,758	51,070	48,517	46,091	56,588	56,588	56,588	56,588	56,588	56,588	56,588
Expenses																	
Operational & Maintenance Costs	EUR/yr.		-8,363	-16,725	-16,725	-16,725	-16,725	-16,725	-16,725	-6,725	-16,725	-16,725	-16,725	-16,725	-16,725	-16,725	-16,725
Investments																	
Investments Loan	EUR/yr.	40,910	118,985														
Municipality Contribution	EUR/yr.	-53,299								-25,000							
Incentive payment	EUR		106,597														
Loan servicing																	
Payments to EE Fund	EUR/yr.	-773	-12,766	-19,172	-19,172	-9,586											
Cash																	
Cash (beginning of year)		0	-54,072	59,691	80,382	101,072	131,349	168,382	202,727	234,519	248,885	288,748	328,610	368,473	408,335	448,198	488,061
Cash (end of year)		-54,072	59,691	80,382	101,072	131,349	168,382	202,727	234,519	248,885	288,748	328,610	368,473	408,335	448,198	488,061	527,923
Cash Flow Analysis																	
Net Free Cash Flow (including grant)		-94,209	7,543	39,863	39,863	39,863	37,033	34,345	31,792	14,366	39,863	39,863	39,863	39,863	39,863	39,863	39,863
Discounted Free Cash Flow		-94,209	7,050	34,818	32,540	30,411	26,404	22,886	19,798	8,361	21,683	20,264	18,938	17,699	16,542	15,459	14,448
Cumulative Cash Flow		-94,209	-86,666	-46,803	-6,941	32,922	69,955	104,301	136,092	150,458	190,321	230,183	270,046	309,909	349,771	389,634	429,496
Payback Period (yr)	2.67																
IRR	31%																
NPV	213,092																

Table 6.11 Project Cash Flow – Case 3

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Cash Flow Sources																	
Revenues																	
Produced electricity	MWh/yr.		255	511	511	511	485	461	438	416	511	511	511	511	511	511	511
Electricity feed-in-tariff	EUR/MWh		111	111	111	111	111	111	111	111	111	111	111	111	111	111	111
Income from sold electricity	EUR/yr.		28,294	56,588	56,588	56,588	53,758	51,070	48,517	46,091	56,588	56,588	56,588	56,588	56,588	56,588	56,588
Expenses																	
Operational & Maintenance Costs	EUR/yr.		-8,363	-16,725	-16,725	-16,725	-16,725	-16,725	-16,725	-6,725	-16,725	-16,725	-16,725	-16,725	-16,725	-16,725	-16,725
Investments																	
Investments Loan	EUR/yr.	40,910	118,985														
Municipality Contribution	EUR/yr.	-53,299								-25,000							
Incentive payment	EUR		159,896														
Loan servicing																	
Payments to EE Fund	EUR/yr.	-773	-3,180														
Cash																	
Cash (beginning of year)		0	-54,072	122,576	162,438	202,301	242,163	279,197	313,542	345,334	359,699	399,562	439,425	479,287	519,150	559,012	598,875
Cash (end of year)		-54,072	122,576	162,438	202,301	242,163	279,197	313,542	345,334	359,699	399,562	439,425	479,287	519,150	559,012	598,875	638,738
Cash Flow Analysis																	
Net Free Cash Flow (including grant)		-94,209	60,841	39,863	39,863	39,863	37,033	34,345	31,792	14,366	39,863	39,863	39,863	39,863	39,863	39,863	39,863
Discounted Free Cash Flow		-94,209	56,861	34,818	32,540	30,411	26,404	22,886	19,798	8,361	21,683	20,264	18,938	17,699	16,542	15,459	14,448
Cumulative Cash Flow		-94,209	-33,367	6,495	46,358	86,221	123,254	157,599	189,391	203,757	243,619	283,482	323,344	363,207	403,070	442,932	482,795
Payback Period (yr)	1.34																
IRR	48%																
NPV	262,904																

The project payback period for Case 1 is 4.64 years, the IRR is 19%, and the NPV amounts to EUR 171,607. In cases 2 and 3, where the municipality participates in an Operational Programme and is awarded with incentive grant, in spite of the lower feed-in-tariffs, the project payback period decreases to 2.67 and 1.26 years respectively. The IRR in Case 2 is 31% and in Case 3 – 48%. The calculated NPV for Case 2 amounts to EUR 213,092, and for Case 3 to EUR 262,904.

Comparison of the three cases financial indicators is presented in Table 6.12.

Table 6.12 Financial Indicators – Comparison

Parameter	Case 1	Case 2	Case 3
Incentive	0%	50%	75%
Payback Period (yr)	4.64	2.67	1.34
IRR	19%	31%	48%
NPV	171,607	213,092	262,904

In conclusion it can be stated that the project cash flow analysis for the three investigated cases indicate that the projects' cash flows are sufficient to service the debt (pay loan interest and repay loan principal) under the loan terms negotiated with the EERSF.

7. CONCLUSIONS

According to EU legislation, the main objective for municipal waste management in the current and future member states is to reduce the negative effects on the environment from waste disposed in landfills as far as possible. This will be achieved mainly through encouraging the separate collection of biodegradable waste, sorting, recovery, and recycling:

(a) not later than five years after the date laid down in Article 18(1), biodegradable municipal waste going to landfills must be reduced to 75% of the total amount (by weight) of biodegradable municipal waste produced in 1995 or the latest year before 1995 for which standardised Eurostat data is available;

(b) not later than eight years after the date laid down in Article 18(1), biodegradable municipal waste going to landfills must be reduced to 50% of the total amount (by weight) of biodegradable municipal waste produced in 1995 or the latest year before 1995 for which standardised Eurostat data is available;

(c) not later than 15 years after the date laid down in Article 18(1), biodegradable municipal waste going to landfills must be reduced to 35% of the total amount (by weight) of biodegradable municipal waste produced in 1995 or the latest year before 1995 for which standardised Eurostat data is available.[3]

However the reduction of the percent of disposed biodegradable waste is a long process and having in mind that according to Eurostat in 2011 94% of the Bulgarian municipal waste is disposed in landfills, significant change in the proportion is not expected in the next few years. This means that in Bulgaria and the neighbour countries in C&E Europe (like Serbia, Former Yugoslav Republic of Macedonia, Bosnia and Herzegovina), there will be a huge potential for LFG recovery projects and these is projects should not be considered just economically feasible business investments, but also means to improve the local air quality, reduce the health risks, and improve the energy independence.

The implementation of LFG projects is currently restricted by the lack of knowledge of the benefits, limited funding sources, and restrictive lending practices. Many organizations (potential project developers and municipal governments) do not possess the capacity to develope well prepared project proposals that could be accepted by the lending institutions. Considering the above the current project had four main basic elements with specific activities as follow:

- Research and assessment.
- Business case development.
- Software development.
- Public awareness.

The software was developed by SCS Engineers, based on the provided by the local partners data. EnEffect was the organization responsible for Bulgaria.

[3] Article 5(2) from Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste

Research and Assessment
During the first months of the project a research and assessment of 5 middle size Bulgarian landfills and Sofia landfill (as the biggest and best maintained in the country) were performed. During the site visits interviews with municipal and landfill operators' representatives were held. Based on these interviews a standard data collection form was filled in.

State of the landfills that were investigated:

- Gabrovo – the existing landfill will be closed soon. Gas wells are not built. A procedure for opening a new landfill next to the old one is currently carried out.
- Vratsa – a well maintained landfill. Cell 1 is under closure and Cell 2 is in operation since 2013.
- Montana – a well maintained landfill, relatively new one.
- Silistra – a very well maintained landfill, but with a very low annual waste disposal rate.
- Sevlievo – a well maintained, relatively new landfill. The amount of waste is insufficient for LFG recovery and use project.
- Sofia – the biggest Bulgarian landfill. Well maintained. A CHP unit with electrical power of 860 kW is under operation. The landfill was investigated in the 2010 report.

Summarized data about the chosen landfills is presented in Section 2 of this report.

The municipal landfill of Vratsa (Mezdra) was chosen for more detailed assessment due to the fact that Cell 1 will be capped in 2013 and its gas collection system will be attached to the existing flare. The assessment results can be confirmed or rejected after the start up of the flare expected in the second half of 2013. For these preliminary assessments of the LFG recovery potential the USEPA LandGem model as modified for Ukraine was used. The landfill is build in compliance with the current Bulgarian and EU requirements for managed landfills. Input/Output tables for the EPA LandGem model and resulting graphs illustrating the landfill gas generation and recovery are in Appendix B. The determined potential of the landfill shows that 80 kW generator can be implemented.

The Vratsa landfill services the Vratsa and Mezdra municipalities and can be considered as typical Bulgarian landfill of average size.

Business Case Development
This business plan includes a cost and financial analysis and a risk sensitivity assessment. It is considered that the municipality gets a loan and owns and operates the landfill. Three variants on this scheme are analyzed based on different amounts of incentive payments:

Case I: No incentive payment is expected.
Case II: Incentive payment in the amount of 50 % (106,597 EUR) is expected after the project completion.
Case III: Incentive payment in the amount of 75% (159,896 EUR) is expected after the project completion.

The methane collection system cost is not included in the total project costs as it is responsibility of the municipality to ensure the gas capture and disposal after the closure of landfill cells.

For this business plan, it is assumed that the loan interest rate amounts to 7%, although a lower interest rate can be negotiated as well. The loan repayment starts in July 2014; before that the borrower pays monthly interest on the outstanding principal during the 12-months grace period.

The cost and financial analyses include a risk sensitivity analysis resulting from a reasonable estimate of the capital cost overrun, start-up delay, and operational delays that decrease the net revenue generation.

In summary, the financial viability of the project depends on the amount of the incentive payment. For the three investigated cases the payback period (PBP) ranges from 4.64 to 1.34 years and the respective internal rate of return (IRR) ranges from 19% to 48%.

Based on the developed Business Plan, the following conclusions were done:

- Low risk project – the technology and equipment have been implemented all over the world. The modeling results can be confirmed with none or minor investments.
- Good financial parameters – PB = 4.64 years, IRR = 19%, NPV = 171,607 EUR in Case 1 without incentive payment. For the worse case risk sensitivity the PBP is 5.72 years and the IRR is 15%.
- Environmental benefits – reduction of the greenhouse gas emissions is expected after the project implementation.

Software development
During the first year of the project, the database with information about the landfills in Bulgaria, Serbia, Poland, and Ukraine was updated. Having into consideration this new data the development of a new version of the software for estimation of methane resources in these countries' landfills has begun. During the submission of the current report Beta version of the software, as well as User's manual are available for testing.

The software considers the following main factors influencing the amount of LFG:

- Average precipitation.
- Amount of waste (disposal waste).
- Morphological content.
- Type of landfill.
- Operational practices.
- Quality of gas collection system.

The new software is with expanded scope that allows besides the assessment of the landfill as a whole, assessment of the section where the gas collection system acts alone.

Public Awareness

During the current project life three workshops and one training, concerning issues related to LFG recovery and landfill maintenance were organised. The following subjects were discussed and recommendations were given to the participants:

- Landfill design – what should be considered before landfill build up;
- Landfill maintenance – exploitation practices as an important factor for the amount of LFG captured, and pollution reduction;
- Modelling – Ukrainian and C&E Europe LandGem models and how to use them;
- LFG utilization – what is LFG-to-energy project and how to implement such type of project;
- Business plan – the results of the developed business plan (key technical and financial conclusions) were presented.

Information about the project was periodically issued in the Municipal Energy Efficiency Network bulletin.

8. RECOMMENDATIONS

<u>Landfills supervision</u>

Landfill operators in Bulgaria are responsible for the control and monitoring of the facilities in order to reduce the negative effects on the environment. However, the municipalities should supervise the operational practices and give recommendations to the operators in order to:

- Reduce the greenhouse gas emitted in the atmosphere. It is well known that the methane is twenty-three times more harmful for the environment than the carbon dioxide.
- Increase the amount of recovered and utilized LFG. The proper operational practises will lead to a better financial feasibility of the potential LFG recovery projects.

The main activities and systems that should be verified by the municipal supervisors and/or external consultants are compacting, daily cover, cells isolation, drainage and gas capture systems.

<u>Adequate morphological researches</u>

The main objective standing in front of Bulgaria and the neighbouring countries, potential new EU members is to decrease the disposal of biodegradable municipal waste. To achieve this goal adequate morphological research of the waste composition is required. Funds for such researches should be foreseen during the next budget period in the framework of the Environment Operational Programme.

The investigation of the morphological content in different regions, and different types of habitats will provide an adequate database for determination of future steps in order to comply with the **Council Directive 1999/31/EC** of 26 April 1999 on the landfill of waste.

<u>Demo project</u>

There is already a LFG project implemented in Sofia landfill. However this landfill cannot be considered relevant to the middle sized Bulgarian landfills, where the amount of waste disposed and the percentage of biodegradable waste are both lower. An implemented LFG project in a middle size landfill can demonstrate the cost-effectiveness and feasibility of LFG utilization.

The project implemented in Sofia can be relevant for landfills of cities like Plovdiv (Tsalapitsa) and Varna (Aksakovo) investigated in the previous report submitted in August 2010. However if a project is implemented in Vratsa (Mezdra) landfill it can be relevant and a good example for smaller municipal landfills like those in Silistra, Montana, Rouse, etc.

<u>Financing</u>

During the next EU programming period 2014-2020 funding not only for reduction of biodegradable waste disposed to the landfill, but also funding for LFG utilization project in the existing landfills should be foreseen. It is obvious from the developed business plan that incentive payment can significantly improve the financial parameters of such type of projects, despite the lower feed-in-tariff in case of subsidies used for the project implementation. Therefore, it is highly recommendable to foresee funds for LFG projects implementation during the next budget period in the framework of the Environment Operational Programme.

Awareness

Although a cogeneration unit, that generated 1,000 MWh of electricity only in 2011 and is still in operation, was installed in the Suhodol landfill, this information is not widespread by mass media and among the business community. A good example of transparency and public awareness is given by the website of the Electricity System Operator EAD, where the actual load of the Bulgarian power system can be seen in real-time. Such data can be published for the CHP unit installed in Suhodol landfill, and why not in the future, for the potential installation in Vratsa landfill.

In case Vratsa municipality is interested to implement the proposed business model it is advisable to make publicly known the amount of captured LFG, as wells as the amount of generated electricity. During the project implementation information about the main problems and the project development should be spread through newspapers, local cable televisions, internet sites and radios in order to reach the largest audience possible.

APPENDIX A: QUESTIONNARIE

U.S. EPA Global Methane Initiative (GMI)
Solid Waste Disposal (SWD) Site Data Collection Form

Information collected on this form will be used by GMI to update the International Landfill Database (ILD) and analyze the potential for implementation of a SWD site biogas energy project.

Date:

Form completed by:

SWD SITE DETAILS AND LOCATION

SWD site name:

SWD site physical address:

SWD site city, postal code:

SWD site country:

SWD site longitude/latitude:

SWD SITE OWNER CONTACT INFORMATION

SWD site owner organization:

SWD site owner organization address:

SWD site owner contact person and title:

Contact person phone and email:

SWD SITE OPERATOR CONTACT INFORMATION (if different than owner)

SWD site operator organization:

SWD site operator organization address:

SWD site operator contact person and title:

Contact person phone and email:

SWD SITE DESIGN DATA

SWD Site Type (sanitary landfill, controlled landfill/dump, open dump):

SWD site size (designed area for waste placement - in hectares):

Designed SWD site capacity (cubic meters or tonnes):

Waste-in-place (cubic meters or tonnes):

Waste-in-place year:

Average Waste Depth (meters):

Year SWD site began accepting waste:

Year SWD site closed or will close:

Describe the leachate collection and removal system (if any)?

SWD SITE OPERATIONAL DATA

Waste Characteristics
Please estimate the percent composition of each material accepted at the site.

Waste Types	Percent of Waste Stream
Municipal	
Industrial	
Construction and demolition materials	
Inert	
Other:	
Other:	

Annual Waste Acceptance Data
Please provide specific waste acceptance quantities for **each** year the SWD site accepted waste. Please add additional lines or attach a separate document if more space is needed.

Source of Waste Acceptance Data (i.e. scales, estimates, etc.)	Year	Waste Accepted (cubic meters or tonnes)

SWD SITE OPERATIONAL DATA (continued)

Describe how the SWD site measures waste acceptance rates (i.e. truck scales, vehicle counts, annual growth rates, estimates, no measurement, other)?

Is the waste covered at the end of each working day? Material used?

Does the SWD site apply a thicker layer of waste cover material (intermediate cover) to portions/sections of the SWD site that are not currently being used? Material used?

Do closed portions of the SWD site have a permanent final capping system in place? Material used?

Does the SWD site have a bottom liner? Material used?

Are the waste materials compacted? Equipment used (compactor, bulldozer)?

Describe waste filling process (i.e. large shallow lifts, small deep lifts):

Is there evidence of or is there a history of fires at the SWD site (i.e. surface or subsurface)?

Describe waste scavenging and recycling practices (if any):

Describe SWD site security or access controls (i.e. fence, security guards):

What other waste management practices are in place at the SWD site or adjacent to the SWD site (i.e. recycling, composting, waste treatment or conversion)?

Other SWD site conditions/operational practices to note:

SWD SITE BIOGAS SYSTEM INFORMATION

Is a SWD site biogas collection and control system in place?

If yes, is the collection system actively collecting or passively venting the SWD site biogas?

Is the SWD site biogas collection system required by any regulation or law (if yes, explain requirements/applicable law)?

Types (vertical or horizontal) and quantities of SWD site biogas extraction wells:

Average depth of SWD site biogas extraction wells (meters):

SWD site biogas flow rate (m^3/hr):

Methane content of the SWD site biogas (percent by volume):

Potential/viable biogas utilization options or interests - are any industries nearby?

Additional details on the SWD site biogas collection and control system?

DATA ON OPERATIONAL, UNDER CONSTRUCTION, PLANNED, OR SHUTDOWN SWD SITE BIOGAS PROJECTS (COMPLETE AS INFORMATION IS AVAILABLE)

Project Type	Status of Project Development (Planned, In Construction, Operational, or Shutdown)	Year Project Began Operation or Expected to Begin Operation	SWD Site Biogas Flow to Project (enter value and units (e.g. m^3/hr)	What is the Rated Capacity of the Biogas Flare and Utilization Equipment?	Additional Project Details (i.e. biogas end-users, size, amount of electricity produced, number of flares/engines, reason for shut-down, financial incentives/green tariff)
Open Flare					
Enclosed Flare					
Electricity Generation					
Other Type of Biogas Utilization (i.e. boiler, heater, pipeline injection)					

If there are other planned, operational, or shutdown projects at this SWD site please copy this sheet to describe additional projects.

APPENDIX B: LANDFILL MODELING

The quantity of recoverable methane was determined using the 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[4]. 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 mega-joules per hour (MJ/hr), the system collection efficiency, the maximum power plant capacity that could be fueled by the collected LFG (MW), and the

[4] 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.

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 four climate regions within Ukraine based primarily on average annual precipitation[5]. 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.

A preliminary assessment of the potential for a landfill gas (LFG) recovery and utilization project has been prepared for the Vratsa landfill, located near the town of Vtarsa. The assessment was based on information provided by the landfill operator, from observations made during the site visit on 5 June, 2012, and from the annual reports of the landfill operator concerning the condition of the facility. The investigated part of the landfill began operation in October 2000. Cell 1 is projected to close in the end of 2012, while Cell 2 is put into operation.

Vratsa (Mezdra) landfill modeling (Cell 1)

The recovery of the methane from the Vratsa landfill was assessed, using a USEPA landfill model for Ukraine that is a modified version of the USEPA LandGem model that is used for landfills in the USA. Specific morphological and waste data for the Vratsa landfill were used (considering a pessimistic approach) for input to the model. Where meteorological data was needed Ukraine and Bulgarian data were compared, and Ukraine model regional data that most matched Bulgarian data, was used.

The information presented within this report is based on the data provided by the landfill operator during a site visit and the annual report of the landfill operator concerning the condition of the facility. Such reports are submitted annually by the

[5] The appropriate zone for Bulgaria is selected based on comparable precipitation at Vratsa landfill.

operators of the Bulgarian landfills in order to maintain the required for their activities Complex Permission. EnEffect cannot take responsibility for the accuracy of this data. It should be taken into consideration that the landfill conditions may vary with the changes in the waste input, the management and engineering practices, and the climate conditions (particularly rainfalls and temperatures). Therefore, the quantity and quality of the landfill gas extracted from the landfill may vary from the values stated in this report.

EnEffect 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, average waste depth, disposal rate, disposal area (present and future).

Detailed description of the landfill is presented in Section 2 of this report.

The modelling results for Cell 1 are shown in Tables B.1, B.2 and Figure B.1 below. The calculated efficiency of the gas collection system is estimated at 65%. The results indicate that an 80 kilowatt gas generator could be used for 6,500 hours/year to produce an annual electricity output of 520 megawatt-hours (MWh). After deduction of the internal consumption of electricity by the facility, 510.64 MWh remain for sale to the NEK national utility.

Table B.1 Model Input Table (Cell 1)

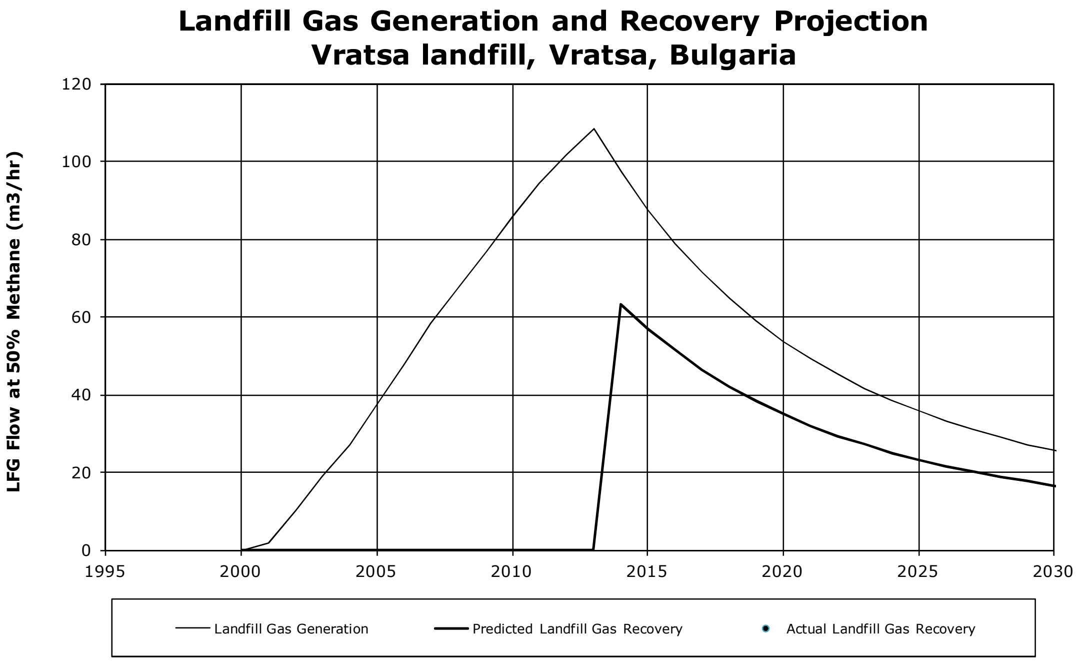
PROJECTION OF LANDFILL GAS GENERATION AND RECOVERY INPUT WORKSHEET			
1	Landfill name:	Vratsa landfill	
2	City:	Vratsa	
3	Province:	Kiev	3
4	Site-specific waste composition data?	Yes	
5	Year opened:	2000	
6	Annual disposal for latest year with data in tonnes per year (Mg/yr)	23,000	Mg
7	Year of annual disposal estimate	2012	
8	Waste in place estimate available in tonnes (Mg)?	Yes	
9	Waste in place estimate for end of 2008 or most recent year:	231,404	Mg
10	Estimated in-place waste density in Mg per m^3 (typical range: 0.5-1.0):	0.75	Mg/m^3
11	If waste in place estimate is in volume (m3), convert to Mg:	231,404	Mg
12	Year of waste in place estimate:	2012	
13	Projected or actual closure year:	2012	
14	Estimated growth in annual disposal:	0.0%	
15	Average landfill depth:	11	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:	75%	
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?	No	
26	Is waste delivered to a focused tipping area?	Yes	
27a	Does the landfill experience leachate surface seeps or surface ponding?	No	
27b	If 23a answer is yes, does this occur only after rainstorms?	Yes	
28	Collection efficiency estimate:	65%	

Table B.2 Model Output Table (Cell 1)

PROJECTION OF LANDFILL GAS GENERATION AND RECOVERY
Vratsa landfill
Vratsa, Kiev, Ukraine

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)
2000	2,368	2,368	0	0	0	0%	0	0	0	0.0	0	0	0
2001	11,419	13,787	2	1	34	0%	0	0	0	0.0	0	0	0
2002	12,918	26,705	10	6	193	0%	0	0	0	0.0	0	0	0
2003	13,696	40,401	19	11	356	0%	0	0	0	0.0	0	0	0
2004	17,591	57,992	27	16	513	0%	0	0	0	0.0	0	0	0
2005	19,093	77,085	38	22	708	0%	0	0	0	0.0	0	0	0
2006	20,699	97,784	48	28	904	0%	0	0	0	0.0	0	0	0
2007	20,110	117,894	58	34	1,102	0%	0	0	0	0.0	0	0	0
2008	21,676	139,570	67	40	1,271	0%	0	0	0	0.0	0	0	0
2009	22,979	162,549	77	45	1,445	0%	0	0	0	0.000	0	0	0
2010	23,095	185,644	86	51	1,620	0%	0	0	0	0.000	0	0	0
2011	22,760	208,404	94	56	1,780	0%	0	0	0	0.000	0	0	0
2012	23,000	231,404	102	60	1,919	0%	0	0	0	0.000	0	0	0
2013	0	231,404	109	64	2,048	0%	0	0	0	0.000	0	0	0
2014	0	231,404	97	57	1,837	65%	63	37	1,194	0.105	0	198	4,168
2015	0	231,404	88	52	1,652	65%	57	33	1,074	0.094	0	178	3,748
2016	0	231,404	79	46	1,490	65%	51	30	968	0.085	0	161	3,380
2017	0	231,404	71	42	1,347	65%	46	27	876	0.077	0	146	3,056
2018	0	231,404	65	38	1,222	65%	42	25	794	0.070	0	132	2,772
2019	0	231,404	59	35	1,112	65%	38	23	723	0.063	0	120	2,522
2020	0	231,404	54	32	1,014	65%	35	21	659	0.058	0	110	2,301
2021	0	231,404	49	29	929	65%	32	19	604	0.053	0	100	2,107
2022	0	231,404	45	27	853	65%	29	17	554	0.049	0	92	1,935
2023	0	231,404	42	25	786	65%	27	16	511	0.045	0	85	1,782
2024	0	231,404	38	23	726	65%	25	15	472	0.041	0	78	1,647
2025	0	231,404	36	21	673	65%	23	14	438	0.038	0	73	1,527
2026	0	231,404	33	20	626	65%	22	13	407	0.036	0	68	1,420
2027	0	231,404	31	18	584	65%	20	12	380	0.033	0	63	1,325
2028	0	231,404	29	17	546	65%	19	11	355	0.031	0	59	1,240

Figure B.1 Model Output Graph (Cell 1)



Vratsa (Mezdra) landfill modeling (Cell 2)

The amount of recovered from Cell 1 LFG gas will reduce in the years and if the installation starts operating in 2014 after 2018 it will operate with reduced load. However, EnEffect experts recommend partly closing Cell 2 in the year 2021 and connecting its gas collection system to the installed CHP unit in 2022. The results indicate that after the connection of the gas capture system is established, the gas generator could operate at nominal load after the year 2022. The modelling results for partly capped Cell 2 are shown in Tables B.1, B.2 and Figure B.1 below. The calculated efficiency is estimated at 62%, lower than the efficiency of Cell 1, because Cell 2 will not be fully closed.

Table B.3 Model Input Table (Cell 2)

PROJECTION OF LANDFILL GAS GENERATION AND RECOVERY INPUT WORKSHEET			
1	Landfill name:	Vratsa landfill	
2	City:	Vratsa	
3	Province:	Kiev	3
4	Site-specific waste composition data?	Yes	
5	Year opened:	2013	
6	Annual disposal for latest year with data in tonnes per year (Mg/yr)	23,000	Mg
7	Year of annual disposal estimate	2013	
8	Waste in place estimate available in tonnes (Mg)?	Yes	
9	Waste in place estimate for end of 2008 or most recent year:	23,000	Mg
10	Estimated in-place waste density in Mg per m^3 (typical range: 0.5-1.0):	0.35	Mg/m^3
11	If waste in place estimate is in volume (m3), convert to Mg:	23,000	Mg
12	Year of waste in place estimate:	2013	
13	Projected or actual closure year:	2027	
14	Estimated growth in annual disposal:	0.0%	
15	Average landfill depth:	11	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:	2022	
19	Percent of waste area with wells:	75%	
20	Percent of waste area with final cover:	25%	
21	Percent of waste area with intermediate cover:	75%	
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?	Yes	
27a	Does the landfill experience leachate surface seeps or surface ponding?	No	
27b	If 23a answer is yes, does this occur only after rainstorms?	Yes	
28	Collection efficiency estimate:	62%	

Table B.4 Model Output Table (Cell 2)

PROJECTION OF LANDFILL GAS GENERATION AND RECOVERY Vratsa landfill Vratsa, Kiev, Ukraine													
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)
2013	23,000	23,000	0	0	0	0%	0	0	0	0.000	0	0	0
2014	23,000	46,000	17	10	329	0%	0	0	0	0.000	0	0	0
2015	23,000	69,000	33	19	621	0%	0	0	0	0.000	0	0	0
2016	23,000	92,000	47	27	881	0%	0	0	0	0.000	0	0	0
2017	23,000	115,000	59	35	1,113	0%	0	0	0	0.000	0	0	0
2018	23,000	138,000	70	41	1,321	0%	0	0	0	0.000	0	0	0
2019	23,000	161,000	80	47	1,507	0%	0	0	0	0.000	0	0	0
2020	23,000	184,000	89	52	1,675	0%	0	0	0	0.000	0	0	0
2021	11,500	195,500	97	57	1,826	0%	0	0	0	0.000	0	0	0
2022	0	195,500	95	56	1,798	62%	59	35	1,115	0.098	0	185	3,891
2023	0	195,500	85	50	1,612	62%	53	31	999	0.088	0	166	3,487
2024	0	195,500	77	45	1,448	62%	48	28	898	0.079	0	149	3,134
2025	0	195,500	69	41	1,305	62%	43	25	809	0.071	0	134	2,824
2026	0	195,500	62	37	1,179	62%	39	23	731	0.064	0	122	2,552
2027	0	195,500	57	33	1,069	62%	35	21	663	0.058	0	110	2,313
2028	0	195,500	51	30	971	65%	33	20	631	0.055	0	105	2,204

Figure B.2 Model Output Graph (Cell 2)