Carbon brainprint case study

Training for landfill gas inspectors

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Summary

Anaerobic deterioration of biodegradable wastes in landfill sites is an important source of greenhouse gases. Of the estimated UK total of 2330 kt methane emitted in 2008, 966 kt (equivalent to 24 Mt of carbon dioxide) came from landfill, compared with 876 kt from livestock agriculture, the next largest source. Increasing the amount of methane that is recovered and used as fuel is an important method of reducing emissions.

In 2008 Cranfield University was asked by the Environment Agency (EA) to run a 12 day course to train 12 EA officers, based on the knowledge of a retired EA industry expert. At the end of the course, the students split into two groups, each of which undertook 12 site visits. These 24 sites were subsequently assessed by the EA, who estimated that the additional measures recommended had collected an additional 7,600 m^3/hr of landfill gas. A further 12 officers have now received the advanced training, and another 70 have attended a foundation course in which they learn how to audit and assess landfill gas controls on sites.

The additional collection of methane resulting from the first set of visits is equivalent to 453 kt CO_2e/year. Extrapolating from this by making conservative assumptions about possible diminishing returns, the savings to the end of 2010 from the two groups (the retrospective brainprint) are about 1,330 kt CO_2e with a 95% confidence range of 1,091–1,570 kt CO_2e. Using the same assumptions, if both groups continue working for a further three years, the savings over the five year period (the prospective brainprint) will be 5,380 kt CO_2e with a 95% confidence range of 3,695–7,309 kt CO_2e.

General description

It is estimated that 52,600 t of municipal solid waste were disposed of in landfill in 2008 (GHGI). The biodegradable organic matter is broken down, primarily by anaerobic bacteria, to produce landfill gas consisting mainly of methane and carbon dioxide in roughly equal amounts, although the composition changes with time. With the current average composition, 1 t of waste produces about 100 m^3 of gas. Methane is of particular concern, because it has a GWP 25 times that of carbon dioxide (IPCC, 2007). Of the estimated UK total of 2330 kt methane emitted in 2008, 966 kt came from landfill, compared with 876 kt from livestock agriculture (enteric fermentation and manure management), the next largest source (NAEI, 2011).

Emissions from landfill have been reduced from 2372 kt in 1990 by several measures (Figure 1). Increased methane recovery is the major cause of the reduction (MacCarthy *et al.*, 2010a), assisted by improved management practices, for example dividing the landfill into discrete cells which are capped when full. The Landfill Directive (EC, 1999) changed the way in which landfill sites were managed and, in particular, prioritized reducing the amount of biodegradable waste being sent to landfill, to reduce emissions in the longer term. The UK greenhouse gas inventory estimates that 2561 kt of methane were recovered in 2008, so emissions are now less than 30% of the total produced (MacCarthy *et al.*, 2010b). Landfill gas that is captured and used is an important source of renewable energy, because it is derived from biogenic materials, such as food waste and paper. The contribution of landfill gas to UK energy generation in 2009 was 23.8% of all renewable energy sources, equal to approximately 1,640 kt of oil (DECC, 2010).

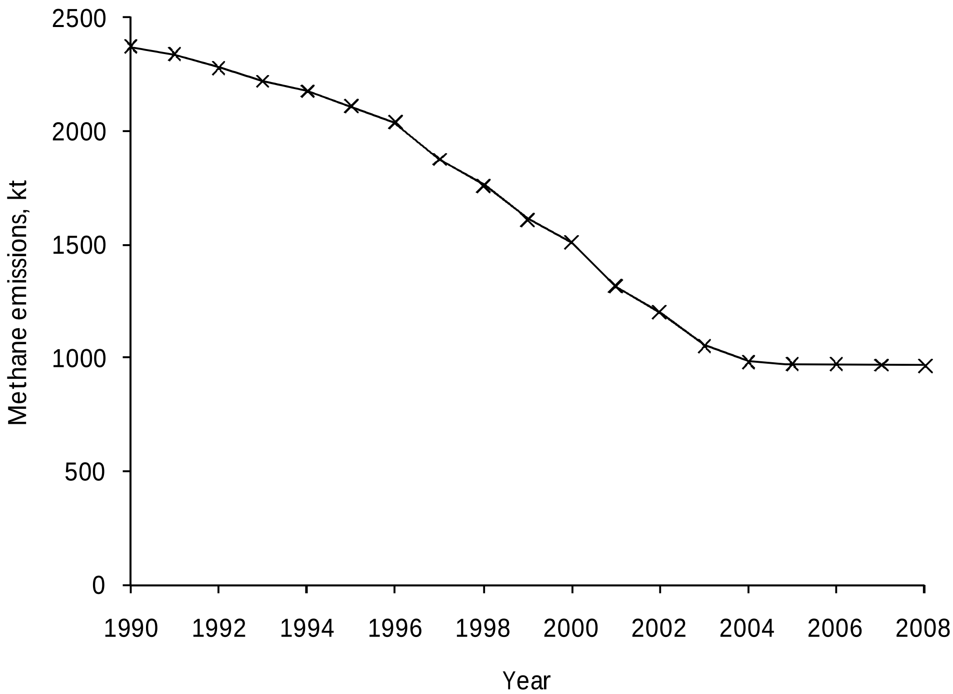

Figure 1. Annual methane emissions from landfill sites (NAEI, 2011)

In 2008 Cranfield University was asked by the Environment Agency (EA) to run a 12 day course to train 12 EA officers, based on the knowledge of a retired EA industry expert. At the end of the course, the students split into two groups, each of which undertook 12 site visits. These 24 sites were subsequently assessed by the EA, who estimated that the additional measures recommended had collected an additional 7,600 m^3/hr. A further 12 officers have now received the advanced training, and another 70 have attended a foundation course in which they learned how to audit and assess landfill gas controls on sites.

This case study used information provided by the Environment Agency's assessment of the first course to estimate the total GHG emissions reduction that were and could be obtained as a result of this training.

System boundaries

The case study considered the potential results from the EA officers who have already received the advanced training, that is a total of 24 officers. It considered a period of 5 years, to limit the uncertainties about staffing, changes in performance and other changes in landfill regulation and management. It was assumed that there was no decrease in the number of trained officers operating in this period, with any departures being replaced by officers who had attended the foundation course.

In accordance with the general principles, only the emissions reductions arising directly from the recommendations of the officers were included in the assessment; secondary benefits that might arise, for example by similar practices being adopted at other sites, were excluded.

The GWP estimates were based solely on the amount of methane collected, assuming that this would all otherwise have been emitted to the atmosphere. The carbon dioxide in the landfill gas collected was not be included, although it is above the 1% cut off level, because it would ultimately be emitted to the atmosphere.

The methane collected would normally be burned, either as fuel or by flaring, so the emission reduction was the net effect of the difference between methane collected and carbon dioxide released. The use of the methane as a fuel could have an additional benefit, by displacing fossil fuel use, this was not assessed.

Data

The available data on the emissions saving were given in the general description.

In order to collect additional gas from the sites, it would normally be necessary to add extra wells and connecting pipes with consequent life cycle emissions, but existing equipment such as engines/generators would normally be adequate to use the gas (P. Longhurst, personal communication). A recent study calculated the total cost of equipment needed on nine landfill sites of different sizes to collect landfill gas following best practice (Raventós Martín & Longhurst, 2011). The largest site required about 42 km of medium density polyethylene (MDPE) pipe of diameter 90–450 mm and wall thickness, measured by standard dimension ration (SDR) of 11 or 17.6 according to purpose (P. Longhurst, personal communication). The linear density for each pipe size was obtained from a supplier's web site (Radius Systems, 2011). Using this data, and adding 5% for joints and other fittings, the total mass of MDPE was 573 t.

The emission factor for MDPE pipe was not available in the standard inventory databases. CCaLC-Tool (Azapagic, 2011) gave 2.56 kg CO_2e/kg for HDPE pipe, 1.99 for HDPE granules and 2.16 for LDPE granules, from which it appeared likely that the value for MDPE pipe would be within 10% of that for HDPE pipe. The emissions reported for 1.5 mm MDPE sheeting were 2.54 kg CO_2e/kg (Baldasano Recio *et al.*, 2005), which agrees closely with the value for HDPE pipe, so this value was used.

Using these data, the total emissions from the piping for this installation were 1.455 kt CO_2e. This is less than 1% of the gas captured in one year, so no estimates of equipment life cycle emissions were included in the brainprint calculations.

Brainprint

Retrospective Brainprint

As noted in the system description, the original 12 students worked as two groups of six, each of which undertook 12 site visits. The EA assessed the results and estimated that the measures taken had resulted in the collection of an additional 7,600 m^3/hr of landfill gas. The composition of landfill gas varies with time, so the EA suggested taking a conservative estimate that the methane content was 40% v/v, giving 26.63×10^6 m^3 methane/year. Assuming a density of 0.68 kg/m^3 at 15°C and 1 atm pressure gave 18.1 kt/year. Methane has a GWP of 25, so this was 453 kt CO_2e/year. However, the methane collected would ultimately be burnt, emitting carbon dioxide in the ratio 44:16 or 2.75 kg/kg, so the net reduction in emissions was 403 kt CO_2e/year.

Note that the estimates of GWP made by the EA differed slightly, because they used the density of methane at 0°C, giving 19.022 kt methane/year, and the IPCC 1996 GWP of 21, used for the national inventory, with no adjustment for combustion, giving 399 kt CO_2e/year.

In the absence of data on the continued work of this group and of the second group of students, it was necessary to make assumptions to make a conservative estimate of the total effect to date. Assuming

- the emissions savings from the first group began at the start of 2009,
- they declined (due to changes in the underlying emissions and possible reduction in effectiveness) by 10%/year,
- no new sites were visited,
- the savings from the second group began at the start of 2010,
- they achieved 70% of the first, to allow for the possibility that the first groups of sites were chosen because there was greatest potential for savings

the total emissions saved to the end of 2010 were 1,048 kt CO_2e (Table 1).

Table 1. Estimated methane emissions saved (kt CO_2e) by inspectors trained to date assuming group 1 made no further site visits and group 2 made one set of visits

Year	Group 1	Group 2	Total
2009	403		403
2010	363	282	645
Total	766	282	1,048

Assuming that the first group also made site visits in 2010 and achieved the same results as the second group, the total emissions saved to the end of 2010 were 1,330 kt CO_2e (Table 2).

Table 2. Estimated methane emissions saved (kt CO2e) by inspectors trained to date assuming group 1 and group 2 made one set of visits each in 2010. The totals columns include savings from new visits and diminishing savings from the previous year.

Year	Group 1 new visits	Group 1 total	Group 2 new visits	Group 2 total	Total
2009	403	403			403
2010	282	645	282	282	927
Total		1,048		282	1,330

Prospective Brainprint

Attempting to predict the future impact of the two groups that have been trained required further assumptions about future activity and effectiveness. Assuming pattern used above of declining returns from new site visits and declining emissions savings from sites previously visited continued for 5 years, the total emissions reduction was 5,380 kt CO_2e (Table 3).

Table 3. Estimated methane emissions saved (kt CO2e) by inspectors trained over 5 years. The totals columns include savings from new visits and diminishing savings from previous years.

Year	Group 1 new visits	Group 1 total	Group 2 new visits	Group 2 total	Total
2009	403	403			403
2010	282	645	282	282	927
2011	197	778	197	451	1,229
2012	138	838	138	544	1,383
2013	97	851	97	587	1,438
Total		**3,515**		**1,865**	**5,380**

As noted in the system description, the total methane emitted from landfill sites in 2008 was 966 kt (21,494 kt CO_2e) and 2,561 kt (56,982 kt CO_2e) was recovered. Supposing that emissions could be reduced by 10% would save 2,149 kt CO_2e/year, compared with 1,438 kt CO_2e in the final year above, so the estimate in Table 3 from site visits to 216 of about 400 operational landfill sites seems plausible, especially if those with the highest emissions were selected.

Uncertainties

The volume of additional landfill gas recovered as a result of the first set of visits was measured by the EA and was treated as certain. The methane content of 40% used by the EA was chosen as a conservative value; for example the national emissions inventory uses 50%. A survey of seven UK landfill sites found concentrations in the range 37–65% (Allen *et al.*, 1997). One site was sampled 15 times over 15 months, and gave a range of 37–62%. The other sites were each sampled once. The mean of all 21 values was 49.9% and, by inspection, the distribution was almost uniform. The uncertainty analysis used a uniform distribution in the range (36,64) to give a mean of 50 and similar extrema to those observed.

The numbers of future visits, their effectiveness and the change in emissions are all unknown and could, in principle, increase instead of decreasing. However, visiting the sites with the highest potential savings first would be a reasonable strategy, so a generally decreasing return is likely. In the absence of data, a normal distribution with a coefficient of variation of 0.5 was assumed for both parameters: the decrease in emissions and decrease in the combined number and effectiveness, and the parameters were generated independently for each year. This gave a probability of about 2.5% of an increase (a negative decrease) in any year.

The analysis was performed using the free Simulación add-in for Excel (Varela, 2011) using 10,000 iterations. The resulting retrospective brainprint, assuming that both groups were active in the second year had mean 1,331 kt CO_2e and 95% confidence interval 1,091–1,570 kt CO_2e. For the prospective brainprint the mean was 5,380 kt CO_2e and the 95% confidence interval was 3,695–7,309 kt CO_2e.

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