blue environment pty ltd

Landfill gas combustion and the carbon farming initiative

prepared for

Australian Landfill Owners Association

Final report
23 March 2011

Landfill gas combustion and the carbon farming initiative

Final report: P193
23 March 2011

Author
Joe Pickin

Reviewer
Bill Grant

blue environment pty ltd
abn 78 118 663 997
271 mont albert road, surrey hills vic 3127
email: blue@blueenvironment.com.au
web: www.blueenvironment.com.au
phone 0408 540 980

CONTENTS

Figures

Abbreviations used

ALOA	Australian Landfill Owners Association
CFI	Carbon Farming Initiative
CO_2-e	carbon dioxide equivalent
kt	kilotonnes (thousand tonnes)
n/a	not applicable
Mt	megatonne (million tonnes)
NGERS	National Greenhouse And Energy Reporting Scheme
WMAA	Waste Management Association of Australia

yr	year

1. Introduction

Organic matter breaking down in landfills generates a mixture of gases that include the potent greenhouse gas, methane. One practical method of reducing methane emissions is to capture and combust landfill gas. This is occurring at many landfills across Australia using either combustion flares or, at some sites, using engines to harvest energy that is usually fed into the electricity grid.

The Australian Government is considering a suite of economic incentives to reduce greenhouse gas emissions. These include the Carbon Farming Initiative (CFI), which could provide an incentive to reduce emissions from 'legacy' waste deposited prior to some nominated date. Abatement exceeding some baseline level would qualify for credits that could be sold into international and voluntary carbon markets.

The Australian Landfill Owners Association (ALOA) commissioned Blue Environment to estimate the additional methane likely to be captured from a group of landfills assuming emissions from legacy waste are included in a CFI. The group of landfills to be assessed comprises operating sites listed as not capturing landfill gas in the landfills database held by the Waste Management Association of Australia (WMAA). The estimate of additional methane likely to be captured excludes any additional capture associated with:

- landfills that are not listed in the WMAA database – since the survey was undertaken in 2008 over 300 more landfills have been identified (Johnson pers. comm.)
- closed landfills – which continue to generate gas for many years as organic degradation continues
- efficiency improvements in existing systems.

This report describes the method, results and conclusions of the work. It is submitted together with an Excel-based model that was established for the investigation.

2. Overview of the research method

The investigation involved research, data gathering and modelling as outlined step-by-step below.

Estimating additional methane that could be captured

1. Blue Environment liaised with WMAA to obtain data from their survey of Australian landfills on landfills that do not currently capture methane for combustion. This provided the average annual tonnage received and the weighted average number of years of operation of landfills that have been grouped as follows:
    - landfill input/size category (25-50 kt/yr; >50-100 kt/yr; >100 kt/yr)
    - waste type accepted (putrescible; inert only)
    - state or territory.
2. Research was undertaken to estimate an appropriate baseline value upon which 'additionality' could be assumed under the CFI.

3. The first-order decay model that was established for the National Greenhouse and Energy Reporting Scheme (NGERS) was used to estimate methane generation from the 'average' landfills accepting each waste type in each size category and state/territory.
4. Results were adjusted to estimate the quantity of methane that could potentially be captured.

Modelling additional capture of landfill methane

5. Itemised generic cost data on flare system installation and operating costs were obtained.
6. A model was constructed to calculate the methane gas that would be captured from these landfills, taking into account factors such as gas system costs, methane collection efficiencies, the proportion of available methane that would attract credits and abatement credit prices.

Analysis

7. The model was run for several scenarios to explore sensitivity to credit prices and decision factors. The results were assessed and reported.

3. Estimating additional methane that could be captured

3.1 WMAA data

WMAA undertakes periodic surveys of Australian landfills in which it asks, among other things, whether the sites capture methane, how much waste they received during the previous year and how long they have been operating. This information allows approximation of the quantities of methane generated from these sites. The most recent survey was for 2007/08. Privacy provisions associated with that survey prevent the WMAA from providing disaggregated site data, even with site names removed. Instead, aggregated averages were obtained in various categories of input tonnage, jurisdiction and waste type. The waste type classes divided landfills that accept domestic waste (putrescible sites) from those that do not (assumed to be inert sites).

The data obtained are presented below. Forty-nine putrescible and six inert sites are listed as having no gas capture account. They account for 5.1 million tonnes of putrescible waste (80% of which is in Queensland and New South Wales) and 1.7 million tonnes of inert waste. This compares with an estimated 21 million tonnes of waste to landfill in Australia in 2006/07 (Commonwealth of Australia 2010 p.24).

Figure 1 WMAA data on landfills that did not capture methane in 2007/08

For each size range, waste type and jurisdiction, the table shows the number of sites, their average age in years and their average receipts in kilotonnes in 2007/08. Where there is only one site in a category its age and kilotonnage receipts are not shown here for commercial confidentiality reasons.

	NSW			Qld			SA			Tas			Vic			WA		
Putrescible landfills	No.	Av. age	Av. kt	No.	Av. age	Av. kt	No.	Av. age	Av. kt	No.	Av. age	Av. kt	No.	Av. age	Av. kt	No.	Av. age	Av. kt
25-50kt (small)	7	34	35	7	20	37	1	-	-	1	-	-	5	29	33	1	-	-
50-100kt (medium)	3	27	72	4	28	71	0	n/a	n/a	1	-	-	1	-	-	5	13	75
100kt + (large)	6	24	261	6	23	252	1	-	-	0	n/a	n/a	0	n/a	n/a	0	n/a	n/a
Inert landfills																		
50-100kt (medium)	0	n/a	n/a	1	-	-	0	n/a	n/a	0	n/a	n/a	0	n/a	n/a	1	-	-
100kt + (large)	1	-	-	3	22	380	0	n/a	n/a	0	n/a	n/a	0	n/a	n/a	0	n/a	n/a

As discussed in the introduction, this represents only a sample of all landfills. Blue Environment believes that more than 10 Victorian landfills accepting 25 to 100kt per year that do not capture methane. The WMAA database contains only six.

3.2 Baseline value

The consultation paper on the design of the CFI states that “a project must result in abatement that would not have occurred in the absence of the scheme”, and that emission reductions are excluded if they “would have occurred in the normal course of business” (DCCEE 2010: p.9). The paper also comments that activities “mandated under Commonwealth, state, territory or local government regulations could not be approved as these form part of business-as-usual” (DCCEE 2010 p.11).

Blue Environment understands that consideration is being given to the development of a single national baseline value based on averages and commonalities, and sought to mimic this approach in the modelling. However, determining an appropriate baseline value is difficult, given the variability of landfills in relation to a wide range of relevant factors.

One of these factors is state and territory regulations over landfill gas. Although these “vary considerably” (Norton Rose 2011 p.1), most jurisdictions have provisions that require control measures where methane concentrations at the site boundary exceed a level indicating an explosion risk, or where landfill gas is creating off-site odours. Methane capture to the level required to achieve this level of performance could be considered to represent the baseline.

However, the degree of capture to prevent offsite odour and appropriately mitigate explosion risks would vary widely. It would be affected by factors such as the waste types accepted, the quantity of waste in place, the integrity of the lining, the proximity of neighbours, the permeability of the geology and regional rainfall patterns.

In a recent communication with the Commonwealth, ALOA suggested that a single average baseline value could be set with reference to Clean Development Mechanism[1] (CDM) projects (Spedding pers. comm.). The CDM has a similar need for a baseline or 'adjustment factor' from which additionality is calculated.

Spedding (pers. comm.) cited a landfill gas recovery CDM project at Copiulemu landfill in Chile[2] . For this project, it was assumed that safety and odour requirements would be achieved by a passive gas capture system i.e. one in which no suction is applied to gas wells. It was estimated that a passive system would capture about 17% of the gas that would be captured by the planned active system. This 17% value was was adopted as the adjustment factor.

Blue Environment reviewed a number of other CDM registered projects to determine the adjustment factors used. The prescribed method for calculating the CDM adjustment factor requires consideration of specific project circumstances, leading to a range of adjustment factors. Most are zero; the remainder were 20% or less[3]. Note that these values are relative to the amount of gas captured through the gas system. There is no reference to total methane generated, which can be modelled is not measurable.

Figure 2 Adjustment factors used in a range of CDM landfill gas projects

Adjustment factor %	Host party (project reference number)
0%	Israel (3820), S. Africa (3677), Syria (2453), Colombia (2554), Indonesia (2518), (2028), Argentina (1442), China (1075), S. Korea (2834)
0 - 5%	Ecuador (3362), Colombia (3995), Chile (254), Chile (2028)
6 - 10%	Chile (170), Brazil (91), Chile (97)
10 - 15%	S. Korea (851)
15 - 20%	Chile (96), Brazil (164), Brazil (373)

Determination of an appropriate baseline would require detailed consideration in an Australian context, but for this project Blue Environment draws on these CDM projects to set what it considers a conservative baseline figure of 25%. It is assumed that state and territory regulators would ensure that appropriate capture systems are installed so that landfills comply with odour and safety requirements.

3.3 Methane availability model

Blue Environment modelled landfill gas generation from the relevant landfills using the NGERS first-order decay model. The following assumptions were made to in relation to model inputs:

- The CFI becomes operational at the start of the 2012/13 financial year.
- The characteristics of landfills recorded in the WMAA database for 2007/08 is representative of the characteristics in 2011/12 in relation to tonnages and methane capture.

[1] A mechanism established under the Kyoto Protocol to encourage greenhouse gas abatement in developing countries.
[2] Information about the project is available at http://cdm.unfccc.int/Projects/DB/DNV-CUK1126875537.72/view
[3] The CDM adjustment factor at one additional site was 61%, but this was based on an existing power station .

- The quantity of waste received at each landfill increased in every year since opening by 1.2%, which is understood to be close to the average rate of growth in waste quantities applied in the National Greenhouse Accounts.
- Waste deposition ceases at the end of the 2011/12 financial year. This means that the model first-order decay model will estimate methane generated from legacy waste only.
- Sites accepting domestic waste are putrescible. The proportional composition of waste materials they accept annually is constant and is equal to: 40% municipal waste; 40% commercial and industrial waste; and 20% construction and demolition waste. The mixes of waste materials in these waste streams are as set out in the NGERS model.
- Sites not accepting domestic waste are inert. The proportional mix of waste materials they accept annually is constant and is equal to that set out in the NGERS model for construction and demolition material.
- The proportion of the organic carbon in each waste material that degrades (DOC_f) is as recently applied in the National Greenhouse Accounts, rather than the average value (0.5) that was used previously and remains in the NGERS model.

Apart from the DOC_f values, the NGERS model defaults, including the global warming potential of methane, were left unchanged.

Data were entered into a NGERS model for each of the average landfills within categories shown in Figure 1. The methane generation estimate was adjusted to estimate methane likely to be captured and to be eligible for credits should a gas collection system be installed (i.e. creditable methane). This involved subtracting a proportion of the estimated generation to take into account methane that:

- the gas collection system does not capture – the instantaneous capture rate of the well system was allocated an initial value of 75%, representing a reasonably efficient flaring system
- is not eligible for credits because it falls within the baseline – as discussed above, a value of 25% is assumed
- is not eligible for credits because, in the absence of the gas collection project, it would have been oxidised as it passed through the cap – the default NGERS value of 10% is assumed.

The results are shown in Figures 3 and 4 for 2012/13, which is the peak year of methane generation from the legacy waste. Figure 3 shows the total creditable abatement available – it amounts to about 2.2 Mt CO_2-e across all the sites. Figure 4 shows the total abatement available i.e. including methane abatement that would not attract credits but would also be captured should gas capture systems be installed. The total abatement available is estimated at about 3.3 Mt CO_2-e across all the sites.

Figure 3 Estimate of creditable abatement available in 2013 at landfills on the WMAA database should gas capture systems be installed

Data in kilotonnes of carbon dioxide equivalent

Putrescible landfills	NSW	Qld	SA	Tas	Vic	WA	Australia
25-50kt in 07/08	120	112	10	12	72	11	338
50-100kt in 07/08	98	135	0	11	35	96	375
100kt/yr + in 07/08	691	682	30	0	0	0	1,404
Inert landfills							
50-100kt/yr in 07/08	0	4	0	0	0	4	8
100kt/yr + in 07/08	15	82	0	0	0	0	98
All sites	**925**	**1,016**	**41**	**23**	**107**	**111**	**2,223**

Figure 4 Estimate of total abatement available in 2013 at landfills on the WMAA database should gas capture systems be installed

Data in kilotonnes of carbon dioxide equivalent

Putrescible landfills	NSW	Qld	SA	Tas	Vic	WA	Australia
25-50kt in 07/08	178	166	15	18	107	17	501
50-100kt in 07/08	146	200		16	51	143	556
100kt/yr + in 07/08	1,024	1,011	45				2,080
Inert landfills							
50-100kt/yr in 07/08	22	122					144
100kt/yr + in 07/08	**22**	**128**	**0**	**0**	**0**	**5**	**156**
All sites	**1,371**	**1,505**	**60**	**34**	**158**	**165**	**3,293**

4. Modelling additional capture of methane

The second part of the study involved preparing and running an impact model to estimate how many gas collection systems would be installed under various CFI scenarios.

4.1 Flare system cost model

Generic unit cost estimates of were sought in relation to landfill gas flare systems that use the simple vertical well approach. Estimates are tabulated below. The capital costs were derived from discussions with industry sources. The operating costs are from the US EPA (2010 p.3.5) and confirmed as reasonable by an industry source.

Figure 5 Unit costs for landfill gas flaring systems

	Capital costs			Annual operating costs
Wells	$12,000			$3,500
	500 m^3/hr	*1000 m^3/hr*	*1500 m^3/hr*	
Flares	$300,000	$350,000	$400,000	$4,500 (incl. power)

Gas system costs by site type and jurisdiction were calculated based on these unit cost data, assuming characteristics of landfills and methane as tabulated below.

Figure 6 Assumed characteristics of landfills and methane

Site size (kt in 07/08)	25-50	50-100	100+
Average landfill depth (m)	20	25	30
Site type	Putrescible	Inert	
Av. density waste in place (t/m3)	1	1.3	*Source: Veolia*
Average no. wells per hectare	7	5	
Density methane (kg/m3)	0.67	*Assumed temperature = 19C*	
% methane in LFG	50%	*DCCEE standard assumptions*	
GWP methane	21		

The estimated ranges for system capital and operating costs based on these values are tabulated below.

Figure 7 Estimated capital and operating costs of landfill gas flaring systems by landfill size

Data in thousands of dollars

	Putrescible landfills			Inert landfills	
kt in 07/08	25-50	50-100	100+	50-100	100+
Capital	$540 - $732	$492 - $1,334	$1,190 - $2,744	$528 - $540	$984 - $1,874
Operating	$75 - $131	$61 - $209	$167 - $493	$71 - $75	$204 - $366

4.2 Impact model

The impact model was constructed to assess how flaring systems would be installed assuming that the landfill gas recovery market responds efficiently to the price signals and constructs gas systems become operational with the CFI at the start of the 2012/13.

The model firstly calculates the break-even price over the crediting period for each jurisdiction, landfill size category and waste type. The crediting period is the time during which the Commonwealth fixes conditions for determining the baseline notwithstanding, for example, any changes to state regulations over gas capture. It was set at seven years

Secondly, the model calculates the price that credits would need to average in order that costs are recouped within a set payback period (ignoring the time-cost of money). Capital costs are depreciated over the crediting period. The payback period was initially set at three years.

Thirdly, the model assesses the quantity of methane abatement at a given credit price. The credit price was initially set at $17 per tonne CO_2-e, representing the mid-point of a historical price range for equivalent credits in international markets of €8-16 (Lebbon, pers. comm.), which is assumed to equate to a dollar price range of $10-24. Abatement is estimated under both decision scenarios i.e. where the requirement is to break even over the crediting period, or to achieve payback of capital investment over a specified time period.

5. Results of the investigation

The results are based on the initial parameter settings are presented first. A second section examines the sensitivity of these results to different assumptions about credit prices.

5.1 Results based on initial parameter settings

Break-even credit prices over the seven-year crediting period are shown in Figure 8 for landfill size and waste type. Recall that the calculations were undertaken for 'average' landfills in each jurisdiction – the range figures represent the lowest and highest prices across the jurisdictions. For all the average putrescible landfills, the break-even price falls within the historical price range for credits in international markets ($10-24).

Figure 8 Credit prices at which gas flaring breaks even over the crediting period

kt in 07/08	25-50	50-100	100+
Putrescible landfills	$15-17	$11-15	$9-11
Inert landfills	n/a	$39-43	$24-26

Credit prices needed for a payback of three years are shown in Figure 9 for each landfill size and waste type. All large putrescible landfills fall within the historical price range for credits. There is also some overlap in relation to the medium-sized sites.

Figure 9 Credit prices at which gas flaring becomes viable based on a three-year payback

kt in 07/08	25-50	50-100	100+
Putrescible landfills	$25-32	$21-27	$16-22
Inert landfills	n/a	$77-88	$43-46

If investment decisions are made on the requirement of breaking even over the crediting period, then a credit price of $17 per tonne CO_2-e is sufficient to prompt system installation at all the putrescible sites modelled. This would lead to abatement of 3.2 Mt CO_2-e in 2012/13, the peak year for generation from legacy waste. If decisions were made on the requirement that payback is achieved within three years, then a credit price of $17 per tonne CO_2-e would result in new gas systems at 12 large (100kt+)

putrescible sites in NSW and Queensland. This would give rise to abatement of 2.1 Mt CO_2-e in 2012/13. No installation of gas systems would occur at inert sites under either decision scenario.

5.2 Sensitivity analysis

The sensitivity of the results to credit price assumptions was tested. Average prices were set firstly at \$12, then at \$24 per tonne CO_2-e. The results are shown in Figure 10. At the reduced credit price of \$12 per tonne, a break even decision scenario would result in 2.3 Mt CO_2-e of additional abatement in 2012/13 but under a three-year payback requirement there would be no new gas systems or abatement. At \$24 per tonne, the break-even abatement is unchanged from the initial settings, but the payback requirement would result in abatement of 2.3 Mt CO_2-e.

Figure 10 Sensitivity of the results to credit price assumptions

Assumed credit price	\$17	\$12	\$24	\$17	\$12	\$24
Investment decision basis	Break even over crediting period			Payback over 3 years		
Abatement, Austr. 12/13 (Mt CO_2-e)	3.2	2.3	3.2	2.1	0	2.3
No. flaring systems installed	49	18	49	12	0	18

6. Discussion and conclusions

The modelling suggests that incorporation of landfill legacy emissions in the CFI should lead to significant abatement. It must be remembered that the installation of gas systems produces ongoing abatement not only of emissions from legacy waste but also new waste deposited subsequent to the CFI start date – this has not been examined here.

A key uncertainty that would influence the extent of gas abatement under a CFI environment is operators expectations (and subsequent experience) of credit prices, and how these affect investment decisions e.g. through payback requirements.

There are three major limitations of this analysis:

- The data pertains to a limited group of sites. The CFI is likely to prompt additional abatement from: operating landfills without gas systems that were not in the WMAA data; closed landfills; and open or closed landfills that increase their capture efficiency due to the CFI.
- The landfill data are rather old (2007/08). Changes are likely to have occurred since then, including installation and decommissioning of landfill gas systems. The landfill database is also incomplete.
- The privacy provisions associated with the WMAA landfill survey required aggregation of data into groups, which were averaged for modelling purposes. The effect of this in the model is to increase the 'lumpiness' of responses, especially in the sensitivity analysis. It is likely, for example, that the zero abatement in sensitivity scenario 2 would not have eventuated should site-by-site data be available.

Blue Environment understands that a new and more comprehensive landfill survey is currently underway and the revised privacy provisions may allow for release of disaggregated data for specific purposes with site identifiers removed. The model could therefore potentially be re-run in the near future with all major limitations significantly reduced.

References

Commonwealth of Australia (2010) *National Waste Report*, prepared by the Environment Protection and Heritage Council, March

DCCEE (Department of Climate Change and Energy Efficiency 2010) *Design of the Carbon Farming Initiative: Consultation Paper*, available at http://www.climatechange.gov.au/government/submissions/carbon-farming-initiative.aspx

Johnson A, coordinator of WMAA landfill seminar (personal communication), telephone call with Joe Pickin of Blue Environment, 15 March 2011

Lebbon M, LMS Pty Ltd corporate development and researcher on the CFI (personal communication), discussion with Joe Pickin of Blue Environment, 17 March 2012

Norton Rose (2011) *Legal requirements for landfill gas management.* Unpublished internal memorandum, January

Spedding M, ALOA Secretary (personal communication), email to the Department of Climate Change and Energy Efficiency, 28 February 2012

US EPA (United States Environmental Protection Agency 2010) *Landfill Methane Outreach Program Project Development Handbook*, available at http://epa.gov/lmop/publications-tools/handbook.html