Landfill Gas Emission Reduction Opportunities Study

Prepared for:

Regional District of Central Kootenay

FINAL REPORT REV 1

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1. INTRODUCTION

Greenhouse gases (GHGs) are a major contributor to climate change and are responsible for roughly 30% of global warming. During 2021, landfills in Canada were estimated to account for 19% of national methane emissions and 2.5% of national GHG emissions. As methane is a particularly potent GHG, atmospheric levels of methane respond quickly to changes in emissions. Therefore, reducing methane emissions has the potential to bring large, near-term climate benefits and are important to pursue when the size of the landfill allows. (Canada Department of the Environment; Canada Department of Health, 2024)

The Regional District of Central Kootenay (RDCK) operates two active landfills—Ootischenia Landfill and Creston Landfill—that will continue to be utilized for waste disposal in the short to mid-term future. While neither site is required under the BC Landfill Gas Management Regulation (BCLGMR) to actively manage landfill gas (LFG), the RDCK has received a grant from the Green Municipal Fund to identify viable options to pursue the reduction of GHG emissions at these facilities. Sperling Hansen Associates (SHA) and Methane Expert Engineering (MethaneXE) were retained by the RDCK to assess landfill gas-to-energy system related to landfills, evaluate emission reduction opportunities in the LFG sector, and identify related funding and revenue opportunities that could be feasible within the RDCK's system.

This report details the estimated generation and collection rates of LFG at the two sites and uses those estimated LFG flows to identify and refine potential opportunities for emission reduction. Several sources were used to compile a long list of strategies which were then reviewed for costs and emission reduction potential at a high level to determine the three best strategies at each site for a detailed review.

The detailed review of each strategy included an estimate of the GHG reduction achieved over the current estimated lifespan of the landfill, as well as the costs associated with the strategy (capital and operating). These were then used to determine the estimated cost per tonne of GHG reduced, therefore allowing for a direct comparison between strategies. Once the detailed analysis was completed, a recommendation was made for each of the landfill sites based on SHA's knowledge and the completed analysis, and a proposed business model was developed. Along with the business model an equity assessment was conducted, and partnership opportunities were identified for the proposed option.

It was found that the Ootischenia site will benefit the most from application of a biocover as an intermediate strategy to oxidize surface methane emissions from the waste, followed by early installation of the LFG management system. A further benefit may be realized from the implementation of a processing plant to convert the landfill gas to compressed natural gas which can be utilized within vehicles as an alternative fuel.

The Creston site will benefit the most from the installation of a second passive flare with the next closure, which can be supplemented by the application of an intermediate biocover to oxidize surface emissions. These strategies provide an overall low cost initiative to reduce the emissions from the Creston site.

2. QUANTIFICATION OF LFG EMISSIONS

To evaluate the GHG emission reduction opportunities at each site it is essential to first understand the quantity of gas that is being produced or emitted at a landfill, and the amount of that gas that could potentially be collected for use. To estimate methane generation at each site, SHA applied various methods of assessment for each of the two landfills considered in this study. These approaches are discussed in the following section.

2.1 Ootischenia Methane Generation and Collection

The Ootischenia Landfill has been in operation since 1968 and currently accepts residential, industrial, commercial, and institutional waste from much of the RDCK. Since 2015, the landfill has accepted approximately 20,000 tonnes of waste each year. However, since the RDCK's Nakusp Landfill is no longer accepting waste for burial (awaiting final closure), this tonnage is expected to increase by around 1,500 to 2,000 tonnes per year. The landfill is currently unlined and has not yet undergone progressive closure works since waste placement is planned overtop of current and historic filling areas. There is no LFG management infrastructure installed at the Ootischenia Landfill at this time.

Given that the Ootischenia Landfill will serve as the RDCK's regional landfill, MethaneXE conducted surface emissions monitoring to quantify the amount of methane that is being emitted from the surface of the landfill. MethaneXE's letter report to SHA on the findings of this surface scan is provided in Appendix A of this report. Throughout this feasibility study, emissions data will be coupled with the draft Environment and Climate Change Canada (ECCC) methane modelling completed by the RDCK in 2026 (Appendix B) which were compared to the most recent LFG generation assessment completed in 2024 (Abedini, 2024), and found to be reasonably similar for the purposes of this feasibility study.

It is important to understand that while the amounts of methane generated at a site may seem that they are enough to support many strategies, the amount of landfill gas and therefore methane that can be collected/recovered from the landfill is much less than the generation rate. This is especially true for landfills such as the Ootischenia site which does not have a basal liner to contain the gas and the sandy nature of the soils in the area which are conducive to lateral gas migration underneath/around any closure liner that may be constructed. (Conestoga-Rovers & Associates, 2007) These conditions mean that the amount of methane recovered will be in the range of 50% to 70% of the methane generated, which is similar to SHA's experience with other landfills in the region. For the purposes of this study a collection rate of 60% has been assumed at the Ootischenia site.

To estimate the amount of landfill gas that can be collected at the Ootischenia Landfill throughout the lifespan considered in this study, SHA has utilized the ECCC methane generation modelling results provided by the RDCK, specifically the estimated methane generation each year. Table 2 showcases the values used for this study. To convert the estimated methane generation to a flow rate in standard cubic feet per minute (scfm), SHA used the following formula:

$$scfm = (tonnes/year)/(0.716\frac{kg}{m^3}) * (1000\frac{kg}{tonne}) * (35.315ft^3/m^3\ )/(525{,}600\frac{min}{yr})$$

It is important to note that the LFG generation and the methane generation are two different measurements and are used in different locations throughout this report. Methane generation/collection is approximately 50% of the overall gas generation/collection with the remaining portions made up largely of carbon dioxide, with less than 1 percent non-methane organic compounds and trace amounts of inorganic compounds (USEPA, 2024).

Table 1: Ootischenia Landfill Gas Generation and Collection

Year	Waste Disposal		Methane Generation			LFG Generation	LFG Collection
	Annual	Waste-in-Place					
	tonnes	tonnes	tonnes	m^3	scfm	scfm	scfm
2025	23,011	606,785	710	991,620	67	133	80
2026	22,898	629,683	731	1,020,950	69	137	82
2027	22,664	652,347	751	1,048,883	70	141	85
2028	22,433	674,780	770	1,075,419	72	145	87
2029	22,204	696,984	786	1,097,765	74	148	89
2030	21,978	718,962	800	1,117,318	75	150	90
2031	21,754	740,716	813	1,135,475	76	153	92
2032	21,532	762,248	825	1,152,235	77	155	93
2033	21,312	783,560	835	1,166,201	78	157	94
2034	21,095	804,655	843	1,177,374	79	158	95
2035	20,880	825,535	851	1,188,547	80	160	96
2036	20,667	846,202	857	1,196,927	80	161	97
2037	20,456	866,658	863	1,205,307	81	162	97
2038	20,660	887,318	867	1,210,894	81	163	98
2039	20,867	908,185	872	1,217,877	82	164	98
2040	21,076	929,261	878	1,226,257	82	165	99
2041	21,286	950,547	884	1,234,637	83	166	100
2042	21,499	972,046	890	1,243,017	84	167	100
2043	21,714	993,760	896	1,251,397	84	168	101
2044	21,931	1,015,691	903	1,261,173	85	169	102
2045	22,151	1,037,842	910	1,270,950	85	171	102
2046	22,372	1,060,214	917	1,280,726	86	172	103
2047	22,596	1,082,810	924	1,290,503	87	173	104
2048	23,048	1,105,858	932	1,301,676	87	175	105
2049	23,509	1,129,367	870	1,215,084	82	163	98
2050	23,979	1,153,346	812	1,134,078	76	152	91
2051	24,459	1,177,805	759	1,060,056	71	142	85
2052	24,948	1,202,753	710	991,620	67	133	80
2053	25,447	1,228,200	664	927,374	62	125	75
2054	25,956	1,254,156	622	868,715	58	117	70
2055	26,475	1,280,631	582	812,849	55	109	66
2056	27,004	1,307,635	546	762,570	51	102	61
2057	27,544	1,335,179	512	715,084	48	96	58

2058	28,095	1,363,274	481	671,788	45	90	54
2059	28,657	1,391,931	452	631,285	42	85	51
2060	29,230	1,421,161	425	593,575	40	80	48
2061	29,815	1,450,976	400	558,659	38	75	45
2062	30,411	1,481,387	376	525,140	35	71	42
2063	31,019	1,512,406	354	494,413	33	66	40
2064	31,640	1,544,046	334	466,480	31	63	38
2065	32,273	1,576,319	315	439,944	30	59	35
2066	32,918	1,609,237	297	414,804	28	56	33
2067	33,576	1,642,813	281	392,458	26	53	32
2068	34,248	1,677,061	266	371,508	25	50	30
2069	34,933	1,711,994	251	350,559	24	47	28
2070	35,632	1,747,626	238	332,402	22	45	27
2071	36,344	1,783,970	225	314,246	21	42	25
2072	37,071	1,821,041	213	297,486	20	40	24
2073	37,813	1,858,854	202	282,123	19	38	23
2074	38,569	1,897,423	192	268,156	18	36	22
2075	39,340	1,936,763	182	254,190	17	34	20

2.2 Ootischenia Surface Methane Emissions

In October of 2025, MethaneXE completed a methane emission quantification study at the Ootischenia Landfill using the Surface Scan Emission Quantification Technique (SSEQT). This assessment was completed in alignment with the newly released federal landfill gas emission regulation from ECCC, which specifies scanning surface methane concentrations in 10-meter spaced traverse lines. The landfill surface was divided into discrete, measurable grids as shown in Figure 1. Next the emissions recorded were used to calculate methane emission rates for each grid zone (Table 2).

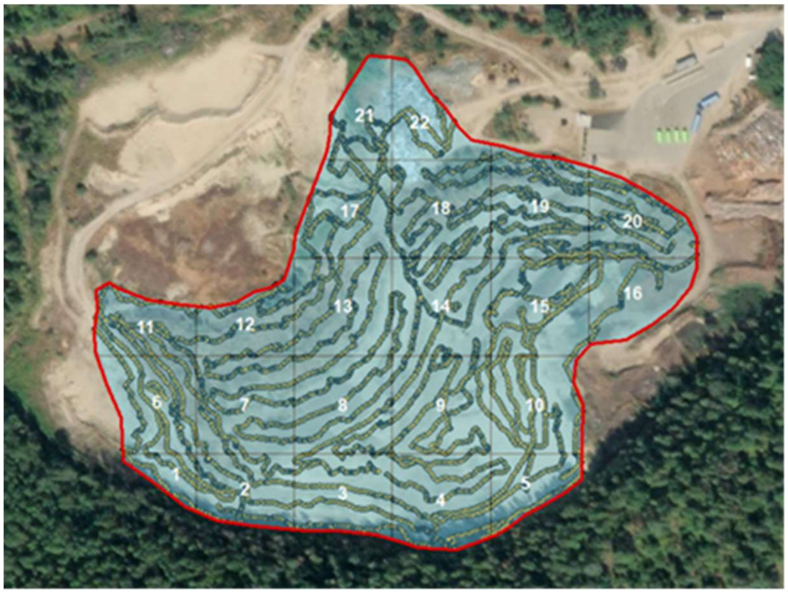

Figure 1: SSEQT Pathway and Grid Layout

Table 2: Methane Surface Emission Rates per Zone at Ootischenia Landfill

Zone ID	Area (m^2)	Average Methane Emission (tonnes/yr)	Average LFG Flow (scfm @ 50% CH_4)
1	1,052	2.6	0.5
2	2,975	34.4	6.9
3	3,378	50.4	10.1
4	3,931	51.9	10.4
5	2,215	27.0	5.4
6	3,541	7.7	1.5
7	4,225	13.9	2.8
8	4,225	150.5	30.1
9	4,225	23.1	4.6
10	3,829	11.5	2.3
11	2,589	2.6	0.5
12	2,664	9.3	1.9
13	4,225	7.1	1.4
14	4,225	28.6	5.7
15	4,209	6.6	1.3
16	3,126	2.8	0.6
17	3,729	3.1	0.6
18	4,225	61.2	12.2
19	4,423	8.9	1.8
20	3,124	2.6	0.5
21	2,333	1.8	0.4
22	2,438	1.9	0.4
Total	**74,906**	**509.7**	**101.9**

The methane emission rates measured in 2025 were lower than the predicted generation assessment rates. This is expected, as the surface emission measurements do not account for methane that is biologically oxidized within the waste mass or the lateral migration of LFG. Overall, the surface scan showed notably elevated methane concentrations along the southern slopes of the waste fill, as shown in Figures 2 and 3.

Figure 2: View of Slopes in Areas of High Methane Concentrations

Figure 3: Area of High Surface Methane Concentrations at the Ootischenia Landfill

2.3 Creston Generation and Collection

The Creston Landfill receives waste from the Town of Creston and surrounding areas, with 6,747 tonnes of waste landfilled in 2023 and 6,351 tonnes in 2024. The RDCK currently operates a small passive LFG system, which has been flaring gas collected from the three closed phases of the landfill. Although consistent flare monitoring data was not available, the site's environmental monitoring program has included monitoring of the flare data since 2023. These figures indicate an average LFG flow rate of 19.6 scfm with a methane concentration of 54% over the past three years. While 54% methane content is expected and within the typical range for landfill gas, the 19.6 scfm is high for this type of passive system.

For the purposes of this study, MethaneXE conducted advanced LFG modelling for the Creston site using the UBC iModel which is believed by the SHA and MethaneXE team to be a closer representation of the actual methane generation compared the provincial or federal models. This was not done for the Ootischenia site as the ECCC modelling was already available and provided sufficient data for the purposes of this study. The full results of the UBC iModel are provided in Appendix C, with a summary of the modelling results provided below in Table 3.

Table 3: Creston Landfill Gas Generation and Collection

Year	Methane Generation			LFG Generation	LFG Collection
	tonnes	m3	scfm	scfm	scfm
2025	237	330,544	22	47	21
2026	241	336,123	23	48	22
2027	244	340,307	23	48	22
2028	248	345,886	23	49	22
2029	251	350,070	24	50	23
2030	254	354,254	24	50	23
2031	258	359,833	24	51	23
2032	261	364,017	24	52	23
2033	264	368,201	25	52	23
2034	268	373,780	25	53	24
2035	271	377,964	25	54	24
2036	274	382,148	26	54	24
2037	278	387,727	26	55	25
2038	281	391,911	26	56	25
2039	284	396,095	27	56	25
2040	288	401,674	27	57	26
2041	291	405,858	27	58	26
2042	294	410,042	28	58	26
2043	298	415,621	28	59	27
2044	301	419,805	28	60	27
2045	304	423,989	28	60	27
2046	307	428,173	29	61	27
2047	311	433,752	29	62	28
2048	314	437,936	29	62	28
2049	318	443,515	30	63	28
2050	321	447,699	30	64	29
2051	322	449,093	30	64	29

2052	294	410,042	28	58	26
2053	270	376,569	25	54	24
2054	248	345,886	23	49	22
2055	229	319,386	21	45	20
2056	211	294,282	20	42	19
2057	196	273,361	18	39	18
2058	182	253,835	17	36	16
2059	169	235,704	16	33	15
2060	157	218,968	15	31	14
2061	147	205,021	14	29	13
2062	137	191,074	13	27	12
2063	128	178,522	12	25	11
2064	120	167,364	11	24	11
2065	113	157,601	11	22	10
2066	106	147,838	10	21	9
2067	100	139,470	9	20	9
2068	94	131,102	9	19	9
2069	89	124,128	8	18	8
2070	84	117,155	8	17	8
2071	79	110,181	7	16	7
2072	75	104,603	7	15	7
2073	71	99,024	7	14	6
2074	67	93,445	6	13	6
2075	64	89,261	6	13	6

3. IDENTIFICATION OF POTENTIAL EMISSION REDUCTION STRATEGIES

To determine and evaluate emission reduction opportunities at the RDCK landfills, SHA relied on two main sources to develop a 'long list' of potential strategies and management practices. These resources were developed by the BC Ministry of Environment (ENV) and the California Integrated Waste Management Board to determine technologies and management options for reducing GHG emissions from landfills (Conestega-Rovers & Associates, 2011; SCS Engineers, 2008).

Following the development of this long list, SHA first reviewed each strategy to determine their general relevance and suitability for each site, with non-applicable strategies removed from consideration. The strategies considered in the long list and rationale for their inclusion are described in the following section.

3.1 Long List of Strategies for Emission Reduction

This section provides all the strategies for emissions reduction considered for the RDCK landfills. Each strategy is briefly described along with its general feasibility for the sites, with sites that are not considered feasible at a high level not considered further in the study. For those strategies that are considered further, a brief description of the general risk, cost, and GHG emission reduction potential at each site is given to inform the later analysis that seeks to reduce the list of strategies that will undergo detailed analysis to three (3) per site.

3.1.1 LFG Collection

These strategies seek to go above and beyond what is currently required under the regulations for LFG collection and control. As the Ootischenia site does not currently have a landfill gas collection system, much of these are not applicable and should instead be considered during the development of the LFG Facilities Design Plan required under the BC Landfill Gas Management Regulation.

Horizontal Collectors or Surface Collectors

The typical way of collecting landfill gas is to install vertical gas collection wells following the completion of final cover over a portion of the site. To supplement this or control surface emissions, horizontal collectors can be installed while the landfill is being filled to collect additional gas from recently placed waste in the interim period before final grade is reached. These collectors are best implemented when filling will occur above that area or final grade will not be reached for some time. As the Ootischenia site does not have a gas collection system and the RDCK will need to determine the landfill gas collection strategy at the site, this strategy will not be considered for Ootischenia. The Creston site may benefit from these collectors, as additional gas can be transferred to the flare before closure occurs and therefore this strategy will be considered further for the Creston site.

At the Creston site, this strategy has a generally moderate risk as passive systems may not be able to take full advantage of more collectors. The cost of construction is generally high as this will require excavation within the landfilled waste and is more expensive than simply waiting until the landfill is closed and is receiving final cover. The potential for GHG reduction is moderate as the site does not produce large amounts of gas, but additional gas will be collected while the site is being filled, and not only after closure.

Increased Collection Well Density

This strategy looks to decrease the spacing between horizontal collectors or vertical wells in a landfill gas collection system and therefore increase the amount of gas collected. There are some specific nuances associated with this strategy that need to be accounted for in the detailed design such as overlapping areas of influence and excessive draw bringing oxygen into the landfill. This strategy may be applicable to the Creston site and therefore will be considered further in this study.

This strategy has a relatively high risk, as the Creston site does not have an active gas collection system and additional collection will have to rely on increased pressure from within the landfill, or an easier pathway to the flare. This approach has a relatively 'medium' cost and 'medium' GHG reduction potential.

Early Installation of LFG Collection System

The regulatory timeline for the Ootischenia Landfill is to have an active system in place by 2035, while the Creston landfill will likely never reach regulated gas quantities but already has a system in place. Early installation of the system allows for additional gas to be collected during the unregulated years, which otherwise would have been vented to the atmosphere. This strategy has a high potential for emission reduction and is considered very applicable to the Ootischenia site as it will be regulated in the future to have an LFG collection system installed and will be considered further in this study.

This strategy comes with a very low overall risk as the site will be regulated to collect gas starting in 2035, and at that time will also be subject to regular surface emissions monitoring requirements. As this is not additional work, the only additional cost will be the extra years of operating and maintaining the system before the site is regulated to collect landfill gas. The emissions reduction potential is also very high, as the additional years of operating the LFG management system will destruct methane instead of venting the gas to the atmosphere.

Mixed Horizontal and Vertical Well Systems

Horizontal collectors offer earlier collection of gas, but their efficiency is limited as gas typically travels easier through the horizontal plane compared to the vertical plane. Therefore, a hybrid system is typically the most successful for collection of landfill gas, with horizontals providing early collection and vertical wells installed after completion of filling (SCS Engineers, 2008). This strategy is feasible at most landfills, and for the purposes of this study will be considered only for the Creston site, as the Ootischenia Landfill does not yet have an LFG collection strategy in place.

Using a mixture of horizontal and vertical wells at the Creston site will carry some risk due to the low amount of gas produced and the lack of an active collection system at the site. The main risk is associated with the cost of the system which can be quite high compared to following the current practice of installing sub-liner collectors on the surface of the landfill during closure. The GHG reduction potential is also limited for similar reasons, as with no active collection system the site will rely on pressure built up from the production of gas.

Connection of Leachate Collection System Gravel Layer to Gas Collection System

New landfills are constructed with a bottom leachate collection system which can be connected to the landfill gas collection system to collect gas beneath the refuse. This increases the collection of an existing system but does require the site to have a basal liner and leachate collection system installed (SCS Engineers, 2008). As neither of the RDCK sites have a basal liner installed, this strategy will not be considered further.

Deep Multi-Depth Vertical Wells

This strategy looks to construct nested wells in the same borehole so that a greater vacuum can be applied to the deeper well with a lesser risk of oxygen intrusion through the surface of the waste. (SCS Engineers, 2008) As neither RDCK site currently operates an active system, this strategy is not considered further in this study.

Maximize Borehole and Well Diameters

When installing wells in the landfill, larger sizes allow for more gas to flow to the flare and provide additional strength against the pressures of the waste. This strategy is most applicable to sites where high gas production is expected (SCS Engineers, 2008). As Ootischenia does not have a landfill gas collection plan in place, and the Creston site does not produce large amounts of gas, this strategy is not considered further in this study.

Enhance Seals on LFG Wells and Boreholes

This strategy is similar to preventing surface emissions; however, it is focused around increasing the seal around closure liner penetrations to prevent gas from leaking in those specific locations. This can be done through bentonite seals, compacted clay, or engineered plastics (SCS Engineers, 2008). This is not applicable to Ootischenia at this time and will be dealt with through the ECCC regulations once the site is regulated, however this may be applicable at Creston as the sub-liner gas collectors penetrate the liner to convey gas to the flare. This strategy is considered further for Creston as the Ootischenia site does not yet have a collection system installed.

This is a low-risk strategy, and it will be relatively inexpensive to increase the seal around any liner penetrations for the gas collection system. However, as the site already relies on built up gas pressure to bring gas to the flare and the path of least resistance is provided through the collection system, the emissions reduction potential of this strategy is minimal.

Dewater Gas Wells

When gas collection pipes fill with water they cease to perform as intended, as the gas cannot flow through the liquid. Therefore, having proper drainage or pumping mechanisms in place to keep leachate out of the collection system will greatly enhance the performance of the landfill gas collection at a site (SCS Engineers, 2008). This strategy is not applicable to Ootischenia, and as the Creston site has only sub-liner collectors installed it is unlikely that leachate is an issue at the site in relation to gas collection. However, this strategy has been considered further for the Creston site to ensure a complete study has been conducted.

This strategy is most effective when the collection system at a site is inhibited by water in the collection wells, and as the Creston site has not previously had this issue and the site receives a relatively low amount of precipitation each year this strategy comes with some risk. Pumping of the wells can be somewhat expensive especially if the existing system does not lend itself to this activity. Given the low precipitation received at the site and lack of current issues, this strategy has a low emission reduction potential.

3.1.2 LFG Utilization

LFG utilization can be implemented in addition to the LFG collection and flaring system and uses collected gas to generate energy usually in the form of heat, electricity, or natural gas. This energy, which offsets other energy production, can then be used on site, in a nearby capacity, or sold back to the local utility provider. These technologies provide the base level of emission reduction through the conversion of methane to carbon dioxide; however additional offset is provided by replacing 'dirty' energy forms. It should be noted in BC where hydroelectric dams provide much of the electricity, this offset is smaller than in other regions where power is produced through technologies that have a much higher GHG footprint. This may be feasible at the RDCK sites, and consideration of this strategy is a requirement for the grant funding this study, therefore LFG utilization will be considered in detail moving forward.

Utilization of LFG is undertaken by construction of an additional system to the regular LFG collection for energy generation in the form of heat, electricity, or natural gas (Conestega-Rovers & Associates, 2011). The emission benefit of this approach is that not only is the methane in the LFG converted to carbon dioxide, but the energy also produces offsets emissions that would be produced if that energy was obtained from a different source. In British Columbia, most of our power is produced through hydroelectricity, which is a relatively clean form of power and thus the offset benefit is somewhat limited.

In addition to traditional electricity generation, there is potential to implement a combined heat and power system (CHP). Electricity generation technologies typically produce thermal energy in the form of steam or hot water as a byproduct. This heat can be captured and utilized on site for various applications, such as heating for scale houses, site offices, or other nearby buildings, or other processes requiring thermal energy (USEPA, 2025). Landfill Gas to Energy (LFGTE) systems typically operate with a30 to 40% of the incoming energy be converted to electricity, 40 to 50% of the energy converted to heat, and the remainder lost to the combustion process.

Depending on the type of LFG utilization, some treatment of the gas may be required beforehand to remove moisture, particles, or other impurities, with the amount of treatment dictated by the specific technology used. Minimal treatment is required for direct use of the gas in boilers or kilns, while advanced treatment is necessary when using LFG to create electricity or if it will be injected into the existing natural gas pipeline.

The following section lists potential LFGTE project types with a brief description of each and the general guidelines around the size of the project suited to the technology.

Direct-Use

LFG can be a cost-effective alternative to other fossil fuels, with typical direct-use projects including boilers, leachate evaporation, and direct thermal applications such as kilns, infrared heaters, furnaces, greenhouses, and others. The amount of gas flow varies per application, but some technologies such as greenhouses and infrared heaters can use minimal amounts of gas (USEPA, 2024).

RNG Processing Plant

LFG can be processed to create pipeline-quality gas, and in some cases can be directly used as an alternative fuel. This approach has numerous end uses and as such can be an attractive alternative for LFGTE projects. To upgrade LFG to pipeline quality gas and use as natural gas for vehicles, electricity, or thermal energy production the gas flow must typically be a minimum of 1,000 cubic feet per minute (cfm) to be cost effective. However, to use as a local fuel alternative for vehicles, some compressed natural gas (CNG) projects can utilize as low as 50 cfm (USEPA, 2024).

Internal Combustion Engine

Internal combustion engines are the most common technology used in LFG applications due to its relatively low cost and high efficiency, as well as their availability. These engines do require primary treatment of gas, and may need secondary treatment to achieve the best performance. These projects cannot operate with LFG volumes lower than intended, so it is extremely important that the project be designed with several smaller engines, or with a guaranteed gas flow rate. The typical application for internal combustion engines is landfill gas flows ranging from 300 to 1,100 cfm (USEPA, 2024).

Gas Turbine

These are typically used in larger LFG energy projects as they benefit significantly from economies of scale, with the cost per kilowatt decreasing for larger projects. Turbines are typically more resistant to the contaminants in landfill gas; however primary treatment is recommended and secondary may be required to achieve better performance. Minimum gas flows for turbines are around 1,300 cubic feet per minute, but they are typically used when the flow exceeds 2,100 cfm (USEPA, 2024).

Microturbines

Microturbines are small turbine projects that have a higher cost per kW but are attractive for smaller LFGTE projects as they can operate on LFG with a lower methane content, have lower emissions, and because they simply require less LFG volume than internal combustion engines. However, this technology does require extensive treatment of the LFG to remove contaminants before the LFG can be utilized. Typical gas flows for microturbine implementation ranges from 20 to 200 cubic feet per minute (USEPA, 2024).

Combined Heat and Power

Construction of an additional system to capture the thermal energy produced from the electricity generation project can significantly increase the efficiency of the system. These projects are typically feasible for any LFGTE project that produces electricity, however there must be demand or a use for this energy, such as a nearby greenhouse or industrial process, or an on-site process that requires heat (USEPA, 2024).

3.1.3 LFG Systems and Operation and Maintenance

These strategies look to use alternative or enhanced methods of LFG management to reduce emissions from the site.

Gas Mover Equipment and Vacuum Control

The sources that SHA has considered for this study list several practices/strategies to reduce emissions that are related to the vacuum of an active collection system. As neither the Ootischenia nor the Creston site have an active collection system in place, these strategies have not been considered in this study.

Redundant Flare Station Equipment

Down time is inevitable for any flare station; however, it is possible to reduce this downtime through the installation of redundancies in the equipment. While this doesn't apply now to the Ootischenia site and typically refers to having a secondary blower or enough spare parts in stock, there is the potential to have a secondary flare at the Creston site. As the current passive flare cannot draw any more gas out of the landfill (as it doesn't actively draw gas), a second flare would allow for additional venting of gas especially if connected to subsequent closure area. Therefore, this strategy has been considered further for the Creston site.

This strategy has a low to moderate level of risk due as gas quality and quantity will decline as the site ages, but this can be mitigated by alternating which flare closure works / system are connected to. This strategy also has a medium cost and a medium to high emission reduction potential – the flare will allow for additional gas to be destructed, but there will be some overlap between the two flares.

3.1.4 Other LFG

LFG Master Planning

An LFG 'master plan', or landfill gas facilities design plan, is required under the BC Landfill Gas Management Regulations for regulated landfills, and is required to determine how the installation, operation, and maintenance of the landfill gas facilities will be undertaken throughout the life of the site. This includes details about the type of collection system what will be installed, the methane destruction method, and recommendations for optimizing landfill gas collection at the site (SCS Engineers, 2008). While this is likely to be defined in the DOCP for the Creston site as it is far from being regulated, the Ootischenia site will benefit from a master plan as it will be regulated under the federal regulations. The ECCC regulations do not require a master plan, but will support determining the optimal collection system layout, liquids management, and integration with other emission control methods that are implemented at the site.

At the Ootischenia site the development of an LFG master plan is considered to have very low risk, as this may be required if the site is ever regulated under the BC Landfill gas management regulation. The cost is also relatively low, but there will be no direct GHG emissions reduced via this strategy. Rather, this will provide the RDCK to have a planned pathway forward when completing the detailed designs for landfill gas collection systems at the site, and therefore this approach has a low to moderate emission reduction potential.

Enhanced Gas Migration Monitoring

Monitoring of gas migration at a landfill site allows the owner/operator to have insight into the effectiveness of the LFG collection system. By installing soil gas probes around the perimeter of the site and regular monitoring, the RDCK will be able to understand if and where gas is migrating off of the site and provide the ability to take measures to control the migration and instead direct that gas to the flare. This is applicable to both sites, but the Ootischenia site will further benefit from this strategy during the design of the LFG management facilities.

This strategy has a low risk as it will simply seek to assist the RDCK in understanding how gas is migrating off-site and design the system accordingly. Cost is neither high nor low, with simple installation but increased operating costs for the continued monitoring. GHG reduction potential is low to medium, as it depends on the amount of gas migrating offsite and the ability of the system to intercept this gas and direct it towards the destruction system.

Improved Modelling and Testing for LFG Design

Most landfill gas management designs utilize best practices and the most recent modelling data for the site. This is good but facility design can be improved by using detailed modelling for gas flow throughout the waste, as well as inclusion of the latest waste composition data to provide more accurate gas generation rates. This strategy is relatively simple and can be completed as part of detailed design or DOCP updates for facilities, and as such is not considered for detailed analysis in this study.

3.1.5 Other Landfill Design and Operations

Reducing Surface Area of Exposed Tipping Face

The tipping face of a landfill is the only area where waste is exposed and allows LFG emissions to vent to the atmosphere without passing through any form of cover. By reducing the size of the active face, the volume of direct emissions can be reduced as gas may be oxidized through the landfill cover or collected by an installed LFG collection system. This strategy is applicable to the RDCK sites and will be considered further.

This strategy has low risk and low cost as it simply changes operating procedures, however SHA's experience with the sites indicates that the landfill operators currently maintain relatively small active filling areas. This means that the GHG reduction potential of this strategy is quite low.

Bioreactor Landfill Design

Bioreactor landfills are typically used for new landfills as they require significant control over the leachate collection and recirculation as well as the gas collection systems. There are three main types of bioreactor landfills, which seek to control LFG production in different ways:

Anaerobic bioreactor landfills are sealed with an impermeable liner, and then moisture is added to the waste to achieve optimal moisture levels for LFG production under anaerobic conditions. In this way LFG is produced at an accelerated rate and LFG controls are required for a shorter period of time compared to traditional landfills which produce a lower LFG flowrate over a longer period of time. Retrofitting an existing landfill to an anaerobic bioreactor is possible, but extremely difficult without a basal liner in place at the site.

Aerobic bioreactor landfills are similar to anaerobic landfills, however along with moisture air is also forced into the waste so that LFG is produced under aerobic conditions. This aerobic process is faster compared to the anaerobic process and technically does not produce any methane emissions, thus reducing the emissions of the site (Conestega-Rovers & Associates, 2011).

Biocell landfills extend the bioreactor landfill and incorporate the benefits of both aerobic and anaerobic decomposition. The landfill is operated in two stages, with enhanced LFG production using recirculation to accelerate LFG production and then aerobic conditions used to stabilize the waste.

Bioreactor landfills are typically reserved for new landfills as all systems (leachate, gas, liner, etc.) must be designed specifically for the purpose of a bioreactor landfill. As the Ootischenia and Creston landfills do not have basal liners, this strategy is not feasible and will not be considered further in this study.

Surface Emissions Prevention

Surface emissions prevention looks to detect leaks in the surface of the landfill and remediate any hotspot areas. This is done through surface emissions scans like the one conducted at Ootischenia for this study and then improving the intermediate or final cover in areas that indicate high remission rates. This is intended to direct this gas, which otherwise would have vented to the atmosphere, to the landfill gas collection system.

Surface emissions prevention is now part of the ECCC Landfill Methane Regulations for landfills that the regulations apply to. As the Ootischenia Landfill is regulated to implement surface emissions monitoring and prevention starting in 2035, SHA has not considered this strategy for the Ootischenia site. However, as the Creston landfill will likely never be considered regulated under the ECCC regulations, this strategy has not been considered further.

This strategy is relatively low risk as it will provide information to the RDCK of how the cover system at the Creston landfill is performing, and steps can be taken to mitigate any issues identified. The surface emissions monitoring cost is neither high nor low, with the number of monitoring events per year dictated by the Regional District's funding and how aggressively this strategy is pursued. The emission reduction potential is low to medium and decreases with time as obvious issues will be remediated in the first few events.

Construct Deeper Landfills

This is a simple strategy that creates landfills with smaller surface areas which then minimize the surface emissions that can occur at the site. This is best done by creating deeper landfills either by lowering the bottom of the landfill or increasing the height of the crest. In addition to lowering the surface emissions, the deeper site also promotes anaerobic conditions and allows for collection of the gas (Conestega-Rovers & Associates, 2011). This strategy is possible at the RDCK landfills within the constraints of the landfill area and any limits on the height and will be considered further in this study.

This strategy is relatively low risk but requires additional planning and potentially permitting from the Ministry of Environment, as taller landfills are more visible to the public and the top crest area can become a limiting factor for operations. For the Ootischenia site, it will be difficult to go higher than planned due to the already visible nature of the landfill, and for Creston, the strategy of filling and accelerating closures prevents this strategy. This strategy has a relatively low cost as it requires changing the filling plan, and the emissions reduction potential is moderate.

Bale Waste Prior to Disposal

Instead of the traditional bulk landfilling of waste as it arrives, waste can be compacted into bales and wrapped with a low-density polyethylene before being placed in the landfill (SCS Engineers, 2008). This essentially prevents air and moisture from contacting the waste and reduces the rate of decomposition therefore reducing the emissions from the landfill. This is not a common practice, and little is known about the long-term effects of this practice. However, there does not seem to be a barrier to using this strategy, other than increased operational costs due to baling activities, at the RDCK landfill sites and therefore it is considered further in this study.

This strategy has a relatively high risk due to the unknown long-term effects of baling the waste prior to disposal, with a low to moderate cost due to the RDCK not currently having the infrastructure for this practice. This strategy has been identified as having a low to medium emission reduction potential (SCS Engineers, 2008).

Segregation of Organics in Dedicated Cells

This strategy includes the use of two separate active cells at the site, with any waste containing organics being placed in one cell, while inert waste is placed in the other. This means that landfill gas collection is only required in the organics cell, and LFG will be more concentrated than if the waste streams were combined. However, this requires a large area to manage organic waste separately – further to this, the RDCK is already looking to separate organics from the waste stream entirely through composting programs, and therefore this strategy is not applicable to the RDCK sites.

3.1.6 Alternative Covers and Systems

Intermediate cover is placed over portions of the landfill when that area will not actively be receiving waste for some time, and final cover is placed when that portion of the landfill has reached the final design elevations. These covers seek to control litter and vector access to the waste, promote runoff, and reduce infiltration from precipitation. SHA has not included strategies that are baseline regulatory requirements for the Ootischenia and Creston sites.

Use of Alternative Daily Cover

To control litter from blowing over the site and vector access during times that the landfill is closed, daily cover is applied to the landfill via a layer of soil which is typically removed before filling begins the next day. This removal will ultimately cause disturbances in the waste which may allow gas to escape, and as such the use of alternative daily cover seeks to minimize these disturbances. This can be done through a deployable tarp or the use of large steel plates placed over the waste instead of soil. As the RDCK already utilizes alternative daily cover at these sites, this strategy is not applicable for the purposes of this study.

Use of Evapotranspirative Cover

Evapotranspirative cover is typically applied to landfills undergoing final closure as the design and construction of the system is somewhat intensive and difficult to remove when waste will be placed in that area again. Further to this, as both landfills will have a landfill gas system installed during their lifespan, evapotranspirative cover does not provide the same amount of control over LFG collection as an impervious barrier layer would. Therefore, evapotranspirative cover is not applicable for the purposes of this study.

Use of Biocover

Methane oxidation through the cover materials is referred to as a biocover which typically consists of wood waste, biosolids, or compost although the design can differ depending on availability of materials. These materials oxidize the methane as it travels through the surface of the landfill therefore reducing the amount of methane emitted. This can be used as either a final or intermediate cover, but in the case of the RDCK landfills it is more appropriate to use as an intermediate cover and seek to reduce the surface methane emissions from the site before final cover is implemented. This strategy is considered applicable and will be considered further in this study.

At the Creston and Ootischenia sites, this strategy is low risk especially if local resources such as compost, biosolids, or wood chips can be sourced for this purpose. Biocover has a low to moderate cost which is dependent on the size of the area it is applied to. The GHG reduction potential is also moderate, with the material in the biocover dictating the amount of methane oxidized. Biocover systems should be designed to utilize an optimal blend of materials to maximize emission reduction potential.

Use of Solar Geomembrane

This is a rare form of alternative cover which seeks to place solar cells over the landfill which will serve a similar function as a geomembrane closure but will not require topsoil to be applied to the surface and will offset GHG reductions through the generation of ‘clean’ electricity from the solar cells. Due to it’s limited use to this point, the capital costs for this technology are likely high and operation and maintenance costs are also higher than a traditional geomembrane final cover system. However, it may be feasible for use in the RDCK and therefore will be considered further in this study.

For both sites the use of a solar geomembrane has a relatively high risk as there has not been any significant use of this material within Canada – a better approach would likely be to install solar panels (an established technology) on the closed landfill surface. The cost for this approach is high, especially for the solar geomembrane which is not readily available. The emissions offset for this strategy is limited to the reduction in emissions from the typical power generation source, which in British Columbia is hydro – an already renewable and relatively clean source of energy.

Biofilters

Biofilters perform in the same way as biocovers, but instead of being applied over the surface of the landfill, they are installed in areas where methane is encouraged to vent as the rest of the site is covered with an impermeable layer such as geomembrane or low permeability soil. Below this impermeable layer, a gravel layer is typically installed to allow the gas to move freely towards the biofilters. This technology is typically applied to smaller landfills undergoing final closure with no LFG collection in place, as any vacuum system will prevent gas from emitting through the cover.

The other application of this technology is in a containerized form, wherein the biofilter stands in place of a flare with the passive collection system connected to the container and then the gas is forced through the biofilter media which oxidizes the methane. As the Ootischenia landfill is a large site that is expected to have an active collection and flaring system and the Creston site already has a flare installed, this strategy is not applicable for the purposes of this study.

3.1.7 Other Solid Waste Strategies

Diversion of Organic Waste

The source of emissions from within a landfill is due to the organic waste deposited throughout the lifespan of the site. Therefore, diverting organics waste from the landfill will reduce the emissions from the start, by instead composting or finding an alternative use for the waste. Since the RDCK already has measures to divert organic waste this strategy is not applicable to the Ootischenia or Creston Landfills.

3.2 Evaluation of Long List of Strategies

This section evaluates the strategies that were identified as applicable to the RDCK sites and determines which strategies should be included in the detailed analysis. Following the initial description and screening of the strategies completed in Section 3.1, Table 4 below indicates the strategies to be considered for each site.

Table 4: Applicability of Strategies to Each RDCK Site

Strategy	Ootischenia	Creston
LFG Collection		
Horizontal Collectors or Surface Collectors	*	X
Increased Well Collection Density	*	X
Early Installation of LFG Collection System	X	
Mixed Horizontal and Vertical Well Systems	*	X
Connection of LCS Layer to Gas Collection System	*	
Deep Multi-Depth Vertical Wells	*	
Maximize Borehole and Well Diameters	*	
Enhance Seals on LFG Wells and Boreholes	*	X
Dewater Gas Wells	*	X
LFG Utilization		
Direct-Use	X	X
RNG Processing Plant (RNG, CNG)	X	
Electricity Production - Internal Combustion Engine		
Electricity Production - Gas Turbine		
Electricity Production - Microturbine	X	X
Combined Heat and Power	X	
LFG Systems and Operation & Maintenance		
Gas Mover Equipment and Vacuum Control	*	
Redundant Flare Station Equipment	*	X
Other LFG		
LFG Master Planning	X	**X**
Enhanced Gas Migration Monitoring	X	X
Improved Modelling and Testing for LFG Design		
Other Landfill Design and Operations		
Reducing Surface Area of Exposed Tipping Face	X	X
Bioreactor Landfill Design		
Surface Emissions Prevention	*	X
Construct Deeper Landfills	X	X
Bale Waste Prior to Disposal	X	X
Segregation of Organics in Dedicated Cells		
Alternative Covers and Systems		
Use of Alternative Daily Cover	**X**	**X**
Use of Evapotranspirative Cover		
Use of Biocover	X	X
Use of Solar Geomembrane	X	X
Biofilters		
Other Solid Waste Strategies		
Diversion of Organic Waste	**X**	**X**

*not applicable at this time as there is no LFG management system in place, but will be considered during detailed design of the system
X strategy is applicable to the site
X strategy is already implemented at the site, and further emissions reductions are unlikely

As this study is seeking to identify 3 strategies for each site, SHA scored each of the strategies according to their general risk, cost, and emission reduction potential at each site. This was based on background knowledge of the sites, understanding of the strategies, the LFG modelling, and the sources used to determine the 'long list' of strategies.

3.3 Ootischenia Strategies for Detailed Analysis

Using the descriptions above and SHA's understanding of each strategy, scores from 1 to 5 have been assigned to each approach that is applicable to the Ootischenia site according to the overall risk/feasibility, the cost, and the GHG emission reduction potential of the strategy. A low-risk strategy was assigned a score of 5, while high risk strategies were ranked as a 1, with this applied similarly to low and high cost. The GHG reduction potential score was given a 5 for those strategies with a high reduction potential, while strategies that will likely not result in significant reduction were given a score of 1.

The sum of scores from each of the three categories was then utilized to determine which strategies should be evaluated further. Table 5 shows the scoring results for the Ootischenia Landfill. As the cost of each Landfill Gas utilization option requires a somewhat detailed analysis, SHA has considered this as a more general strategy, and a detailed analysis of each type of utilization is provided later in this report.

Table 5: Scoring of Strategies Applicable to the Ootischenia Landfill

Strategy	Risk	Cost	GHG	Total
LFG Collection				
Early Installation of LFG Collection System	5	5	5	15
LFG Utilization				
Direct-Use	3	3	5	11
RNG Processing Plant (RNG, CNG)	3	3	5	11
Electricity Production - Microturbine	2	2	5	9
Combined Heat and Power	3	2	5	10
Other LFG				
LFG Master Planning	5	5	2	12
Enhanced Gas Migration Monitoring	5	3	2	10
Other Landfill Design and Operations				
Reduced Surface Area of Exposed Tipping Face	5	5	1	11
Construct Deeper Landfills	1	5	3	9
Bale Waste Prior to Disposal	1	4	2	7
Alternative Covers and Systems				
Use of Biocover	5	4	3	12
Use of Solar Geomembrane	1	1	1	3

Given the scoring above, there are three clear strategies that should be considered for reduction of GHG emissions at the Ootischenia Landfill: early installation of the LFG collection system, LFG master planning, and use of biocover to oxidize surface emissions. However, given the potential for the site to be required to have an LFG master plan prepared under the BC Landfill Gas Management Regulation and the RDCK's specific interest in LFG utilization, the strategy of LFG utilization will replace the master planning in the detailed analysis portion of this study. While the individual LFG utilization strategies are scored differently, SHA has included a detailed analysis of all 4 so that a clear understanding of the potential for LFG utilization at the Ootischenia site is given in this report.

3.4 Creston Strategies for Detailed Analysis

The same approach as the Ootischenia site was used for the strategies applicable to Creston, with Table 6 showing the scoring assigned and the overall results.

Table 6: Scoring of Strategies Applicable to the Creston Site

Strategy	Risk	Cost	GHG	Total
LFG Collection				
Horizontal Collectors or Surface Collectors	3	1	3	7
Increased Well Collection Density	1	3	3	7
Mixed Horizontal and Vertical Well Systems	1	1	3	5
Enhanced Seals on LFG Wells and Boreholes	5	5	1	11
Dewater Gas Wells	2	2	2	6
LFG Utilization				
Direct-Use	3	3	5	11
Electricity - Microturbine	2	2	5	9
Combined Heat and Power	3	2	5	10
LFG Systems Operation & Maintenance				
Redundant Flare Station Equipment	4	3	4	11
Other LFG				
Enhanced Gas Migration Monitoring	5	3	2	10
Other Landfill Design and Operations				
Reducing Surface Area of Exposed Tipping Face	5	5	1	11
Surface Emissions Prevention	3	3	2	8
Construct Deeper Landfills	2	5	3	10
Bale Waste Prior to Disposal	1	4	2	7
Alternative Covers and Systems				
Use of Biocover	5	4	3	12
Use of Solar Geomembrane	1	1	1	3

The Creston site has 5 strategies that are ranked in the top two scores, with use of biocover as an intermediate cover option to oxidize surface emissions before final closure receiving the highest score. Of the four options receiving the second highest score, SHA believes that the use of redundant flare station equipment and LFG utilization have the most potential for GHG emission reduction, and this is reflected in the score assigned to each strategy. Therefore, these two options will be considered further over the approaches of enhancing seals on LFG wells and boreholes (no vertical wells in place at the site) and reducing the size of the exposed tipping face. Similar to the detailed analysis for Ootsichenia, all three of the LFG utilization strategies have been included in the detailed analysis so that a complete understanding of the potential can be provided through this report.

4. ANALYSIS OF EMISSION REDUCTION STRATEGIES - OOTISCHENIA

This section outlines the three strategies selected for detailed evaluation in this feasibility study to reduce GHG emissions at the Ootischenia Landfill. These strategies are tailored to the landfill's current conditions and reflect it's status as an unlined facility that is regulated to implement active LFG collection in 2035. SHA has also considered that the current expected lifespan of the LFG collection system will be until 2070, with decommissioning in 2070.

4.1 Early Installation of LFG Collection System

As discussed in Section 3, constructing the LFG collection and destruction system before the regulated timeline will allow the RDCK to begin reducing emissions from the site through the additional methane that will be destroyed. This captures emissions that would otherwise be vented to the atmosphere and can provide a high level of emission reduction. As Phase 1 of the site is expected to meet final contours in the next few years it is a prime candidate for early installation of the gas collection system. In addition to the crest of Phase 1, the northern slopes of the current waste mass can have vertical wells installed to draw additional gas out of the landfill, but this should be confirmed through an LFG master plan or through detailed design of the system.

As the mandated timeline for this strategy is to have an active system installed by 2035, implementation of this strategy will likely be driven by its economic feasibility. To determine the economic feasibility of early installation it is important to also understand the costs associated with the baseline scenario as capital costs will be the same or very similar, but operating costs will need to be accounted for in the additional years of operation.

SHA conducted a detailed cashflow analysis for both the baseline scenario and the early installation to estimate the lifetime capital costs and the operating costs for each option, as well as the expected emission reduction. Expected costs were developed from the Landfill Gas Energy Cost Model, developed by the US EPA Landfill Methane Outreach Program (USEPA, 2021). The detailed analysis is presented in Appendix D, with a summary of the results shown in Table 7. It should be noted that theses costs are for high level estimation purposes only, and all funds are presented in 2026 Canadian Dollars.

Table 7: Costs and Emission Reduction for Flare Installation at the Ootischenia Landfill

Item	2030 Installation	2035 Installation
Collection and Flaring Capital Expenditures	$3,953,000	$3,953,000
Collection and Flaring Operating Expenditures	$7,524,000	$7,009,000
Baseline Emission Reduction (tonnes CO_2e)	381,000	381,000
Additional Emission Reduction (tonnes CO_2e)	69,000	0
Total Cost per Tonne of CO_2e Reduced	**$26**	**$29**

Capital costs for the LFG management system include the construction of the collection system which has been assumed to include only vertical wells on closed portions of the landfill, as well as the flaring system itself. The collection system will be installed in phases with new wells installed with each closure at 1 well per acre. As the same area will be covered by the collection system there is no difference in capital expenditures for the two options, however the operating costs are increased for the early installation option due to the additional years of operation.

Operating costs include the electricity required to have the blower draw gas out of the landfill, as well as general maintenance costs for the collection system such as well field balancing, compliance analysis and reporting and personnel / staff effort. The flare will also require regular maintenance each year which has been included in the financial analysis.

Early installation of the flare would normally have potential to be eligible for GHG credits from the provincial government, however the Province is not currently purchasing these credits and it is unknown if they will be purchasing them in the future (BC ENV, 2025). It should be noted that the provincial GHG credit program disqualifies projects in British Columbia from applying for the federal GHG offset program, which currently excludes BC, Alberta, and Quebec due to their standalone GHG emission credit programs. It is unknown currently if the Province is intending to accept applications later, which creates a barrier to the success of projects such as LFGTE and conversion of LFG to RNG. Should the projects become eligible under the federal program, there is not set price on emission offset credits but it is assumed that the benefits would be similar or better to the provincial program.

4.1.1 Strategy Risks and Mitigation Options

The risk associated with the early installation of the LFG management system is relatively low, as the landfill will need to construct this infrastructure either way. The main risk associated with this strategy is that landfilling operations may be impacted by gas wells if they are installed on the current north slope. This can be mitigated through specific management techniques such as connecting the wells to isolated headers and then burying the headers (and wells) in the waste once filling progresses to that point. This is a risk that can be effectively mitigated through the development of and LFG master plan for the site.

4.2 Use of Biocover as an Alternative Cover

Biocovers increase the organic content in intermediate cover soils through the addition of materials such as wood, biosolids, or compost to enhance the populations of methanotrophic organisms. These bacteria are responsible for oxidizing methane from landfill gas as it travels through the cover, thus converting the methane into carbon dioxide and water (SCS Engineers, 2008). Biocovers may be applied across the entire landfill or over select portions that exhibit elevated methane emissions, such as the high-emission zones identified in the surface scan completed by MethaneXE as part of this study. This study examines the use of biocover as an intermediate cover before final closure is applied the landfill.

Biocover design is site-specific and relates to both the availability and characteristics of potential cover materials. Biocovers have been successfully implemented throughout British Columbia and are typically utilized for landfills undergoing various stages of landfill closure with some areas under intermediate cover, as they are relatively inexpensive and can easily be removed if filling activities resume.

Emission-reduction benefits from biocovers are dependent on several factors, such as soil temperature, moisture content, pH, and nutrient content. Due to the varying nature of biocovers, it can be difficult to estimate its effectiveness; however, some studies have estimated that well-constructed biocovers utilizing a large volume of aged compost can oxidize up to 80% of fugitive emissions (more at smaller landfills in arid climates), while regular soil covers typically only reach 10% to 25% (SCS Engineers, 2008).

The landfill surface emissions scan undertaken by MethaneXE on behalf of SHA found that several areas of the landfill exhibit high surface emissions, with several zones exceeding the regulatory limits of 500 ppmv at a single point or 25 ppmv for the zone average. With the current average emissions estimated at 510 tonnes of CH_4 per year and an estimated oxidation rate between 40% and 80%, biocovers could reduce emissions by 200 to 400 tonnes per year. With methane's global warming potential of 28, this is equivalent to between 5,700 and 11,400 tonnes of CO_2e (Government of Canada, 2024). As stated earlier, this is highly dependent on the material used for biocover, with a constructed material likely to achieve much higher oxidation rates.

The cost of a biocover system depends widely on the availability of materials and the type of materials utilized in the biocover. At the Ootischenia Landfill, septage ponds provide a potential source of biosolids that could be incorporated into a biocover mixture when combined with woodchips, which SHA understands to be readily available on site. Under the assumption that the RDCK already owns the materials required to implement a biocover, the primary costs associated with this strategy would include mixing of the materials and application on the landfill surface. Considering RDCK's ownership of the materials, we estimate the cost of biocover application to be approximately \$15 - 20/m^2 (\$17/m^2 used). SHA considered two scenarios for the application of biocover: (1) applying biocover across the entire area assessed in the surface scan, and (2) applying biocovers only to high-emission zones. This biocover will be applied as intermediate cover until final closure is constructed, or until filling of waste reaches that area in which case the biocover materials will need to be removed before waste is filled overtop. Associated costs for both scenarios are presented in Table 8. While the biocover may be effective at oxidizing methane during the first year after application, there may be some variation throughout the years as the biocover ages. A study conducted in Denmark found that the biocover at a landfill was just as effective 7 years after installation as when it was first installed (Scheutz, Olesen, Fredenslund, & Kjeldsen, 2022). To be conservative, SHA has utilized a factor of 90% effectiveness each year of operation, with an estimated lifespan of 7 years before it is removed for final closure or continued filling. SHA's detailed calculations are provided for in Appendix D, with Table 8 providing an overview of the costs associated with the biocover and the installation of the LFG management system in 2035, and Table 9 providing an overview with LFG management system installation in 2030.

Table 8: Costs and Emission Reduction of Biocover at the Ootischenia Landfill (2035 Flare)

Item	Coverage of Entire Site	Focused Coverage
Collection and Flaring Capital Expenditures	\$3,953,000	\$3,953,000
Collection and Flaring Operating Expenditures	\$7,009,000	\$7,009,000
Biocover Capital Expenditures	\$1,273,000	\$979,000
Biocover Operating Expenditures	-	-
Baseline Emission Reduction (tonnes CO_2e)	381,000	381,000
Additional Emission Reduction (tonnes CO_2e) [1]	63,000	61,000
Total Cost per Tonne of CO_2e Reduced	**\$28**	**\$27**

[1] Reduction efficiency of 80% assumed for these calculations

Table 9: Costs and Emission Reduction of Biocover at the Ootischenia Landfill (2030 Flare)

Item	Coverage of Entire Site	Focused Coverage
Collection and Flaring Capital Expenditures	$3,953,000	$3,953,000
Collection and Flaring Operating Expenditures	$7,524,000	$7,524,000
Biocover Capital Expenditures	$1,273,000	$979,000
Biocover Operating Expenditures	-	-
Baseline Emission Reduction (tonnes CO_2e)	450,000	450,000
Additional Emission Reduction (tonnes CO_2e)[1]	41,000	39,000
Total Cost per Tonne of CO_2e Reduced	**$26**	**$25**

[1] Reduction efficiency of 80% assumed for these calculations

While the cost of implementing biocovers may appear high, the benefit of biocover material is that it can be applied as materials are available, focusing on areas that are suspected to have higher surface emissions. The costs would also be spread out over time, as it is unlikely that this large amount of material is readily available – preliminary estimates show that approximately 45,000 m^3 is needed to cover the landfill with 0.6 m of material.

Benefits of this approach include improved support for vegetative growth on landfill surfaces, some areas of which are highly visible to the public. Establishing vegetation enhances the landfill's visual appearance for visitors or residences who view the site from across the river. A further benefit is that landfill airspace is preserved, since the septage or biosolids material is placed as intermediate cover instead of monofilled within the landfill.

There is potential within this strategy to partner with the local municipality or nearby municipalities that require disposal of biosolids. In addition to local partners, the Metro Vancouver Regional District often has a surplus of materials suitable for biocover applications; while these materials may come at a higher cost due to transportation, they are typically well suited for supporting methane oxidation.

4.2.1 Strategy Risks and Mitigation Options

There are minimal risks associated with this approach, with the primary limitation being material availability. While it is understood that the RDCK has a large volume of woodchips available at its solid waste sites (landfills and transfer stations), the availability and supply of biosolids or septage is a greater unknown. This risk can be mitigated through alternative material design of biocovers, with the potential for inert fill or failed compost to be mixed with the woodchips and applied over the landfill. This may increase the cost as hauling from other sites will be required.

This strategy may be perceived to increase the risk of landfill fires at the site, however in practice it effectively reduces the risk by increasing the cover thickness (and decreasing cover porosity) – this prevents oxygen intrusion into the waste which lowers the risk of fire.

4.3 LFG Utilization

Given the descriptions in previous sections and the typical gas flows required as well as the estimated gas flows at the site, SHA has considered direct-use, processing of LFG to CNG, a microturbine, and a combined heat and power project with a microturbine for LFG utilization opportunities at the Ootischenia Landfill. For the purposes of this study, it is assumed that these would be implemented in 2035 and would operate as long as feasible or until the site is closed.

To determine costs of the project, SHA utilized information from the Landfill Gas Energy Cost Model, developed by the US EPA Landfill Methane Outreach Program (USEPA, 2021) as well as the Catalog of CHP Technologies (ICF International, 2017). All costs are presented in 2026 Canadian Dollars and are presented as high-level estimates only and should not be used for budgeting purposes. Values have been rounded to the nearest thousand. For values that were not provided in 2026 dollars, an annual inflation value of 4% has been utilized.

Each of these projects still require the construction of an LFG collection and flaring system, to both account for the collection of the LFG from the landfill but also to account for any downtime experienced by the LFGTE project. The overall costs are provided below in Table 10, with the explanation of what is included in each technology described in the following sections.

Table 10: Costs and Emission Reduction for LFG Utilization at the Ootischenia Landfill

Item	Direct-Use	CNG	Microturbine	CHP
Collection Capital Expenditures	$3,953,000	$3,953,000	$3,953,000	$3,953,000
Collection Operating Expenditures	$7,009,000	$7,009,000	$7,009,000	$7,009,000
LFG Utilization Capital Expenditures	$3,965,000	$2,554,000	$5,243,000	$5,400,000
LFG Utilization Operating Expenditures	$2,590,000	$3,825,000	$3,058,000	$3,058,000
Revenue or Financial Offset	$1,962,000	$10,150,000	$3,677,000	$5,955,000
Flare Emission Reduction (tonnes CO2e)	233,815	192,000	-	-
Other Offset Emission Reduction (tonnes CO2e)	155,412	197,550	382,300	394,568
Total Cost per Tonne of CO2e Reduced	**$40**	**$18**	**$41**	**$34**

During the detailed analysis of these technologies, SHA utilized several assumptions/factors, which are presented here in Table 11. The detailed analysis including formulas and calculations used is provided in Appendix D.

Table 11: Reference Values Utilized in Detailed Analysis

Factor/Characteristic	Value
Emission Factors	
Hydroelectricity Generation Emissions	0.0003 tonne CO_2e/kWh
Natural Gas Production Emissions	0.0501 tonne CO_2e/GJ
Diesel Production Emissions	0.0026 tonne CO_2e/L
Electricity and Diesel Costs	
FortisBC Electricity Rate	$0.13/kWh
Electricity Buyback Value (70%)	$0.09/kWh
Diesel Cost	$1.642/L
LFG and Methane Characteristics	
LFG Methane Content	50% by volume
Methane Density at STP	0.000717 tonne/m^3
Methane Global Warming Potential	28 tonne CO_2e/tonne CH_4
Lower Heating Value of Methane	0.0358 GJ/m^3
Lower Heating Value of Methane	964 Btu/ft^3
Lower Heating Value of LFG	506 Btu/ft^3

Efficiencies	
LFG to CNG Conversion Efficiency	65%
LFG Boiler Efficiency	80%
Microturbine Parasitic Loss Efficiency	83%
Methane Destruction Efficiency – Enclosed Flare	99.5%
Methane Destruction Efficiency – Boiler	98%
Methane Destruction Efficiency – Turbine	99.5%
Methane Destruction Efficiency – CNG Plant	95%
Fuel Use Rates	
Microturbine Fuel Use Rate	14,000 Btu/kWh
CNG Plant Fuel Use Rate	128,488 Btu/kWh
FortisBC Gas Rates	
Basic Charge	$4.35/day
Delivery Charge	$5.38/GJ
Storage and Transport Charge	$2.05/GJ
Cost of Gas	$1.66/GJ

4.3.1 Direct-Use of LFG

There are several direct-use cases of LFG that could be possible at the Ootischenia site, including heating of nearby (within 7 km) buildings (greenhouse or regular use) – after about 7 km, the cost of installing a direct pipeline to the site where the LFG will be utilized becomes cost prohibitive for most projects (USEPA, 2024). SHA has assumed that any pipeline installed would not cross the river via the bridges, as this would create large additional costs thus lowering the feasible radius. For the purposes of this project, SHA has utilized a 5 km distance to where the LFG is utilized, as a median distance to the opportunities identified below.

SHA has identified that within the 5 km radius of the landfill, there are a handful of businesses that may be able to use this technology or may be willing to partner with the RDCK: Selkirk College, FortisBC's Kootenay Operations Centre, or larger/industrial buildings in the vicinity of the West Kootenay Regional Airport. It is likely that these buildings currently use natural gas for their main source of heating, and a boiler that uses LFG to create heat could be implemented into their current systems.

There are several financial components associated with the direct use, including construction of the LFG pipeline, the installation of an LFG boiler or retrofitting an existing one, operating costs for the system, as well as offset costs from the avoided cost of purchased RNG. These costs were determined using the Landfill Gas Energy Cost Model, using the formulas presented in Appendix D which provides SHA's detailed cost analysis for each technology.

SHA assumed that the boiler would operate under the minimum flow conditions, as larger boilers may need a consistent flow of gas that the site would be unable to provide. Therefore, the minimum expected gas flowrate of 28 scfm during the project's lifetime was assumed to be used in the boiler, with the remainder of the collected gas being destroyed in an enclosed flare. This means that there are three ways that emissions are reduced in this strategy – through flaring (baseline condition), through utilization in the boiler, and by offsetting emissions that would otherwise occur from production of natural gas used in a boiler. This natural gas offset is also reflected in the costs, as any partner utilizing the gas would otherwise need to purchase gas for the boiler from FortisBC.

4.3.2 Processing of LFG to Compressed Natural Gas

The processing of LFG to compressed natural gas (CNG) would allow the RDCK to utilize this product within government-owned vehicles that run off of this renewable fuel, or the CNG could be sold to private users. In most examples of this strategy being used, the CNG is utilized by the local government producing it to power their waste collection or transfer vehicles, thus offsetting the cost of purchasing diesel that would otherwise be required. As fuel costs continue to rise over recent years this option can become very attractive as a lesser cost alternative, even though the vehicles are more expensive or will require retrofitting to be able to accommodate the CNG (Rogoff & Gardner, 2014).

At the Ootischenia site, SHA has assumed that the landfill gas would be treated and upgraded to CNG to be utilized in on-site vehicles or other waste collection and transfer vehicles owned by the RDCK. The CNG would be stored on site in pressurized containers, and a fueling station would allow employees to refuel vehicles as required. Locating the storage and fueling station at the Ootischenia site would assist with lowering shipping costs for the end product and provide the RDCK with a local fuel supply.

SHA has identified that there may be an opportunity for a partnership with a local collection service provider, as the RDCK does not provide local collection but contracts this service to others, or the RDCK could utilize this fuel for other vehicles they own. Should the collection or transfer contract need renewing, the RDCK could partner with service providers who can utilized CNG fueled equipment using the RDCK's fuel created from landfill gas at the Ootischenia site. Similarly, the RDCK could look to partner with the City of Castlegar for other municipality-owned vehicles or their waste collection service provider.

There are several financial components associated with this strategy, and SHA has utilized the Landfill Gas Energy Cost Model, developed by the US EPA Landfill Methane Outreach Program (USEPA, 2021) to develop the estimated costs to implement this emission reduction strategy. The RDCK is still required to design and implement a landfill gas collection system with a flare to account for downtime of the CNG system, which can be implemented as part of the greater landfill gas management system at the Ootischenia site. Capital costs for the CNG station include the conversion system as well as a fuelling station; while operating and maintenance costs are relatively standard for these systems. SHA has not included the costs of the collection vehicle fleet nor the maintenance of this fleet as these will be highly dependent on which type of vehicle is being fueled by the CNG. As described above, a large offset will be provided by the cost of the diesel that would otherwise be required with an estimated savings of around $400,000 per year that the program is operating and diesel prices remain similar to current rates.

In addition to direct financial offsets, the federal Canadian government has provided funding sources for the reduction of fuel consumption and greenhouse gas emissions through the Green Freight Program. This is provided for under two key funding streams, and the conversion of vehicles to CNG fuel falls under the first stream with provides grants for equipment assessment and retrofits. There is a maximum of $15,000 available for fleet energy assessments, and for vehicles retrofits the program will provide up to 50% per eligible device with a maximum of $250,000 available per applicant (Government of Canada, 2026).

There are three main ways that emissions are reduced through the creation of CNG from the Ootischenia Landfill – these are the destruction of methane through CNG production/use, the offset of not burning diesel, and flaring of the remaining gas not utilized in CNG production. A minimum flow rate is assumed to be used in the production of compressed natural gas at the Ootischenia Landfill so that a consistent supply can be realized, which means that not all of the landfill gas collected is utilized and the remainder will need to be destroyed through conventional flaring.

It is important to note that the amount of CNG produced is presented in units of Diesel Liter Equivalent (DLE) or Diesel Gallon Equivalent (DGE).

4.3.3 Microturbine Electricity Generation

There are several ways to generate electricity from Landfill Gas, however as described in Section 3.1.2, a microturbine is best suited for the amount of landfill gas that is expected to be collected at the Ootischenia Landfill. This technology requires advanced treatment of landfill gas so the capital expenditures are significantly higher than the direct-use and CNG production strategies, however the electricity produced by the microturbine can be either utilized on site or sold back to FortisBC. In this, there is the potential for a partnership with FortisBC to develop and implement the project at the site.

The size of the microturbine that could be used was determined by calculating the size required to utilize all of the gas projected to be recovered from the landfill. The maximum size determined to be needed over the lifespan of the project was then used for calculations, as microturbines are able to operate below their maximum capacity without significant efficiency losses.

The financial component of the strategy includes the initial investment in the microturbine installation, as well as a complete overhaul of the system every 10 years. This is based on an overhaul timeline of approximately 40,000 to 80,000 hours after which the engine is required to be remanufactured or replaced with a new one – SHA has assumed that this will cost 50% of the initial capital expenditures. In addition to the capital expenditures, regular operation and maintenance costs will need to be accounted for, which is based on the size of the microturbine as well as the amount of power produced each year. SHA's detailed financial analysis is included in Appendix D.

The emissions offset from implementation of a microturbine is derived from both the destruction of methane within the device as well as the offset from the electricity generated by the microturbine. As most of BC's power is received from hydroelectric power generation, a relatively clean form of energy, the offset provided is somewhat low.

4.3.4 Combined Heat and Power Generation

At the Ootischenia Landfill electricity generation will likely be best achieved by a microturbine, and utilizing this technology in a combined heat and power generation project will increase the feasibility of its implementation. A Combined Heat and Power (CHP) project would capture the thermal energy produced by the microturbine and use it beneficially either on site or at a nearby facility that requires this heat.

There are currently limited uses for heat at the Ootischenia site other than warming of the scale hut or other buildings on site during the winter months. This presents the opportunity for a partnership with a third party who can utilize the thermal energy in a commercial or industrial process such as greenhouses, infrared heating, or artisan studios.

SHA was unable to identify any processes adjacent to the site that may require thermal energy, so there is potential for the RDCK to partner with an entity that requires heat if they are able to construct a facility in close proximity to the landfill, as the steam or hot water produced by the process is not economically transported long distances (USEPA, 2024).

The finances of this approach are very similar to the regular microturbine strategy described in Section 4.3.3, however there are some additional capital costs associated with the heat exchangers and there is additional revenue or financial offset available for the capture heat. The revenue available from the exhaust heat recovered was determined by the cost of natural gas required to produce the same amount of thermal energy. Like the financial components, the only additional emissions offset is provided by the amount of CO_2e that would have been produced by the natural gas required to create the heat. SHA's detailed analysis of the financial and emissions implications of this strategy is provided in Appendix D.

4.3.5 Strategy Risks and Mitigation Options

The risk associated with LFGTE projects is generally higher than other strategies simply because of the increased factors that are involved with these projects. However, most of the risks are associated with the quantity and quality of gas that is being extracted from the landfill. Because LFG modelling is an estimate and the collection efficiency can vary widely from site to site based on specific conditions such as soil structure and collection well density, the amount of gas estimated to be collected is not guaranteed.

The first risk is the quality of gas – a turbine or RNG processing plant will require a minimum methane concentration in the landfill gas to operate reliably which will be especially present towards the end of the project's life. This risk can be mitigated through additional pre-treatment of the gas, but this would increase the capital costs of the project.

The second risk pertains to gas quantity – the installation of a gas-to-energy facility will be extremely costly if the quantity of gas is insufficient to support the facility. To mitigate this risk, the gas-to-energy system should be constructed after the LFG collection system is in place and operating parameters and outputs can be identified. This will also assist in spreading out the capital investments over a longer period of time.

A third risk is related to the diversion of organic waste within the region. As the RDCK seeks to limit their disposal of organics in the landfill, the volume of biodegradable material entering the landfill will decrease, lowering methane generation over time. This reduction will impact the viability of the gas-to-energy system and influence total GHG reductions available through LFG management.

Diesel and fuel costs are volatile and represent a large portion of the advantages to constructing a CNG processing plant. Should diesel prices fall the cost per tonne of CO_2e reduced will dramatically increase – if diesel prices returned to the 2024 average of $1.282/L the cost per tonne of CO_2e rises from $18 to $24 (Kalibrate Technologies, 2026). While this risk is low, it should be considered during any detailed studies that arise from this feasibility study.

5. ANALYSIS OF EMISSION REDUCTION STRATEGIES – CRESTON

This section outlines the three strategies selected for detailed evaluation in this feasibility study to reduce GHG emissions at the Creston Landfill. These strategies are tailored to the landfill's current conditions and reflect its status as a partially closed landfill with a passive LFG collection system coupled with a small candlestick flare. Strategies that are already in place at the landfill have not been considered for further analysis.

5.1 Use of Biocover as an Alternative Cover

As described in the Ootischenia strategy, biocovers can be a relatively inexpensive and simple approach to reduce emissions from the landfill site. In this situation, biocover is not used as a replacement to a flare or other LFG destruction system, but rather as a supplement to these other GHG-reducing systems. Biocover would be applied on side slopes of the active filling areas and would supplement intermediate cover as materials are available to reduce the amount of fugitive methane emissions from the site. As the Creston Landfill is designed to have smaller active areas (1 Ha) with progressive closure implemented as soon as reasonably possible, the biocover works very well as an interim solution before passive LFG collection is installed with closure.

To determine the cost of emission reduction through the use of biocover at the Creston Landfill, SHA estimated the surface emissions at the site using the ratio of emissions to estimated methane generation at the Ootischenia site. The surface emissions monitoring conducted in late 2025 at the Ootischenia site estimated that emissions range from 60% to 80% of the modelled methane generation. As the sites are somewhat similar, this ratio has been utilized for the Creston Landfill – with an estimated generation rate in 2027 of 244 tonnes of CH_4 and an open area of approximately 26% of the landfill footprint, the surface emissions at the site are estimated to be approximately 45 tonnes of CH_4 in the first year after placement. Utilizing similar assumptions as for the Ootischenia Site including the cost of biocover, this strategy presents an emissions reduction cost of $33 per tonne of CO_2e reduced.

Table 12: Lifetime Costs and Emission Reduction of Biocover at the Creston Landfill

Item	Current Open Area
Area (m^2)	10,000
Reduction in Emissions in First Year of Operation (tonne CH_4) [1]	36
Reduction in Emissions During First Year of Operation (tonne CO_2e)	1,007
Lifetime (7 Years) Reduction in Emissions (tonne CO_2e)	5,444
Estimated Biocover Cost	$170,000
Emission Reduction Cost ($/tonne CO_2e)	**$31**

[1] Reduction efficiency of 80% assumed for these calculations

5.1.1 Strategy Risks and Mitigating Options

This strategy has similar risks to those present at the Ootischenia site, with the primary risk being material availability. If there is limited material available, the biocover may need to be applied in a somewhat thinner lift thus providing less emission reduction – a relatively minor consequence as less material will also have lower costs.

5.2 LFG Utilization

At the Creston Landfill, utilization of LFG will require additional gas management infrastructure such as an active collection system to have a continuous flow of LFG for any end-use, including electricity generation. The costs of this active system have been included in the analysis, using the same principles and assumptions used for the Ootischenia site. Otherwise, this strategy utilizes the same principles as the Ootischenia Landfill site with the key difference being the flow of landfill gas at the smaller site (expected maximum of 45 scfm with 70% collection under an active system). Given this expected maximum flow, the construction of an upgrading plant to produce LNG or CNG has not been considered for Creston as these technologies typically require a minimum gas flow of 2,400 scfm or 50 scfm, respectively (USEPA, 2024).

SHA has provided our detailed analysis for LFGTE at the Creston site in Appendix E, with a summary of the costs and emission reduction benefits provided below in Table 13, and a description of the details considered under each strategy

Table 13: Costs and Emission Reduction for LFG Utilization at the Creston Landfill

Item	Direct-Use	Microturbine	CHP
Collection Capital Expenditures	\$1,258,000	\$1,258,000	\$1,258,000
Collection Operating Expenditures	\$2,688,000	\$2,688,000	\$2,688,000
LFG Utilization Capital Expenditures	\$3,955,000	\$3,130,000	\$3,236,000
LFG Utilization Operating Expenditures	\$2,275,000	\$2,037,000	\$4,665,000
Revenue or Financial Offset	\$1,192,000	\$1,761,000	\$2,881,000
Flare Emission Reduction (tonnes CO2e)	95,000		
Other Offset Emission Reduction (tonnes CO2e)	92,000	183,600	189,600
Emission Reduction Cost (\$/tonne CO_2e)	**\$48**	**\$40**	**\$47**

5.2.1 Direct-Use

Direct-use of LFG at the Creston site was assumed to be a boiler that utilizes the LFG to create thermal energy in place of a natural gas boiler. This will be most efficient if the boiler is located within 5 km of the landfill site – within this range of the Creston Landfill site, there are private homes, but also some larger facilities that may be able to make use of this technology including the Creston Airport, the Creston Golf Club, or the Yaqan Nuʔkiy School. These facilities provide potential for a partnership, or the RDCK could seek to develop (or partner to develop) a new facility in closer proximity to the site such as a greenhouse.

The most prominent financial burden for this project development is seen in the pre-treatment of LFG for the boiler as well as the pipeline required to deliver the gas to the end use location. The financial offset that can be realized comes from the value of the gas compared to purchasing natural gas from the local utility provider.

Emissions reduction from this technology are derived from the utilization of the gas and destruction of methane within the boiler, flaring of the gas not utilized, and the offset from production of the natural gas that would otherwise be required. Overall, this technology provides somewhat minimal additional emissions reduction compared to the current technology utilized at the Creston site, for a significant cost increase.

5.2.2 Electricity Generation – Microturbine

Electricity generation at the Creston Landfill was assumed to be sold back FortisBC to the grid, as the site currently utilize minimal amounts of power for daily operations. This presents limited partnership opportunities other than the local utility provider unless a facility that requires this power is developed adjacent to the site.

Microturbines are relatively inexpensive, however the operations and maintenance can be significant due to the overhaul/replacement required every 10 years of operation. The value of the electricity produce does provide some offset, but this revenue is expected to be less than the costs of operating the microturbine each year.

As the power grid in British Columbia is constructed mainly of hydroelectricity, a generally 'clean' technology, the additional emissions reduction is relatively low compared to regions where power is produced from fossil fuels. With the emissions reduction for this technology provided by the destruction of methane within the microturbine and the emissions that would otherwise be produced in the generation of the electricity, there are minimal advantages to using this technology over the current flare.

5.2.3 Combined Heat and Power – Microturbine

Taking electricity generation a step further, the Combined Heat and Power project seeks to also capture the exhaust heat created by the microturbine and beneficially utilize this thermal energy. This beneficial use would likely need a partnership as the Creston site will not provide enough demand to use all the heat produced. Potential partners would be similar to the direct-use technology, as both produce heat that can be utilized for building heat or other industrial applications.

There is some increased capital due to the heat exchangers and pipeline required, and the main increase in operating expenditures is realized in the pipeline required to bring the steam or hot water to the end use location. These pipelines are required to be heavily insulated to retain the heat produced and therefore can be quite costly – the typical maximum distance that the water can be transported is around 3 km before the energy loss in the pipe makes the project infeasible (USEPA, 2024).

5.3 Redundant Flare Station Equipment

Having redundant flare station equipment typically refers to having additional spare parts or other built-in redundancies in the LFG management system. However, SHA has also considered the installation of a redundant/secondary flare at the Creston landfill site to allow for additional gas to be destroyed through the flaring process. The current candlestick flare is limited in the amount of gas that can be passed through the device and is also somewhat limited by the pressure created by gas production within the landfill, which forces LFG through the current collection system. Installing a second passive flare would provide additional capacity for gas flow at the Creston site while not requiring the construction of an active management system.

The cost of a second flare is relatively low, with a new flare estimated at around $60,000 to install and only an additional $5,000 in annual operating costs. There are limited partnership opportunities for this strategy at the Creston landfill unless a third party can be found that is looking to acquire 'soft' carbon credits. Soft credits allow businesses to finance part of a project and then claim the reduced emissions towards being carbon neutral, but this would have not benefits with respect to the provincial carbon credit program – the Province is not purchasing GHG credits at this time and it is unknown if they will be purchased at a later date.

If this secondary flare is installed during the next progressive closure project, the current flare will continue to operate in a similar capacity while the new flare will provide additional capacity – accounting for overlap between the two collection zones, SHA estimates that this additional flare will provide an additional 60% to 75% reduction in emissions each year. To account for the decline in gas production over time, landfill closures can be connected to alternating flares to provide new gas flow each time a closure is implemented. SHA's detailed analysis of the emission reductions and costs for this approach are provided in Appendix E, with a summary provided below in Table 14. Installation of the flare provides significant additional emission reductions at a very similar cost to the current operating parameters. SHA has assumed that the secondary flare will be operational in 2028, and flares will operate until 2060 approximately 10 years after final closure of the site.

Table 14: Costs and Emission Reduction for a Second Flare at the Creston Landfill

Item	Single Flare	Double Flare
Collection and Flaring Capital Expenditures	$30,000	$90,000
Collection and Flaring Operating Expenditures	$310,000	$495,000
Baseline Emission Reduction (tonnes CO_2e)	95,000	95,000
Additional Emission Reduction (tonnes CO_2e)		80,000
Emission Reduction Cost ($/tonne CO_2e)	**$3.58**	**$3.34**

6. OOTISCHENIA LANDFILL EMISSION REDUCTION FEASIBILITY

Provided the analysis completed and described above in Section 4, SHA recommends that the RDCK complete a combination of the three strategies analyzed for emissions reduction at the Ootischenia Landfill. Early installation of the landfill gas collection system will allow the RDCK to reduce the site emissions while potentially saving on construction costs that rarely decrease over time, as well as confirm operating parameters before the site is regulated under the federal Landfill Gas Emissions Regulations. Prior to and during this implementation, biocover can be utilized in specific areas of the site to reduce surface emissions from the landfill as identified in the scan completed by MethaneXE in late 2025. Using readily available residual materials such as biosolids, chipped wood or compost will allow the RDCK a relatively inexpensive way to target high emission areas. Finally, following construction and operation of the landfill gas collection and flaring system, the implementation of a processing plant to convert LFG to CNG should be further studied as the expected flow of landfill gas from the collection system will be better understood at that time. Figure 4 indicates a high-level schedule concerning when these action items can be implemented.

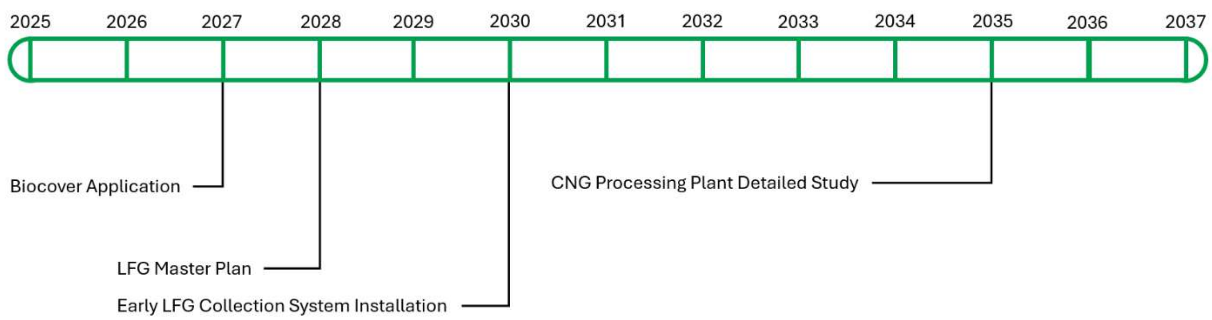

Figure 4: Recommended Implementation Schedule at the Ootischenia Landfill

This approach allows the RDCK flexibility in their emissions reduction, and a further explanation of the recommended implementation model is presented throughout this section.

6.1 Business Model

As the RDCK currently owns the Ootischenia Landfill, it is expected that any LFG infrastructure will also be owned by the RDCK, as the limited revenue potential makes external ownership unlikely. This includes both the LFG collection and destruction system, along with any biocover applied. The basis for the installation of this infrastructure will be driven by the RDCK's commitment to reducing landfill-related GHG emissions, or by regulatory requirements such as the BC LFGMR or the recently introduced ECCC federal regulations. Key components of the system would include the LFG collection wellfield, any gas headers, condensate management infrastructure, and the methane destruction system.

With ownership, the RDCK would also be responsible for operating the LFG system, unless an agreement is made with the site contractor who is currently responsible for daily landfill operations. If biocover materials are already available on site, the RDCK may choose to hire a contractor to prepare a homogenous mixture of these materials at a specific design blend rate, providing a material well-suited for biocover application.

Financing for the collection system that is installed will need to be sourced from reserve capital or borrowing. Repayment could occur through tipping fees or taxation, depending on the RDCK's solid waste budget model. There is limited potential for revenue from these installed collection systems as they will be required under regulations. However, should the CNG project move forward following the detailed study which can consider the actual collection rates.

As previously described, carbon offset credits are available to projects that remove or reduce their GHG emissions through direct, beyond business-as-usual actions (BC ENV, 2025). This means that these credits would be available for either the installation of a collection and flaring system before it is regulated or the addition of a LFGTE project that also offsets emissions from the production of electricity and heat. However, to have a monetary value the credits must be verified by a third party which comes at a cost, and the province is not currently accepting applications to sell credits to the province (BC ENV, 2025) As an indicator of the potential revenue from offset credits, the Province purchased GHG Offset Credits from the Salmon Arm Landfill in 2020 and 2021 for a price of $13/tonne, which would result in a revenue of up to approximately $150,000 per year for the Ootischenia site until it is regulated to collect and destroy LFG under the federal or provincial regulations. This revenue would be offset somewhat by the third-party verification, which is estimated to cost $30,000 to $50,000 annually and would reduce the benefits from the program. Otherwise, the RDCK could use these credits as 'soft credits' to offset GHG emissions from another source and thus work towards being carbon neutral.

It should be noted that the provincial GHG credit program disqualifies projects in British Columbia from applying for the federal GHG offset program, which currently excludes BC, Alberta, and Quebec due to their standalone GHG emission credit programs. It is unknown currently if the Province is intending to accept applications later, which creates a barrier to the success of projects such as LFGTE and conversion of LFG to RNG. Should the projects become eligible under the federal program, there is not set price on these emission offset credits but it is assumed that the benefits would be similar or better to the provincial program.

There are several grants that may be available for projects such as this:

- CleanBC Industry Fund – this fund supports adoption of innovative, clean technologies that reduce greenhouse gas emissions and stimulate investment in developing technology (Government of BC, 2026). While LFGTE projects are not new, these types of projects are generally not implemented at smaller landfills so the Ootischenia site may be eligible for a grant if explored further. Biocover projects are a somewhat emerging technology with limited documented/studied use in BC and therefore may be eligible under this grant.
    - Amounts provided are highly variable ($200K up to $25 million, but typically more is allocated to projects that reduce more GHG emissions.
- Local Government Climate Action Plan – these funds are received by regional districts in the province according to population and must be utilized for achieving community and provincial climate objectives (Government of BC, 2026). While likely not a large source of funding, this is available to the RDCK for this project.
    - Typical amount provided: $132,000/year
- Innovative Clean Energy Fund – This fund is designed to support BC's energy, economic, environmental, and greenhouse gas reduction priorities and to advance clean energy in the province (Government of BC, 2025). With waste to energy projects previously included in this

fund, this fund is a prime candidate to provide funding for an LFGTE project at the Ootischenia Landfill.

  - Typical grant amount: $500k - $1 million

- Canada Community-Building Fund – This fund provides funding to provinces and territories who in turn provide funds to communities that can make investments into 19 different project categories, including solid waste management and community energy systems (Government of Canada, 2025). With over $300 million allocated to British Columbia each year until 2029, there is opportunity for a LFGTE project to be developed and implemented under this fund.
  - The RDCK has received an average of $1.3 million from this fund each year since 2005
- While there are no open applications for unique federal funding open at the time of this report, the federal government often opens applications for funding that may include projects of this nature.

6.2 Equity Assessment

As part of this analysis, SHA conducted an equity assessment to address how local Indigenous or other equity-deserving groups may be engaged in, benefit from, or be potentially burdened by the LFG management systems proposed. The assessment also includes strategies to mitigate any potential negative impacts and addresses any potential barriers to their participation. To conduct the equity assessment, SHA first identified user groups affected by each strategy, along with potential effects of each strategy on each group.

No Indigenous or equity-deserving groups were identified as being directly impacted by any LFG projects at the Ootischenia Landfill, other than those who fall within broader affected groups.

There may be opportunities to include indigenous groups in the operational tasks of an active landfill gas management system including training, monitoring, balancing systems and associated reporting duties.

These broader groups are identified as follows:

1. **Residents of the RDCK:** Additional programs will ultimately increase taxes or tipping fees to pay for the system. These costs are unavoidable if the RDCK chooses to implement programs above and beyond those required by regulations. Cost recovery should follow regular RDCK policies to ensure that no group within the RDCK is unduly impacted. It should also be noted that public consultation was undertaken as part of the Resource Recovery Plan development, and investigation of feasible LFG management strategies was approved by the public.
2. **Nearby Residents and Landowners:** Application of biocover may result in additional construction noise as material is placed and removed. Depending on the composition of the biocover, odour management may also be required. Noise can be mitigated by ensuring that the application or removal of biocover only occurs during the daytime or operational hours to limit additional noise produced. Odour can be managed through an odour management plan prior to application of the biocover if biosolids are used in its construction, with proper planning being the optimal mitigating strategy. Typically, when blending biocover feedstocks and applying biocover material, any odors will dissipate in the short term and will not pose long term odor issues for local residents of business. In addition to an odour management plan, the RDCK is planning to acquire adjacent lands

from the province to maintain the current buffers between the landfill and nearby residences. It should be noted that biocover application would reduce LFG emission related odors.

7. CRESTON LANDFILL EMISSION REDUCTION FEASIBILITY

Following the detailed analysis of the three options for the Creston Landfill, SHA recommends that the RDCK seek to install a second flare during the next closure construction to capture additional landfill gas and utilize biocover as an intermediate cover material to reduce surface emissions at the site. This study found that landfill gas to energy projects will require significant outside funding to reduce a moderate amount of additional emissions. This limited return on investment and greater inherent risks associated with LFGTE projects make these projects economically and operationally challenging at the Creston site.

It is recommended that the RDCK pursue application of biocover on the side slopes and other open/active areas of the landfill to reduce fugitive surface emissions from the active waste footprint. Feedstocks for the biocover should be sourced from residual materials at the landfill such as wood waste, compost facility 'overs', local soils from with the landfills' operational footprint (passively creating additional airspace) and wastewater treatment plant residuals. While not considered in the detailed analysis of this study, the RDCK may also benefit from conducting a surface emissions scan at the Creston Landfill to identify areas with elevated surface emissions and prioritize these zones for biocover application.

7.1 Business Model

Similar to the Ootischenia Landfill, biocover application presents limited opportunity for revenue as septage and wood materials are already owned by the Regional District and a tipping fee is already charged for drop off of these materials. However, it could provide beneficial use of residual materials that may currently cost the RDCK funds in preparing materials for export or that consume landfill airspace, which reduce future revenue by consuming airspace that could otherwise be used to landfill waste products that carry a higher tip fee / revenue. As a result, the Creston Landfill would follow a similar business model for ownership, operations, and financing. Ownership of the site is expected to remain with the RDCK and therefore, biocover materials would likely need to be under the same ownership. This could be achieved through partnerships with nearby municipalities for acceptance of biosolids or dewatered septage or supplemented by waste wood or compost coming from existing RDCK facilities. This provides the simplest ownership model, as the absence of revenue means that third parties will likely not be interested.

Biocover application on the landfill can be completed either in-house by RDCK staff or by the landfill's operating contractor. As biocover materials must be removed before any additional waste is placed, it is operationally efficient for the landfill operations contractor to also be in charge of the biocover application and removal, coordinating with the RDCK to address priority areas and ongoing filling. Depending on the availability of materials and the desired composition of the biocover, it may be more cost-effective to hire an external contractor to mix the materials on site upon delivery. This approach minimizes additional workload for the landfill operations contractor and ensures a properly blended, homogenous mixture for the biocover.

The benefit of utilizing biocover for methane emissions control is that much of the materials would otherwise enter in the waste stream. Furthermore, the RDCK already has a large amount of these materials (especially woodchips) stockpiled at other sites and readily available for use. Financing for the mixing and installation of the biocover would be best supported through the site operations budget and there may also be opportunities for grant funding, particularly if biocovers are used as part of research or pilot studies, such as the evaluation of biocover configurations, thicknesses, or material blends to determine optimal performance. As identified previously in this report, funding may be available from the CleanBC Industry Fund or other grants listed above for this purpose.

Installation of an additional flare would take the same format as the current system, with the RDCK covering capital costs through the closure construction and then being responsible for maintenance but taking full benefit and ownership of the ‘soft credits’ provided by the methane destruction. These soft credits allow the RDCK to work towards being carbon neutral but provide no monetary value. These credits could be shared with another party who is interested in soft credits through cost sharing of the installation and maintenance costs, however additional effort may be required to find an organization interested in the soft credits.

7.2 Equity Assessment

The equity assessment for this strategy at the Creston Landfill did not identify any direct impacts of biocover application or flare installation on Indigenous or other equity-deserving groups. There is one nearby residence adjacent to the landfill property, and other land uses adjacent to the Creston Landfill site include agricultural operations and the Creston Valley Regional Airport. The same primary groups affected by the Ootischenia site will apply to the Creston Landfill; however, maintaining the buffer between nearby properties and the landfill property is less critical.

8. LIMITATIONS

Sperling Hansen Associates (SHA) have prepared this report on behalf of the Regional District of Central Kootenay (RDCK) in accordance with generally accepted engineering practices, to a level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions in British Columbia.

The report is based on site visits, project experience, and analysis of data compiled during the preparation of this report from several sources, done by SHA staff. Except where specifically stated to the contrary, the information on which this study is based has been obtained from external sources. This external information has not been independently verified or otherwise examined by SHA to determine its accuracy and completeness. SHA has relied in good faith on this information and does not accept responsibility of any deficiency, misstatements or inaccuracies contained in the reports as a result of omissions, misinterpretation and/or fraudulent acts of the persons interviewed or contacted, or errors or omissions in the reviewed documentation.

The report is intended solely for the use of the RDCK. Any use which other parties makes of this report, or any reliance on, or decisions to be made based on it, are the responsibilities of such other parties. SHA does not accept any responsibility for other uses of the material contained herein nor for damages, if any, suffered by any third party because of decisions made or actions based on this report. Copying of this intellectual property for other purposes is not permitted.

The findings and conclusions of this report are valid only as of the date of this report. The interpretations presented in this report and the conclusions and recommendations that are drawn are based on information that was made available to SHA during the course of this project. Should additional new data become available in the future, SHA should be requested to re-evaluate the findings of this report and modify the conclusions and recommendations drawn, as required.

Report Prepared by:

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APPENDICES

APPENDICES

APPENDIX A

Letter Report of MethaneXE Surface Emissions Scan of Ootischenia Landfill

Matthew Doornbos

From: Ali Abedini <ali.abedini@ch4xe.com>
Sent: December 2, 2025 11:28 AM
To: Scott Garthwaite
Cc: Mehrnoush Mohammadali; Pedram Shaygan
Subject: RDCK - Ootischenia Landfill Methane Emission Scan - Email Report

Follow Up Flag: Follow up
Flag Status: Flagged

Hello Scott,

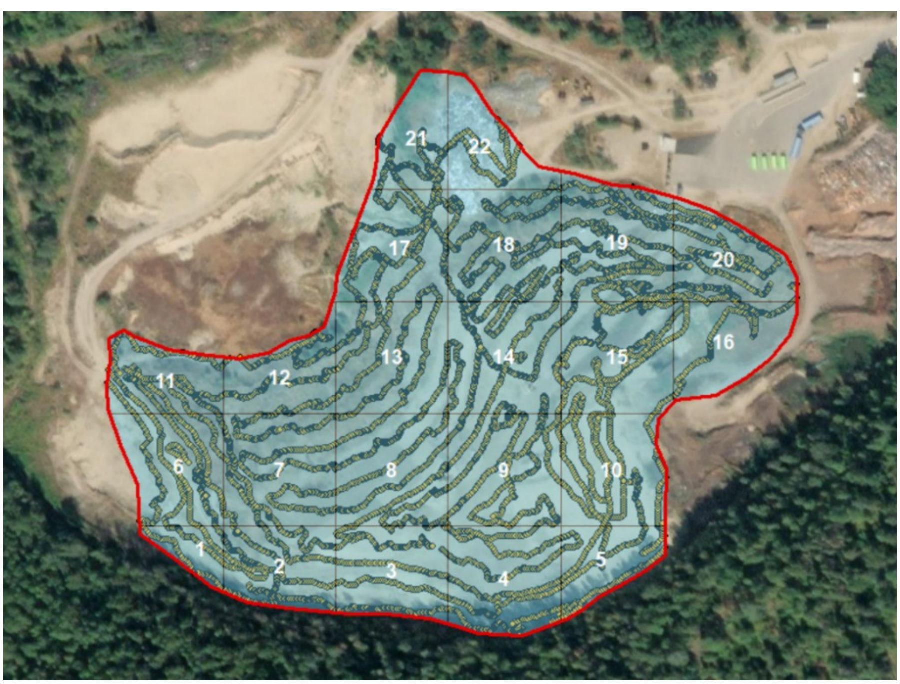
As promised, below is a concise summary of our field investigations and findings for full-scale methane emission quantification for the Ootischenia Landfill, completed in October 2025. Please feel free to RDCK folks to review after which I suggest we hold a call meeting to discuss the findings.

1. **Technical Approach**

On 16th of October 2025, MethaneXE (on behalf of Sperling Hansen Associates(SHA)) performed a comprehensive, full-scale methane emission quantification at the Ootischenia Landfill using *Surface Scan Emission Quantification Technique (SSEQT)*, a patented methodology developed by Dr. Ali Abedini of MethaneXE at the University of British Columbia (UBC). This work was completed as part of a bigger project through which SHA/MethaneXE will be developing LFG management strategies for the RDCk's selected Landfills.

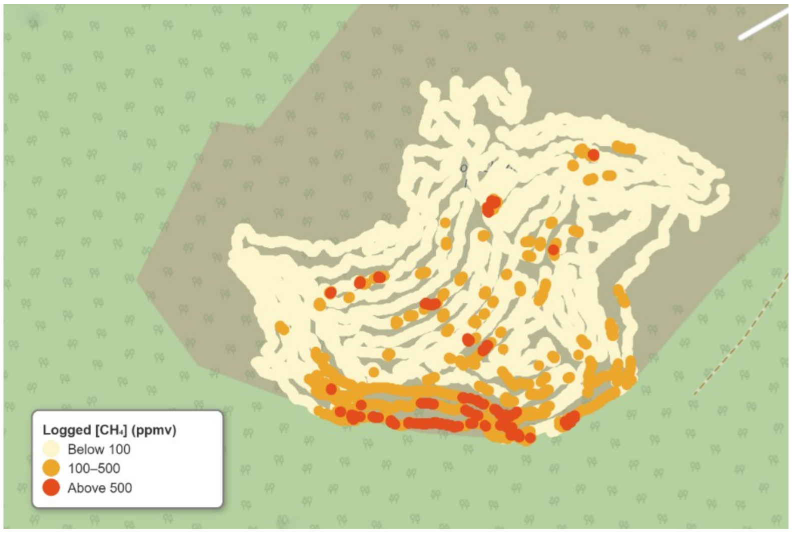
2. **Methodology (Scan Pathways and Data Points)**

In alignment with recent ECCC framework of reducing waste emissions, the waste footprint (approximately 7.5 ha) was divided into 22 measurement zones (grids), each with an approximate area of 4,500 m^2, although several zones were smaller due to the natural shape of the waste footprint. Within the pre-defined waste footprint zones, scan pathways were established along approximately 10-meter spaced traverse lines, adjusted as necessary to ensure safe access. Figure below presents the zone numbers as well as the actual scan pathways as well as the associated data points (approx. 11,400) that were collected during the field investigation.



3. Field Investigation (SSEQT) Findings

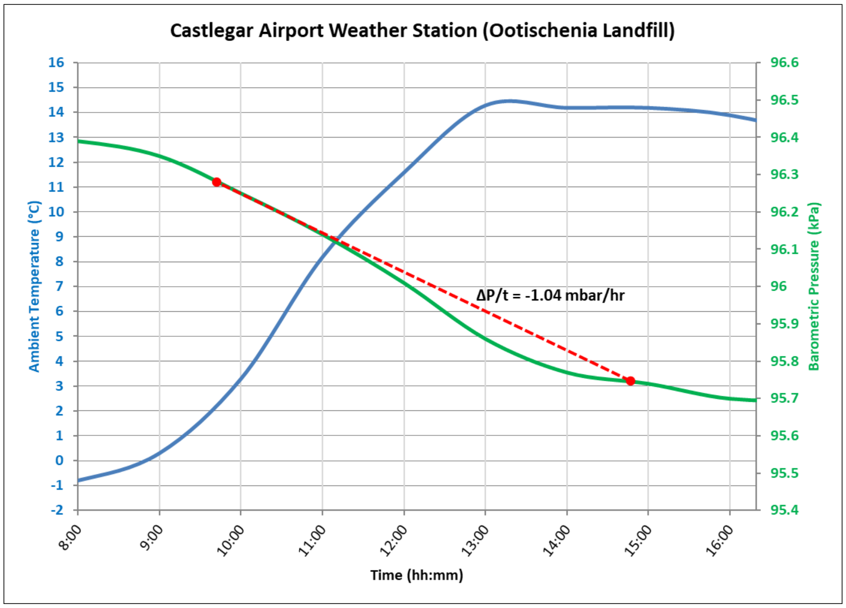
The proposed regulations by ECCC establish explicit limits for methane concentrations. The zone-average methane concentration must not exceed **25 parts per million by volume (ppmv)**, while **instantaneous concentrations** are limited to **500 ppmv.** The figure below illustrates the **spatial distribution of methane concentrations** recorded during the field survey (colour coded in three ranges of below 100ppmv, 100-500ppmv, and above 500ppmv).



The key takeaways from the raw data are summarized in the points below:

- Minimum surface concentration: ~2.1 ppmv (Near Background Concentration)
- Maximum surface concentration: ~21,540 ppmv
- Number of surface methane concentration readings below **100 ppmv: ~9,641 data points = 84.5 %**
- Number of surface methane concentration readings **100** to **500 ppmv: ~1,392 data points= 12.2%**
- Number of surface methane concentration readings above **500 ppmv: ~375 data points = 3.3%**

To account for changes in environmental barometric pressure (BP) during sampling and eliminate its impact on landfill gas atmospheric emission and gas flux intensity, the logged concentration values and the resulting methane emission rates were adjusted for the rate of change in BP values. BP was recorded in the field using MethaneXE's portable weather monitor, and the records were compared against Castlegar Airport weather station data to confirm dataset integrity. Analysis of the data (Figure below) revealed a BP decrease of approximately 1.04 mbar per hour during the field scanning day. Raw SMC data where adjusted using SSEQT algorithm.

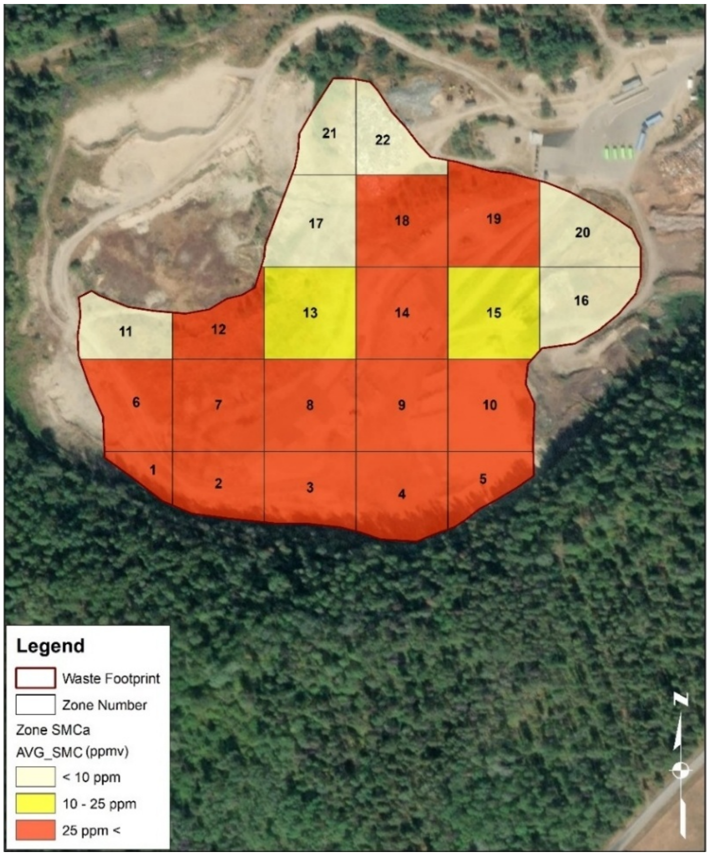


The table below presents the logged (raw) and adjusted surface methane concentration measurements (SMC and SMCa, respectively) along with correlated calculated methane emission rates (MERa) for each measurement zone.

Ootischenia LF Surface Scan Methane Emission Measurement Data Compilation and Results

Zone ID	Area	Surface Methane Conc. (SMC)			Adjusted Surface Methane Conc. (SMCa)			Methane Emission Rate (MERa)		
		MIN	MAX	AVG.	MIN	MAX	AVG.	Min.	Max	AVG.
	(m^2)	(ppmv)			(ppmv)			g/m^2/day		
1	1,052	6.6	144.7	38.6	2.2	47.4	12.6	4.2	6.6	5.4
2	2,975	14.7	1,504.4	227.1	4.8	492.9	74.4	21.9	28.5	25.2
3	3,378	4.1	1,255.0	296.9	1.3	411.2	97.3	28.5	36.6	32.5
4	3,931	7.7	2,031.8	260.8	2.5	665.7	85.5	25.1	32.4	28.7
5	2,215	3.2	3,381.7	239.8	1.0	1,108.0	78.6	23.1	30.0	26.5
6	3,541	2.8	119.8	32.0	0.9	39.3	10.5	3.6	5.9	4.7
7	4,225	4.3	625.0	55.3	1.4	204.8	18.1	5.8	8.6	7.2
8	4,225	3.0	21,540.1	727.0	1.0	7,057.6	238.2	68.8	86.5	77.6
9	4,225	4.5	2,496.7	100.4	1.5	818.0	32.9	10.0	13.8	11.9
10	3,829	4.0	458.8	49.1	1.3	150.3	16.1	5.2	7.8	6.5
11	2,589	2.4	22.3	8.0	0.8	7.3	2.6	1.4	3.1	2.2
12	2,664	2.4	2,336.5	59.5	0.8	765.6	19.5	6.2	9.0	7.6
13	4,225	2.6	337.0	21.8	0.9	110.4	7.1	2.7	4.7	3.7
14	4,225	2.8	14,325.4	127.4	0.9	4,693.7	41.7	12.6	16.9	14.7
15	4,209	2.7	419.1	19.5	0.9	137.3	6.4	2.5	4.4	3.4
16	3,126	2.3	22.0	5.5	0.8	7.2	1.8	1.2	2.8	2.0
17	3,729	2.2	30.8	3.8	0.7	10.1	1.2	1.0	2.6	1.8
18	4,225	2.3	19,220.1	287.6	0.8	6,297.5	94.2	27.6	35.5	31.5
19	4,423	2.2	649.4	28.5	0.7	212.8	9.3	3.3	5.5	4.4
20	3,124	2.1	17.8	4.2	0.7	5.8	1.4	1.0	2.6	1.8
21	2,333	2.2	3.5	2.9	0.7	1.1	1.0	0.9	2.5	1.7
22	2,438	2.4	10.9	3.0	0.8	3.6	1.0	0.9	2.5	1.7
SUM=	74,906	MIN = 2.1	MAX = 21540.1	AVG = 128.1	MIN = 0.7	MAX = 7057.6	AVG = 42	AVG = 14.8 ± 2.2		

As observed, the landfill average SMC is 128 ppm, confirming a site-wide occurrence of methane emissions. While the overall average methane emission rate is 14.8 g/m^2/day, Zone 8 MER reaches 77.6 g/m^2/day, identifying it as the most critical emission zone. Data confirms the total methane release ranged between 435 and 585 tonnes CH4/year (Average of 510 tonnes CH4/year), with Zone 8 alone contributing roughly 150 tonnes CH_4/year. Figure below presents the average SMC for each zone presented in three ranges.

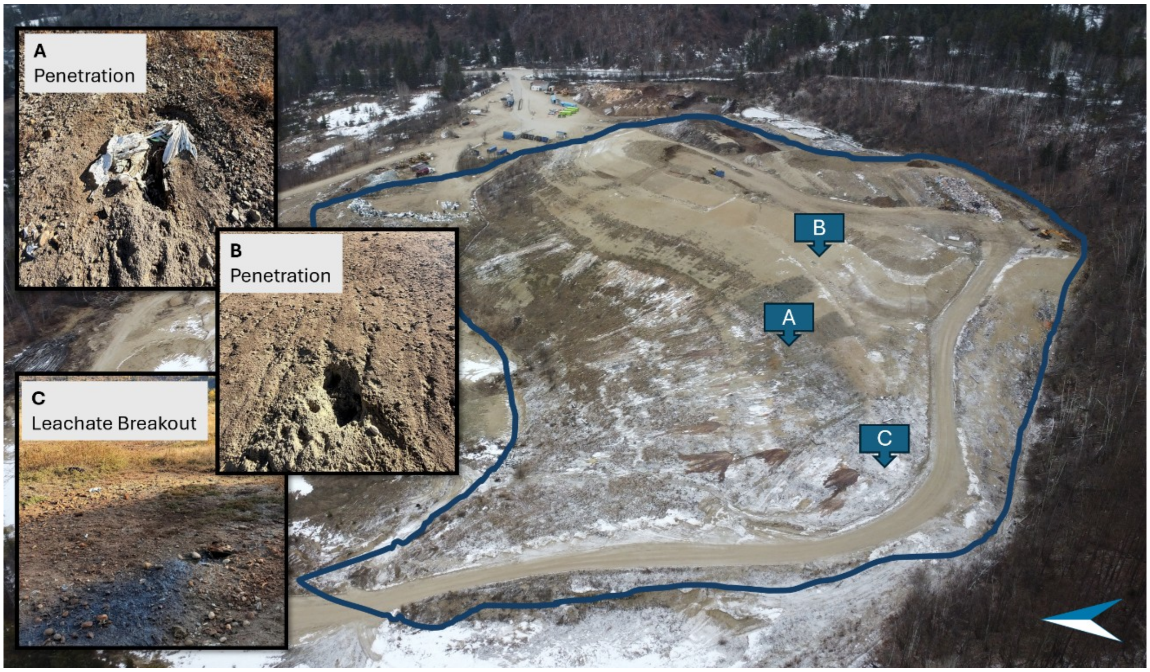


As indicated, several zones exceeded the regulatory limits of 500 ppmv at a single point or 25 ppmv for the zone average. Notably, Zones 2, 3, 4, 5, 8, 14, and 19 exhibited exceedances in both individual readings and zone-average SMC values.

4. Notable Site Visit Observations

- A pronounced cluster of elevated methane concentrations was detected along the southern slopes of the waste fill, indicating significant lateral gas migration and surface emissions in this area. Two perspectives of this area are presented in the figures below.

- Elevated methane concentrations were detected at several openings in the cover soil in the central portion of the landfill. These openings appear to have formed over time due to erosion. Such voids create pathways for air intrusion, increasing the risk of spontaneous combustion and potential landfill fires. Additionally, a leachate breakout was observed along the west slope, indicating additional potential pathways for gas scape.



5. Conclusion and Next Steps

Full-scale surface methane emission scanning at the Ootischenia Landfill confirmed several exceedances of the ECCC proposed regulatory limits, mainly along the southern slopes. Notable, zone 8 showed the highest methane emissions, indicating significant gas escape. A leachate breakout on the west slope and erosion holes in the cover are amongst major methane emission hotspots.

SHA/ MethaneXE will use these information, along with advance LFG generation modeling results to develop a realistic and practical LFG management strategy for the RDCK. We will also provide recommendations for potential mitigation strategies and correction actions to ensure alignment with the ECCC proposed regulatory limits, should the regulation become effective.

Should you have any questions about this submission and our findings, please don't hesitate to reach out.

Cheers,
Ali

Ali R. Abedini, Ph.D., P.Eng.
President & Chief Engineer
Landfill Gas Specialist

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Modernizing Landfills for ZERO EMISSION Operations ...

APPENDIX B

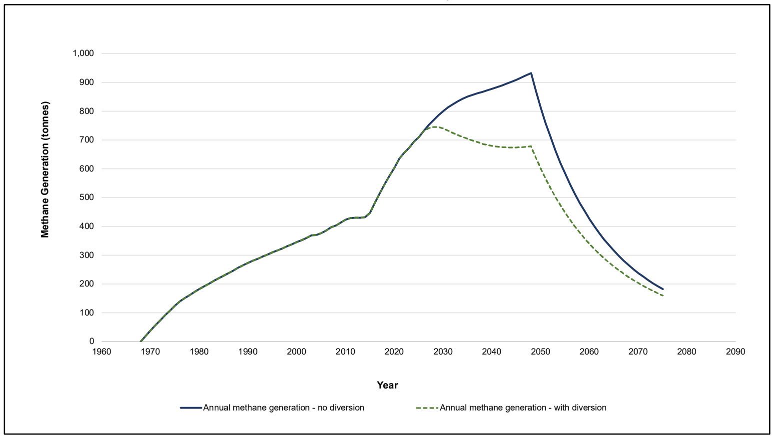
Results from draft RDCK 2026 ECCC Modelling for Ootischenia Landfill

Landfill Methane Modelling Tool: Results

Landfill Name: Ootischenia Landfill

Year opened: 1968 **Province :** BC

Closure year: 2047



User-selected and Default Model parameters

The following material parameters were used in the methane generation calculations, based on user selections and inputs:

Waste Type	Decay Rate (k) (User-selected) Average annual precipitation >500 to 1000mm	DOC (Default)	DOC_f (Default)
Food	0.09	0.15	0.7
Paper	0.04	0.4	0.5
Yard and Garden	0.09	0.2	0.7
Soiled Paper	0.09	0.4	0.5
Wood	0.02	0.43	0.1
Textiles	0.04	0.24	0.5
Pet Waste	0.09	0.24	0.5
Diapers and Sanitary	0.09	0.24	0.5
Rubber and Leather	0.02	0.39	0.1
Other - Residential	0.09	0.1	0.5
Other - ICI	0.09	0.05	0.5
Other - Unknown	0.09	0.05	0.5
Sludge	0.09	0.05	0.7
Soil	0.02	0.03	0.1

Other Parameters and Defaults		Constants	
Methane Correction Factor (MCF)	1	Molar ratio of CH_4:C	1.33
CH_4 content in LFG ($\%CH_4$)	50%	CH_4 density (at 25 °C and 1 atm) (kg/m^3)	0.656

Waste modelled	Bulk MSW
User-specified waste composition?	Yes
Diversion?	Yes

Year	Total Annual Waste Disposed	Total Waste in Place	Methane generation (no diversion)			Methane generation (with diversion)			
	tonnes/year	tonnes	tonnes/year	m^3 methane/year	scfm methane (standard cubic feet per minute)	tonnes/year	m^3 methane/year	scfm methane (standard cubic feet per minute)	% reduction
1968	5,038	5,038	0	0	0	0	0	0	0%
1969	5,141	10,179	20	29,944	6,137	20	29,944	6,137	0%
1970	5,246	15,425	39	58,749	12,042	39	58,749	12,042	0%
1971	5,353	20,778	57	86,510	17,732	57	86,510	17,732	0%
1972	5,462	26,240	74	113,316	23,226	74	113,316	23,226	0%
1973	5,574	31,814	91	139,245	28,541	91	139,245	28,541	0%
1974	5,688	37,502	108	164,379	33,692	108	164,379	33,692	0%
1975	5,804	43,306	124	188,787	38,695	124	188,787	38,695	0%
1976	5,922	49,228	139	212,531	43,562	139	212,531	43,562	0%
1977	6,043	55,271	150	229,288	46,997	150	229,288	46,997	0%
1978	6,166	61,437	161	245,534	50,326	161	245,534	50,326	0%
1979	6,292	67,729	171	261,322	53,562	171	261,322	53,562	0%
1980	6,421	74,150	182	276,703	56,715	182	276,703	56,715	0%
1981	6,552	80,702	191	291,729	59,795	191	291,729	59,795	0%
1982	6,685	87,387	201	306,439	62,810	201	306,439	62,810	0%
1983	6,822	94,209	210	320,870	65,768	210	320,870	65,768	0%
1984	6,961	101,170	220	335,066	68,677	220	335,066	68,677	0%
1985	7,103	108,273	229	349,057	71,545	229	349,057	71,545	0%
1986	7,248	115,521	238	362,878	74,378	238	362,878	74,378	0%
1987	7,396	122,917	247	376,557	77,182	247	376,557	77,182	0%
1988	7,547	130,464	256	390,124	79,963	256	390,124	79,963	0%
1989	7,701	138,165	265	403,604	82,726	265	403,604	82,726	0%
1990	7,858	146,023	274	417,022	85,476	274	417,022	85,476	0%
1991	8,018	154,041	281	427,999	87,726	281	427,999	87,726	0%
1992	8,182	162,223	288	438,891	89,958	288	438,891	89,958	0%
1993	8,349	170,572	295	449,733	92,181	295	449,733	92,181	0%
1994	8,519	179,091	302	460,548	94,397	302	460,548	94,397	0%
1995	8,693	187,784	309	471,360	96,613	309	471,360	96,613	0%
1996	8,871	196,655	316	482,195	98,834	316	482,195	98,834	0%
1997	9,052	205,707	323	493,074	101,064	323	493,074	101,064	0%
1998	9,236	214,943	331	504,015	103,307	331	504,015	103,307	0%
1999	9,425	224,368	338	515,034	105,565	338	515,034	105,565	0%
2000	9,617	233,985	345	526,153	107,844	345	526,153	107,844	0%
2001	9,814	243,799	353	537,384	110,146	353	537,384	110,146	0%
2002	10,116	253,915	360	548,747	112,475	360	548,747	112,475	0%
2003	7,500	261,415	369	562,676	115,330	369	562,676	115,330	0%
2004	9,687	271,102	369	563,147	115,427	369	563,147	115,427	0%
2005	10,453	281,555	377	573,972	117,646	377	573,972	117,646	0%
2006	11,333	292,888	385	587,652	120,449	385	587,652	120,449	0%
2007	9,972	302,860	397	604,528	123,908	397	604,528	123,908	0%
2008	11,036	313,896	403	613,724	125,793	403	613,724	125,793	0%
2009	10,923	324,819	413	630,301	129,191	413	630,301	129,191	0%
2010	10,032	334,851	423	644,911	132,186	423	644,911	132,186	0%
2011	8,779	343,630	429	653,811	134,010	429	653,811	134,010	0%
2012	8,332	351,962	430	655,629	134,382	430	655,629	134,382	0%
2013	9,205	361,167	430	654,962	134,246	430	654,962	134,246	0%
2014	12,966	374,133	432	658,636	134,999	432	658,636	134,999	0%
2015	19,882	394,015	447	680,834	139,549	447	680,834	139,549	0%
2016	19,565	413,580	483	735,997	150,855	483	735,997	150,855	0%
2017	20,274	433,854	515	785,297	160,960	515	785,297	160,960	0%
2018	20,513	454,367	546	832,759	170,688	546	832,759	170,688	0%
2019	21,308	475,675	576	877,754	179,911	576	877,754	179,911	0%
2020	22,573	498,248	605	922,030	188,986	605	922,030	188,986	0%
2021	21,592	519,840	636	969,150	198,644	636	969,150	198,644	0%
2022	21,186	541,026	655	999,212	204,806	655	999,212	204,806	0%

2023	21,645	562,670	673	1,025,391	210,171	673	1,025,391	210,171	0%
2024	21,103	583,773	693	1,056,217	216,490	693	1,056,217	216,490	0%
2025	23,011	606,784	710	1,081,895	221,753	710	1,081,895	221,753	0%
2026	22,898	629,682	731	1,114,784	228,494	731	1,114,784	228,494	0%
2027	22,664	652,346	751	1,145,570	234,804	741	1,129,878	231,588	1%
2028	22,433	674,779	770	1,173,217	240,471	745	1,135,879	232,818	3%
2029	22,204	696,983	786	1,197,971	245,545	745	1,135,376	232,715	5%
2030	21,978	718,961	800	1,220,056	250,071	741	1,129,016	231,411	7%
2031	21,754	740,715	813	1,239,682	254,094	732	1,116,242	228,793	10%
2032	21,532	762,247	825	1,257,036	257,651	724	1,104,396	226,365	12%
2033	21,312	783,559	835	1,272,294	260,779	717	1,093,372	224,105	14%
2034	21,095	804,654	843	1,285,614	263,509	710	1,083,076	221,995	16%
2035	20,880	825,534	851	1,297,150	265,873	704	1,073,425	220,017	17%
2036	20,667	846,201	857	1,307,037	267,900	698	1,064,343	218,155	19%
2037	20,456	866,657	863	1,315,400	269,614	693	1,055,759	216,396	20%
2038	20,660	887,317	867	1,322,355	271,039	687	1,047,612	214,726	21%
2039	20,867	908,184	872	1,329,947	272,595	683	1,041,028	213,377	22%
2040	21,076	929,260	878	1,338,134	274,274	680	1,035,881	212,322	23%
2041	21,286	950,546	884	1,346,878	276,066	677	1,032,055	211,537	23%
2042	21,499	972,045	890	1,356,134	277,963	675	1,029,439	211,001	24%
2043	21,714	993,759	896	1,365,875	279,960	674	1,027,940	210,694	25%
2044	21,931	1,015,690	903	1,376,070	282,049	674	1,027,468	210,597	25%
2045	22,151	1,037,841	910	1,386,689	284,226	674	1,027,942	210,694	26%
2046	22,372	1,060,213	917	1,397,713	286,485	675	1,029,290	210,971	26%
2047	22,596	1,082,809	924	1,409,112	288,822	677	1,031,442	211,412	27%
2048	23,048	1,105,857	932	1,420,869	291,232	679	1,034,339	212,006	27%
2049	23,509	1,129,366	870	1,325,893	271,765	638	972,631	199,357	27%
2050	23,979	1,153,345	812	1,238,076	253,765	600	915,218	187,590	26%
2051	24,459	1,177,804	759	1,156,839	237,114	565	861,769	176,634	26%
2052	24,948	1,202,752	710	1,081,654	221,703	533	811,980	166,429	25%
2053	25,447	1,228,198	664	1,012,035	207,434	502	765,572	156,917	24%
2054	25,956	1,254,154	622	947,539	194,214	474	722,289	148,045	24%
2055	26,475	1,280,629	582	887,756	181,961	447	681,893	139,766	23%
2056	27,004	1,307,633	546	832,314	170,597	423	644,170	132,034	23%
2057	27,544	1,335,178	512	780,870	160,053	399	608,919	124,808	22%
2058	28,095	1,363,273	481	733,108	150,263	378	575,957	118,052	21%
2059	28,657	1,391,930	452	688,741	141,169	358	545,115	111,731	21%
2060	29,230	1,421,161	425	647,502	132,717	339	516,238	105,812	20%
2061	29,815	1,450,975	400	609,150	124,856	321	489,183	100,267	20%
2062	30,411	1,481,387	376	573,460	117,540	304	463,819	95,068	19%
2063	31,019	1,512,406	354	540,228	110,729	289	440,023	90,190	19%
2064	31,640	1,544,046	334	509,265	104,383	274	417,685	85,612	18%
2065	32,273	1,576,319	315	480,399	98,466	260	396,701	81,311	17%
2066	32,918	1,609,237	297	453,470	92,946	247	376,976	77,268	17%
2067	33,576	1,642,813	281	428,333	87,794	235	358,422	73,465	16%
2068	34,248	1,677,061	266	404,852	82,981	224	340,959	69,885	16%
2069	34,933	1,711,994	251	382,906	78,483	213	324,512	66,514	15%
2070	35,632	1,747,626	238	362,379	74,276	203	309,011	63,337	15%
2071	36,344	1,783,970	225	343,167	70,338	193	294,393	60,341	14%
2072	37,071	1,821,041	213	325,175	66,650	184	280,598	57,513	14%
2073	37,813	1,858,854	202	308,313	63,194	176	267,573	54,844	13%
2074	38,569	1,897,423	192	292,501	59,953	167	255,267	52,321	13%
2075	39,340	1,936,763	182	277,662	56,912	160	243,633	49,937	12%

APPENDIX C

Results from MethaneXE UBCi Modelling for Creston Landfill

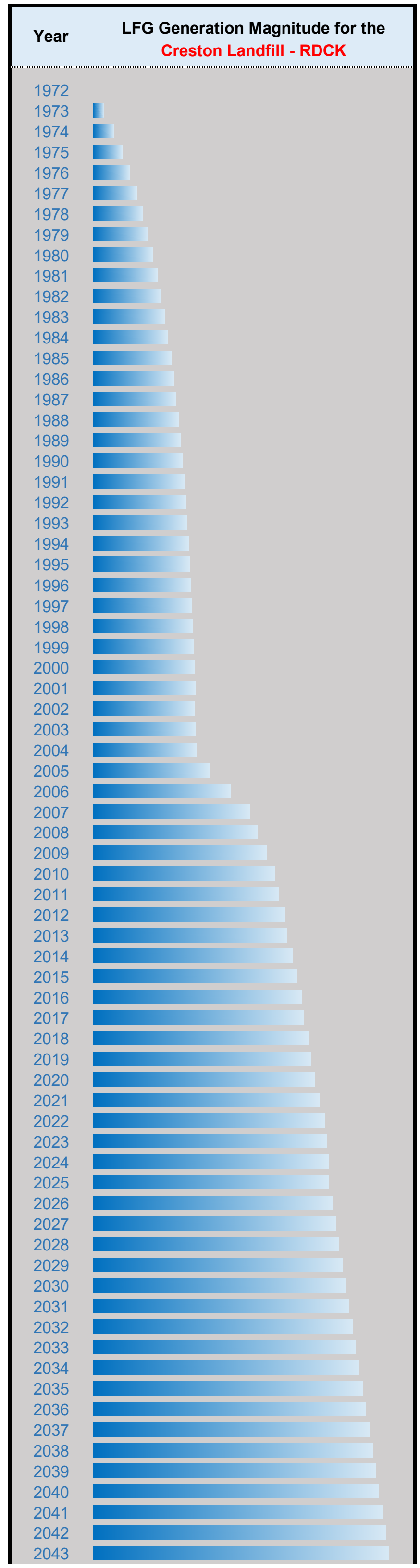
Methane Generation Estimates from the Creston Landfill - RDCK

Actual CH_4 Yields

L_o (m^3/tonne)							
	102	126	114	57	90	90	63.2

Methane generation estimates for the Creston Landfill - RDCK

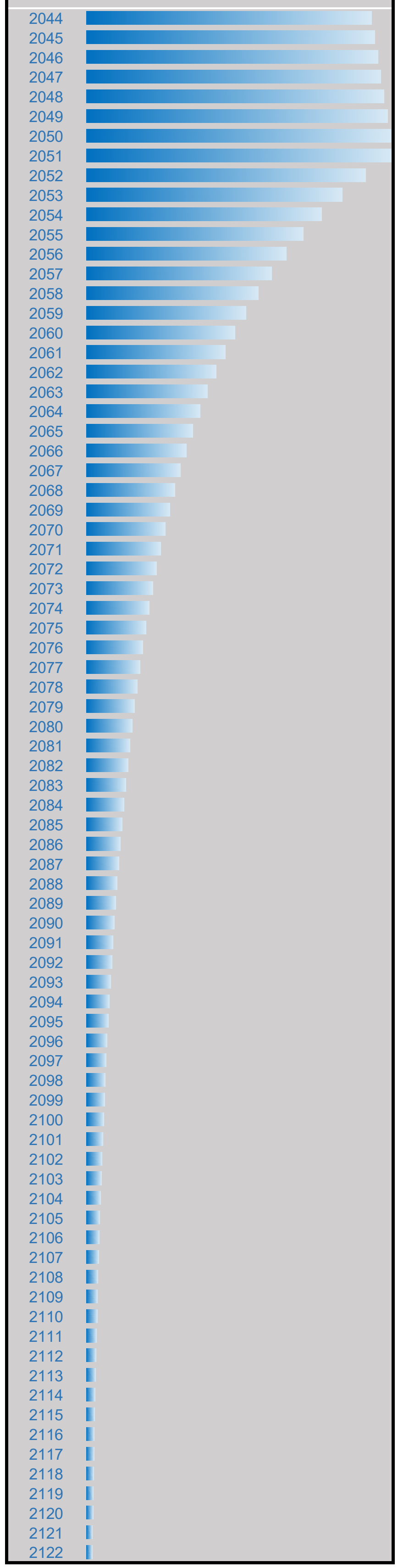
Year	Food (tonnes)	Garden (tonnes)	Paper (tonnes)	Wood (tonnes)	Textile (tonnes)	Nappies (tonnes)	Total (tonnes)	Methane Generation Potential (L_o, m^3/tonne)	Total LFG Flow Rate Estimated (scfm)
1972	1	0	0	0	0	0	1	73.7	0
1973	9	1	2	0	1	0	12	73.7	2
1974	15	1	3	1	1	0	22	73.7	4
1975	21	2	5	1	2	0	30	73.7	6
1976	26	2	6	1	2	0	38	73.7	7
1977	30	3	7	1	3	0	45	73.7	9
1978	34	3	8	2	3	0	51	73.7	10
1979	37	3	10	2	4	0	56	73.7	11
1980	40	4	11	2	4	0	61	73.7	12
1981	42	4	12	3	5	0	65	73.7	13
1982	44	4	13	3	5	0	69	73.7	14
1983	46	5	14	3	5	0	73	73.7	14
1984	48	5	15	3	6	0	76	73.7	15
1985	49	5	16	3	6	0	79	73.7	16
1986	50	5	16	4	6	0	82	73.7	16
1987	51	5	17	4	7	0	84	73.7	17
1988	52	6	18	4	7	0	86	73.7	17
1989	53	6	19	4	7	0	88	73.7	18
1990	53	6	19	4	7	0	90	73.7	18
1991	54	6	20	5	8	0	92	73.7	18
1992	54	6	20	5	8	0	93	73.7	19
1993	55	6	21	5	8	0	95	73.7	19
1994	55	6	22	5	8	0	96	73.7	19
1995	55	7	22	5	8	0	98	73.7	19
1996	55	7	23	5	9	0	99	73.7	20
1997	56	7	23	6	9	0	100	73.7	20
1998	56	7	24	6	9	0	101	73.7	20
1999	56	7	24	6	9	0	102	73.7	20
2000	56	7	24	6	9	0	103	73.7	20
2001	56	7	25	6	9	0	103	73.7	21
2002	55	7	25	6	9	0	102	73.7	20
2003	55	7	25	6	10	0	104	73.7	21
2004	56	7	26	6	10	0	105	73.7	21
2005	65	8	28	7	11	0	118	73.7	23
2006	79	9	31	8	12	0	138	73.7	27
2007	92	10	34	8	13	0	158	61.1	31
2008	94	10	37	9	15	1	166	61.1	33
2009	97	10	39	9	17	2	174	61.1	35
2010	99	10	42	10	18	3	183	61.1	36
2011	100	10	44	10	20	3	187	61.1	37
2012	101	10	46	11	21	4	193	61.1	38
2013	100	10	47	11	22	4	195	61.1	39
2014	101	10	49	12	23	5	201	61.1	40
2015	102	10	51	12	25	6	206	61.1	41
2016	102	10	53	12	26	6	210	61.1	42
2017	102	10	54	13	27	7	212	61.1	42
2018	103	10	56	13	28	7	217	61.1	43
2019	103	10	57	13	28	8	219	61.1	43
2020	103	10	58	14	29	8	223	61.1	44
2021	104	11	60	14	30	9	228	61.1	45
2022	106	11	61	14	31	9	233	61.1	46
2023	106	11	62	15	32	9	235	61.1	47
2024	105	11	63	15	33	10	237	61.1	47
2025	104	11	64	15	33	10	237	61.1	47
2026	105	11	65	16	34	10	241	61.1	48
2027	106	11	66	16	35	11	244	61.1	48
2028	107	11	67	16	36	11	248	61.1	49
2029	107	11	68	16	36	11	251	61.1	50
2030	108	11	70	17	37	12	254	61.1	50
2031	109	11	71	17	38	12	258	61.1	51
2032	110	11	72	17	38	12	261	61.1	52
2033	111	11	73	18	39	13	264	61.1	52
2034	112	11	74	18	40	13	268	61.1	53
2035	113	11	75	18	40	13	271	61.1	54
2036	114	11	76	19	41	14	274	61.1	54
2037	115	11	77	19	42	14	278	61.1	55
2038	116	11	78	19	42	14	281	61.1	56
2039	117	12	79	19	43	14	284	61.1	56
2040	118	12	80	20	44	15	288	61.1	57
2041	119	12	81	20	44	15	291	61.1	58
2042	120	12	82	20	45	15	294	61.1	58
2043	121	12	83	21	45	15	298	61.1	59



Methane generation estimates for the Creston Landfill - RDCK

Year	Food (tonnes)	Garden (tonnes)	Paper (tonnes)	Wood (tonnes)	Textile (tonnes)	Nappies (tonnes)	Total (tonnes)	Methane Generation Potential (L_o, m^3/tonne)	Total LFG Flow Rate Estimated (scfm)
2044	122	12	84	21	46	16	301	61.1	60
2045	123	12	85	21	47	16	304	61.1	60
2046	125	12	86	21	47	16	307	61.1	61
2047	126	12	87	22	48	16	311	61.1	62
2048	127	12	88	22	48	17	314	61.1	62
2049	128	12	89	22	49	17	318	61.1	63
2050	129	13	90	23	50	17	321	61.1	64
2051	129	13	90	23	50	17	322		64
2052	111	12	86	22	47	16	294		58
2053	95	11	82	21	45	16	270		54
2054	82	10	78	21	43	15	248		49
2055	71	9	74	20	41	14	229		45
2056	61	8	70	20	39	13	211		42
2057	52	8	67	19	37	13	196		39
2058	45	7	64	18	35	12	182		36
2059	39	7	60	18	33	12	169		33
2060	33	6	58	17	32	11	157		31
2061	29	6	55	17	30	11	147		29
2062	25	5	52	16	29	10	137		27
2063	21	5	50	16	27	10	128		25
2064	18	4	47	15	26	9	120		24
2065	16	4	45	15	25	9	113		22
2066	14	4	43	15	24	8	106		21
2067	12	4	41	14	22	8	100		20
2068	10	3	39	14	21	7	94		19
2069	9	3	37	13	20	7	89		18
2070	7	3	35	13	19	7	84		17
2071	6	3	33	13	18	6	79		16
2072	6	2	32	12	17	6	75		15
2073	5	2	30	12	17	6	71		14
2074	4	2	29	11	16	5	67		13
2075	4	2	27	11	15	5	64		13
2076	3	2	26	11	14	5	61		12
2077	3	2	25	10	14	5	58		11
2078	2	1	23	10	13	4	55		11
2079	2	1	22	10	12	4	52		10
2080	2	1	21	10	12	4	49		10
2081	1	1	20	9	11	4	47		9
2082	1	1	19	9	11	4	45		9
2083	1	1	18	9	10	3	43		8
2084	1	1	17	8	10	3	41		8
2085	1	1	16	8	9	3	39		8
2086	1	1	16	8	9	3	37		7
2087	1	1	15	8	8	3	35		7
2088	1	1	14	8	8	3	33		7
2089	0	1	13	7	7	3	32		6
2090	0	1	13	7	7	2	30		6
2091	0	1	12	7	7	2	29		6
2092	0	0	12	7	6	2	28		5
2093	0	0	11	6	6	2	26		5
2094	0	0	11	6	6	2	25		5
2095	0	0	10	6	6	2	24		5
2096	0	0	10	6	5	2	23		5
2097	0	0	9	6	5	2	22		4
2098	0	0	9	6	5	2	21		4
2099	0	0	8	5	5	2	20		4
2100	0	0	8	5	4	1	19		4
2101	0	0	7	5	4	1	18		4
2102	0	0	7	5	4	1	18		3
2103	0	0	7	5	4	1	17		3
2104	0	0	6	5	4	1	16		3
2105	0	0	6	5	3	1	15		3
2106	0	0	6	4	3	1	15		3
2107	0	0	5	4	3	1	14		3
2108	0	0	5	4	3	1	13		3
2109	0	0	5	4	3	1	13		3
2110	0	0	5	4	3	1	12		2
2111	0	0	4	4	2	1	12		2
2112	0	0	4	4	2	1	11		2
2113	0	0	4	4	2	1	11		2
2114	0	0	4	3	2	1	10		2
2115	0	0	4	3	2	1	10		2
2116	0	0	3	3	2	1	9		2
2117	0	0	3	3	2	1	9		2
2118	0	0	3	3	2	1	9		2
2119	0	0	3	3	2	1	8		2
2120	0	0	3	3	2	1	8		2
2121	0	0	3	3	2	1	8		2
2122	0	0	3	3	1	0	7		1

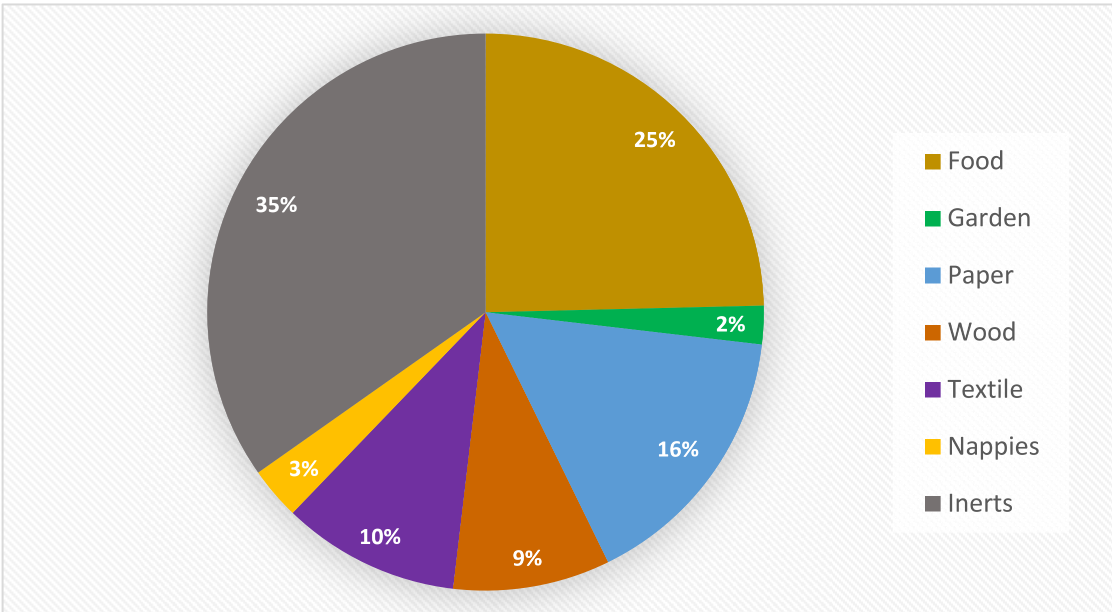
Year | LFG Generation Magnitude for the Creston Landfill - RDCK



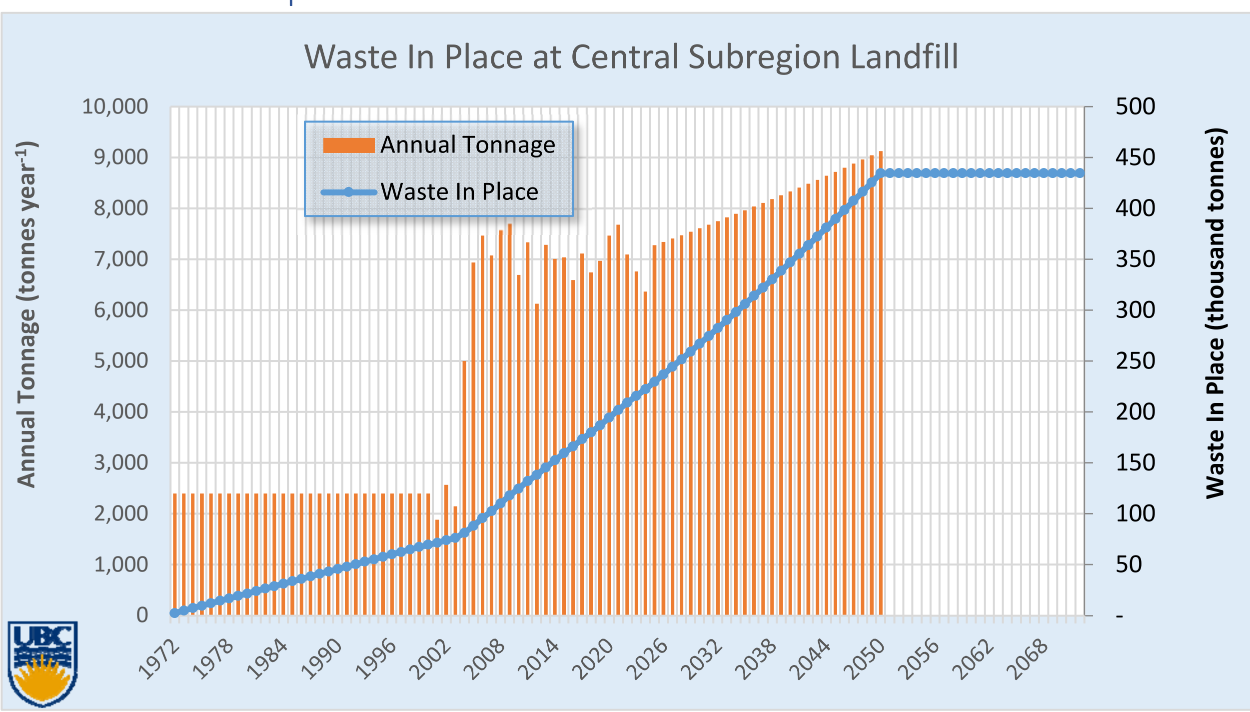
Creston Landfill - RDCK

Landfill Gas Generation Analysis **GRAPHICAL RESULTS**

Average Deposited Waste Composition

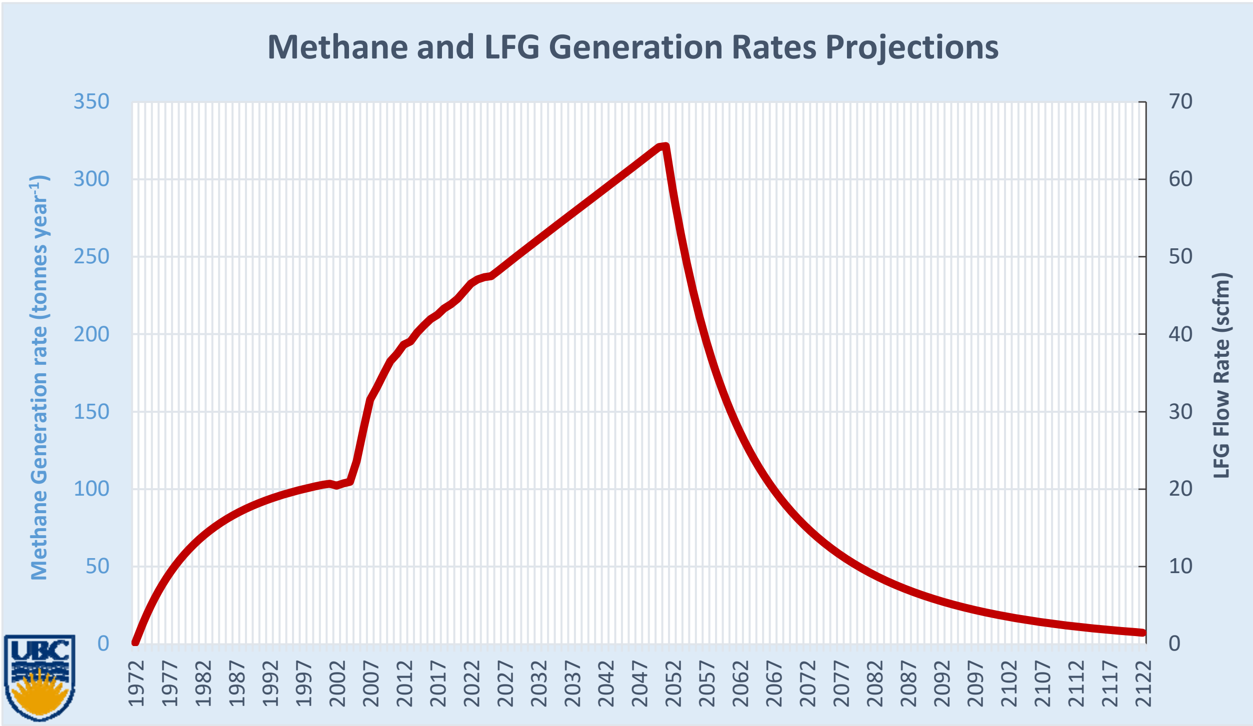


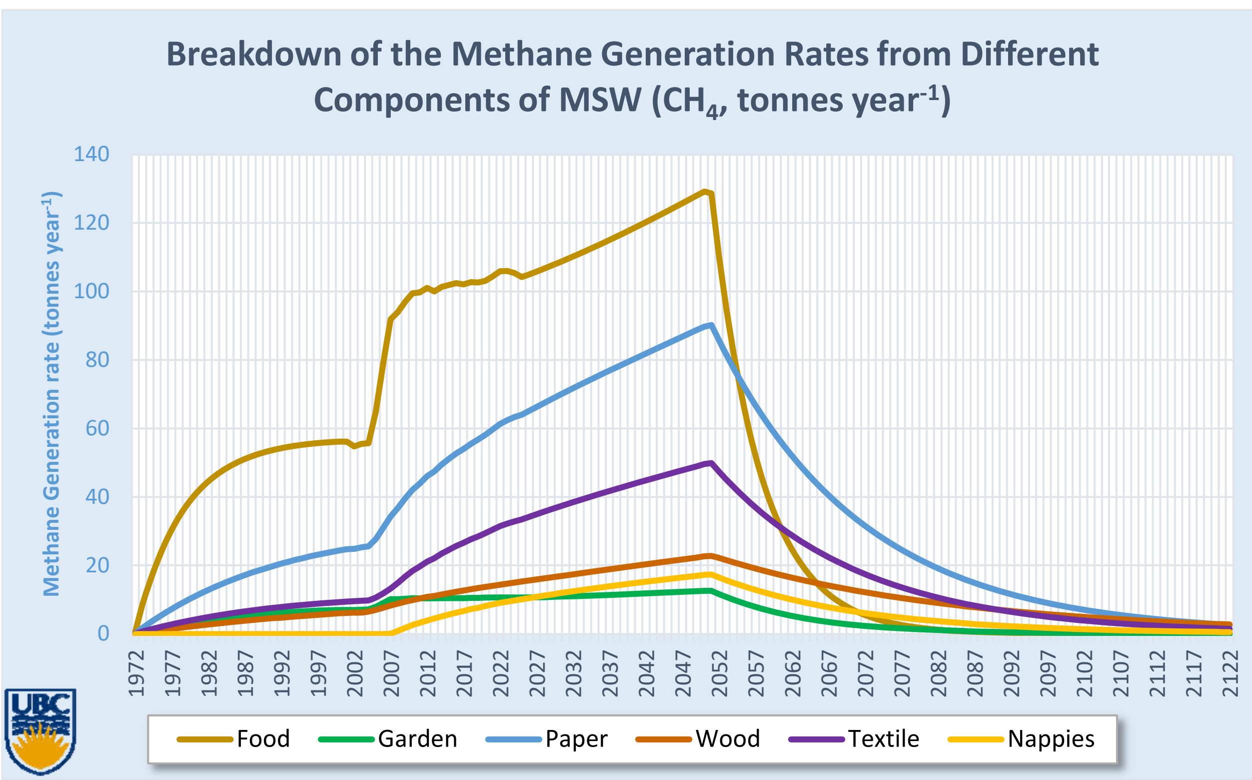
Annual MSW Deposition Rates and Total Waste In Place



Creston Landfill - RDCK

Landfill Gas Generation Analysis **GRAPHICAL RESULTS**





APPENDIX D

Detailed Analysis Tables for Ootischenia

Biocover Application - Ootischenia

Fugutive Emissions Rate		Biocover Cost	$	17.00	/m^2
Focused Area	66%				
Entire Site	68%	**Biocover Capital Cost**			
Biocover Methane Oxidation Rate	80%	Focused Coverage Area	$	979,000	
Year Over Year Biocover Effectiveness	90%	Entire Site Coverage Area	$	1,273,000	
Methane Global Warming Potential	28				

Focused Coverage Area	57,567	m2
Entire Site Coverage Area	74,906	m2

2035 Flare Installation

Year	CH_4 Generation	Fugitive Emissions (tonne CH_4)		Oxidized Emissions (Focused Area)		Oxidized Emissions (Entire Site)	
	tonnes CH_4	Focused Area	Closed Area	tonne CH_4	tonne CO_2e	tonne CH_4	tonne CO_2e
2027	751	495	510	396.0	11,088	408.0	11,424
2028	770	508	523	365.4	10,232	376.5	10,542
2029	786	518	534	335.7	9,400	345.9	9,685
2030	800	527	543	307.5	8,611	316.8	8,871
2031	813	536	552	281.3	7,875	289.8	8,114
2032	825	544	560	256.9	7,192	264.7	7,410
2033	835	550	567	234.0	6,552	241.1	6,750
Total	***5,580***	***3,678***	***3,789***	***2,177***	***61,000***	***2,243***	***63,000***

2030 Flare Installation

Year	CH_4 Generation	Fugitive Emissions (tonne CH_4)		Oxidized Emissions (Focused Area)		Oxidized Emissions (Entire Site)	
	tonnes CH_4	Focused Area	Closed Area	tonne CH_4	tonne CO_2e	tonne CH_4	tonne CO_2e
2027	751	495	510	396.0	11,088	408.0	11,424
2028	770	508	523	365.4	10,232	376.5	10,542
2029	786	518	534	335.7	9,400	345.9	9,685
2030	800	527	543	307.5	8,611	316.8	8,871
2031	813			0.0	-	0.0	-
2032	825			0.0	-	0.0	-
2033	835			0.0	-	0.0	-
Total	***5,580***	***2,048***	***2,110***	***1,405***	***39,000***	***1,447***	***41,000***

$$Open\ Area\ Fugitive\ Emissions = (CH_4 Generation) * (Fugitive\ Emissions\ Rate) * (Ratio\ of\ Open\ Area)$$

$$Oxidized\ Emissions(tonne\ CH_4) = (Open\ Area\ Fugitive\ Emissions) * (Biocover\ Methane\ Oxidation\ Rate) * (Year\ over\ Year\ Biocover\ Effectiveness)^{(Current\ Year - Biocover\ Installed\ Year)}$$

$$Oxidized\ Emissions(tonne\ CO_2e) = Oxidized\ Emissions\ (tonne\ CH_4) * Methane\ GWP$$

Collection and Flare System - 2035 Installation

Capital Expenditures			
Well installation including LFG header	$	36,000	per well
Contractor Mobilization	$	47,000	per system install
Condensate knockout, blower, and flare system	$	184,000	=x^0.61*4,600 x is the maximum scfm handled, converted from 2013 USD
Decommissioning Cost	$	161,000	=50% of CAPEX up to $100k decomissioning, then add 5% for CAPEX over that.

Operating Expenditures			
Blower Electricity Usage		0.002	kWh/ft^3
Blower Electricity Cost, Based on FortisBC Rate	$	0.00026	/ft^3
O&M for collection system	$	2,600	per well per year
O&M for flare	$	12,000	per flare per year

Data		
Minutes in a year	525,600	minutes/year
Methane Density at STP	0.000717	tonne/m^3
Methane Global Warming Potential	28	tonne CO2e/tonne
LFG Methane Content	50%	CH4 by volume
ft3 to m3 conversion	0.028	m^3/ft^3
Enclosed flare destruction efficiency	99.5%	

Year	LFG Collection		Costs			CO2e Offset	# of Wells
	scfm	ft3	CAPEX	OPEX	Total	LFG Combustion	1 per acre
Equation		*1*				*2*	
2035	96	50,367,837	$ 1,311,000	$ 103,000	$ 1,414,000	14,245	30
2036	97	50,722,957		$ 103,000	$ 103,000	14,346	30
2037	97	51,078,077	$ 1,127,000	$ 181,000	$ 1,308,000	14,446	60
2038	98	51,314,824		$ 181,000	$ 181,000	14,513	60
2039	98	51,610,757		$ 181,000	$ 181,000	14,597	60
2040	99	51,965,877		$ 182,000	$ 182,000	14,697	60
2041	100	52,320,997		$ 182,000	$ 182,000	14,798	60
2042	100	52,676,117		$ 182,000	$ 182,000	14,898	60
2043	101	53,031,237		$ 182,000	$ 182,000	14,998	60
2044	102	53,445,543		$ 182,000	$ 182,000	15,116	60
2045	102	53,859,850		$ 182,000	$ 182,000	15,233	60
2046	103	54,274,156		$ 182,000	$ 182,000	15,350	60
2047	104	54,688,463		$ 182,000	$ 182,000	15,467	60
2048	105	55,161,956		$ 182,000	$ 182,000	15,601	60
2049	98	51,492,384		$ 181,000	$ 181,000	14,563	60
2050	91	48,059,558		$ 180,000	$ 180,000	13,592	60
2051	85	44,922,666		$ 180,000	$ 180,000	12,705	60
2052	80	42,022,520		$ 179,000	$ 179,000	11,885	60
2053	75	39,299,934		$ 178,000	$ 178,000	11,115	60
2054	70	36,814,095	$ 407,000	$ 204,000	$ 611,000	10,412	70
2055	66	34,446,629		$ 203,000	$ 203,000	9,742	70
2056	61	32,315,910		$ 202,000	$ 202,000	9,140	70
2057	58	30,303,564		$ 202,000	$ 202,000	8,571	70
2058	54	28,468,778		$ 201,000	$ 201,000	8,052	70
2059	51	26,752,365		$ 201,000	$ 201,000	7,566	70
2060	48	25,154,325		$ 201,000	$ 201,000	7,114	70
2061	45	23,674,659		$ 200,000	$ 200,000	6,696	70
2062	42	22,254,180	$ 947,000	$ 265,000	$ 1,212,000	6,294	95
2063	40	20,952,073		$ 264,000	$ 264,000	5,926	95
2064	38	19,768,340		$ 264,000	$ 264,000	5,591	95
2065	35	18,643,794		$ 264,000	$ 264,000	5,273	95
2066	33	17,578,434		$ 264,000	$ 264,000	4,972	95
2067	32	16,631,448		$ 263,000	$ 263,000	4,704	95
2068	30	15,743,648		$ 263,000	$ 263,000	4,453	95
2069	28	14,855,849		$ 263,000	$ 263,000	4,202	95
2070			$ 161,000			-	
Total	**2,562**	**1,346,673,803**	**$ 3,953,000**	**$ 7,009,000**	**$ 10,801,000**	**381,000**	

#	Formula
1	$LFG\ Collected\ (ft^3) = LFG\ Collected\ (scfm) * 525{,}600\ min/yr$
2	$CO2e\ Offset = LFG\ Collected * LFG\ Methane\ Content * Methane\ Density * Methane\ GWP * Enclosed\ Flare\ Destruction\ Efficiency$

Collection and Flare System - 2030 Installation

Capital Expenditures			
Well installation including LFG header	$	36,000	per well
Contractor Mobilization	$	47,000	per system install
Condensate knockout, blower, and flare system	$	184,000	=x^0.61*4,600 x is the maximum scfm handled
Decommissioning Cost	$	161,000	=50% of CAPEX up to $100k decomissioning, then add 5% for CAPEX over that.

Operating Expenditures			
Blower Electricity Usage		0.002	kWh/ft^3
Blower Electricity Cost, Based on FortisBC Rate	$	0.00026	$/ft^3$
O&M for collection system	$	2,600	per well per year
O&M for flare	$	12,000	per flare per year

Data		
Minutes in a year	525,600	minutes/year
Methane Density at STP	0.000717	$tonne/m^3$
Methane Global Warming Potential	28	tonne CO2e/tonne
LFG Methane Content	50%	CH4 by volume
ft3 to m3 conversion	0.028	m^3/ft^3
Enclosed flare destruciton efficiency	99.5%	

Year	**LFG Collection**		**Costs**			**CO2e Offset**	**# of Wells**
	scfm	ft3	CAPEX	OPEX	Total	LFG Combustion	1 per acre
Equation		*1*				*2*	
2030	90	47,349,318	$ 1,311,000	$ 102,311	$ 1,413,311	13,391	30
2031	92	48,118,745		$ 102,511	$ 102,511	13,609	30
2032	93	48,828,985		$ 102,696	$ 102,696	13,810	30
2033	94	49,420,851		$ 102,849	$ 102,849	13,977	30
2034	95	49,894,344		$ 102,973	$ 102,973	14,111	30
2035	96	50,367,837		$ 103,096	$ 103,096	14,245	30
2036	97	50,722,957		$ 103,188	$ 103,188	14,346	30
2037	97	51,078,077	$ 1,127,000	$ 181,280	$ 1,308,280	14,446	60
2038	98	51,314,824		$ 181,342	$ 181,342	14,513	60
2039	98	51,610,757		$ 181,419	$ 181,419	14,597	60
2040	99	51,965,877		$ 181,511	$ 181,511	14,697	60
2041	100	52,320,997		$ 181,603	$ 181,603	14,798	60
2042	100	52,676,117		$ 181,696	$ 181,696	14,898	60
2043	101	53,031,237		$ 181,788	$ 181,788	14,998	60
2044	102	53,445,543		$ 181,896	$ 181,896	15,116	60
2045	102	53,859,850		$ 182,004	$ 182,004	15,233	60
2046	103	54,274,156		$ 182,111	$ 182,111	15,350	60
2047	104	54,688,463		$ 182,219	$ 182,219	15,467	60
2048	105	55,161,956		$ 182,342	$ 182,342	15,601	60
2049	98	51,492,384		$ 181,388	$ 181,388	14,563	60
2050	91	48,059,558		$ 180,495	$ 180,495	13,592	60
2051	85	44,922,666		$ 179,680	$ 179,680	12,705	60
2052	80	42,022,520		$ 178,926	$ 178,926	11,885	60
2053	75	39,299,934		$ 178,218	$ 178,218	11,115	60
2054	70	36,814,095	$ 407,000	$ 203,572	$ 610,572	10,412	70
2055	66	34,446,629		$ 202,956	$ 202,956	9,742	70
2056	61	32,315,910		$ 202,402	$ 202,402	9,140	70
2057	58	30,303,564		$ 201,879	$ 201,879	8,571	70
2058	54	28,468,778		$ 201,402	$ 201,402	8,052	70
2059	51	26,752,365		$ 200,956	$ 200,956	7,566	70
2060	48	25,154,325		$ 200,540	$ 200,540	7,114	70
2061	45	23,674,659		$ 200,155	$ 200,155	6,696	70
2062	42	22,254,180	$ 947,000	$ 264,786	$ 1,211,786	6,294	95
2063	40	20,952,073		$ 264,448	$ 264,448	5,926	95
2064	38	19,768,340		$ 264,140	$ 264,140	5,591	95
2065	35	18,643,794		$ 263,847	$ 263,847	5,273	95
2066	33	17,578,434		$ 263,570	$ 263,570	4,972	95
2067	32	16,631,448		$ 263,324	$ 263,324	4,704	95
2068	30	15,743,648		$ 263,093	$ 263,093	4,453	95
2069	28	14,855,849		$ 262,863	$ 262,863	4,202	95
2070			$ 161,000			-	
Total	**3,026**	**1,590,286,046**	**$ 3,953,000**	**$ 7,524,000**	**$ 11,316,000**	**450,000**	

#	**Formula**
1	$LFG\ Collected\ (ft^3) = LFG\ Collected\ (scfm) * 525{,}600\ min/yr$
2	$CO2e\ Offset = LFG\ Collected * LFG\ Methane\ Content * Methane\ Density * Methane\ GWP * Enclosed\ Flare\ Destruction\ Efficiency$

Direct Use of Methane On Site in Boiler

Project LFG Design Rate (minimum flow) 28 scfm

Capital Expenditures			
Skid mounted filter, compressor, and dehydration unit	$ 1,959,000	=\$360x + \$830,000	x = scfm (converted from 2013 USD)
Pipeline	$ 1,727,000	=\$80x + \$178,000	x = feet of pipeline (converted from 2013 USD)
Decomissioning Cost	$ 279,000	=50% of CAPEX up to \$100k decomissioning, then add 5% for CAPEX over that.	
Operating Expenditures			
Electricity Usage for Pipelines less than 5 miles	0.002	kWh/ft3	
Annual Pipeline OPEX (excluding electricity)	$ 70,000	$=\$57,000 * (x/700)^{0.2}$	x = scfm (converted from 2013 USD)

Data		
Minutes in a year	525600	min/yr
FortisBC commercial electricity rate	$ 0.13	/kWh
LFG Methane Content	50%	by volume
Lower Heating Value of methane	0.0358	GJ/m^3
Methane density at STP	0.000717	$tonne/m^3$
Methane Global Warming Potential	28	tonne CO_2e/tonne CH_4
LFG Boiler Efficiency	80%	
Enclosed flare methane destruction efficiency	99.5%	
Boiler methane destruction efficiency	98.0%	
RNG production emissions	0.050149	tonne CO2e/GJ

FortisBC Commercial Gas Prices	
Basic Charge per Day	$ 4.35
Delivery Charge per GJ	$ 5.38
Storage and Transport Charge per GJ	$ 2.05
Cost of Gas per GJ	$ 1.66

Year	LFG Collection		LFG Utilized		CH4 Utilized		Costs				CO2e Offset/Reduction			Financial Offset
	scfm	ft3	scfm	ft3	m3	GJ	CAPEX	OPEX	Electricity Usage	Total	Flaring	Utilization	RNG Production	RNG Offset
Equation		*1*	*2*	*3*	*4*	*5*					*6*	*7*	*8*	*9*
2035	96	50,367,837	28	14,855,849	210,335	6,024	$ 3,686,000	$ 70,000	$ 4,000	$ 3,760,000	10,044	4,138	302	$ 56,000
2036	97	50,722,957	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	10,144	4,138	302	$ 56,000
2037	97	51,078,077	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	10,244	4,138	302	$ 56,000
2038	98	51,314,824	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	10,311	4,138	302	$ 56,000
2039	98	51,610,757	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	10,395	4,138	302	$ 56,000
2040	99	51,965,877	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	10,496	4,138	302	$ 56,000
2041	100	52,320,997	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	10,596	4,138	302	$ 56,000
2042	100	52,676,117	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	10,696	4,138	302	$ 56,000
2043	101	53,031,237	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	10,797	4,138	302	$ 56,000
2044	102	53,445,543	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	10,914	4,138	302	$ 56,000
2045	102	53,859,850	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	11,031	4,138	302	$ 56,000
2046	103	54,274,156	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	11,148	4,138	302	$ 56,000
2047	104	54,688,463	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	11,266	4,138	302	$ 56,000
2048	105	55,161,956	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	11,400	4,138	302	$ 56,000
2049	98	51,492,384	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	10,362	4,138	302	$ 56,000
2050	91	48,059,558	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	9,391	4,138	302	$ 56,000
2051	85	44,922,666	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	8,504	4,138	302	$ 56,000
2052	80	42,022,520	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	7,683	4,138	302	$ 56,000
2053	75	39,299,934	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	6,913	4,138	302	$ 56,000
2054	70	36,814,095	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	6,210	4,138	302	$ 56,000
2055	66	34,446,629	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	5,541	4,138	302	$ 56,000
2056	61	32,315,910	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	4,938	4,138	302	$ 56,000
2057	58	30,303,564	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	4,369	4,138	302	$ 56,000
2058	54	28,468,778	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	3,850	4,138	302	$ 56,000
2059	51	26,752,365	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	3,365	4,138	302	$ 56,000
2060	48	25,154,325	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	2,913	4,138	302	$ 56,000
2061	45	23,674,659	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	2,494	4,138	302	$ 56,000
2062	42	22,254,180	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	2,092	4,138	302	$ 56,000
2063	40	20,952,073	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	1,724	4,138	302	$ 56,000
2064	38	19,768,340	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	1,389	4,138	302	$ 56,000
2065	35	18,643,794	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	1,071	4,138	302	$ 56,000
2066	33	17,578,434	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	770	4,138	302	$ 56,000
2067	32	16,631,448	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	502	4,138	302	$ 56,000
2068	30	15,743,648	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	251	4,138	302	$ 56,000
2069	28	14,855,849	28	14,855,849	210,335	6,024		$ 70,000	$ 4,000	$ 74,000	-	4,138	302	$ 56,000
2070					-	-	$ 279,000			$ 279,000	-	-	-	$ 2,000
Total						**210,840**	**$ 3,965,000**	**$ 2,450,000**	**$ 140,000**	**$ 6,555,000**	**233,815**	**144,838**	**10,573**	**$ 1,962,000**

#	Equation
1	$LFG\ Collected\ (ft^3) = LFG\ Collected\ (scfm) * 525{,}600\ min/yr$
2	$LFG\ Utilized\ (scfm) = minimum(LFG\ collected\ (scfm))$
3	$LFG\ Utilized\ (ft^3) = LFG\ Utilized\ (scfm) * 525{,}600\ min/yr$
4	$CH_4\ Utilized\ (m^3) = LFG\ Utilized\ (ft^3) * LFG\ Methane\ Content * (0.0283\frac{m^3}{ft^3})$
5	$CH4\ Utilized\ (GJ) = CH4\ Utilized\ (m^3) * LFG\ Boiler\ Efficiency * Lower\ Heating\ Value\ of\ Methane$
6	$Flaring\ Offset = (LFG\ Collected - LFG\ Utilized) * LFG\ Methane\ Content * \left(0.0283\frac{m^3}{ft^3}\right) * Methane\ Density * Methane\ GWP * Flare\ Destruction\ Efficiency$
7	$Utilization\ Offset = Methane\ Utilized * Methane\ Density * Methane\ GWP * Boiler\ Destruction\ Efficiency$
8	$RNG\ Production\ Offset = Methane\ Utilized * RNG\ Production\ Emissions$
9	$RNG\ Financial\ Offset = (FortisBC\ Basic\ Charge * 365) + Methane\ Utilized * (Delivery\ Charge + Storage\ and\ Transport\ Charge + Cost\ of\ Gas)$

Upgrading LFG to Compressed Natural Gas

Project LFG Design Flow Rate (minimum) 51 scfm

Capital Expenditures		
Onsite CNG conversion and fueling station equipment	$ 2,341,000	=$95,000($x^{0.6}$) x = scfm, converted from 2013 USD
Decomissioning Cost	$ 213,000	=50% of CAPEX up to $100k decomissioning, then add 5% for CAPEX over that.

Operating Expenditures		
Media and equipment replacement and parasitic load	$ 2.33	per diesel gallon equivalent, converted from 2013 USD

LFG to CNG Conversion Efficiency	65%	
LFG Methane Content	50%	
Lower Heating Value of Methane	964	Btu/ft3
CNG Station Fuel Use Rate	128,488	Btu/DGE
Gallon to Litre Conversion	0.264	gal/L
CNG Production Rate	**0.009**	**DLE/ft^3 LFG**
CNG Plant Methane Destruction Efficiency	95%	

Diesel Cost	$ 1.64	$/L
Diesel Use Emissions	0.002681	tonne CO2e/L
Flaring Destruction Efficiency	99.5%	
Methane Density	0.000717	tonne/m3
Methane GWP	28	tonne CO2e/tonne CH4
Landfill Gas Methane Content	50%	

Year	LFG Collection		LFG Utilized		CNG Production		Costs			CO2e Offset		
	scfm	ft3	scfm	ft3 LFG	DLE	Diesel Equivalent Cost	CAPEX	OPEX	Total	CNG Production	Diesel Usage	Flaring of Remainder
Equation		*1*	*2*	*3*	*4*	*5*				*6*	*7*	*8*
2035	96	50,367,837	51	26,752,365	246,930	$ 406,000	$ 2,341,000	$ 153,000	$ 2,494,000	7,224	662	6,679
2036	97	50,722,957	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	6,779
2037	97	51,078,077	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	6,880
2038	98	51,314,824	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	6,947
2039	98	51,610,757	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	7,031
2040	99	51,965,877	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	7,131
2041	100	52,320,997	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	7,231
2042	100	52,676,117	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	7,332
2043	101	53,031,237	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	7,432
2044	102	53,445,543	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	7,549
2045	102	53,859,850	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	7,667
2046	103	54,274,156	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	7,784
2047	104	54,688,463	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	7,901
2048	105	55,161,956	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	8,035
2049	98	51,492,384	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	6,997
2050	91	48,059,558	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	6,026
2051	85	44,922,666	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	5,139
2052	80	42,022,520	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	4,319
2053	75	39,299,934	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	3,549
2054	70	36,814,095	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	2,846
2055	66	34,446,629	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	2,176
2056	61	32,315,910	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	1,574
2057	58	30,303,564	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	1,004
2058	54	28,468,778	51	26,752,365	246,930	$ 406,000		$ 153,000	$ 153,000	7,224	662	485
2059	51	26,752,365	51	26,752,365	246,930	$ 406,000	$ 213,000	$ 153,000	$ 366,000	7,224	662	-
2060	48	25,154,325							$ -	-	-	7,114
2061	45	23,674,659							$ -	-	-	6,696
2062	42	22,254,180							$ -	-	-	6,294
2063	40	20,952,073							$ -	-	-	5,926
2064	38	19,768,340							$ -	-	-	5,591
2065	35	18,643,794							$ -	-	-	5,273
2066	33	17,578,434							$ -	-	-	4,972
2067	32	16,631,448							$ -	-	-	4,704
2068	30	15,743,648							$ -	-	-	4,453
2069	28	14,855,849							$ -	-	-	4,202
2070									$ -	-	-	-
Total	**2,562**	**1,346,673,803**				**$ 10,150,000**	**$ 2,554,000**	**$ 3,825,000**	**$ 6,379,000**	**181,000**	**16,550**	**192,000**

#	Equation
1	$LFG\ Collected\ (ft^3) = LFG\ Collected\ (scfm) * 525{,}600\ min/yr$
2	$LFG\ Utilized\ (scfm) = minimum(LFG\ collected\ (scfm))$
3	$LFG\ Utilized\ (ft^3) = LFG\ Utilized\ (scfm) * 525{,}600\ min/yr$
4	$CNG\ Production\ (DLE) = (LFG\ Utilized\ (ft^3)) * (CNG\ Production\ Rate)$
5	$Diesel\ Equivalent\ Cost = CNG\ Production\ (DLE) * Deisel\ Cost$
6	$CO_2e\ Offset\ (CNG\ Production) = (LFG\ Utilized) * (LFG\ Methane\ Content) * (Methane\ Density) * (Methane\ GWP) * (CNG\ Plant\ Methane\ Destruction\ Efficiency)$
7	$CO_2e\ Offset\ (Diesel\ Usage) = (Annual\ Gas\ Utilized) * (LFG\ Methane\ Content) * (Methane\ Heat\ Content\ ) * (Conversion\ Efficiency\ of\ LFG\ to\ CNG) * (CO_2e\ Emissions\ from\ Diesel\ Combustion)$
8	$CO_2e\ Offset\ (Flaring) = (LFG\ Utilized - LFG\ Collected) * (LFG\ Methane\ Content) * (Methane\ Density) * (Methane\ GWP) * (Enclosed\ Flare\ Methane\ Destruction\ Efficiency)$
9	$CNG\ Production\ Rate\left(\frac{DLE}{ft^3 LFG}\right) = \frac{(LFG\ to\ CNG\ Conversion\ Efficiency) * (LFG\ Methane\ Content) * (Methane\ Heat\ Content)}{(CNG\ Station\ Fuel\ Use\ Rate) * \left(0.264\frac{gallon}{litre}\right)}$

Electricity Generation - Microturbine

Microturbine Size (maximum) 284 kW

Capital Expenditures			
Gas compression/treatment, microturbine/generator, site work, housings, and electrical interconnect equipment			
	$	2,019,000	=$19,278*(x^0.6207) x is kW capacity, converted from 2006 USD
10-year overhaul cost	$	1,009,500	=50% of Installation CAPEX
Decomissioning cost	$	195,950	=50% of CAPEX up to $100k decomissioning, then add 5% for CAPEX over that.

Operating Expenditures			
O&M of compression/treatment and microturbine (excluding energy)			
	$	0.06	=0.0948 - 0.008ln(x) $/kWh, x is kW capacity, converted from 2006 USD

Data		
Minutes in a year	525,600	minutes/year
Microturbine Operating Hours	7,008	hours/year
Fuel Use Rate	14,000	Btu/kWh generated
LFG Lower Heating Value	506	Btu/ft^3
Parasitic Loss Efficiency	83%	
Electricity Buyback Value	$ 0.09	$/kWh
Hydroelectric Emissions Offset	0.00003	tonne CO2e/kWh
Methane Density (at STP)	0.000717	tonne/m^3
Methane Global Warming Potential	28	tonne CO2e/tonne
LFG Methane Content	50%	CH4 by volume
Microturbine methane destruction efficiency	99.5%	

Year	LFG Collection		Electricity Generation			Costs			CO2e Offset	
	scfm	ft3	Potential (kWh)	Capacity (kW)	Buyback Value	CAPEX	OPEX	Total	LFG Combustion	Electricity Generation
Equation		1	2	3	4				5	6
2035	96	50,367,837	1,510,963	260	$ 137,498	$ 2,019,000	$ 114,386	$ 2,133,386	14,245	45
2036	97	50,722,957	1,521,616	262	$ 138,467		$ 115,193	$ 115,193	14,346	46
2037	97	51,078,077	1,532,269	263	$ 139,437		$ 115,999	$ 115,999	14,446	46
2038	98	51,314,824	1,539,371	265	$ 140,083		$ 116,537	$ 116,537	14,513	46
2039	98	51,610,757	1,548,249	266	$ 140,891		$ 117,209	$ 117,209	14,597	46
2040	99	51,965,877	1,558,902	268	$ 141,860		$ 118,015	$ 118,015	14,697	47
2041	100	52,320,997	1,569,555	270	$ 142,830		$ 118,822	$ 118,822	14,798	47
2042	100	52,676,117	1,580,208	272	$ 143,799		$ 119,628	$ 119,628	14,898	47
2043	101	53,031,237	1,590,861	274	$ 144,768		$ 120,435	$ 120,435	14,998	48
2044	102	53,445,543	1,603,290	276	$ 145,899		$ 121,376	$ 121,376	15,116	48
2045	102	53,859,850	1,615,719	278	$ 147,030	$ 1,009,500	$ 122,316	$ 1,131,816	15,233	48
2046	103	54,274,156	1,628,147	280	$ 148,161		$ 123,257	$ 123,257	15,350	49
2047	104	54,688,463	1,640,576	282	$ 149,292		$ 124,198	$ 124,198	15,467	49
2048	105	55,161,956	1,654,780	284	$ 150,585		$ 125,274	$ 125,274	15,601	50
2049	98	51,492,384	1,544,698	266	$ 140,568		$ 116,940	$ 116,940	14,563	46
2050	91	48,059,558	1,441,718	248	$ 131,196		$ 109,144	$ 109,144	13,592	43
2051	85	44,922,666	1,347,616	232	$ 122,633		$ 102,020	$ 102,020	12,705	40
2052	80	42,022,520	1,260,616	217	$ 114,716		$ 95,434	$ 95,434	11,885	38
2053	75	39,299,934	1,178,942	203	$ 107,284		$ 89,251	$ 89,251	11,115	35
2054	70	36,814,095	1,104,370	190	$ 100,498		$ 83,605	$ 83,605	10,412	33
2055	66	34,446,629	1,033,350	178	$ 94,035	$ 1,009,500	$ 78,229	$ 1,087,729	9,742	31
2056	61	32,315,910	969,431	167	$ 88,218		$ 73,390	$ 73,390	9,140	29
2057	58	30,303,564	909,064	156	$ 82,725		$ 68,820	$ 68,820	8,571	27
2058	54	28,468,778	854,023	147	$ 77,716		$ 64,653	$ 64,653	8,052	26
2059	51	26,752,365	802,533	138	$ 73,030		$ 60,755	$ 60,755	7,566	24
2060	48	25,154,325	754,594	130	$ 68,668		$ 57,126	$ 57,126	7,114	23
2061	45	23,674,659	710,206	122	$ 64,629		$ 53,765	$ 53,765	6,696	21
2062	42	22,254,180	667,594	115	$ 60,751		$ 50,540	$ 50,540	6,294	20
2063	40	20,952,073	628,532	108	$ 57,196		$ 47,582	$ 47,582	5,926	19
2064	38	19,768,340	593,022	102	$ 53,965		$ 44,894	$ 44,894	5,591	18
2065	35	18,643,794	559,287	96	$ 50,895	$ 1,009,500	$ 42,340	$ 1,051,840	5,273	17
2066	33	17,578,434	527,328	91	$ 47,987		$ 39,921	$ 39,921	4,972	16
2067	32	16,631,448	498,920	86	$ 45,402		$ 37,770	$ 37,770	4,704	15
2068	30	15,743,648	472,287	81	$ 42,978		$ 35,754	$ 35,754	4,453	14
2069	28	14,855,849	445,654	77	$ 40,555		$ 33,738	$ 33,738	4,202	13
2070			-	0	$ -	$ 195,950	$ -	$ 195,950	-	-
Total	**2,562**	**1,346,673,803**	**40,398,290**		**$ 3,677,000**	**$ 5,243,000**	**$ 3,058,000**	**$ 8,302,000**	**381,000**	**1,300**

#	Equation
1	$LFG\ Collected\ (ft^3) = LFG\ Collected\ (scfm) * 525{,}600\ min/yr$
2	$Potential\ Electricity\ Generation\ (kWh) = \frac{LFG\ Collected}{(Microturbine\ Fuel\ Use\ Rate) * (LFG\ Lower\ Heating\ Value) * (Parasitic\ Loss\ Efficiency)}$
3	$Microturbine\ Capacity = \frac{Potential\ Electricity\ Generated}{System\ Operating\ Schedule * Parasitic\ Loss\ Efficiency}$
4	$Electricity\ Buyback\ Value = (Potential\ Electricity\ Generated) * (Electricity\ Buyback\ Value)$
5	$CO_2e\ Offset\ (LFG\ Combustion) = (LFG\ Collected) * (LFG\ Methane\ Content) * (Methane\ Density) * (Methane\ GWP) * (Microturbine\ Methane\ Destruction\ Efficiency)$
6	$CO_2e\ Offset\ (Electricity\ Generation) = (Potential\ Electricity\ Generated) * (Hydroelectric\ Emissions\ Offset)$

Combined Heat and Power - Microturbine

Capital Expenditures				
Gas compression/treatment, microturbine/generator, site work, housings, and electrical interconnect equipment				
	$	2,019,000	=19278*(x^0.6207)	x is kW capacity, converted from 2006 USD
Installed cost of heat recovery exchangers	$	114,000	=$20,057*($x^{0.6207}$)*0.06	x is turbine size, converted from 2008 USD
Installed cost of water pipelines (2 lines for supply and return)	$	986.32		per meter of trench, converted from 2008 USD
Installed cost of circulation pump	$	34,000		per system, converted from 2008 USD
10-year overhaul of microturbine	$	1,010,000	=50% of Installation CAPEX	
Decomissioning Cost	$	203,000	=50% of CAPEX up to $100k decomissioning, then add 5% for CAPEX over that.	

Operating Expenditures				
O&M of compression/treatment and microturbine (excluding energy)				
	$	0.06	=0.0948 - 0.008ln(x)	$/kWh, x is kW capacity, converted from 2006 USD

Fortis Commercial Gas Costs		
Basic Charge per Day	$	4.35
Delivery Charge per GJ	$	5.38
Storage and Transport Charge per GJ	$	2.05
Cost of Gas per GJ	$	1.66

Data			
Microturbine Size		284	kW
Fuel use rate		14,000	Btu/kWh
Parasitic Loss Efficiency		83%	
Electricity Buyback Value	$	0.09	$/kWh
Hot Water Production		5800	Btu/kWh generated
Distance to use of thermal energy		3	km
Operating Hours		7,008	hours/year
Hydro System Emissions Offset		0.00003	tonne CO2e/kWh
Methane Density (at STP)		0.000717	kg/m^3
Methane Global Warming Potential		28	tonne CO2e/tonne
LFG Methane Content		50%	CH4 by volume
Microturbine Methane Destruction Efficiency		99.5%	
RNG Production Emissions		0.050149	tonne CO2e/GJ

Year	LFG Collection		Electricity Generation			Exhaust Heat Recovery (H_2O @ 90°C)			Costs			CO2e Offset		
	scfm	ft3	Potential (kWh)	Power (kW)	Buyback Value	million Btu	GJ	Heat Value	CAPEX	OPEX	Total	LFG Combustion	Electricity Generation	Heat Recovery
Equation		*1*	*2*	*3*	*4*	*5*	*6*	*7*				*8*	*9*	*10*
2035	96	50,367,837	1,510,963	260	$ 137,498	8,764	9,150	$ 84,741	$ 2,167,000	$ 114,386	$ 2,281,386	14,245	45	459
2036	97	50,722,957	1,521,616	262	$ 138,467	8,825	9,214	$ 85,327		$ 115,193	$ 115,193	14,346	46	462
2037	97	51,078,077	1,532,269	263	$ 139,437	8,887	9,279	$ 85,914		$ 115,999	$ 115,999	14,446	46	465
2038	98	51,314,824	1,539,371	265	$ 140,083	8,928	9,322	$ 86,305		$ 116,537	$ 116,537	14,513	46	467
2039	98	51,610,757	1,548,249	266	$ 140,891	8,980	9,375	$ 86,793		$ 117,209	$ 117,209	14,597	46	470
2040	99	51,965,877	1,558,902	268	$ 141,860	9,042	9,440	$ 87,379		$ 118,015	$ 118,015	14,697	47	473
2041	100	52,320,997	1,569,555	270	$ 142,830	9,103	9,505	$ 87,966		$ 118,822	$ 118,822	14,798	47	477
2042	100	52,676,117	1,580,208	272	$ 143,799	9,165	9,569	$ 88,552		$ 119,628	$ 119,628	14,898	47	480
2043	101	53,031,237	1,590,861	274	$ 144,768	9,227	9,634	$ 89,138		$ 120,435	$ 120,435	14,998	48	483
2044	102	53,445,543	1,603,290	276	$ 145,899	9,299	9,709	$ 89,822		$ 121,376	$ 121,376	15,116	48	487
2045	102	53,859,850	1,615,719	278	$ 147,030	9,371	9,784	$ 90,506	$ 1,010,000	$ 122,316	$ 1,132,316	15,233	48	491
2046	103	54,274,156	1,628,147	280	$ 148,161	9,443	9,859	$ 91,190		$ 123,257	$ 123,257	15,350	49	494
2047	104	54,688,463	1,640,576	282	$ 149,292	9,515	9,935	$ 91,874		$ 124,198	$ 124,198	15,467	49	498
2048	105	55,161,956	1,654,780	284	$ 150,585	9,598	10,021	$ 92,656		$ 125,274	$ 125,274	15,601	50	503
2049	98	51,492,384	1,544,698	266	$ 140,568	8,959	9,354	$ 86,598		$ 116,940	$ 116,940	14,563	46	469
2050	91	48,059,558	1,441,718	248	$ 131,196	8,362	8,730	$ 80,930		$ 109,144	$ 109,144	13,592	43	438
2051	85	44,922,666	1,347,616	232	$ 122,633	7,816	8,161	$ 75,752		$ 102,020	$ 102,020	12,705	40	409
2052	80	42,022,520	1,260,616	217	$ 114,716	7,312	7,634	$ 70,964		$ 95,434	$ 95,434	11,885	38	383
2053	75	39,299,934	1,178,942	203	$ 107,284	6,838	7,139	$ 66,469		$ 89,251	$ 89,251	11,115	35	358
2054	70	36,814,095	1,104,370	190	$ 100,498	6,405	6,688	$ 62,365		$ 83,605	$ 83,605	10,412	33	335
2055	66	34,446,629	1,033,350	178	$ 94,035	5,993	6,257	$ 58,457	$ 1,010,000	$ 78,229	$ 1,088,229	9,742	31	314
2056	61	32,315,910	969,431	167	$ 88,218	5,623	5,870	$ 54,939		$ 73,390	$ 73,390	9,140	29	294
2057	58	30,303,564	909,064	156	$ 82,725	5,273	5,505	$ 51,617		$ 68,820	$ 68,820	8,571	27	276
2058	54	28,468,778	854,023	147	$ 77,716	4,953	5,172	$ 48,588		$ 64,653	$ 64,653	8,052	26	259
2059	51	26,752,365	802,533	138	$ 73,030	4,655	4,860	$ 45,754		$ 60,755	$ 60,755	7,566	24	244
2060	48	25,154,325	754,594	130	$ 68,668	4,377	4,569	$ 43,116		$ 57,126	$ 57,126	7,114	23	229
2061	45	23,674,659	710,206	122	$ 64,629	4,119	4,301	$ 40,673		$ 53,765	$ 53,765	6,696	21	216
2062	42	22,254,180	667,594	115	$ 60,751	3,872	4,043	$ 38,328		$ 50,540	$ 50,540	6,294	20	203
2063	40	20,952,073	628,532	108	$ 57,196	3,645	3,806	$ 36,179		$ 47,582	$ 47,582	5,926	19	191
2064	38	19,768,340	593,022	102	$ 53,965	3,440	3,591	$ 34,224		$ 44,894	$ 44,894	5,591	18	180
2065	35	18,643,794	559,287	96	$ 50,895	3,244	3,387	$ 32,368	$ 1,010,000	$ 42,340	$ 1,052,340	5,273	17	170
2066	33	17,578,434	527,328	91	$ 47,987	3,059	3,193	$ 30,609		$ 39,921	$ 39,921	4,972	16	160
2067	32	16,631,448	498,920	86	$ 45,402	2,894	3,021	$ 29,046		$ 37,770	$ 37,770	4,704	15	152
2068	30	15,743,648	472,287	81	$ 42,978	2,739	2,860	$ 27,580		$ 35,754	$ 35,754	4,453	14	143
2069	28	14,855,849	445,654	77	$ 40,555	2,585	2,699	$ 26,114		$ 33,738	$ 33,738	4,202	13	135
2070			-	0	$ -		-	$ -	$ 203,000	$ -	$ 203,000	-	-	-
Total	**2,562**	**1,346,673,803**	**40,398,290**		**$ 3,676,000**	**234,310**		**$ 2,279,000**	**$ 5,400,000**	**$ 3,058,000**	**$ 8,458,000**	**381,000**	**1,300**	**12,268**

#	Equation
1	$LFG\ Collected\ (ft^3) = LFG\ Collected\ (scfm) * 525{,}600\ min/yr$
2	$Potential\ Electricity\ Generation\ (kWh) = \frac{LFG\ Collected}{(Microturbine\ Fuel\ Use\ Rate) * (LFG\ Lower\ Heating\ Value) * (Parasitic\ Loss\ Efficiency)}$
3	$Microturbine\ Capacity = \frac{Potential\ Electricity\ Generated}{System\ Operating\ Schedule * Parasitic\ Loss\ Efficiency}$
4	$Electricity\ Buyback\ Value = (Potential\ Electricity\ Generated) * (Electricity\ Buyback\ Value)$
5	$Exhaust\ Heat\ Recovery\ (MMBtu) = \frac{(Potential\ Electricity\ Generation) * (\text{Microturbine Hot Water Production})}{1{,}000{,}000}$
6	$Exhaust\ Heat\ Recovery\ (GJ) = \frac{Exhaust\ Heat\ Recovery\ (MMBtu) * 1{,}000{,}000}{957{,}800\ \frac{GJ}{Btu}}$
7	$Heat\ Value = (FortisBC\ Daily\ Charge\ * 365) + (Exhaust\ Heat\ Recovery\ (GJ)) * (Delivery\ Charge + Storage\ and\ Transport\ Charge + Cost\ of\ Gas)$
8	$CO_2e\ Offset\ (LFG\ Combustion) = (LFG\ Collected) * (LFG\ Methane\ Content) * (Methane\ Density) * (Methane\ GWP) * (Microturbine\ Methane\ Destruction\ Efficiency)$
9	$CO_2e\ Offset\ (Electricity\ Generation) = (Potential\ Electricity\ Generated) * (Hydroelectric\ Emissions\ Offset)$
10	$CO_2e\ Offset\ (Heat\ Recovery) = (Exhaust\ Heat\ Recovery\ (GJ)) * (RNG\ Production\ Emissions)$

APPENDIX E

Detailed Analysis Tables for Creston

Biocover Application - Creston

Fugutive Emissions Rate		70%
Biocover Methane Oxidation Rate		80%
Year Over Year Biocover Effectiveness		90%
Methane Global Warming Potential		28
	m^2	% of total
Open Area	10,000	26%
Closed Area	28,000	74%

Year	CH_4 Generation	Fugitive Emissions (tonne CH_4)		Oxidized Emissions	
	tonnes	Open Area	Closed Area	tonne CH_4	tonne CO_2e
2027	244	45	126	36.0	1,007
2028	248	46	128	32.9	921
2029	251	46	129	30.0	839
2030	254	47	131	27.3	764
2031	258	48	133	24.9	698
2032	261	48	135	22.7	636
2033	264	49	136	20.7	579
Total	***1,780***	***328***	***918***	***194***	***5,444***

$$Open\ Area\ Fugitive\ Emissions = (CH_4 Generation) * (Fugitive\ Emissions\ Rate) * (Ratio\ of\ Open\ Area)$$

$$Oxidized\ Emissions (tonne\ CH_4) = (Open\ Area\ Fugitive\ Emissions) * (Biocover\ Methane\ Oxidation\ Rate) * (Year\ over\ Year\ Biocover\ Effectiveness)^{(Current\ Year - Biocover\ Installed\ Year)}$$

$$Oxidized\ Emissions (tonne\ CO_2 e) = Oxidized\ Emissions\ (tonne\ CH_4) * Methane\ GWP$$

Collection and Flare System - Single Flare

Capital Expenditures		
Open flare system	$ 60,000	SHA/MethaneXE estimate based on recent projects
Decommissioning Cost	$ 30,000	50% of CAPEX

Operating Expenditures		
O&M for flare	$ 10,000	per year

Data		
Minutes in a year	525,600	minutes/year
Methane Density at STP	0.000717	tonne/m^3
Methane Global Warming Potent	28	tonne CO2e/tonne
LFG Methane Content	50%	CH4 by volume
ft3 to m3 conversion	0.028	m^3/ft^3
Open flare destruction efficiency	96.0%	

Year	LFG Collection		Costs			CO2e Offset
	scfm	ft3	CAPEX	OPEX	Total	LFG Combustion
Equation		*1*				*2*
2028	20	10,301,760		$ 10,000	$ 10,000	2,811
2029	20	10,512,000		$ 10,000	$ 10,000	2,868
2030	20	10,512,000		$ 10,000	$ 10,000	2,868
2031	20	10,722,240		$ 10,000	$ 10,000	2,926
2032	21	10,932,480		$ 10,000	$ 10,000	2,983
2033	21	10,932,480		$ 10,000	$ 10,000	2,983
2034	21	11,142,720		$ 10,000	$ 10,000	3,041
2035	22	11,352,960		$ 10,000	$ 10,000	3,098
2036	22	11,352,960		$ 10,000	$ 10,000	3,098
2037	22	11,563,200		$ 10,000	$ 10,000	3,155
2038	22	11,773,440		$ 10,000	$ 10,000	3,213
2039	22	11,773,440		$ 10,000	$ 10,000	3,213
2040	23	11,983,680		$ 10,000	$ 10,000	3,270
2041	23	12,193,920		$ 10,000	$ 10,000	3,327
2042	23	12,193,920		$ 10,000	$ 10,000	3,327
2043	24	12,404,160		$ 10,000	$ 10,000	3,385
2044	24	12,614,400		$ 10,000	$ 10,000	3,442
2045	24	12,614,400		$ 10,000	$ 10,000	3,442
2046	24	12,824,640		$ 10,000	$ 10,000	3,500
2047	25	13,034,880		$ 10,000	$ 10,000	3,557
2048	25	13,034,880		$ 10,000	$ 10,000	3,557
2049	25	13,245,120		$ 10,000	$ 10,000	3,614
2050	26	13,455,360		$ 10,000	$ 10,000	3,672
2051	26	13,455,360		$ 10,000	$ 10,000	3,672
2052	23	12,193,920		$ 10,000	$ 10,000	3,327
2053	22	11,352,960		$ 10,000	$ 10,000	3,098
2054	20	10,301,760		$ 10,000	$ 10,000	2,811
2055	18	9,460,800		$ 10,000	$ 10,000	2,582
2056	17	8,830,080		$ 10,000	$ 10,000	2,410
2057	16	8,199,360		$ 10,000	$ 10,000	2,237
2058	14	7,568,640		$ 10,000	$ 10,000	2,065
2059	13	6,937,920		$ 10,000	$ 10,000	1,893
2060	12	6,517,440		$ 10,000	$ 10,000	1,778
2061			$ 30,000			-
Total	**659**	**346,475,520**	**$ 30,000**	**$ 310,000**	**$ 310,000**	**95,000**

#	Formula
1	$LFG\ Collected\ (ft^3) = LFG\ Collected\ (scfm) * 525{,}600\ min/yr$
2	$CO2e\ Offset = LFG\ Collected * LFG\ Methane\ Content * Methane\ Density * Methane\ GWP * Enclosed\ Flare\ Destruction\ Efficiency$

Collection and Flare System - Redundant Flare

Capital Expenditures		
Open flare system	$ 60,000	SHA/MethaneXE estimate based on recent projects
Decommissioning Cost	$ 30,000	50% of CAPEX

Operating Expenditures		
O&M for 2 flares	$ 15,000	per year

Data		
Minutes in a year	525,600	minutes/year
Methane Density at STP	0.000717	tonne/m^3
Methane Global Warming Potential	28	tonne CO2e/tonne
LFG Methane Content	50%	CH4 by volume
ft3 to m3 conversion	0.028	m^3/ft^3
Open flare destruction efficiency	96.0%	

Year	LFG Collection		Costs			CO2e Offset
	scfm	ft3	CAPEX	OPEX	Total	LFG Combustion
Equation	*1*	*2*				*3*
2028	34	18,028,080	$ 60,000	$ 15,000	$ 75,000	4,919
2029	35	18,396,000		$ 15,000	$ 15,000	5,020
2030	35	18,396,000		$ 15,000	$ 15,000	5,020
2031	36	18,763,920		$ 15,000	$ 15,000	5,120
2032	36	19,131,840		$ 15,000	$ 15,000	5,221
2033	36	19,131,840		$ 15,000	$ 15,000	5,221
2034	37	19,499,760		$ 15,000	$ 15,000	5,321
2035	38	19,867,680		$ 15,000	$ 15,000	5,421
2036	38	19,867,680		$ 15,000	$ 15,000	5,421
2037	39	20,235,600		$ 15,000	$ 15,000	5,522
2038	39	20,603,520		$ 15,000	$ 15,000	5,622
2039	39	20,603,520		$ 15,000	$ 15,000	5,622
2040	40	20,971,440		$ 15,000	$ 15,000	5,723
2041	41	21,339,360		$ 15,000	$ 15,000	5,823
2042	41	21,339,360		$ 15,000	$ 15,000	5,823
2043	41	21,707,280		$ 15,000	$ 15,000	5,923
2044	42	22,075,200		$ 15,000	$ 15,000	6,024
2045	42	22,075,200		$ 15,000	$ 15,000	6,024
2046	43	22,443,120		$ 15,000	$ 15,000	6,124
2047	43	22,811,040		$ 15,000	$ 15,000	6,225
2048	43	22,811,040		$ 15,000	$ 15,000	6,225
2049	44	23,178,960		$ 15,000	$ 15,000	6,325
2050	45	23,546,880		$ 15,000	$ 15,000	6,425
2051	45	23,546,880		$ 15,000	$ 15,000	6,425
2052	41	21,339,360		$ 15,000	$ 15,000	5,823
2053	38	19,867,680		$ 15,000	$ 15,000	5,421
2054	34	18,028,080		$ 15,000	$ 15,000	4,919
2055	32	16,556,400		$ 15,000	$ 15,000	4,518
2056	29	15,452,640		$ 15,000	$ 15,000	4,217
2057	27	14,348,880		$ 15,000	$ 15,000	3,915
2058	25	13,245,120		$ 15,000	$ 15,000	3,614
2059	23	12,141,360		$ 15,000	$ 15,000	3,313
2060	22	11,405,520		$ 15,000	$ 15,000	3,112
2065			$ 30,000			-
Total		**642,756,240**	**$ 90,000**	**$ 495,000**	**$ 555,000**	**175,000**

#	Formula
1	$LFG\ Collected\ (scfm) = LFG\ Collected\ with\ 1\ Flare\ (scfm) * 1.75$
2	$LFG\ Collected\ (ft^3) = LFG\ Collected\ (scfm) * 525{,}600\ min/yr$
3	$CO2e\ Offset = LFG\ Collected * LFG\ Methane\ Content * Methane\ Density * Methane\ GWP * Enclosed\ Flare\ Destruction\ Efficiency$

Active Collection and Flare System

Capital Expenditures			
Well installation including LFG header	$	36,000	per well
Contractor Mobilization	$	47,000	per system install
Condensate knockout, blower, and flare system	$	184,000	=x^0.61*4,600 x is the maximum scfm handled
Decommissioning Cost	$	130,000	=50% of CAPEX up to $100k decomissioning, then add 5% for CAPEX over that.

Operating Expenditures			
Blower Electricity Usage		0.002	kWh/ft^3
Blower Electricity Cost, Based on FortisBC Rate	$	0.00026	$/ft^3$
O&M for collection system	$	2,600	per well per year
O&M for flare	$	12,000	per flare per year

Data		
Minutes in a year	525,600	minutes/year
Methane Density at STP	0.000717	$tonne/m^3$
Methane Global Warming Potential	28	tonne CO2e/tonne
LFG Methane Content	50%	CH4 by volume
ft3 to m3 conversion	0.028	m^3/ft^3
Enclosed flare destruciton efficiency	99.5%	

Year	**LFG Collection**		**Costs**			**CO2e Offset**	**# of Wells**
	scfm	ft3	CAPEX	OPEX	Total	LFG Combustion	1 per acre
Equation		*1*				*2*	
2030	90	47,349,318	$ 699,000	$ 58,111	$ 757,111	13,391	13
2031	92	48,118,745		$ 58,311	$ 58,311	13,609	13
2032	93	48,828,985		$ 58,496	$ 58,496	13,810	13
2033	94	49,420,851		$ 58,649	$ 58,649	13,977	13
2034	95	49,894,344		$ 58,773	$ 58,773	14,111	13
2035	96	50,367,837		$ 58,896	$ 58,896	14,245	13
2036	97	50,722,957		$ 58,988	$ 58,988	14,346	13
2037	97	51,078,077		$ 59,080	$ 59,080	14,446	13
2038	98	51,314,824		$ 59,142	$ 59,142	14,513	13
2039	98	51,610,757		$ 59,219	$ 59,219	14,597	13
2040	99	51,965,877	$ 155,000	$ 67,111	$ 222,111	14,697	16
2041	100	52,320,997		$ 67,203	$ 67,203	14,798	16
2042	100	52,676,117		$ 67,296	$ 67,296	14,898	16
2043	101	53,031,237		$ 67,388	$ 67,388	14,998	16
2044	102	53,445,543		$ 67,496	$ 67,496	15,116	16
2045	102	53,859,850		$ 67,604	$ 67,604	15,233	16
2046	103	54,274,156		$ 67,711	$ 67,711	15,350	16
2047	104	54,688,463		$ 67,819	$ 67,819	15,467	16
2048	105	55,161,956		$ 67,942	$ 67,942	15,601	16
2049	98	51,492,384		$ 66,988	$ 66,988	14,563	16
2050	91	48,059,558	$ 155,000	$ 73,895	$ 228,895	13,592	19
2051	85	44,922,666		$ 73,080	$ 73,080	12,705	19
2052	80	42,022,520		$ 72,326	$ 72,326	11,885	19
2053	75	39,299,934		$ 71,618	$ 71,618	11,115	19
2054	70	36,814,095		$ 70,972	$ 70,972	10,412	19
2055	66	34,446,629		$ 70,356	$ 70,356	9,742	19
2056	61	32,315,910		$ 69,802	$ 69,802	9,140	19
2057	58	30,303,564		$ 69,279	$ 69,279	8,571	19
2058	54	28,468,778		$ 68,802	$ 68,802	8,052	19
2059	51	26,752,365		$ 68,356	$ 68,356	7,566	19
2060	48	25,154,325	$ 119,000	$ 73,140	$ 192,140	7,114	21
2061	45	23,674,659		$ 72,755	$ 72,755	6,696	21
2062	42	22,254,180		$ 72,386	$ 72,386	6,294	21
2063	40	20,952,073		$ 72,048	$ 72,048	5,926	21
2064	38	19,768,340		$ 71,740	$ 71,740	5,591	21
2065	35	18,643,794		$ 71,447	$ 71,447	5,273	21
2066	33	17,578,434		$ 71,170	$ 71,170	4,972	21
2067	32	16,631,448		$ 70,924	$ 70,924	4,704	21
2068	30	15,743,648		$ 70,693	$ 70,693	4,453	21
2069	28	14,855,849		$ 70,463	$ 70,463	4,202	21
2070			$ 130,000			-	
Total	**3,026**	**1,590,286,046**	**$ 1,258,000**	**$ 2,688,000**	**$ 3,816,000**	**450,000**	

#	**Formula**
1	$LFG\ Collected\ (ft^3) = LFG\ Collected\ (scfm) * 525{,}600\ min/yr$
2	$CO2e\ Offset = LFG\ Collected * LFG\ Methane\ Content * Methane\ Density * Methane\ GWP * Enclosed\ Flare\ Destruction\ Efficiency$

Direct Use of Methane On Site in Boiler

Project LFG Design Rate (minimum flow) 17 scfm

Capital Expenditures			
Skid mounted filter, compressor, and dehydration unit	$ 1,949,000	=$360x + $830,000	x = scfm (converted from 2013 USD)
Pipeline	$ 1,727,000	=$80x + $178,000	x = feet of pipeline (converted from 2013 USD)
Decomissioning Cost	$ 279,000	=50% of CAPEX up to $100k decomissioning, then add 5% for CAPEX over that.	
Operating Expenditures			
Electricity Usage for Pipelines less than 5 miles	0.002	kWh/ft3	
Annual Pipeline OPEX (excluding electricity)	$ 63,000	$=\$57,000 * (x/700)^{0.2}$	x = scfm (converted from 2013 USD)

Data		
Minutes in a year	525600	min/yr
FortisBC commercial electricity rate	$ 0.13	/kWh
LFG Methane Content	50%	by volume
Lower Heating Value of methane	0.0358	GJ/m^3
Methane density at STP	0.000717	$tonne/m^3$
Methane Global Warming Potential	28	tonne CO_2e/tonne CH_4
LFG Boiler Efficiency	80%	
Enclosed flare methane destruction efficiency	99.5%	
Boiler methane destruction efficiency	98.0%	
RNG production emissions	0.050149	tonne CO2e/GJ

FortisBC Commercial Gas Prices	
Basic Charge per Day	$ 4.35
Delivery Charge per GJ	$ 5.38
Storage and Transport Charge per GJ	$ 2.05
Cost of Gas per GJ	$ 1.66

Year	LFG Collection		LFG Utilized		CH4 Utilized		Costs				CO2e Offset/Reduction			Financial Offset
	scfm	ft3	scfm	ft3	m3	GJ	CAPEX	OPEX	Electricity Usage	Total	Flaring	Utilization	RNG Production	RNG Offset
Equation		*1*	*2*	*3*	*4*	*5*					*6*	*7*	*8*	*9*
2030	35	18,396,000	17	8,830,080	125,020	3,581	$ 3,676,000	$ 63,000	$ 2,000	$ 3,741,000	2,705	2,460	180	$ 34,000
2031	36	18,763,920	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	2,810	2,460	180	$ 34,000
2032	36	19,131,840	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	2,914	2,460	180	$ 34,000
2033	36	19,131,840	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	2,914	2,460	180	$ 34,000
2034	37	19,499,760	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	3,018	2,460	180	$ 34,000
2035	38	19,867,680	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	3,122	2,460	180	$ 34,000
2036	38	19,867,680	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	3,122	2,460	180	$ 34,000
2037	39	20,235,600	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	3,226	2,460	180	$ 34,000
2038	39	20,603,520	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	3,330	2,460	180	$ 34,000
2039	39	20,603,520	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	3,330	2,460	180	$ 34,000
2040	40	20,971,440	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	3,434	2,460	180	$ 34,000
2041	41	21,339,360	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	3,538	2,460	180	$ 34,000
2042	41	21,339,360	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	3,538	2,460	180	$ 34,000
2043	41	21,707,280	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	3,642	2,460	180	$ 34,000
2044	42	22,075,200	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	3,746	2,460	180	$ 34,000
2045	42	22,075,200	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	3,746	2,460	180	$ 34,000
2046	43	22,443,120	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	3,850	2,460	180	$ 34,000
2047	43	22,811,040	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	3,954	2,460	180	$ 34,000
2048	43	22,811,040	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	3,954	2,460	180	$ 34,000
2049	44	23,178,960	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	4,058	2,460	180	$ 34,000
2050	45	23,546,880	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	4,162	2,460	180	$ 34,000
2051	45	23,546,880	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	4,162	2,460	180	$ 34,000
2052	41	21,339,360	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	3,538	2,460	180	$ 34,000
2053	38	19,867,680	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	3,122	2,460	180	$ 34,000
2054	34	18,028,080	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	2,601	2,460	180	$ 34,000
2055	32	16,556,400	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	2,185	2,460	180	$ 34,000
2056	29	15,452,640	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	1,873	2,460	180	$ 34,000
2057	27	14,348,880	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	1,561	2,460	180	$ 34,000
2058	25	13,245,120	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	1,249	2,460	180	$ 34,000
2059	23	12,141,360	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	937	2,460	180	$ 34,000
2060	22	11,405,520	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	728	2,460	180	$ 34,000
2061	20	10,669,680	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	520	2,460	180	$ 34,000
2062	19	9,933,840	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	312	2,460	180	$ 34,000
2063	18	9,198,000	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	104	2,460	180	$ 34,000
2064	17	8,830,080	17	8,830,080	125,020	3,581		$ 63,000	$ 2,000	$ 65,000	-	2,460	180	$ 34,000
2065					-	-	$ 279,000			$ 279,000	-	-	-	$ 2,000
Total						**125,320**	**$ 3,955,000**	**$ 2,205,000**	**$ 70,000**	**$ 6,230,000**	**95,000**	**86,000**	**6,000**	**$ 1,192,000**

#	Equation
1	$LFG\ Collected\ (ft^3) = LFG\ Collected\ (scfm) * 525{,}600\ min/yr$
2	$LFG\ Utilized\ (scfm) = minimum(LFG\ collected\ (scfm))$
3	$LFG\ Utilized\ (ft^3) = LFG\ Utilized\ (scfm) * 525{,}600\ min/yr$
4	$CH_4\ Utilized\ (m^3) = LFG\ Utilized\ (ft^3) * LFG\ Methane\ Content * (0.0283\frac{m^3}{ft^3})$
5	$CH4\ Utilized\ (GJ) = CH4\ Utilized\ (m^3) * LFG\ Boiler\ Efficiency * Lower\ Heating\ Value\ of\ Methane$
6	$Flaring\ Offset = (LFG\ Collected - LFG\ Utilized) * LFG\ Methane\ Content * \left(0.0283\frac{m^3}{ft^3}\right) * Methane\ Density * Methane\ GWP * Flare\ Destruction\ Efficiency$
7	$Utilization\ Offset = Methane\ Utilized * Methane\ Density * Methane\ GWP * Boiler\ Destruction\ Efficiency$
8	$RNG\ Production\ Offset = Methane\ Utilized * RNG\ Production\ Emissions$
9	$RNG\ Financial\ Offset = (FortisBC\ Basic\ Charge * 365) + Methane\ Utilized * (Delivery\ Charge + Storage\ and\ Transport\ Charge + Cost\ of\ Gas)$

Combined Heat and Power - Microturbine

Microturbine Size (maximum) 121 kW

Capital Expenditures			
Gas compression/treatment, microturbine/generator, site work, housings, and electrical interconnect equipment			
	$	1,190,000	=$19,278*(x^0.6207) x is kW capacity, converted from 2006 USD
10-year overhaul cost	$	595,000	=50% of Installation CAPEX
Decomissioning cost	$	154,500	=50% of CAPEX up to $100k decomissioning, then add 5% for CAPEX over that.

Operating Expenditures			
O&M of compression/treatment and microturbine (excluding energy)			
	$	0.09	=0.0948 - 0.008ln(x) $/kWh, x is kW capacity, converted from 2006 USD

Data		
Minutes in a year	525,600	minutes/year
Microturbine Operating Hours	7,008	hours/year
Microturbine Fuel Use Rate	14,000	Btu/kWh generated
LFG Lower Heating Value	506	Btu/ft^3
Parasitic Loss Efficiency	83%	
Electricity Buyback Value	$ 0.09	$/kWh
Hydroelectric Emissions Offset	0.00003	tonne CO2e/kWh
Methane Density (at STP)	0.000717	tonne/m^3
Methane Global Warming Potential	28	tonne CO2e/tonne
LFG Methane Content	50%	CH4 by volume
Microturbine methane destruction efficiency	99.5%	

Year	LFG Collection		Electricity Generation			Costs			CO2e Offset	
	scfm	ft3	Potential (kWh)	Capacity (kW)	Buyback Value	CAPEX	OPEX	Total	LFG Combustion	Electricity Generation
Equation		1	2	3	4				5	6
2030	35	18,396,000	551,854	95	$ 50,219	$ 1,190,000	$ 58,098	$ 1,248,098	5,203	17
2031	36	18,763,920	562,891	97	$ 51,223		$ 59,260	$ 59,260	5,307	17
2032	36	19,131,840	573,928	99	$ 52,227		$ 60,422	$ 60,422	5,411	17
2033	36	19,131,840	573,928	99	$ 52,227		$ 60,422	$ 60,422	5,411	17
2034	37	19,499,760	584,965	101	$ 53,232		$ 61,584	$ 61,584	5,515	18
2035	38	19,867,680	596,002	102	$ 54,236		$ 62,746	$ 62,746	5,619	18
2036	38	19,867,680	596,002	102	$ 54,236		$ 62,746	$ 62,746	5,619	18
2037	39	20,235,600	607,039	104	$ 55,241		$ 63,908	$ 63,908	5,723	18
2038	39	20,603,520	618,076	106	$ 56,245		$ 65,070	$ 65,070	5,827	19
2039	39	20,603,520	618,076	106	$ 56,245		$ 65,070	$ 65,070	5,827	19
2040	40	20,971,440	629,113	108	$ 57,249	$ 595,000	$ 66,232	$ 661,232	5,931	19
2041	41	21,339,360	640,150	110	$ 58,254		$ 67,394	$ 67,394	6,035	19
2042	41	21,339,360	640,150	110	$ 58,254		$ 67,394	$ 67,394	6,035	19
2043	41	21,707,280	651,187	112	$ 59,258		$ 68,556	$ 68,556	6,139	20
2044	42	22,075,200	662,224	114	$ 60,262		$ 69,718	$ 69,718	6,243	20
2045	42	22,075,200	662,224	114	$ 60,262		$ 69,718	$ 69,718	6,243	20
2046	43	22,443,120	673,262	116	$ 61,267		$ 70,880	$ 70,880	6,347	20
2047	43	22,811,040	684,299	118	$ 62,271		$ 72,042	$ 72,042	6,451	21
2048	43	22,811,040	684,299	118	$ 62,271		$ 72,042	$ 72,042	6,451	21
2049	44	23,178,960	695,336	120	$ 63,276		$ 73,204	$ 73,204	6,556	21
2050	45	23,546,880	706,373	121	$ 64,280	$ 595,000	$ 74,366	$ 669,366	6,660	21
2051	45	23,546,880	706,373	121	$ 64,280		$ 74,366	$ 74,366	6,660	21
2052	41	21,339,360	640,150	110	$ 58,254		$ 67,394	$ 67,394	6,035	19
2053	38	19,867,680	596,002	102	$ 54,236		$ 62,746	$ 62,746	5,619	18
2054	34	18,028,080	540,817	93	$ 49,214		$ 56,936	$ 56,936	5,099	16
2055	32	16,556,400	496,668	85	$ 45,197		$ 52,289	$ 52,289	4,683	15
2056	29	15,452,640	463,557	80	$ 42,184		$ 48,803	$ 48,803	4,370	14
2057	27	14,348,880	430,446	74	$ 39,171		$ 45,317	$ 45,317	4,058	13
2058	25	13,245,120	397,335	68	$ 36,157		$ 41,831	$ 41,831	3,746	12
2059	23	12,141,360	364,223	63	$ 33,144		$ 38,345	$ 38,345	3,434	11
2060	22	11,405,520	342,149	59	$ 31,136	$ 595,000	$ 36,021	$ 631,021	3,226	10
2061	20	10,669,680	320,075	55	$ 29,127		$ 33,697	$ 33,697	3,018	10
2062	19	9,933,840	298,001	51	$ 27,118		$ 31,373	$ 31,373	2,810	9
2063	18	9,198,000	275,927	47	$ 25,109		$ 29,049	$ 29,049	2,601	8
2064	17	8,830,080	264,890	46	$ 24,105		$ 27,887	$ 27,887	2,497	8
2065			-	0	$ -	$ 154,500	$ -	$ 154,500	-	-
Total	**1,227**	**644,963,760**	**19,347,991**		**$ 1,761,000**	**$ 3,130,000**	**$ 2,037,000**	**$ 5,166,000**	**183,000**	**600**

#	Equation
1	$LFG\ Collected\ (ft^3) = LFG\ Collected\ (scfm) * 525{,}600\ min/yr$
2	$Potential\ Electricity\ Generation\ (kWh) = \frac{LFG\ Collected}{(Microturbine\ Fuel\ Use\ Rate) * (LFG\ Lower\ Heating\ Value) * (Parasitic\ Loss\ Efficiency)}$
3	$Microturbine\ Capacity = \frac{Potential\ Electricity\ Generated}{System\ Operating\ Schedule * Parasitic\ Loss\ Efficiency}$
4	$Electricity\ Buyback\ Value = (Potential\ Electricity\ Generated) * (Electricity\ Buyback\ Value)$
5	$CO_2e\ Offset\ (LFG\ Combustion) = (LFG\ Collected) * (LFG\ Methane\ Content) * (Methane\ Density) * (Methane\ GWP) * (Microturbine\ Methane\ Destruction\ Efficiency)$
6	$CO_2e\ Offset\ (Electricity\ Generation) = (Potential\ Electricity\ Generated) * (Hydroelectric\ Emissions\ Offset)$

Combined Heat and Power - Microturbine

Capital Expenditures			
Gas compression/treatment, microturbine/generator, site work, housings, and electrical interconnect equipment			
	$ 1,190,000	=19278*(x^0.6207)	x is kW capacity, converted from 2006 USD
Installed cost of heat recovery exchangers	$ 67,000	$=\$20{,}057*(x^{0.6207})*0.06$	x is turbine size, converted from 2008 USD
Installed cost of water pipelines (2 lines for supply and return)	$ 986.32		per meter of trench, converted from 2008 USD
Installed cost of circulation pump	$ 34,000		per system, converted from 2008 USD
10-year overhaul of microturbine	$ 595,000	=50% of Installation CAPEX	
Decomissioning Cost	$ 160,000	=50% of CAPEX up to $100k decomissioning, then add 5% for CAPEX over that.	

Operating Expenditures			
O&M of compression/treatment and microturbine (excluding energy)			
	0.0874	=0.0948 - 0.008ln(x)	$/kWh, x is kW capacity, converted from 2006 USD
Annual Pipeline OPEX (excluding electricity)	$ 73,000	$=\$57{,}000 * (x/700)^{0.2}$	x = scfm (converted from 2013 USD)

Data		
Microturbine Size	121	kW
Fuel use rate	14,000	Btu/kWh
Parasitic Loss Efficiency	83%	
Electricity Buyback Value	$ 0.09	$/kWh
Hot Water Production	5800	Btu/kWh generated
Distance to use of thermal energy	3	km
Operating Hours	7,008	hours/year
Hydro System Emissions Offset	0.00003	tonne CO2e/kWh
Methane Density (at STP)	0.000717	kg/m^3
Methane Global Warming Potential	28	tonne CO2e/tonne
LFG Methane Content	50%	CH4 by volume
Microturbine Methane Destruction Efficiency	99.5%	
RNG Production Emissions	0.050149	tonne CO2e/GJ

Fortis Commercial Gas Costs	
Basic Charge per Day	$ 4.35
Delivery Charge per GJ	$ 5.38
Storage and Transport Charge per GJ	$ 2.05
Cost of Gas per GJ	$ 1.66

Year	LFG Collection		Electricity Generation			Exhaust Heat Recovery (H_2O @ 90°C)			Costs			CO2e Offset		
	scfm	ft3	Potential (kWh)	Power (kW)	Buyback Value	million Btu	GJ	Heat Value	CAPEX	OPEX	Total	LFG Combustion	Electricity Generation	Heat Recovery
Equation		*1*	*2*	*3*	*4*	*5*	*6*	*7*				*8*	*9*	*10*
2030	35	18,396,000	551,854	95	$ 50,219	3,201	3,342	$ 31,959	$ 1,291,000	$ 131,098	$ 1,422,098	5,203	17	168
2031	36	18,763,920	562,891	97	$ 51,223	3,265	3,409	$ 32,566		$ 132,260	$ 132,260	5,307	17	171
2032	36	19,131,840	573,928	99	$ 52,227	3,329	3,475	$ 33,174		$ 133,422	$ 133,422	5,411	17	174
2033	36	19,131,840	573,928	99	$ 52,227	3,329	3,475	$ 33,174		$ 133,422	$ 133,422	5,411	17	174
2034	37	19,499,760	584,965	101	$ 53,232	3,393	3,542	$ 33,781		$ 134,584	$ 134,584	5,515	18	178
2035	38	19,867,680	596,002	102	$ 54,236	3,457	3,609	$ 34,388		$ 135,746	$ 135,746	5,619	18	181
2036	38	19,867,680	596,002	102	$ 54,236	3,457	3,609	$ 34,388		$ 135,746	$ 135,746	5,619	18	181
2037	39	20,235,600	607,039	104	$ 55,241	3,521	3,676	$ 34,996		$ 136,908	$ 136,908	5,723	18	184
2038	39	20,603,520	618,076	106	$ 56,245	3,585	3,743	$ 35,603		$ 138,070	$ 138,070	5,827	19	188
2039	39	20,603,520	618,076	106	$ 56,245	3,585	3,743	$ 35,603		$ 138,070	$ 138,070	5,827	19	188
2040	40	20,971,440	629,113	108	$ 57,249	3,649	3,810	$ 36,211	$ 595,000	$ 139,232	$ 734,232	5,931	19	191
2041	41	21,339,360	640,150	110	$ 58,254	3,713	3,876	$ 36,818		$ 140,394	$ 140,394	6,035	19	194
2042	41	21,339,360	640,150	110	$ 58,254	3,713	3,876	$ 36,818		$ 140,394	$ 140,394	6,035	19	194
2043	41	21,707,280	651,187	112	$ 59,258	3,777	3,943	$ 37,425		$ 141,556	$ 141,556	6,139	20	198
2044	42	22,075,200	662,224	114	$ 60,262	3,841	4,010	$ 38,033		$ 142,718	$ 142,718	6,243	20	201
2045	42	22,075,200	662,224	114	$ 60,262	3,841	4,010	$ 38,033		$ 142,718	$ 142,718	6,243	20	201
2046	43	22,443,120	673,262	116	$ 61,267	3,905	4,077	$ 38,640		$ 143,880	$ 143,880	6,347	20	204
2047	43	22,811,040	684,299	118	$ 62,271	3,969	4,144	$ 39,248		$ 145,042	$ 145,042	6,451	21	208
2048	43	22,811,040	684,299	118	$ 62,271	3,969	4,144	$ 39,248		$ 145,042	$ 145,042	6,451	21	208
2049	44	23,178,960	695,336	120	$ 63,276	4,033	4,211	$ 39,855		$ 146,204	$ 146,204	6,556	21	211
2050	45	23,546,880	706,373	121	$ 64,280	4,097	4,277	$ 40,462	$ 595,000	$ 147,366	$ 742,366	6,660	21	215
2051	45	23,546,880	706,373	121	$ 64,280	4,097	4,277	$ 40,462		$ 147,366	$ 147,366	6,660	21	215
2052	41	21,339,360	640,150	110	$ 58,254	3,713	3,876	$ 36,818		$ 140,394	$ 140,394	6,035	19	194
2053	38	19,867,680	596,002	102	$ 54,236	3,457	3,609	$ 34,388		$ 135,746	$ 135,746	5,619	18	181
2054	34	18,028,080	540,817	93	$ 49,214	3,137	3,275	$ 31,351		$ 129,936	$ 129,936	5,099	16	164
2055	32	16,556,400	496,668	85	$ 45,197	2,881	3,008	$ 28,922		$ 125,289	$ 125,289	4,683	15	151
2056	29	15,452,640	463,557	80	$ 42,184	2,689	2,807	$ 27,100		$ 121,803	$ 121,803	4,370	14	141
2057	27	14,348,880	430,446	74	$ 39,171	2,497	2,607	$ 25,277		$ 118,317	$ 118,317	4,058	13	131
2058	25	13,245,120	397,335	68	$ 36,157	2,305	2,406	$ 23,455		$ 114,831	$ 114,831	3,746	12	121
2059	23	12,141,360	364,223	63	$ 33,144	2,112	2,206	$ 21,633		$ 111,345	$ 111,345	3,434	11	111
2060	22	11,405,520	342,149	59	$ 31,136	1,984	2,072	$ 20,418	$ 595,000	$ 109,021	$ 704,021	3,226	10	104
2061	20	10,669,680	320,075	55	$ 29,127	1,856	1,938	$ 19,203		$ 106,697	$ 106,697	3,018	10	97
2062	19	9,933,840	298,001	51	$ 27,118	1,728	1,805	$ 17,989		$ 104,373	$ 104,373	2,810	9	90
2063	18	9,198,000	275,927	47	$ 25,109	1,600	1,671	$ 16,774		$ 102,049	$ 102,049	2,601	8	84
2064	17	8,830,080	264,890	46	$ 24,105	1,536	1,604	$ 16,166		$ 100,887	$ 100,887	2,497	8	80
2065			-	0	$ -		-	$ -	$ 160,000	$ 73,000	$ 233,000	-	-	-
Total	**1,227**	**644,963,760**	**19,347,991**		**$ 1,761,000**	**112,218**		**$ 1,120,000**	**$ 3,236,000**	**$ 4,665,000**	**$ 7,901,000**	**183,000**	**600**	**6,000**

#	Equation
1	$LFG\ Collected\ (ft^3) = LFG\ Collected\ (scfm) * 525{,}600\ min/yr$
2	$Potential\ Electricity\ Generation\ (kWh) = \frac{LFG\ Collected}{(Microturbine\ Fuel\ Use\ Rate) * (LFG\ Lower\ Heating\ Value) * (Parasitic\ Loss\ Efficiency)}$
3	$Microturbine\ Capacity = \frac{Potential\ Electricity\ Generated}{System\ Operating\ Schedule * Parasitic\ Loss\ Efficiency}$
4	$Electricity\ Buyback\ Value = (Potential\ Electricity\ Generated) * (Electricity\ Buyback\ Value)$
5	$Exhaust\ Heat\ Recovery\ (MMBtu) = \frac{(Potential\ Electricity\ Generation) * (\text{Microturbine Hot Water Production})}{1{,}000{,}000}$
6	$Exhaust\ Heat\ Recovery\ (GJ) = \frac{Exhaust\ Heat\ Recovery\ (MMBtu) * 1{,}000{,}000}{957{,}800 \frac{GJ}{Btu}}$
7	$Heat\ Value = (FortisBC\ Daily\ Charge\ * 365) + (Exhaust\ Heat\ Recovery\ (GJ)) * (Delivery\ Charge + Storage\ and\ Transport\ Charge + Cost\ of\ Gas)$
8	$CO_2e\ Offset\ (LFG\ Combustion) = (LFG\ Collected) * (LFG\ Methane\ Content) * (Methane\ Density) * (Methane\ GWP) * (Microturbine\ Methane\ Destruction\ Efficiency)$
9	$CO_2e\ Offset\ (Electricity\ Generation) = (Potential\ Electricity\ Generated) * (Hydroelectric\ Emissions\ Offset)$
10	$CO_2e\ Offset\ (Heat\ Recovery) = (Exhaust\ Heat\ Recovery\ (GJ)) * (RNG\ Production\ Emissions)$