Appendix A7.8 SKM Enviros 2013 Outline Life Cycle Assessment

Kerdiffstown Landfill

TASK 14 OUTLINE LIFE CYCLE ASSESSMENT

- Final
- August 2013

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Contents

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1. Introduction

The former landfill and waste processing facility at Kerdiffstown has now closed and is in the early stages of remediation. The Environmental Protection Agency (EPA) are using powers under Section 56 of the Waste Management Act 1996 (as amended) to restore the site and put in place appropriate aftercare measures to prevent and limit pollution from the materials which are present at the site.

In February 2013 SKM Enviros (SKME) were appointed as a framework contractor by the EPA to provide technical environmental support services in relation to the remediation of Kerdiffstown Landfill. Phase 1 of the contract involves the completion of a number of discrete technical tasks in order to progress towards identification of potential remedial options for the site.

Task 14 sets out considerations that apply to the Life Cycle Assessment (LCA) of the remediation and potential end use scenarios at Kerdiffstown landfill. This assessment looks at the overall impact of the various possible remediation scenarios to the extent that they are known at the present time, including different quantities and types of emissions that would be generated, (volumes of leachate, quantities of landfill gas, total LCA GHG emissions) against a Do Nothing scenario.

For the purpose of this study, in the absence of detailed remedial proposals or designs, the difference of potential environmental impacts, in terms of leachate, surface water and landfill gas emissions, as well as the predicted total carbon equivalent rating arising from associated material movement, transportation and imbedded carbon have been compared at a high level making various assumptions in terms of emissions estimates and timescales for remedial works.

The feasibility of arriving at meaningful life-cycle comparisons relating to the likely end-use options and remediation scenarios are set out below

1.1. End-use Options for the Site

A range of potential end use options have been considered during the Phase 1 assessment, including; (a) medium to high density mixed use development; (b) completion of the site in accordance with previous planning permissions and restoration proposals; and, (c) some form of passive amenity function/open space end use. Currently, the preferred option is the latter, due to improved potential landscape and visual impacts, flexibility with remedial proposals and longer term provision of an amenity site for the local community. Such an end-use could typically include a car park, and recreational features, for instance a mountain bike track, playground, or educational habitat zoning. It is unlikely that the end-use will feature any high intensity process or major new emission sources, industrial uses, or significant traffic emissions. As such, it is considered that the emissions from the remediated site will vary insignificantly during end-use, regardless of the finer details of the final end-use design option.

The essential emission control systems for the remediated site, including landfill gas flaring, and leachate collection/ removal, will remain as long-term requirements regardless of which end use option is selected. The predicted emissions that will arise during the end-use will be determined by the chosen remediation infrastructure, which are summarised below. A detailed emissions appraisal for the end-use phase of the site is therefore not considered warranted, as the end-use options are expected to all feature very similar emission and carbon considerations.

1.2. Remediation Scenarios Appraisal

The Scenarios available for the remediation of the site do require a detailed emissions and carbon appraisal, as their emissions impact may vary significantly. For the purposes of this assessment it is considered relevant to compare proposed remediation of the site against an essentially un-remediated site baseline (i.e. Do Nothing). Therefore, the following scenarios were assessed:

- **Scenario 1 –Do Nothing-**

  Assume that the landfill site will not be remediated, and remains uncapped, and with only partial liner facilitating incomplete leachate collection. Under this scenario, all the gas generated in the waste body is released as fugitive emissions.

- **Scenario 2 – "In situ" remediation of landfill –**

  Assume the waste remains in situ to extent possible, with waste re-profiling or waste excavation/ movement minimised. The whole site will be capped, reducing surface water infiltration, and reducing diffuse landfill gas emissions. Gas extraction will occur from the full site after 2015. However the site remains unlined in the northwestern area of the site.

- **Scenario 3 – Full site remediation –**

  This includes lining of waste body and full capping. This scenario would require all waste to be moved, landfill liners to be placed at the bottom of engineered waste cells, and all waste to be re-emplaced. The re-emplaced waste would be fully capped, facilitating more complete landfill gas extraction, as well as more complete leachate capture. Under this scenario the restoration period would last longer, with no effective gas extraction until site works have finished, estimated for 2020. A phased reduction of fugitive emissions would be anticipated during the construction period (say notionally for the purposes of this assessment 2014-2020), and finally a more complete emission control achieved after 2020 following successful remediation.

The above Scenarios have been assessed in the following sections for PRTR emissions reporting, and for a LCA of GHG emissions. The assessments are based on the existing site conditions (landfill gas generation and flaring, current leachate removal volumes, etc.) and modelled emission projections were generated to compare the three scenarios highlighted above.

2. PRTR and ELV Assessment

Emissions from a landfill activity are generally reported to the EPA as part of the facilities' annual environmental report (AER) and would include monitoring of the in-waste landfill gas and flares against set emissions limit values (ELVs), reporting of the quantity and constituents of leachate removed from the site, as well as reporting on licensed discharges to surface waters, where relevant. Depending on the quantity of emissions, reporting is also required under the European Pollution Release and Transfer Register (E-PRTR), as well as inclusion in the National Greenhouse Gas (GHG) reporting.

The EPA has combined the reporting by licensed facilities of PRTR, ELV and GHG in one web-based reporting tool, which all licensed facilities have to complete as part of their AER. The EPA in turn reports to the EU any emissions that exceed the E-PRTR thresholds, and compiles the submitted data for the National GHG report.

2.1. E-PRTR

E-PRTR Regulation (EC) No 166/2006 concerning the establishment of a European Pollutant Release and Transfer Register came into force in February 2006, and was brought into Irish law through S.I. No. 123 of 2007. It set up a European wide data-base of significant environmental emissions, which is accessible and searchable by any member of the public. The aim of PRTR is to enhance public access to environmental information across Europe, to contribute to prevention and reduction of pollution, as well as to deliver data for policy makers and environmental decision makers.

The Regulations list 65 types of industries (mainly IPPC and Waste facilities) that have to report if they emit any of 91 specified substances to air or water (direct or indirect) and exceed the set reporting thresholds for those substances. Exceeding the reporting thresholds does not imply licence non-compliance, but is merely an indication of the facility being a significant contributor to national emissions, and therefore to be included in the National PRTR report. Accidental Emissions and diffuse source emissions, such as fugitive landfill gas, must also be quantified.

For landfills, such as Kerdiffstown, the relevant emissions which may have to be reported under PRTR include Methane, Carbon Dioxide, Carbon Monoxide, Nitrous Oxides, Ammonia and Sulphur Oxides, if the emissions exceed the specified reporting thresholds. (e.g. above 100,000 kg/annum of methane emissions). In addition the PRTR reporting requires wastes transferred offsite for treatment or recovery to be reported. This applies to leachate removal for offsite treatment, where more than 2,000 tonnes /per year is removed. PRTR reporting of emissions to surface water would include Total Nitrogen, Phosphorous, Chlorides, Metals and solvents, where the reporting thresholds are exceeded.

32 landfills in Ireland were included in the 2011 Irish PRTR Report, with methane emissions and leachate transfers off-site being the main reported parameters in this sector. Emissions to surface water did not feature above PRTR thresholds from any landfills. Details of the Irish PRTR reporting can be viewed at http://prtr.epa.ie/map/default.aspx

The current assessment establishes the current and projected annual emissions from Kerdiffstown, and assesses the likely emission quantities that may require reporting under PRTR, depending on which remediation Scenarios is chosen.

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Predicted methane generation for the site has been undertaken using GasSim, an industry and regulator recognised model, which has been calibrated using site specific information obtained from previous ground investigations and results of collecting and flaring gas from parts of the landfill for over two years.. The modelling was undertaken using current estimated amounts of 3.1 million tonnes of waste in the landfill, and a 35% bio-degradability factor within the wastes. Key outputs for the PRTR and ELV assessment are presented in Tables 1 to 3.

Table 1 below summarises current and peak methane, ammonia and chloride emissions from the landfill.

Table 1.: Current and Peak Emissions from Kerdiffstown Landfill

	Total Estimated Methane Generation kg/annum (GasSIM-Calculation)	Methane Flared (Measured 2011-2012) kg/annum	Net Methane Emissions (Calculated) kg/annum	EPRTR Threshold Reporting Methane >100,000 kg/annum
Estimated peak gas production 2009	**2,775,000**	**none**	**2,775,000**	Above PRTR reporting
Current 2013 (Partial flaring)	**2,163,000**	**222,158**	**1,940,842**	Above PRTR reporting
		Leachate		
	Leachate Volume tonnes/annum	**Ammonia (as Total Nitrogen kg/annum**	**Chlorides kg/annum**	
PRTR reporting Threshold	**2,000 t/a removal**	**50,000**	**2,000,000**	
Scenario 1 –Do nothing Based on current leachate removal	13,540	4,375	5,972	Above PRTR (Volume reporting only)

Table 2 shows the predicted methane emissions from the landfill for the three scenarios highlighted for the period between 2012 and 2044 (i.e. including aftercare), which takes into account an estimate of amount of methane that might be flared off for each Scenarios.

Table 2: Total predicted Methane Emissions over Aftercare (2012 to 2044)

	Total Estimated Methane (Diffuse Emission) in kg (Total methane generated minus amount of projected methane flared in each Scenario)
Scenario 1 –Do nothing	41,415,000
Scenario 2– In situ remediation	19,079,000
Scenario 3 – Waste re-emplacement	13,958,000

Based on the above information included in the above tables it is then possible to evaluate PRTR reporting requirements for each of the above scenarios as summarised in Table 3.

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Table 3: PRTR Reporting under all scenarios (including Do Nothing)

Landfill Gas				
	Total Estimated Methane Generation kg/annum (GasSIM-Calculation)	**Methane Flared (Calculated) kg/annum**	**Net Methane Emissions (Calculated) kg/annum**	**EPRTR Threshold Reporting Methane >100,000 kg/annum**
Scenario 1 – Do nothing--				
2016	1,796,000	none	1,796,000	PRTR reporting required
2026	993,000	none	993,000	Not required
Scenario 2 – In situ remediation				
2016	1,796,000	1,208,000	588,000	Not required
2026	993,000	670,000	323,000	Not required
Scenario 3 – Waste re-emplacement				
2016	1,796,000	539,000	1,257,000	PRTR reporting required
2026	993,000	894,000	99,000	Not required
Leachate				
	Leachate Volume tonnes/annum	**Ammonia (as Total Nitrogen)**	**Chlorides**	
PRTR reporting Threshold	**2,000 t/a removal**	**50,000 kg/annum**	**2,000,000 kg/annum**	
Scenario 1 –Do nothing Based on current leachate removal	13,540	4,375	5,972	Volume report only
Scenario 2 – In situ remediation Based on current volume x 3	40,620	13,125	17,916	Volume report only
Scenario 3 – Waste re-emplacement Based on current volume x 5	67,700	21,875	29,860	Volume report only

2.2. PRTR Discussion

The PRTR assessment for landfill gas emissions and leachate volumes from Kerdiffstown has been carried out for the three remediation scenarios highlighted in Chapter 1. This assessment indicates the following over the total time span of the remaining landfill aftercare (30 years),

- Scenario 2 would provide significant landfill gas and leachate control over the shortest time period (within 3 years);
- Scenario 3 would provide most complete landfill gas control, by maximising the extraction and flaring of methane, but only after 6 years of remediation works;
- Scenario 3 would provide the most complete infrastructure to facility leachate removal from the site, but only after 6 years of remediation works, and,
- Scenario 3 would provide about 12% better methane control than Scenarios 2.

In completing the relative merits in terms of emissions, various other factors and other emission considerations, must be borne in mind. These relate primarily to long term disturbance of site conditions, if the Scenario 3 is chosen, with an estimated timescale for remediation of say 6 years, against a current estimated timescale of 3 years for Scenario 2.

Odour emissions, in particular, would be increased significantly under Scenario 3, as the movement and re-emplacing of all the waste would cause heightened odour emissions over extended periods of time. The long-term disturbance of the site under Scenario 3 would also have significant implications for dust and noise emissions, which would require detailed modelling once a phasing plans was finalised.

Regarding the benefit of Scenario 3 for leachate management, it is evident that improved leachate extraction and removal would be provided by provision of full lining for all wastes. However, this must be weighed up against current evidence of leachate impacting on ground or surface waters, and the long-term disturbance that Scenario 3 would entail.

3. Life Cycle Assessment of GHG emissions

The Life Cycle Assessment of GHG emissions looks at the total GHG emissions from direct and indirect activities associated with the project. This assessment looks at annual emissions and also looks at overall emissions over the lifetime of the project (up to 2044). In assessing the overall impact of the remediation scenarios highlighted in Chapter 1 the following activities have been taken included:

1) Emissions resulting from the energy use of existing and new site buildings;

2) Emissions resulting from the energy use of on-site plant and equipment;

3) Fugitive emissions of methane within landfill gas – CO_2 fugitive emissions, or CO_2 from flared methane are considered to be short-cycle carbon

4) Embodied emissions resulting from use of materials for construction of additional structures;

5) Emissions resulting from transport of materials to and off-site; and,

6) Carbon savings resulting from sequestration from reinstated land cover.

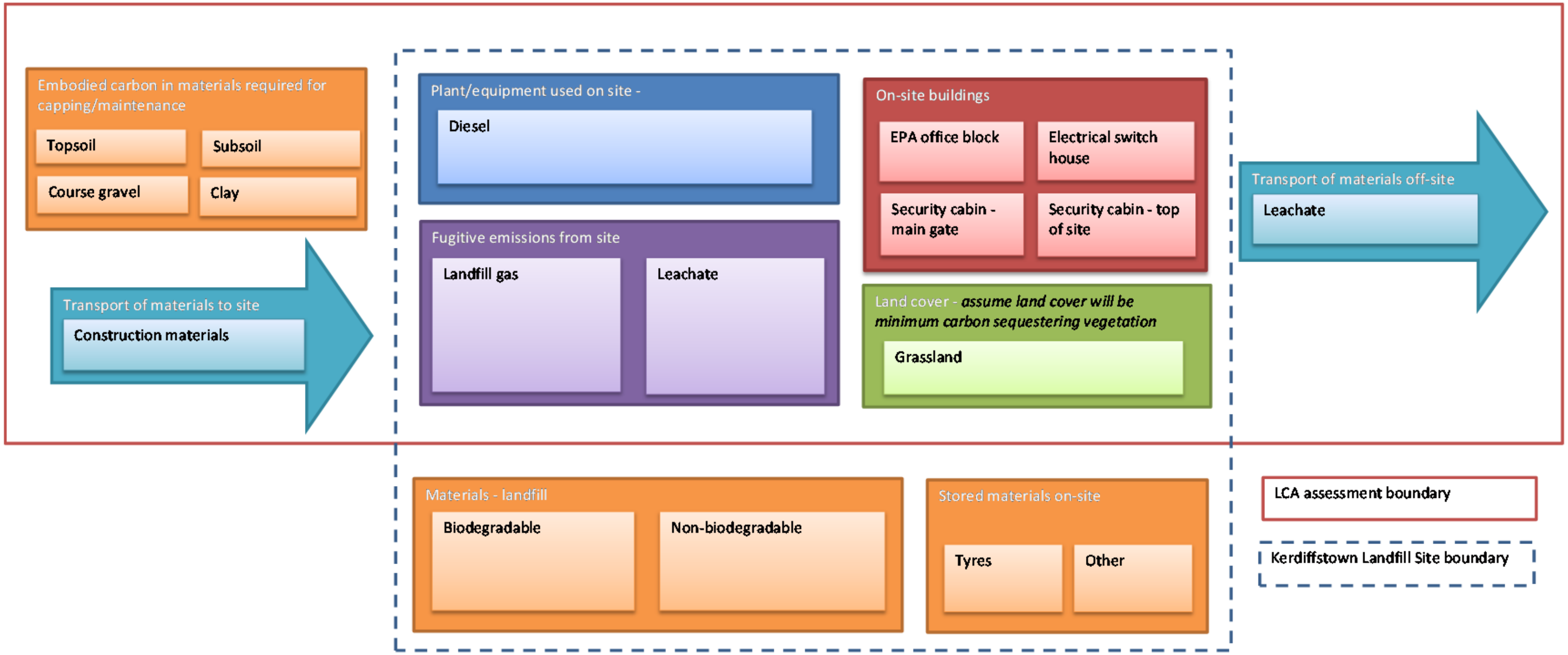
Since methane and other GHGs are likely to be a significant part of the overall current site emissions, the inventory is not a full GHG inventory but measured in tonnes of CO_2e. A simple model of the site, with variables that can be adjusted to model different scenarios has been written in excel, using standard emission factors applicable, where possible, for Ireland or failing that, the UK. The model has been used initially to produce a relative ranking of the three scenarios described previously. As more detailed remedial plans are developed this model will enable refinement of the scenarios and outcomes throughout the initial scoping, design and impact assessment process.

A simplified boundary of the site and the emissions was drawn up for each of the three scenarios. Although there are some minor differences between the boundaries for each of the three scenarios, depending on the site activities that will take place, the basic boundary used is shown on Figure 1 below.

The red line boundary shows the assessment boundary, which includes reasonably anticipated on and off-site activities to the extent that they are currently known. The blue dotted line boundary, shows the site boundary, which includes the materials in the landfill as well as materials stored on-site.

Since none of the remediation Scenarios seek to extract and reuse materials from the landfill (minimal amounts of stored clay could be used in capping but this has been taken off total clay quantities required), the embodied carbon in the materials in the landfill will be the same for all scenarios. Due to the difficulties in calculating this carbon value, they have been excluded for the boundary of all three scenarios.

Figure 1: Indicative boundary for LCA assessment



3.1. Results from the LCA assessment

The initial results of the LCA assessment for the three scenarios are shown in Table 4 below. This shows that Scenario 1 (do nothing) has the highest overall net emissions; Scenario 2 is the lowest (38% less than Scenario 1); and, Scenario 3 is in between with estimated emissions 29% lower than Scenario 1.

For all three Scenarios, the largest single source of emissions is from the methane in fugitive landfill gas. Since Scenarios 2 and 3 involve capping the landfill, capturing the landfill gas and flaring it, the fugitive emissions are lower than for Scenario 1 (uncapped with no flaring).

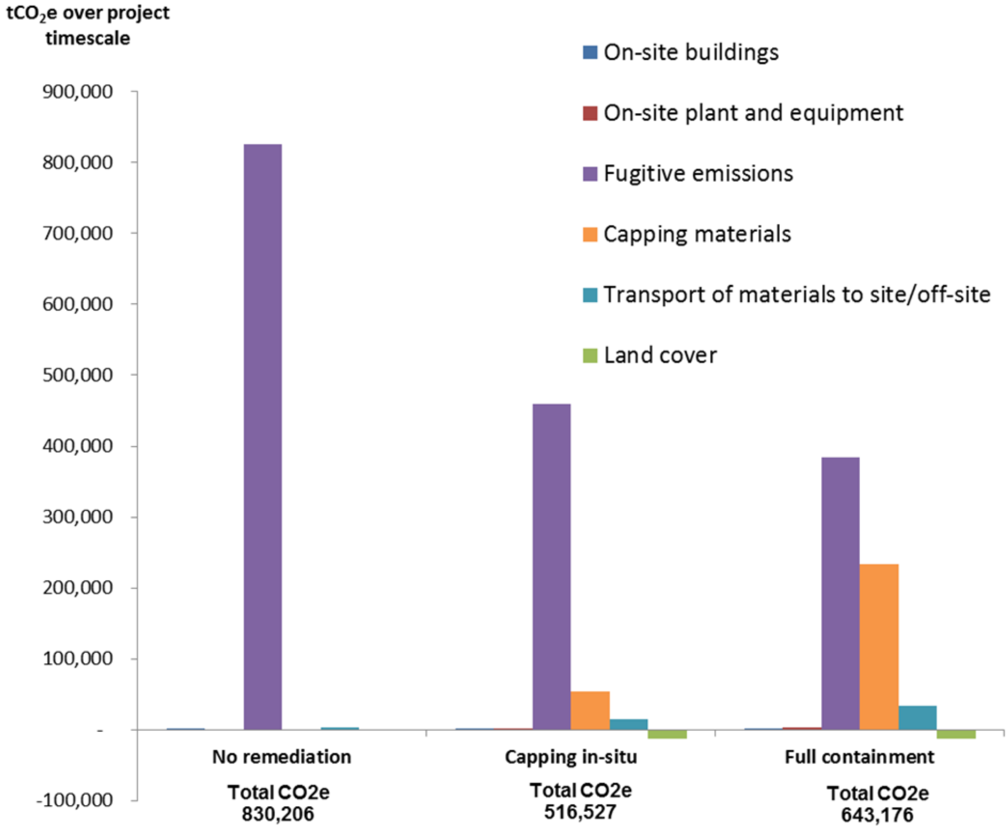
Once landfill gas has been captured and flared, it is converted to CO_2 and is no longer within the boundary of the assessment as this CO_2 is considered to come from a biogenic short-cycle carbon source. However, capping the landfill comes at a cost of embodied carbon for materials and transport of those materials to site. Scenario 3 has higher emissions associated with both capping materials and transport due to the likely greater volume of materials required. There are also more on-site plant emissions due to greater movement of materials around the site. *However, the relative contribution of these activities indicates that, based on current information, the best way to reduce the overall LCA emissions from the site would be to maximise the efficiency of the landfill capture and flaring, but aiming to use the least capping material possible to achieve this outcome*.

Table 4.: Overall emissions over project lifetime under the different Scenarios

Activity	Total lifetime emissions (tonnes of CO2e)		
	Scenario 1	Scenario 2	Scenario 3
On-site buildings	1,055	728	934
On-site plant and equipment		914	2,741
Fugitive emissions	826,554	459,764	384,762
Capping materials		53,861	233,960
Transport of materials to site/off-site	2,994	14,119	33,637
Land cover		-12,858	-12,858
Total	**830,603**	**516,527**	**643,176**

Figure 2 below shows the relative emissions from different activities for the three scenarios. For all three scenarios, the largest single source of emissions is from the methane in fugitive landfill gas. As highlighted above, the relative contribution of the various emissions included within the current model (buildings, plant and equipment, capping and cover materials and transport of materials), the most effective way to reduce the overall LCA emissions from the site would be to maximise the efficiency of the landfill capture and flaring and aiming to use the least capping material possible to achieve this outcome.

Figure 2.: Total estimated lifecycle GHG emissions (tCO2e) over project timescale for different activities



The following three figures (3, 4 and 5) show the distribution of emissions over the assessed timescale (2010 to 2044) for the three scenarios. For all three scenarios, the highest emissions are in the early years (pre-2010 to 2020) when the production of landfill gas is highest and, for scenarios where remedial works are implemented there is maximum activity.

Figure 3.: Annual estimated lifecycle carbon emissions for Scenario 1 – 'No remediation' (tCO2e/annum)

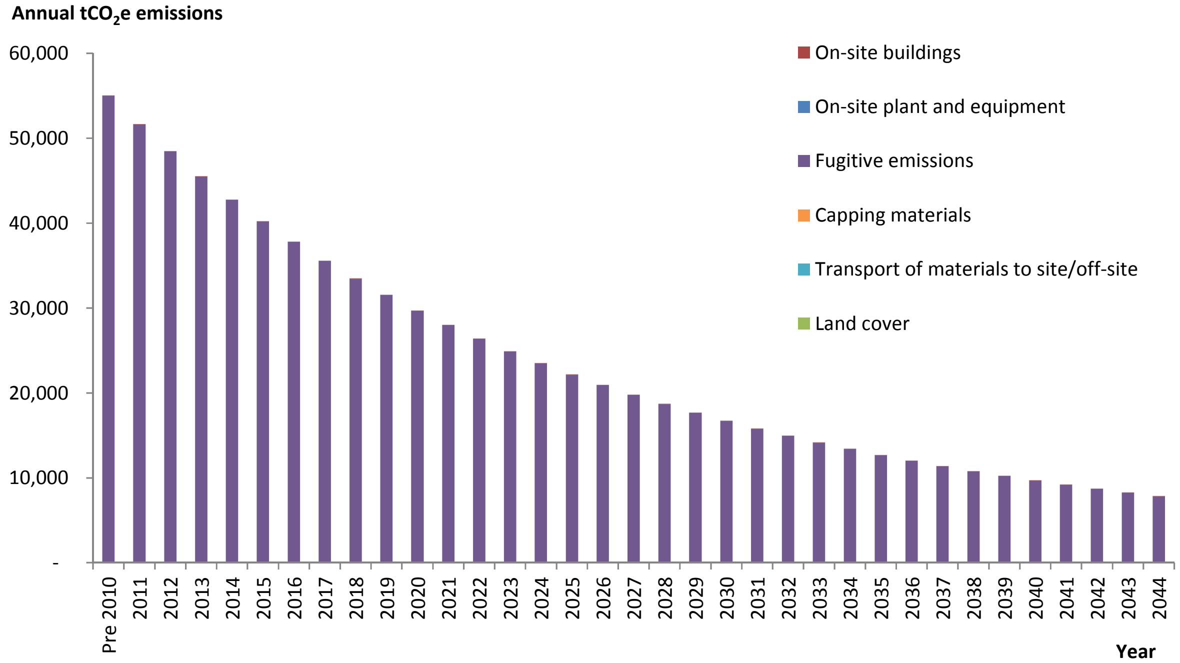


Figure 4.: Annual estimated lifecycle carbon emissions for Scenario 2 – 'Capping In Situ' (tCO2e/annum)

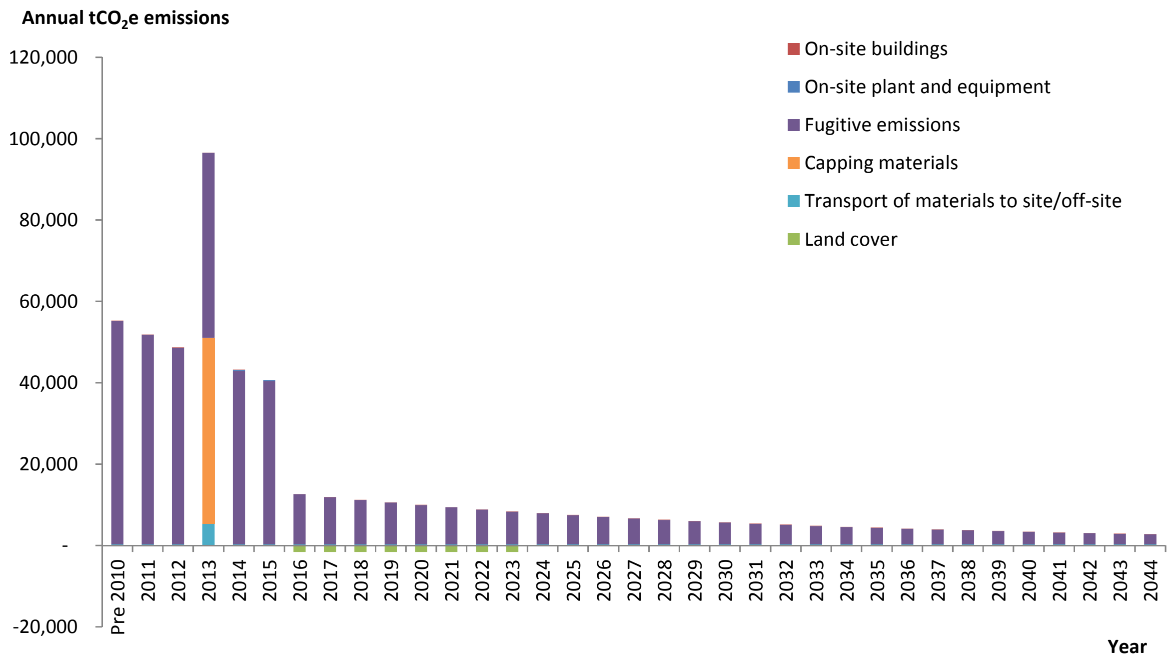
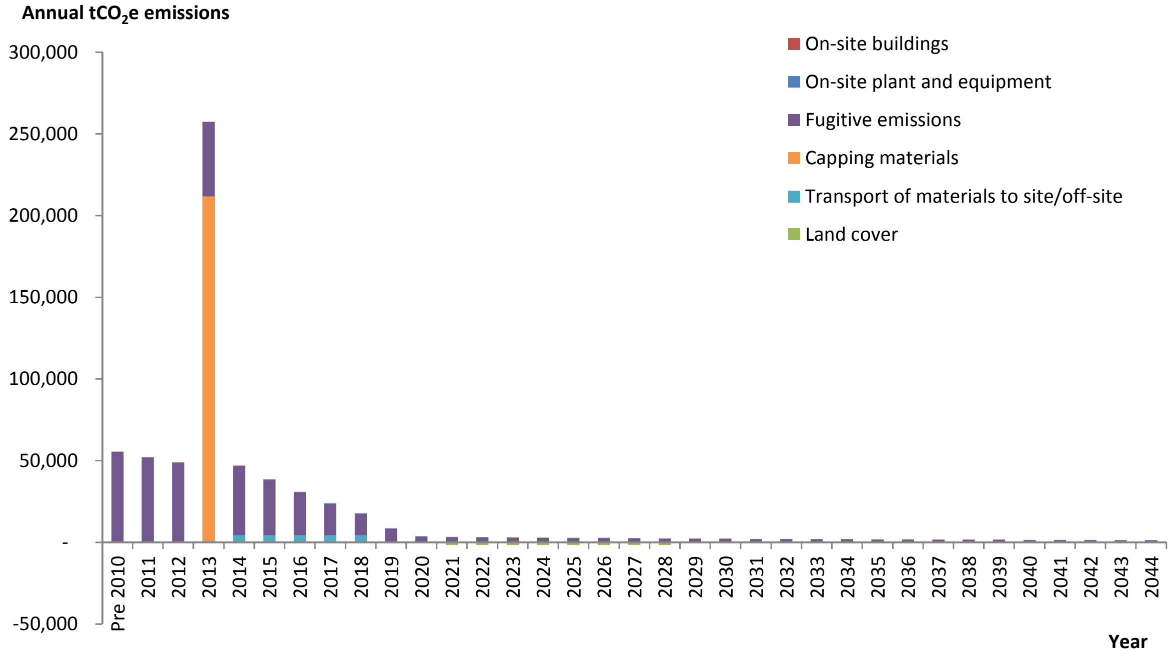


Figure 5.: Annual estimated lifecycle carbon emissions for Scenario 3 – 'Full Remediation' (tCO2e/annum)



3.2. Limitations of Current Models

In completing the assessment at this stage when only high level remedial Scenarios are available then there is a significant degree of uncertainty in relation to some of the key variables which affect the overall outcome of the modelling. The two variables responsible for the large majority of emissions in all scenarios are as follows:

1) Fugitive emissions of methane within landfill gas – CO_2 fugitive emissions or CO_2 from flared methane are considered to be short-cycle carbon;

   - The exact proportion of biodegradable material and hence landfill gas production is not fully known given the history of waste deposition at the site – the current model assumes 35% biodegradable material within the waste to arrive at estimates for future methane generation. However, if this is lower, the fugitive emissions of methane are likely be reduced. Notwithstanding this, all three scenarios would be affected equally;
   - There are a number of assumptions around the proportion of landfill gas that will be fugitive under different scenarios and therefore, improved information about the likely capture rates could change overall emissions for the Scenarios 2 and 3.

2) Embodied emissions resulting from use of materials for construction of additional structures;

- One of the key sources of embodied emissions in the model is from clay, used as a capping material. At the present time the actual source of materials to form the cap, the actual design of the cap in terms of use of clay based capping systems or used of geotextiles has not yet been established. However, the emission factor used in the model is for '*Simple baked clay products'* as there is no factor available for clay as a none-baked material. This factor is likely to significantly overestimate the embodied carbon in clay, which when used in this form, would require very minimal energy input apart from extraction and transport. Once potential sources of clay for capping purposes have been evaluated then the model could be refined further.
- The quantities of materials for Scenario 3 have been estimated based on Scenario 2 and increasing the gravel and clay quantities by a factor of five for initial modelling purposes on the basis that more materials would be required to complete remedial works under this scenario. More detailed work in the future will enable these assumptions to be refined.

3.3. LCA discussion

The results of this initial study indicate that Scenario 1 (Do Nothing), is unlikely to be optimal from the LCA GHG emissions perspective; although this scenario does not require GHG emissions for construction materials and activities, without capping the landfill and enabling capture and flaring of the landfill gas. Emissions resulting from fugitive releases of methane are likely to be very high relative to all other factors.

Currently, at this stage of the overall remediation project there is no design information on which to provide details on construction materials, sourcing, timescales etc., for Scenarios 2 and 3, then there is inherent uncertainty in the selection of key parameters for input into the existing models. Therefore, it is not currently possible to discriminate with a great degree of certainty between Scenarios 2 and 3 in terms of LCA and GHG emissions, although in broad terms it is anticipated that requirements for materials and timescales for remediation would be significantly greater for Scenario 3 than for Scenario 2. However, for both Scenarios, if effective capping and landfill gas capture can be put in place while minimising the need for materials and plant/equipment, this is likely to be optimal in terms of achieving reduction in GHG emissions. Post-remediation site activities, as currently anticipated (i.e. low intensity site end use for public open space/amenity type functions) are unlikely to have a significant impact on the overall LCA emissions.