Understanding the Policy Options for Implementing a Scottish Specific Landfill Tax

Appendices to the Final Report for the Scottish Government

Authors:

Dominic Hogg

Tim Elliott

Ann Ballinger

Maxine von Eye

Thomas Vergunst

18/05/2011

Appendices to Final Report

Report for:

Sandra Dandie: The Scottish Government

Prepared by:

Tim Elliott

Maxine von Eye

Thomas Vergunst

Approved by:

....

(Project Director)

Contact Details

Eunomia Research & Consulting Ltd
37 Queen Square
Bristol
BS1 4QS

United Kingdom

Tel: +44 (0)117 917 2250
Fax: +44 (0)8717 142942

Web: www.eunomia.co.uk

Acknowledgements

Our thanks to all the members of the steering group and those involved in the stakeholder interviews.

Contents

A.1.0 Externalities Associated with Landfill and Incineration

In this appendix a summary of the literature which report the range of externalities associated with landfilling and incineration is given. This is to show the environmental justification for the setting of a landfill tax, but also for an incineration tax.

A.1.1 Externalities Associated with Landfill

The externalities associated with different treatment methods for waste have been provided by a number of studies, with most studies of this nature providing an estimate of the external costs of landfilling waste. A range of external costs from the literature is provided in Table 1. Many of the studies provided a range of values depending on the damage costs used within the modelling; the Table presents average values where this is the case.

The Table confirms that a considerable range of external cost estimates exists. The variation the external cost estimates results from the approach taken in each of the studies with regard to the following:

- The methodology used to value the environmental impacts (i.e., the damage costs used in the study);
- The approach taken to modelling landfill modelled. Particularly important are assumptions surrounding:
  - methane generation from waste; and
  - the capture of landfill gas.
- Elements included in the modelling. Whilst the majority consider the direct emissions to air, other impacts include:
  - Transport; and
  - Disamenity.

For landfill the total damage cost is dominated by climate change impacts. Decisions surrounding the methodology used to value these impacts therefore have a significant impact on the overall total. Assumptions used in the studies presented in the Table include the following:

- The CSERGE study assumes an external cost per tonne of between £1.10-8.50 per tonne of CO_2;
- The HM Customs and Excise study used damage costs from an earlier study by Enviros et al which further assumed a cost per tonne of CO_2 of between £9.50 and £30;
- Rabl et al used £17 per tonne of CO_2;
- Eunomia used the UK Government's recently revised methodology for considering climate change impacts, and this distinguishes between different

types of GHG emissions impacts. The central values for 2009 (used to calculate the values presented in the Table) are as follows:

- £21 per tonne for emissions associated with electricity use and generation;
- £51 per tonne for all other GHG emissions.

The methodology further assumes that the damage costs associated with these emissions increase over time. However the Eunomia study also applied a discount rate of 3.5% in line with guidance published in the Treasury Green Book therefore offsetting some of this damage cost increase.

Most studies place a value on the air quality impacts – these are less significant than climate change when considering impacts at the landfill, because landfill results in the emission of substances that are typically not quantified in health related studies. In addition it is important to note that external costs for both climate change and air quality impacts have tended to increase over time as the impacts on human health have been better understood.

Table 1: Selected Results from Literature per Tonne of Waste Sent to Landfill

	CSERGE 1993[1]	HM C&E 2004[2]	Dijkgraaf & Vollebergh 2004	Rabl et al 2008[3]	Eunomia 2010 (low-high)
Climate change CO_2 CH_4	£0.46 £1.36	£5.73 £6.30	€5.84 (total emissions to air)	€12.50 (total emissions)	£59-71
Direct air pollution impacts	n.a.	£0.01			£1.8-5.2
Offset emissions (electricity from landfill gas)	-£1.12	-£2.15	-€4.21	-€3	
Transport impacts	£1.39			€0.50	
Chemical waste			€2.63		
Land use			€17.88		
NET TOTAL	*£1.94*	*£9.98*	*€22.14*	*€10.00*	*£61-76*

Notes

1. *The results assume electricity generation from landfill gas at a rural landfill site and include the impact of the pollution on Europe (rather than just within the UK). The total reflects the mean of a range of values rather than the total of those presented in the table here. Damage costs are in 1993 prices.*
2. *Results assume electricity generation from landfill gas; values presented here are for the central high scenario*
3. *Offset emissions assume the generation of heat*

Sources: CSERGE, Warren Spring Laboratory and EFTEL (1993) Externalities from Landfill and Incineration, London: HMSO; HM Customs & Excise (2004) Combining the Government's two Heath and Environment Studies to Calculate Estimates for the External Costs of Landfill and Incineration, December 2004; Dijkgraaf E. and Vollebergh H. (2004) Burn or Bury? A Social Cost Comparison of Final Waste Disposal Methods, Ecological Economics, 50, pp.233-247; Rabl, A., Spadaro, J. V. and Zoughaib, A. (2008) Environmental Impacts and Costs of Solid Waste: A Comparison of Landfill and Incineration, Waste Management and Resources, 26, 147-162; Eunomia (2009) International Review of Waste Management Policy, Final Report for the Department of Environment Heritage and Local Government

Many of the studies provide relatively little detail on how landfill is modelled. Assumptions are crucial in determining the overall outcome, as can be seen through a comparison of results from Eunomia and Rabl et al – where is some transparency regarding the landfill modelling:

For Rabl et al the key assumptions with regard to the landfill model are as follows:

1. 70% of the landfill gas was assumed to captured during the first 30 years;
2. The modelling appears to only consider landfill gas generation for 60 years in total;
3. Only 50% of the biogenic carbon is assumed to be potentially degradable.[1]

Relevant assumptions from the Eunomia study are:

1. A landfill gas capture of 50%;
2. Gas generation is assumed to occur over 150 years;
3. All biogenic carbon contained within the waste materials is assumed to be potentially dissimilable (albeit that this degradation occurs at different rates depending on the type of carbon).

Dijkgraaf and Vollebergh do not make it clear what the "land use" element of their study relates to. Their study also uses a much lower damage cost for methane emissions than is used in the later study by Eunomia.[2]

Thus the considerable difference between the total impact seen in Eunomia's study and the rest, therefore, is very likely to be a consequence of:

1) the greater quantity of methane that is assumed to be generated and subsequently emitted to the air; and
2) the higher damage costs used to value the emissions.

In terms of the disamenity associated with landfills, Cambridge Econometrics and EFTEC carried out a major hedonic pricing study which estimated the disamenity associated with landfilling.[3] This was based upon a hedonic pricing study, examining the effect of proximity to landfills on house prices. Recently, a study by Enviros and EFTEC updated the estimates from this study (inflating the estimates in line with

---

[1] The landfill model used by Rabl and Spadaro is the French ADEME model, which has been found to underestimate the methane emissions measured from currently operating landfills in one recent attempt at model calibration carried out by Scharff and Jacobs

[2] Although the damage cost for CO_2 used in Dijkgraaf and Vollebergh is similar to that used by Eunomia, their value for methane is only 11 times greater than the damage assumed for CO_2. This differs from the approach taken by Eunomia, where the damage cost for CO_2 is multiplied by the global warming potential of methane (i.e. costs of

[3] Cambridge Econometrics in association with EFTEC and WRc (2003) *A Study to Estimate the Disamenity Costs of Landfill in Great Britain*, London:Defra, February 2003.

house price inflation), giving a range for landfill disamenity of between £2.50 and £3.59 per tonne. [4] This research further increases the social cost of landfilling.

The evidence highlighted in this summary of landfill modelling is brief compared to the possible depth of analysis. However, it should be clear that although the range of environmental costs associated with landfill is high, the higher costs do reflect more accurately the most up-to-date level of understanding. With this in mind one can suggest that the current landfill tax escalator (at £80 in 2014) is comparable to the environmental damages caused by landfilling. Or put in another way, the environmental externalities of landfilling are potentially fully internalised by the current tax.

A.1.2 Externalities Associated with Incineration

Examples from the literature of the external costs of incinerating residual waste are shown in Table 2. Assumptions used in the studies presented in the Table include the following:

- The CSERGE study assumes an external cost per tonne of between £1.10-8.50 per tonne of CO_2;[5]
- The HM Customs and Excise (HM C&E) study used damage costs from an earlier study by Enviros et al which further assumed a cost per tonne of CO_2 of between £9.50 and £30;[6]
- Rabl et al used €19 per tonne of CO_2;[7]
- Eunomia used a low damage cost for CO_2 of €26 per tonne and a high damage cost of €32 per tonne.[8]

Impacts associated with air pollution are relatively more important for incineration than they are for landfill. As with the climate change impacts illustrated above, damage costs for air pollution are much lower in the earlier studies, even allowing for cost increases as a result of inflation - this reflects the increased awareness over time of the nature of pollution impacts of upon human health. Thus the damage cost for NOx assumed in CSERGE was £628 per tonne, whilst the range for the Enviros study

---

[4] Enviros and EFTEC (2004) *Valuation Of The External Costs And Benefits To Health And Environment Of Waste Management Options* Final Report for Defra, December 2004

[5] CSERGE, Warren Spring Laboratory and EFTEL (1993) *Externalities from Landfill and Incineration,* London: HMSO

[6] HM Customs & Excise (2004) *Combining the Government's Two Heath and Environment Studies to Calculate Estimates for the External Costs of Landfill and Incineration,* December 2004

[7] Rabl, A., Spadaro, J. V. and Zoughaib, A. (2008) Environmental Impacts and Costs of Solid Waste: A Comparison of Landfill and Incineration, *Waste Management and Resources,* 26, pp147-162

[8] Eunomia (2009) *International Review of Waste Management Policy,* Report for DHLG, Republic of Ireland

that provided the damage cost data for the HM C&E study was £154-977.[9] In contrast, the more recent analysis undertaken by Rabl et al suggest impacts of NOx pollution to be €3,400 per tonne whilst Eunomia assumed a low damage cost for NOx of €4,696 and a high damage cost of €13,596.

Results for incineration are also influenced by avoided emissions associated with energy generation, which includes avoided climate change and air quality impacts.

Table 2 confirms that there is some variation in the results for incineration, although the magnitude of variation is less than was seen in the results for landfill. As before, the total damages attributed by Eunomia are much higher than in other analyses. This is principally a reflection of the higher unit damage costs used in this analysis in comparison to the other studies reviewed here.

[9] NOx emissions typically have the greatest impact of the air pollutants when incineration processes are considered

Table 2: Selected Results from Literature per Tonne of Waste Sent for Incineration

	CSERGE et al 1993[1]	HM C&E 2004[1]	Dijkgraaf & Vollebergh 2004	Rabl et al 2008[2]	Eunomia 2009 – Low[3]	Eunomia 2009 – High[3]
Climate change CO_2 CH_4	£2.55	£19.10	€17.26 (total emissions to air)	€15.33	£31	£33
Direct air pollution impacts	£2.01	£0.03		€7.63	£4	£31
Offset emissions - energy generation	-£9.40	-£6.16	-€22.55	-€8.10	-£13	-£15
Offset emissions - materials recycling			-€5.76	-€2.07	-£1	-£1
Transport impacts	£0.69			€0.50		
Chemical waste			€28.69			
NET TOTAL	*-£4.15*	*£12.95*	*€17.64*	*€13.29*	*£21*	*£47*

Notes

1. *Average values are presented for these studies.*
2. *Assumes CHP but study is set in France and thus nuclear is the main source of electricity generation, so effectively no benefit attributed to the electricity generation.*
3. *Low scenario uses lower damage costs and assumes Best Available Technology (BAT) for pollution control (i.e. SCR for NOx emissions); High scenario uses higher damage costs and also assumes the facility just meets the limits of the Waste Incineration Directive (WID). Analysis undertaken by Eunomia also includes the impact of energy used by the facility – it is not clear if this is included in the other studies in this table.*

Sources: CSERGE, Warren Spring Laboratory and EFTEL (1993) Externalities from Landfill and Incineration, London: HMSO; HM Customs & Excise (2004) Combining the Government's two Heath and Environment Studies to Calculate Estimates for the External Costs of Landfill and Incineration, December 2004; Dijkgraaf E. and Vollebergh H. (2004) Burn or Bury? A Social Cost Comparison of Final Waste Disposal Methods, Ecological Economics, 50, pp.233-247; Rabl, A., Spadaro, J. V. and Zoughaib, A. (2008) Environmental Impacts and Costs of Solid Waste: A Comparison of Landfill and Incineration, Waste Management and Resources, 26, 147-162; Eunomia (2009) International Review of Waste Management Policy, Report for DHLG, Republic of Ireland

The CSERGE study is one of two shown in the table where impacts associated with air pollution from the plant are more than offset by avoided emissions associated with energy generation. In the case of the CSERGE analysis, given the timing of the study, the source of avoided electricity generation is likely to be coal, which would increase the relative benefits associated with energy generation.

Total damages calculated by Dijkgraaf and Vollebergh are amongst the highest, but here the authors also included damages associated with chemical waste which are not considered in the other studies. Their total damage costs associated with air pollution (for both climate change and air quality impacts) appear to be relatively low. Excepting the study by CSERGE et al theirs is the only study where avoided emissions associated with energy generation are greater than the impacts associated with direct emissions to air. The authors confirm that gas is the marginal source of electricity generation avoided through energy generation at the incinerator and also confirm that the incinerator is assumed to be operating in CHP mode but further indicate that not all of the heat is assumed to be used (no other details of the energy generation efficiency are provided). No detail is provided either on the pollution control equipment installed in the plant, although the authors indicate that damages for incineration were assumed to be representative of "best practice" in the Netherlands, which is likely to include the use of SCR to significantly reduce the NOx emissions.

Results from the HM C&E study show relatively high damages for climate change impacts, but very low damages for air pollution, again largely reflecting the choice of damage costs used in the analysis.

The two most recent studies whose results are included in the table are those of Rabl et al and Eunomia, undertaken in 2009 and 2009 respectively. Damage costs used by Eunomia for both air quality impacts and climate change are higher than those assumed by Rabl et al even in the “Low” scenario. The Eunomia “Low” scenario assumes good pollution control at the incinerator including the use of SCR, whereas Rabl et al modelled an incinerator that just meets the requirements of the Waste Incineration Directive. Rabl et al also include avoided air quality impacts associated with the recovery of metals which was not included in analysis undertaken by Eunomia, and consequently attributed a greater benefit to this activity.[10]

[10] Much of the impact of air pollution is relatively local in nature (in contrast, climate change is assumed to have a global impact). Both the primary production of metals and the re-processing of recyclate were assumed to occur largely outside of Ireland, where the analysis was being undertaken. It was therefore felt that any benefit associated with avoided air pollution would not have an impact on Irish air quality; as such these impacts were excluded from the analysis.

A.2.0 Environmental Benefits from Landfill Taxation

Most countries use a range of complementary instruments to influence the relative desirability of competing options. Consequently, whilst taxes make specific options less desirable, other policies also influence how materials subject to a tax are dealt with.

Another feature of taxes is that they generate revenue. Many of the countries which deploy taxes do so with the intention of using some or all of the revenue for specific purposes related to waste management (or other environmental purposes).

The environmental impact of taxes, therefore, depends upon both:

a) the extent to which the structure of taxes makes the activities targeted by the tax less desirable;

b) the way in which other policies affect the desirability of alternative management routes (i.e. those not subject to taxes); and

c) the effects of the use of tax revenue in terms of environmental improvement.

Regarding a) and b), own-price and cross-price effects are important. Other things being equal, a tax would be expected to have consequences which relate to its rate. The own- and cross-price effects will be different for different materials and for different waste streams, the reason being that the range of alternatives, as well as the costs thereof, vary by material and stream.

The basic premise is that as landfill prices rise, less waste will be disposed to landfill and more will be minimised, re-used and sent to alternative treatments.

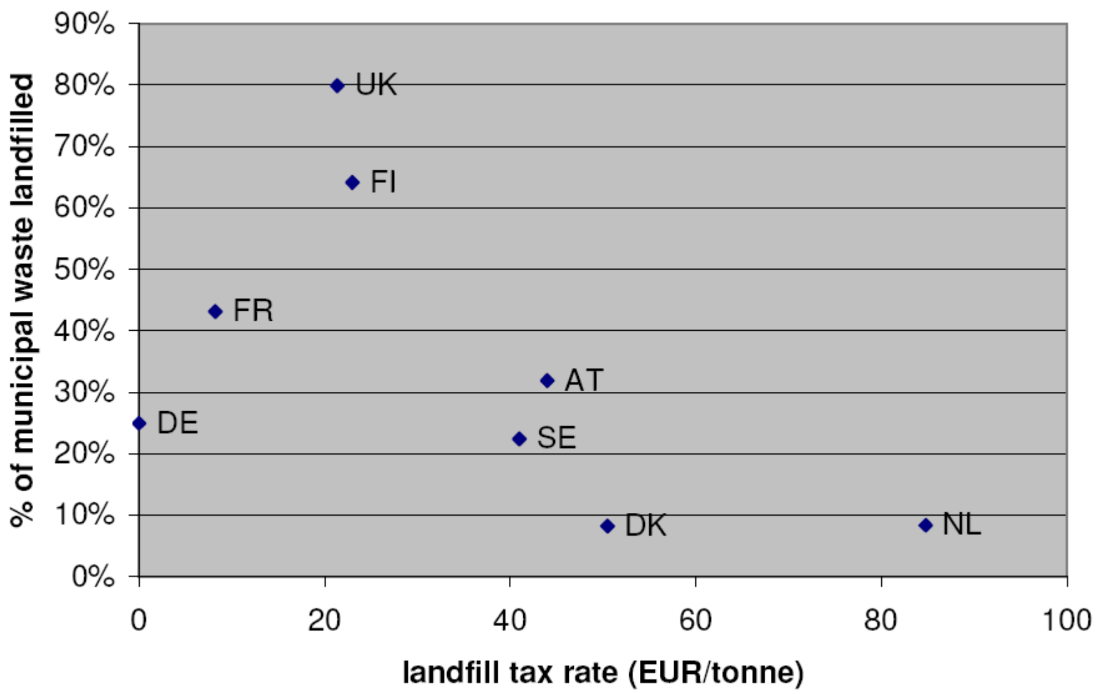
The degree to which this occurs relates to the alternatives available and their price relative to that of landfill. Important here is the cross-price elasticity of demand. This shows how sensitive is the demand for recycling or mechanical biological treatments (MBT), for example, to changes in landfill tax. Where technologies are widely available and where they are competitive in cost, the response can be expected to be considerable. Similarly, where the opposite is true, the shift away from landfill will be more limited. When the cost of disposal increases above the cost of treatment via an alternative method, this price, known as the substitution price, will determine the marginal waste management route, as any rational agent will pursue the most cost effective option (as long as the risks aren't too great) unless, for example, they are restricted by lengthy municipal contracts.

There are generally benefits associated with reducing the quantity of waste disposed of in landfills, though these vary with the nature of the material, and with the change in the management method. For example, when plastics are switched from landfill to incineration, the net impact in terms of climate change is, under most reasonable assumptions, strongly negative.

The level of detailed data that could be used to perform a thorough *ex-post* evaluation of a number of landfill tax mechanisms is simply not available. We have therefore pulled together sparse information from relevant reports and highlighted some of the important issues. We first discuss whether the tax can be strongly linked to a reduction in landfilling, and then, more importantly, specifically seek to understand whether the tax increases waste prevention and recycling.

To determine what environmental benefits are associated with a landfill tax, one study sought to understand whether there is a relationship between the level of the tax and the proportion of waste landfilled in that country. Figure 1 shows that, at a glance, no relationship exists between landfill tax levels and municipal waste landfilled. However, the combination of waste policies in each of the countries, and specific intentions of the landfill tax, are different, making such a univariate analysis almost useless. For example, one of the clear outliers is Germany (DE), with a low level of municipal waste landfilled but no landfill tax. In Germany the Ordinance on Landfilling of waste significantly restricts landfilling (it bans landfilling of waste which has not been pre-treated, and whose calorific value exceeds a specified threshold), and has had a significant effect in reducing the quantity of waste landfilled. Equally, to take the view that the tax is responsible for the low levels of landfilling in Netherlands and Denmark would be to miss the influence of the landfill bans in those countries.

Figure 1: Correlation between Landfill Tax and Waste Landfilled



Source: Bartelings, H., P. van Beukering, O. Kuik, V. Linderhof, F. Oosterhuis, L. Brander and A. Wagtendonk (2005) Effectiveness of Landfill Taxation*, R-05/05, Report Commissioned by Ministerie von VROM, November 24, 2005.*

France (FR) also looks like the tax has had a pronounced effect relative to other EU countries. However, the level indicated in this chart only relates to the level of tax that is chargeable for waste deposited in legal landfill sites. There has historically been a large quantity of waste deposited in unregistered sites in France, and this waste is subject to a higher level of landfill tax (around £30). This and the regulatory ban on a number of waste streams, has had the effect of reducing the quantity of municipal waste to a lower level than in countries with a higher rate for licensed landfills e.g. the UK.

The Netherlands (NL) has, what looks like, an over inflated landfill tax compared to other EU countries whereby similar levels of municipal waste landfilled can be achieved through lower rates. This is most certainly the case, but there has been a relatively unique case in Dutch waste management. In the late 1980s the Dutch were rebuilding their incineration capacity with much higher pollution control mechanisms following a dioxin emissions scandal. Fiscal and regulatory measures were needed to ensure that incineration capacity would be used, and hence, that the high investment cost would not be wasted. A landfill ban on all combustible waste was implemented and the landfill tax was escalated sharply between 1995 and 2003. A Dutch study indicates that in the same period:[11]

> *'the amount of landfilled waste decreased by around two thirds from 8.215 ktonne to 2.753 ktonne. During the same period, the amount of waste incinerated increased by around 75% from 4.695 ktonne to 8.218 ktonne.'*

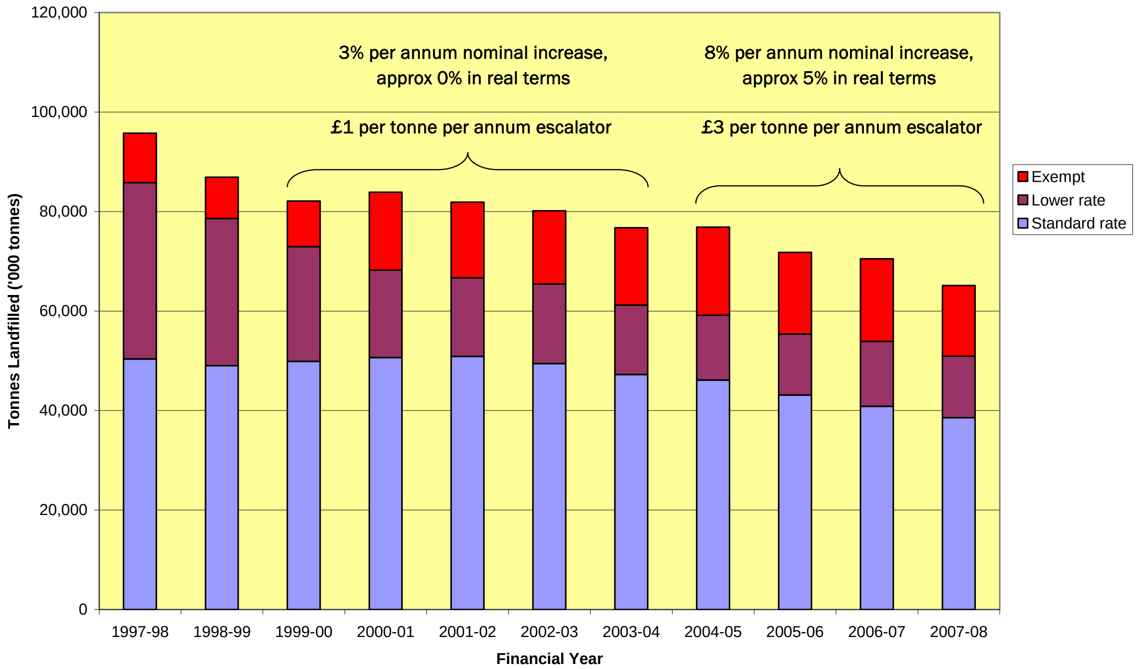
The sharp rise in landfill tax increased the cost of disposal to a point where landfill gate fees exceeded the gate fee for incinerators. Therefore the lower cost of managing waste by incineration meant that incineration *substituted* landfilling, where possible, and thus allowed for a more efficient utilisation of existing capacities.

UK Experience

Figure 2 shows how the quantity of waste landfilled has changed over time in the UK. The most relevant quantity for the purposes of this study is the quantity of waste landfilled in the standard rate category. This remained fairly stable from 1997/98 to 2002/03, but has fallen since then. The fall has been of the order 11 million tonnes. We estimate that changes in the management of municipal waste accounts for around 5 million tonnes of this fall.

[11] MNP (2005), *Milieubalans 2005*. Milieu- en Natuurplanbureau, Bilthoven.

Figure 2: Quantities of Landfilled Waste in the UK



Source: based on data from HMRC

The remaining drop is likely to be due either to a decline in commercial and industrial waste arisings, or to waste moving into other non-landfill routes. This drop would be against the backdrop of our estimate of UK commercial and industrial waste landfilled of the order 34 million tonnes across the UK early in the decade.

The commercial and industrial waste market is, in principle, more dynamic than the municipal one (owing to the more 'naked' nature of the competition), yet at the same time, this competition can have the effect of slowing down development of infrastructure and services (because of the increased risk associated with ensuring sufficient supply into the investment).

The reason for this is that the competition for waste services reduces the security which any developer of more capital intense facilities might have that waste will come into the facility in the quantity and manner desired. In essence, investments are more risky than they are in the case – as with municipal waste – where flows of waste can be more or less guaranteed under long-term contracts.

In order for developers to have some certainty that waste will flow into specific facilities, the economic conditions must be right. The lack of increase (in real terms) in landfill costs implied by the landfill tax in the period to 2003-04 can partly explain what would appear – at least at the UK level - to be a lack of any very strong shift from landfill to other treatments as a result of the tax. This may have changed since 2002-03 (with the increase in landfill tax escalator), but it is more likely that greater changes will come as the escalator increases the tax to £48 per tonne, and possibly beyond.[12] The pre-treatment requirements may also be requiring segregation of wastes by companies which have not hitherto been engaged in any such activity.

With respect to household waste, the landfill tax has been far less influential in driving waste away from landfill. The LA(T)Ss have been more important in recent years.

The evidence does suggest that, alongside a mix of policy instruments, landfill taxes can help reduce the quantity of waste landfilled. In the following sections, research is discussed to seek out the relationship between reduced landfilling and both a reduction in waste generation and increased recycling.

A.2.1 Waste Prevention

The environmental benefits from any waste prevention effects would be expected to include:

- reductions in greenhouse gases and aquatic and soil toxicity effects associated with less material managed in landfill;
- reductions in energy consumption associated with a lower demand for goods; and
- less hazardous material in the waste stream.

A report by Mazzanti and Zoboli on the effectiveness of polices on waste prevention, waste disposal and landfill analysed waste arisings and economic data, produced by the EU 25 from 1995 to 2004, and used multi-variant analysis to attempt to find any decoupling of waste and GDP growth at the European level.[13] One of its conclusions is that '*no landfill or other policy effects seem to provide backward incentives to waste prevention*'. The conclusions also indicate that '*at all levels other socio-economic factors were impacting on waste trends; highlighting the importance of societies' attitudes in waste management.*' This conclusion may have to be considered as a 'loose' one since the cross-country datasets over time on waste are, in our experience, of low quality.

A report on Finnish waste management suggests that waste taxation is considered not to have contributed much to waste prevention, though it does also suggest that the effect is hidden by the combination of waste management policies in place. [14]

---

[12] In the 2007 Budget, the Chancellor wrote: 'In order to encourage greater diversion of waste from landfill and more sustainable waste management options, the Government today announces that, from 1 April 2008 and until at least 2010-11, the standard rate of landfill tax will increase by £8 per tonne each year.' In the most recent Budget statement, he stated 'The Government expects the standard rate to continue to increase beyond 2010-11.'

[13] Mazzanti, M. and Zoboli, R. (2007) *Waste prevention, waste disposal and landfill policies effectiveness: A quantitative analysis on delinking at European level,* Report for Societa Italiana di economia pubblica, http://www-1.unipv.it/websiep/wp/200720.pdf

[14] EIONET: European Topic Centre on Resource and Waste Management (2007) *Finland Waste Factsheet*, Accessed 16th October 2008, http://waste.eionet.europa.eu/facts/factsheets_waste/Finland

However, surveying work by Cambridge Econometrics and ECOTEC, shortly after the introduction of the tax in 1996, showed that 31% of firms contacted were actually considering waste recycling, re-use or minimisation, or stepping up such activity, as a consequence of the tax.[15] For industrial business with large homogenous waste streams this seems logical. Our experience of surveying food manufacturers over the last three years also suggests that, as a direct consequence of increased disposal costs, businesses have sought to change manufacturing processes to minimise waste.

In conclusion, the international evidence on waste minimisation impacts resulting from landfill taxation is inconclusive, but some evidence does exist at the UK level to link the two.

A.2.2 Recycling

Some of the environmental benefits associated with recycling relate, as with waste prevention, to avoidance of landfilling, but there will also be additional savings from avoiding virgin material use, and the associated embodied energy achieved through material recovery.

Recycling rates in most of the countries considered in this report have been increasing (though in some, such as Denmark, this is barely discernable any more). As with waste prevention, however, there is relatively little documented evidence to demonstrate that the introduction of a tax or a ban *on its own* correlates strongly to any increase in recycling.

In the UK, however, one can make some inferences based upon knowledge of a reduction in landfilling and the increase in other management routes. Figure 3 below shows that non-municipal waste landfilled at the standard rate has been decreasing in the period when the tax was on the rise. In fact one can see a significant change after 2001 when the landfill tax escalator was announced. The chart suggests that the rate of reduction in landfill appears to be mirroring the rate of increase of the tax.

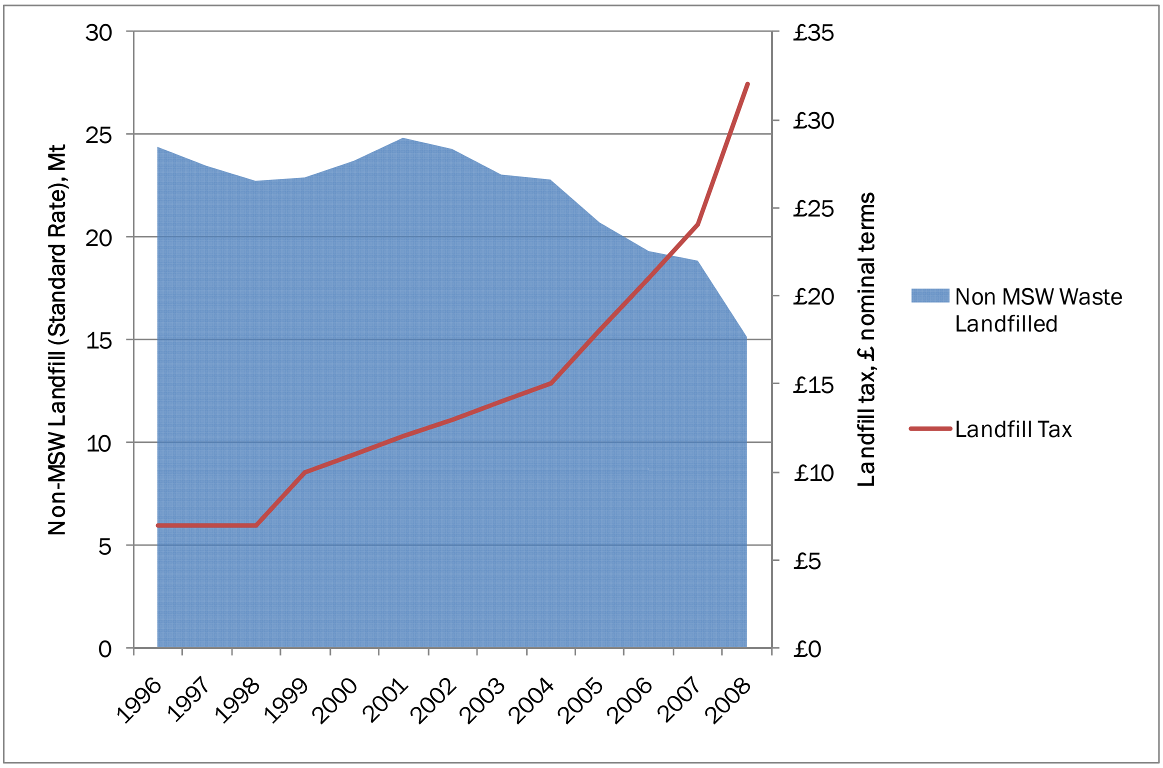
For the business sectors the landfill tax is the key policy driver. Businesses are primarily concerned with costs, and if the cost of disposal increases alternative options are sought out. Therefore, the influence of other drivers is likely to be limited.

Between 2000 and 2008 the quantity of non-MSW landfilled has decreased by 10 million tonnes. Some of this reduction could be attributed to the waste prevention, some to recycling and some to other treatments. As discussed above the waste prevention effect is difficult to quantify and could be limited. Therefore, it could be said, the main shift in waste management was from landfill to recycling or other treatments.

---

[15] ECOTEC (1998) *UK Landfill Tax Study, PART 2: Effectiveness of the Landfill Tax in the UK: Barriers to Increased Effectiveness and Options for the Future*, A report submitted to the European Foundation for the Improvement of Living and Working Conditions

Figure 3: Non-MSW Waste Landfilled at Standard Rate, Mt



Source: Eunomia

The increase in other treatment capacity could be attributed to source segregated industrial wastes or mixed C&I waste. The former is not easily unpicked from national EA data. The latter has been estimated by Eunomia as currently around 250 ktpa; a small fraction of the 10 million tonnes. Even with the limited data on treatment it is certain that some level of additional recycling in the C&I sectors has occurred. C&I waste surveys also suggest this trend.[16]

Given that the key policy driving waste management behaviour in the C&I sectors is the landfill tax one can suggest that the landfill tax does have a direct relationship with increased recycling.

Generally, the absence of strong evidence should not be taken as evidence of the absence of an effect. Most countries which deploy landfill taxes and bans, however, also deploy an armoury of other policy instruments. Taxes and bans tend to support these policies, and assist in moving waste up the hierarchy, but the degree to which they, and not other policies, are responsible is difficult to discern for wastes in the municipal sector. However, the link appears more pronounced when considering non-municipal wastes.

[16] Environment Agency C&I Surveys 1998 and 2002/03, Urban Mines Surveys in the North West and Wales.

A.3.0 Landfill Tax Policy Review

The aim of this literature review is to provide evidence for the range of options that could be modelled in the latter part of the study. A significant amount of experience has been gathered by Eunomia in this field, and this is drawn upon for this review.

To set the scene the UK landfill tax is briefly described. This is followed by an investigation into the types of landfill tax seen in European countries. This includes analysis of the key features of landfill taxes:

- Rationale for the Tax
- Year the Tax was Introduced
- Tax Structure and Rates
- Administration of the Tax
- Use of Revenue
- Exemptions from the Tax
- Perverse Effects of the Tax

The key lessons learned from European landfill taxation are then summarised.

Following this, a short discussion around the environmental justification for landfill taxes is given. The full depth of the field of work cannot be fully appreciated in a summary suitable for this report. However, it was considered useful to put into context the environmental basis for such taxes and whether current rates fully internalise environmental externalities from landfilling waste.

The perceived environmental benefits from landfill taxes are then discussed to ascertain the whether the environmental justifications are being met through the policy alone, or whether other instruments leverage these benefits also.

Finally, given the context of the likely inclusion of landfill bans in Scottish Law, a section weighing up the relationship between landfill taxes and landfill bans is included.

A.3.1 UK Landfill Tax

The UK Landfill Tax was introduced in October 1996. It is a tax on all landfilled waste, with some exemptions. It is applied at two rates: a standard rate, applied to a range of materials, including household waste; and a lower rate, applying to specific ‘qualifying materials’, typically, those deemed to be ‘inert’, including materials such as rubble.

The tax affects all sectors of the economy. As the levels of landfilling at the introduction of the tax were very high, the tax could be considered a ‘general disposal tax’, as most residual waste was (and still is) disposed of to landfill.

The aims of the tax as set out in the UK Waste Strategy were:

'to ensure that landfill costs reflect environmental impact thereby encouraging business and consumers, in a cost effective and non regulatory manner, to produce less waste; to recover value from more of the waste that is produced; and to dispose of less waste in landfill sites (DoE and WO 1995, 12).'

From this, it seems clear that the primary aim was, in the early stages, to internalise environmental impacts within landfill prices. To further explore whether the tax was, and is now, internalising environmental impacts, an analysis of the relevant factors is provided in Appendix A.1.0.

Ecotec's report on taxes and charges in the EU indicates that the tax level and the proposals for the tax were widely consulted on before being introduced. [17] The initial rates at which the tax was set were:

- Inert Wastes (lower rate tax) £2 per tonne
- Active Wastes (standard rate tax) £7 per tonne.

Mixed wastes are taxed as active wastes even if much of the material is 'inert' if certain minimal levels of mixing are exceeded.

A Eunomia report from 2007 describes how the tax has evolved: [18]

- 1993 – The introduction of the Landfill Tax was preceded by an assessment of the external costs associated with landfill and incineration and by work assessing waste management options in the UK after the introduction of such a tax.[19] A proposal for a tax based on a percentage of disposal costs (an ad valorem tax) emerged, with the order of magnitude of the tax heavily influenced by the external costs study;
- November 1994 – Government makes clear its intention to introduce the Landfill Tax;
- March 1995 - a consultation process was undertaken to elicit the views of industry, environmentalists, and local authorities. Its major outcome, as announced in the November 1995 Budget, was a change in the tax design, from a percentage of disposal cost (ad valorem) system, to a weight-based tax. Furthermore, it was intended that there should be no exemptions from the tax; and
- November 1995 – Budget announces the tax will be introduced in October 1996.

---

[17] ECOTEC (2001), *Study on the Economic and Environmental Implications of the use of Env. Taxes & Charges in the EU*

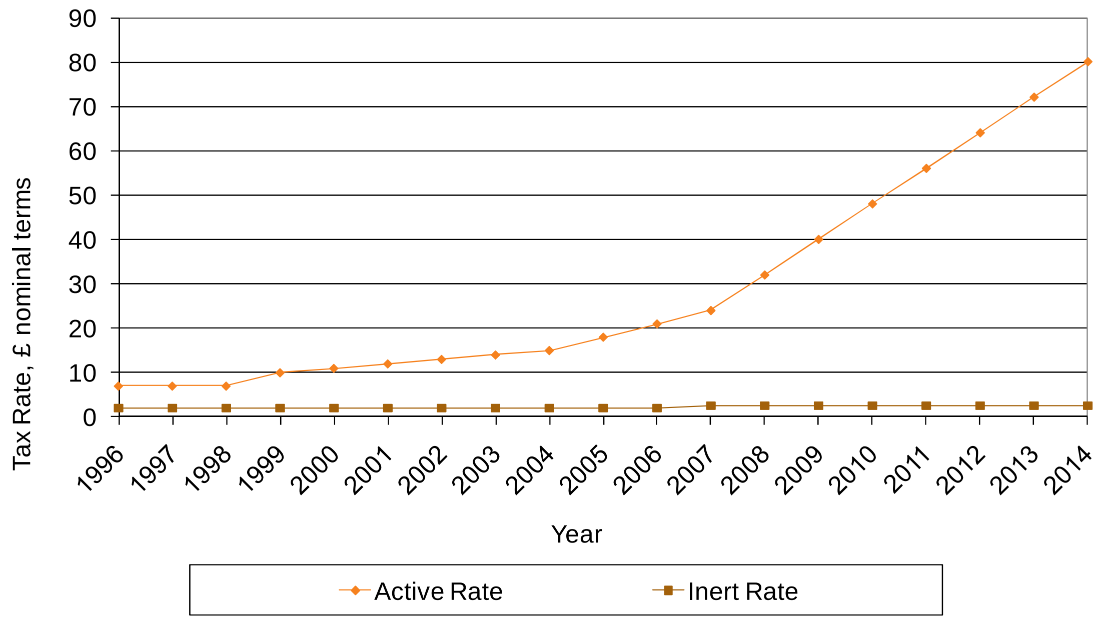
[18] Eunomia et al (2007) *Household Waste Prevention Policy Side Research Programme*, Final Report for Defra

[19] CSERGE, Warren Spring Laboratory and EFTEL (1993), *Externalities for Landfill and Incineration: A Study by CSERGE, Warren Spring Laboratory and EFTEL*. Coopers & Lybrand (1993), *Landfill Costs and Prices: Correcting Possible Market Distortions*.

At the outset typical disposal fees pre-tax for municipal wastes, or non-inert industrial wastes, were between £7-£25 per tonne so that the tax implied an increase in price of between 30-100% in the overall cost of landfilling. The level of taxation for non-inert wastes (i.e. those that degrade to produce GHGs) was increased by means of an annual price escalator that was first introduced in 1998. Since then the magnitude of the escalator has increased (initially £1 per tonne escalator over five years, then £3 per tonne over three years, to current £8 per tonne per year over 3 years, and due to continue at this rate for a further 4 years). As of April 2010, the tax rate is £48 per tonne. The tax rate for inert wastes has remained relatively steady with only a 50p increase to £2.50 per tonne in 2007.

Implemented through central government via the Chancellor of the Exchequer (HM Treasury) and the annual budget, Figure 4 shows the change in tax levels for active and inert wastes from the implementation of the policy in 1996 to 2014 when the current escalator expires at £80 per tonne.

Figure 4: UK's Landfill Tax



The revenues generated from the tax were initially used to allow for a decrease in the employers' higher rate national insurance, along with a scheme to fund waste management research and improvement projects around landfills. Those wishing to utilize the funds had to register as environmental bodies under an organization named ENTRUST. This organisation has adopted the approach of a pro-active regulator with a 'risk based' approach to both the operations of the 2700+ EBs it regulates and the projects delivered. [20]

[20] ENTRUST (2010) ENTRUST, Accessed 15th November 2010, http://www.entrust.org.uk/home/about

Funds are directed to the Landfill Communities Fund, WRAP, LASU, WIP and various other Defra schemes. The Landfill Communities Fund enables operators of landfill sites to contribute money to enrolled Environmental Bodies (EBs) to carry out projects that meet environmental objects contained in the Landfill Tax Regulations.[21] Over 22,000 projects have been submitted to ENTRUST for review and registration since the inception of the Scheme in 1996.

The Government saw the LCF as a way for Landfill Operators (LOs) and EBs to work in partnership to create significant environmental benefits and jobs and to undertake projects which improve the lives of communities living near landfill sites.

A.3.2 Landfill Taxes in EU Member States

The review in this section of the report focuses on key EU Member States, and utilizes a report to Enviros, written as part of the UK landfill tax review in 2001, and a review of international waste policy for the Irish Government.[22,23]

The following countries are covered:

- Austria
- Denmark
- Finland
- Belgium (Flanders)
- France
- Ireland
- Italy
- Netherlands
- Sweden
- Norway
- Switzerland

The structure of this part of the review will, for each country, summarise and draw together relevant information within the following key areas:

- Rationale for the Tax
- Year the Tax was Introduced
- Tax Structure and Rates
- Administration of the Tax

---

[21] ENTRUST (2010) LCF, Accessed 15th November 2010, http://www.entrust.org.uk/home/lcf

[22] Eunomia (2001) *Review of Landfill Tax*, Report to Enviros

[23] Eunomia (2009) International Review of Waste Management Policy, Final Report for the Department of Environment Heritage and Local Government

- Use of Revenue
- Exemptions from the Tax
- Perverse Effects of the Tax

The rationale for presenting the information in this way is to enable the reader to understand, at a glance, how a range of countries address each of a number of specific issues. This will be used to inform the potential range of options for the structure of a future Scotland specific landfill tax.

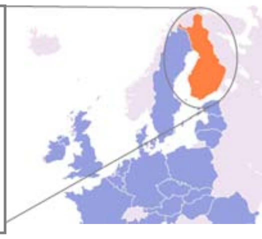
In some of the sections information on the UK tax is included to help with understanding and potential variations in this policy.

A.3.2.1 Rationale for the Tax

In Austria the tax was intended to support the identification and remediation of contaminated sites. In 1989 the Clean-Up of Contaminated Sites Act was introduced as a result of a number of contaminated soil incidents such as the *'Fischer Deponie'* (European Topic Centre on Soil 1997).[24] The Act foresaw increased work in surveying and identification of potential problem sites and thereafter funding for operations to contain and treat them. In Switzerland the Government also implemented a landfill tax in order to meet the costs of cleaning up contaminated land.

In Denmark, the motivation for the landfill tax was the scarcity of available landfill void space. The other key driver in Denmark was the desire to ensure the countries energy from waste capacity was fully utilise. Initially reported as a tool to stimulate recycling, there is now a stagnant recycling market due to the waste required to meet plant capacity.

Finland imposes a tax on municipal waste landfill sites. The rationale behind Finland's municipal waste landfill tax was to stimulate waste minimisation and material re-use. The hazardous waste landfill tax is targeted at the waste processing industry and was introduced to meet waste targets and to raise revenue.



---

[24] Hazardous chemicals had been dumped on this municipal waste site threatening the water resources of 50,000 local inhabitants. The clean-up of this site is still not complete and the total cost of the operation is expected to reach 1,500 – 2,000 M ATS (109 –145 M).

The Flemish tax is intended to discourage landfilling whilst stimulating waste prevention and recycling, as well as financing regional environmental policy. The tax was reinforced by the Flemish waste management plan for 1991-1995 which prohibited the landfilling of domestic wastes from 1995 unless they were pretreated. Building and demolition wastes are also prohibited from landfill if they met the technical criteria for application in road building. The waste management policy implemented in Flanders follows the EU waste management hierarchy. Wallonia introduced a waste tax in regions in which household waste arisings exceeded specified levels, thus providing an incentive to local authorities to promote waste recovery and recycling.

In France the tax is part of a national strategy which aims at restricting disposal to landfill to final waste that cannot be recovered by any other treatment by 2002. This objective has still not been fully realised, however. The tax was implemented with the intention of streamlining French waste management through increasing waste recovery, and providing for full cost recovery of waste management.

In Italy a tax was seen as a means of encouraging source separation of wastes, hence reducing demands on landfill void space. Higher landfill taxes were believed to act as a stimulus to local authorities to activate source separation systems.

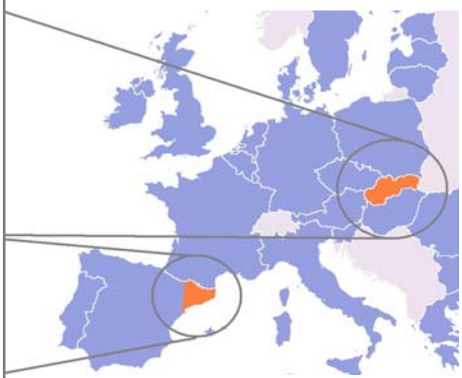
In the Netherlands the idea for a waste disposal tax began in 1992 when an environmental tax on fuel was being developed. The Dutch Parliament asked The Dutch Cabinet to develop other environmental taxes to raise additional revenues, instead of raising fuel tax to unacceptably high levels. By applying the Polluter Pay's Principle to these new environmental taxes it was believed that the tax burden would be more equitably distributed amongst tax payers. The two aims of the waste tax, therefore, are to raise revenue and generate positive environmental effects. Recent increases in waste tax rates have been attributed to a desire to accelerate the "greening of the fiscal system". However, the Dutch were also trying to support their network of incinerators, so changed the structure of the tax to incentivise the shift to EfW plants.

The purpose of Sweden's landfill tax is to increase the costs for landfilling and thus make waste minimisation, reuse, recycling or energy recovery (in district heating plants) more economically feasible. A further aim of the tax is to reduce the number of landfill sites, concentrating disposal at a smaller number of highly engineered sites in the future.

The waste tax in Norway was introduced to reduce the volumes of waste being sent for final disposal and to encourage progression up the waste hierarchy. A further stated aim was to raise the costs of waste disposal, thereby going some way towards internalising the environmental costs of the final treatment of waste. The Norwegian Government also believes that waste taxation is an important tool in helping make the transition from taxation on income and employment (so called red taxes) to taxation on pollution and the use of resources (green taxes).

Another European country to vary tax rates depending on upstream recycling is Slovakia. The tax was implemented in 1992 but the structure changed in 2004 because of the low level of collection systems in place when they joined the EU.

A very different mechanism has been implemented in the Catalonia region of Spain. This is one of few landfill taxes in the country and is structured to incentivise the uptake of collection services for recycling, and fund the separate collection of biowaste.



The Irish levy was designed to encourage the diversion of waste away from landfill and generate revenues that can be applied in support of waste minimisation and recycling initiatives. Recent changes to the levy were implemented to further drive waste away from landfill, and also to internalise the externalities of landfilling.

The rationales described above are summarised in Table 3 below. The data shows that, with the exception of Austria and Switzerland, each of which has instigated a waste tax as a means of raising revenue to pay for contaminated land clean-up, the overwhelming rationale for waste taxes is as a means of stimulating waste reduction as well as promoting the reuse and recycling of waste. In Slovakia and Catalonia the aim is to further incentivise authorities to procure comprehensive source separation (collection) systems, including separated food waste. Finland is perhaps the only country that has explicitly introduced a tax on 'municipal waste landfills' in order to stimulate municipal waste reduction. The prime focus of most other waste taxes is broader waste minimisation and reuse/recycling across both municipal and industry sectors. This is realised by increasing the cost of landfilling, and thus making alternative management methods more cost competitive, and waste prevention more financially rewarding. The distribution of taxation - moving towards a polluter pays world - is also a key factor affecting the structure of taxes in some countries.

Table 3 Reasons for Implementing Landfill Taxes

Country	Stimulating waste reduction, reuse & recycling	Revenue Raising	Internalising Externalities
Austria		✔	✔
Catalonia (Spain)	✔	✔	
Denmark	✔		
Finland	✔		
Flanders (Belgium)	✔	✔	
France	✔		
Ireland	✔	✔	✔
Italy	✔		
Netherlands	✔	✔	
Norway	✔		✔
Slovakia	✔		
Sweden	✔		
Switzerland		✔	✔
UK	✔ (Now)		✔ (Start)*
Wallonia (Belgium)	✔		

** Note: as far as we are aware the UK is the only country to use economic valuations in this process.*

A.3.2.2 Year the Tax was Introduced

Landfill taxes are now applied in a number of EU countries, with the first being introduced in Denmark in 1987 (see Table 4). The most recent introduction has been that in the Catalonia region of Spain, which came into force in 2004.

Table 4: History of Landfill Taxes Start Dates

Country	Date Introduced	Country	Date Introduced
Austria	1989	Italy	1996
Catalonia (Spain)	2004	Netherlands	1995
Denmark	1987	Norway	1999
Finland	1996	Slovakia	1992
Flanders	1987	Sweden	2000
France	1993	Switzerland	2000
Ireland	2002	UK	1996

Note: In Austria, the tax was originally introduced in 1989 but it was not until 1996 that the structure was differentiated and increased. Also in Slovakia, the tax was originally introduced in 1992 but it was not until 2004 that the structure was differentiated.

A.3.2.3 Tax Structure and Rates

In this section a comparison of the structure and rates of landfill taxes across Europe is given. There is, foremost, a table giving summary information and a full list of references. Following this some of the key trends and variations are discussed.

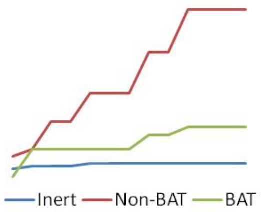
For each country the Table first shows what categories of waste are covered by the tax. Exemptions from payment of the tax are discussed in Section A.3.2.6 below. The tax rate at key dates is then shown. A summary chart to show the evolution of the tax follows. The time frame for the chart is from the start date of the tax (given in Table 4 above) and either 2010 or the final year of any known increases (this range is indicated beneath each chart). The next field gives information relating to whether the tax is dependant in some way upon the performance of some system, be it the landfill or implementation of upstream collection services. As Scotland, in many respects, is a region of the UK, any taxes that operate at the regional level are quite relevant to this study. Therefore any known regional variations in the landfill tax across Europe are highlighted. Finally, any key supporting instruments are indicated.

Following this discussion is a brief summary of the tax structure and rates for inert wastes.

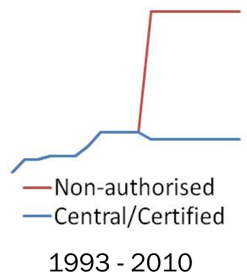
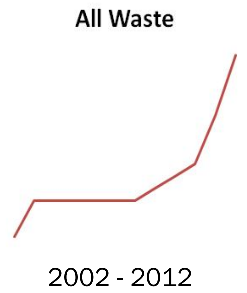
In all cases the tax is measured according the weight of waste landfilled.

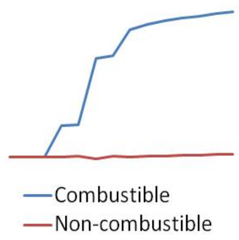
Also note, as exchange rates vary, tax levels given in £ Sterling will only be approximate for countries outside of the UK.

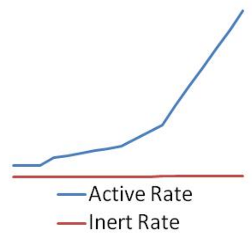
Table 5: Landfill Taxes across European Countries and Regions

Country	Waste Types	Tax Rates, £	Rate of Evolution	Performance Related	Regional Variation	Supporting Policies
Austria	Demolition waste Excavated soil Waste with certain concentrations of dangerous elements Domestic waste or similar	<u>Inert</u> 7.3 € <u>Domestic</u> Massive variation dependent on waste type & landfill quality, latest levels are £23 to £76	 1989 - 2010	Differentiated rates for landfills with Best Available Technology (BAT). Further surcharges for landfills with no basement seal or vertical enclosure or no landfill gas capture and treatment system.	None.	Landfill Ban on wastes covered by the Landfill Directive, and on wastes with a carbon content of 5% or above (this is to ensure the stabilisation of waste before landfilling).
Catalonia (Spain)	Municipal Waste Construction waste	£8.50 for municipalities with separate food waste collection and £17 for those that don't.	The tax rates have not increased but the refunds have.	The tax is differentiated depending on whether the municipality has separate food waste collections in place. Some of the revenue is refunded to stimulate the development of a range of recycling services.	Yes, the autonomous regions of Spain have their own waste management remit. Madrid also has a low level tax on the landfilling of certain wastes.	Objectives to meet recycling rates. No other policies directly related to landfill. Incineration tax.

Country	Waste Types	Tax Rates, £	Rate of Evolution	Performance Related	Regional Variation	Supporting Policies
Denmark	All waste entering landfill site (exemptions apply, mainly hazardous waste and contaminated soil) Sewage Sludge Other Sludges	1987 – £4.70 1992 – £23 1998 – £44 2010 – £44 Higher levels for sludges. From 1998 – £25 for slag and fly ash.	 1987 - 2010	N/A	None.	Waste Tax also covers incineration Landfill ban on combustible waste Natural Resource Tax (equivalent to aggregates tax)
Finland	Wastes at public landfill sites Wastes at private / industrial sites which also accept wastes from multiple sources Hazardous waste	1996 – £13 2001 – £22 2005 – £26 Hazardous waste – £234	 1996 - 2010	Waste taxes are not payable on wastes that are recovered or suitably treated through composting or incineration, for instance.	None.	Landfill ban introduced in 2006. Covers landfill directive wastes, waste that is not pretreated (except inert waste) and household waste, or similar, where the bio fraction has not been separately collected.
Flanders (Belgium)	Household Industrial Inert	£12 to £54 Landfill rates dependent on waste type & landfill quality (Note that a 50 € export tax is imposed to prevent waste tourism to Wallonia)	Increased over time.	One of the most complex systems in the EU. The levies vary based on the possibility to apply more environmentally friendly alternatives for the treatment of the waste, or to promote recycling.	Flanders is an autonomous region of Belgium. To inhibit waste tourism an export tax on waste to Wallonia was introduced.	Challenging minimisation and recovery rates. Landfill bans. Incineration tax.

Country	Waste Types	Tax Rates, £	Rate of Evolution	Performance Related	Regional Variation	Supporting Policies
France	Household Waste Municipal Solid Waste Mixed Industrial Waste	1993 – £2.67 1995 – £3.34 1998 – £5.27 1999 – £8.02 2003 – £32 for non-authorised landfills / £6.57 for sites with EMAS or ISO 14000 certification.		N/A	None.	Ban on untreated waste from 2002.
Italy	Inert waste (industrial) Other waste (urban and assimilated) Special waste	£8.75 - £22 for MSW (Northern and Central) £17.50 - £44 for MSW (South, where a critical waste situation exists) £0.9 - £9.03 (Inert) £4.50 - £9.03 (Special)	N/A – regionally defined	Some regions have established – through regional acts – an increase in the tax if targets for separate collection are not achieved.	Yes. Regional administrations in Italy can set the tax level within upper and lower bounds set by national Government.	Landfill diversion and recycling targets.
Ireland	All waste at authorised and unauthorised treatment facilities.	2002 – £13 2010 – £26 2011 – £44 2012 – £66		N/A	None.	Incineration tax.

Country	Waste Types	Tax Rates, £	Rate of Evolution	Performance Related	Regional Variation	Supporting Policies
The Netherlands	Waste <1,100kg/m3 and certain waste streams (e.g. dangerous waste & shredded waste) Waste >1,100 kg/m3 (inert & non-combustible waste)	Combustible waste (low density) 1995 – £12 2000 – £56 2008 – £77 Non-Combustible waste (high density) 2008 – £13	 1995 -2010	N/A	None.	Ban on landfilling of recyclable and combustible waste (regulated by density measurements only).
Norway	All wastes delivered to landfill. Higher rate for wastes with dispensation from the ban on biodegradable wastes.	1999 – £35 2010 –£28 / £47	Constant until 2010 when rates diverged.	Tax rebates for landfill operators who recover and sell energy generated from the methane gas captured	None.	Incineration tax Ban on biodegradable wastes
Slovakia	Hazardous waste Inert waste MSW Other waste Green waste	Rates in 2004: Haz. – £23 Inert – £0.23 MSW – £3.46 to £6.92 Other – £4.61 Green – £9.23	Not known.	The level of taxation for MSW decreases as components are removed for recycling.	None.	None relevant.

Country	Waste Types	Tax Rates, £	Rate of Evolution	Performance Related	Regional Variation	Supporting Policies
Sweden	All hazardous waste All other waste once a threshold of 50 tonnes per annum is exceeded Tax element refunded if waste is removed within 3 years	2000 – 250 SEK / £24 2001 – 288 SEK / £27 2008 – 370 SEK / £35 2008 – 435 SEK / £41	 2000 - 2010	N/A	None.	Landfill bans on sorted combustible wastes and all organic wastes.
Switzerland	Residual waste Combustion residues Export to disused salt mines	£8.50 – £28	Unknown.	N/A	None.	Ban on landfilling of combustible wastes.
UK	Active waste Inert waste	1996 – £7 2007 – £24 2010 – £48 2014 – £80 Inert: £2.50	 1996 - 2014	N/A	None.	Landfill Allowances Scheme.

Sources:

Umweltbundesamt (2000), Management of contaminated sites in Western Europe, Report for the European Environment Agency. *http://reports.eea.europa.eu/Topic_report_No_131999/en/topic_13_1999.pdf*

Bartelings, H., P. van Beukering, O. Kuik, V. Linderhof, F. Oosterhuis, L. Brander and A. Wagtendonk (2005) Effectiveness of Landfill Taxation, R-05/05, Report Commissioned by Ministerie von VROM, November 24, 2005

Agencia de Residus de Catalunya website (2008) Waste disposal tax, Accessed on 23rd October 2008, http://www.arc.cat/en/municipals/canon/index.html

Swedish Tax Agency (2006) Landfill Tax: Tax rates, Accessed 8th November 2010, http://www.skatteverket.se/foretagorganisationer/skatter/punktskatter/allapunktskatter/avfallsskatt.4.18e1b10334ebe8bc80002886.html?posid=1&sv.search.query.allwords=avfall

EIONET: European Topic Centre on Resource and Waste Management (2007) Waste Factsheets, Accessed 16th October 2008, http://waste.eionet.europa.eu/facts/factsheets_waste

Finnish Ministry of Environment website (2008) Waste taxes and charges, Accessed 10th October 2008 http://www.environment.fi/default.asp?contentid=180501&lan=en

RenoSam (2006) The Danish Model, News from DBDH

ECOTEC (2001), Study on the Economic and Environmental Implications of the use of Env. Taxes & Charges in the EU

European Commission (2008) "Taxes in Europe" database, Accessed 12th October 2008, http://ec.europa.eu/taxation_customs/taxinv/welcome.do;jsessionid=LZJpKGQB7ZRrngVLZhhS5cx7wCkJBrCFL21f5r9t65bYTG6JhKQ5!-966966153

Eunomia et al (2007) Household Waste Prevention Policy Side Research Programme, Final Report for Defra

OECD (2004) Environmental Performance Reviews: Sweden. Paris: OECD

Avfall Sverige (2008) Swedish Waste Management, http://www.avfallsverige.se/se/netset/files3/web/P01.m4n?download=true&id=2371_94867351

The table above provides a useful insight into the range of structure and rates other European countries have. The following sections summarise some of the main trends key considerations.

Overall Structure

The categorisation of wastes differs between countries. However, in most cases, the majority of the national waste arisings are covered by the landfill tax. Mixed household and commercial, specific industrial and construction wastes are covered in these cases. The only real exception to this general principle is in Catalonia where the tax only covers municipal waste. The trend for most countries is that the scope of the tax does no increase over time.

Exemptions for certain waste streams differ between countries. These are discussed in Section A.3.2.6 below.

The structure of the tax is also linked to the general policy aims of the country. In the Netherlands the tax supports the ban on waste under a certain density which was enacted to ensure a feedstock of combustible waste for the national incineration capacity, and in Slovakia and Catalonia the structure has been developed to promote a change in upstream collection systems. In addition, Denmark has increasingly differentiated its waste-tax by disposal route in order to stimulate the use of waste as a fuel for district heating networks.

Different countries also have landfill taxes which sit within a more general waste-tax. For example, Denmark, Flanders and Norway make use of a tax on waste which covers not only landfill, but also incineration with and without energy recovery. The tax therefore applies more widely to cover all waste disposal routes rather than landfill *per se*.

Denmark also appears to be unique in its application of tax to sewage sludge, with tax rates increased by a factor of three for dried sewage sludge destined for landfill, and a factor of four for dry matter from sludge from wastewater treatment plants destined for incineration. However, sewage sludge of a quality suitable for land spreading is exempt, thereby promoting advanced treatments of such sludges.

In some countries that do not tax incineration (e.g. the Netherlands and UK) there is a tendency to tax all forms of ash (i.e. bottom and fly ash), whereas fly ash is exempt from tax in Denmark where an incineration tax applies. In Finland, fly ash and desulphurisation waste from power plants are exempt from tax. Sweden is currently in the process of making changes to its landfill tax. One of the recommendations is that the level of tax on bottom ash be lowered. However, in the Netherlands it is believed that the tax has stimulated the recycling of incineration bottom ash.

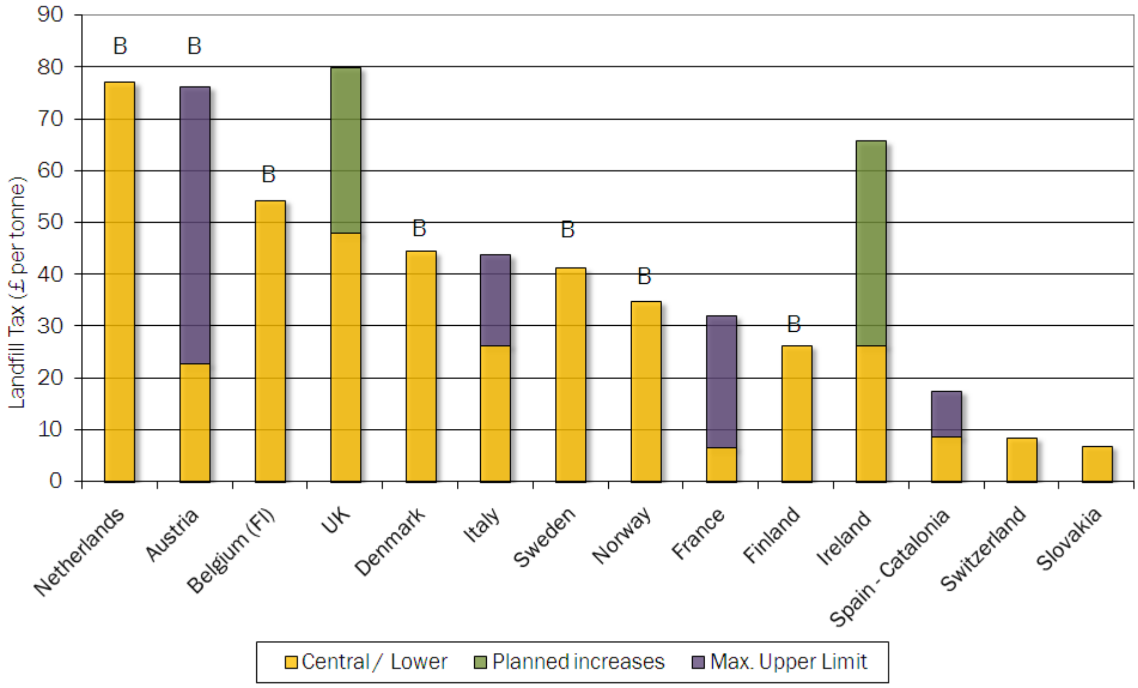
The inclusion of hazardous waste in the tax structure also varies considerably. In Finland, where the state has the majority share in the main hazardous waste reprocessing company, a high rate of tax was set to fund its operation. Slovakia and Sweden also specifically include hazardous waste in the tax structure. Other countries tax all waste and some then include exemptions, and for others, in order to limit the financial burden on businesses and promote the safe disposal of such wastes, hazardous waste is not taxed at all.

Although not necessarily in the structure of the tax itself, some countries also set export taxes to ensure that waste does not migrate for recovery. In Austria the high level of the tax was one reason why an export tax was set. Alternatively, in Belgium an export tax between Flanders and Wallonia was constructed to inhibit waste-tourism between the autonomous regions.

Tax Rates and Evolution

Figure 5 below illustrates the wide-ranging tax rates that are in place across Europe. The figures are from the most recently available data.

Figure 5: Landfill Tax Levels across Europe (Non-Inert Wastes)



B – indicates where a country has a ban in place with the intention of diverting the residual waste stream from landfill. These are policies that go above and beyond specific requirements of the EU Landfill Directive.

Note, the higher rate in Austria is no longer relevant as untreated wastes are banned from landfill.

Source: Eunomia

Although we do not show detailed waste management data for each country, our understanding of the general situation allows us to make the following observations:

- Countries with high levels of landfill diversion (the Netherlands, Austria Flanders and Denmark) are also those with the highest tax rates. Countries with lower rates (France, Finland, Spain and Slovakia) achieve lower levels of diversion;
- Countries with higher tax rates also appear to implement landfill bans which cover mixed residual waste streams. Exceptions include the UK, Italy and France. However, in the case of Italy and France both have considered such bans over the past 10 years but without successful implementation, and in the

UK landfill bans are currently being considered as part of the Coalition Government's review of waste policy;

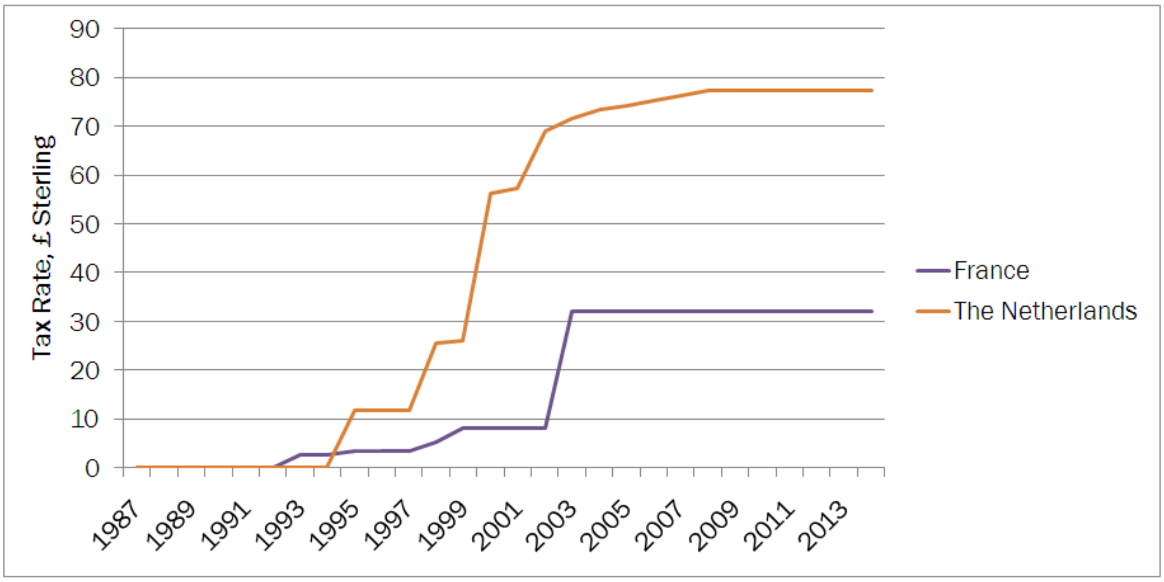
- Although the lower rate for Austria is much less than countries in similar situations the threat of the higher rate of tax changes behaviour. Furthermore, from 2004, untreated waste in banned from landfill. The lower rate relates to low calorific residues from MBT plants. The lower level was set in order to make the gate for MBT plants cost comparable to incineration;
- The rate for standard landfill and incineration in Denmark is high when compared to other countries' standard waste tax rates, reflecting Denmark's desire to raise revenue from waste management activities;
- It is clear that the increases in tax rate by the UK and Irish Governments are in-line with European experience. In fact, other things being equal, at these rates landfill diversion would be expected to increase significantly; and
- The more recent taxes (Switzerland, Slovakia and Catalonia) appear to be the lowest. Some of the most mature tax instruments (Denmark and Austria) are much higher. This appears to suggest that tax levels are initially set low and are increased over time. This is discussed below.

The current rate of taxation is an important factor to consider when assessing landfill taxes, but the rate of evolution also reveals something regarding the rationale and success of any policy. Some are examples are given.

In the Netherlands decreasing landfill space and a need to support national incinerator capacity saw a significant increase in rates over 3-5 years. Also in France the need to get under control the number of unlicensed landfill sites saw a rapid divergence of rates, despite initially marginal increases. It does, however, remain an oddity of the French system that a site can be both 'illegal' and subject to a tax.

The progression of tax rates in shown in Figure 6 below.

Figure 6: Sharp Increases in Tax Rates



Other countries seem to have increased rates less rapidly in the initial few years 5-10 and kept the levels relatively constant.

The staged increase in the evolution of landfill taxes across Europe could be a result of the following factors:

- Uncertainty about the effect of the tax;
- Allowing time for infrastructure to develop without penalising businesses in the short term;
- Nervousness on behalf of Government in introducing significant changes in short periods;
- Desire to maintain revenue generation from the tax.

More staged increases in tax rates can be seen in Figure 7 below.

Two neighbouring countries, the UK and Ireland, show another trend. In both cases early extended periods of a low tax rate resulted in less diversion from landfill than other European states. To increase diversion from landfill, tax rate escalators have been introduced in recent years. This is also shown in Figure 8 below.

Figure 7 Staged Increases in Landfill Tax Rates

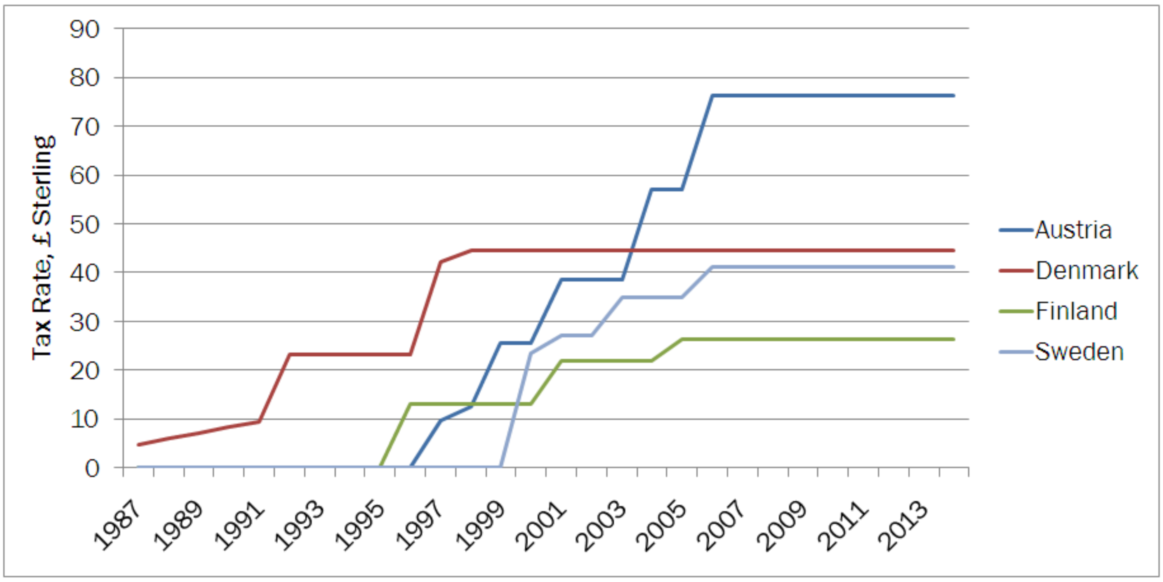
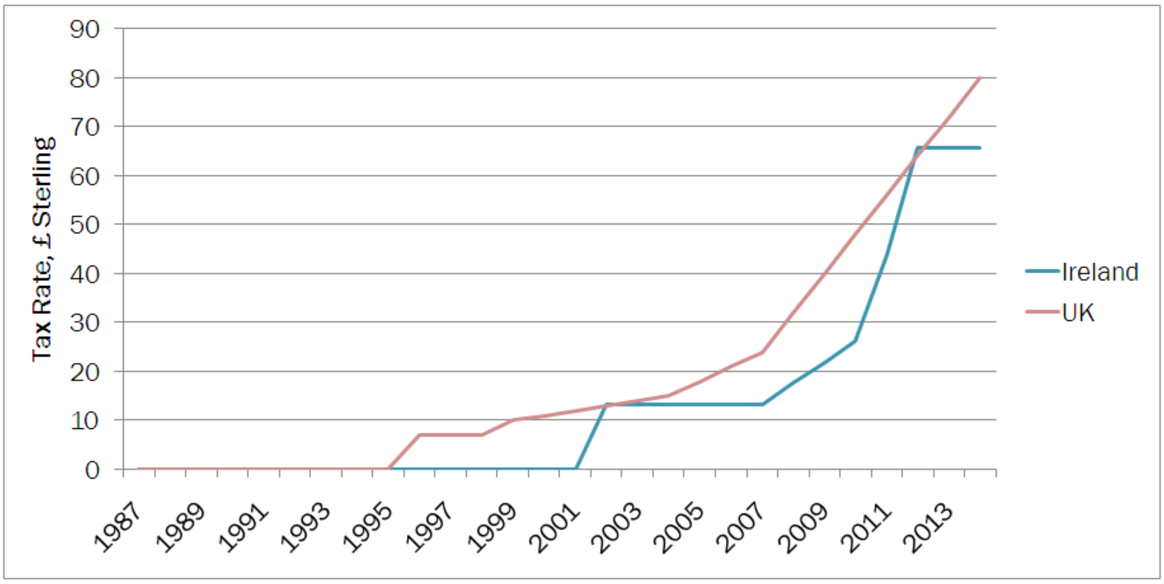


Figure 8: Slow Initial Progression of Landfill Tax Rates



It is only countries that have introduced policies in the last 5-10 years where no increase in tax levels can be seen. It is too early to tell whether they will remain constant or increase over time.

In most countries the following characteristics of the tax hold true:

- Tax levels start at low levels and increase;
- The progression of tax rates appears to have stagnated in a number of countries. One assumes that the level remains constant because policy objectives have been met.

Even without accounting for Purchasing Power Parity, when the UK landfill tax escalator reaches £80 per tonne (and at today's exchange rate), the tax rate will be one of the highest in Europe.

Performance Related Structuring

Italy, Flanders, Catalonia, Slovakia and Wallonia are examples of where differential tax rates are applied according to the proportion of waste that is separated at source, providing a powerful incentive to local authorities to instigate such schemes. However, some of these mechanisms are complex to administer.

Two of the most interesting taxes, in terms of promoting the performance of recycling services, are in Slovakia and Catalonia. Given the high recycling targets in the Towards Zero Waste Plan these particular taxes are described in more detail.

In Slovakia a charge for deposition of waste to landfills was introduced in 1992.[25] It was updated in 2004 and includes scheduled increases from 2008. The revenues are earmarked for the protection of the environment in the relevant municipality, and must be used for waste management purposes only.

There are several bands in this tax system, which include hazardous, inert and municipal waste streams. The level of taxation for MSW decreases as components are removed for recycling i.e., if there is a collection system in place that removes 2 components such as paper and glass, the tax will be lower than for the residual stream. This is most likely to incentivise the uptake of collection systems for recyclables. The rates of tax for different wastes and situations are given in Table 6 below.

Table 6: Landfill Tax Rates in Slovakia

Material Stream	Tax Rate, £ per tonne
Hazardous Waste	23
Inert Waste	0.22
MSW with no separation	6.92
MSW with 1 component separated	6.22
MSW with 2 components separated	5.54
MSW with 3 components separated	4.85
MSW with 4 components separated	4.15
MSW with 5 components separated	3.46
Other Waste	4.61
Green Waste	9.23

[25] EIONET: European Topic Centre on Resource and Waste Management (2007) *Slovakia Waste Factsheet*, Accessed 16th October 2008, http://waste.eionet.europa.eu/facts/factsheets_waste/Slovakia

Taxes for Landfills are not generally implemented in Spain. However, Madrid does have taxes for hazardous waste (£8.75 per tonne), domestic waste (£6.12 per tonne) and C&D waste (£2.63 per tonne). [26]

The tax in Catalonia is levied on the sending of municipal waste to waste disposal facilities controlled by the public or private sector and located in the region. The taxpayers are the local authorities that operate, or contract out the operation of, the municipal waste management service, and municipal waste producers. The tax is implemented at the time the holder delivers the waste to the landfill, and at the point where the facility operator accepts it. A detailed account of the Catalan landfill tax is given in Appendix A.8.0.

In terms of other performance incentives, Austria differentiates between treated and untreated waste as a means of reducing the propensity of waste to degrade in the landfill.

Interestingly, only Norway differentiates between tax rates for landfills with and without gas collection for flaring / energy recovery, though there would be a strong environmental case for doing this on the basis that energy recovered is displacing conventional energy sources. The Austrian tax systems does, however, levy surcharges on landfills without gas collection. One explanation may be that because Norway is outside of the EU it does not have to abide by the Landfill Directive; this being the primary driver on advancing landfill technology in the EU. Additionally, other drivers on gas capture, such as renewable energy generation, are also incentivised by additional policies in some countries. One example is the Renewable Obligations Certificates (ROCs) in the UK.

Regional Variation in Structure or Rates

The Catalonia region of Spain is one example of where the landfill tax varies regionally. The Catalan authorities were contacted to request any information relating to issues with regional implementation. No response has been received, however, some information from regional consultants has been obtained..

> *"As regards MSW, according to the Catalan waste agency, there is no waste travelling at all. Municipal waste is very much under control.*
>
> *This might happen for industrial waste (especially hazardous waste), but Catalonia is not taxing this waste stream."*[27]

The regional Authorities in Italy have powers to set the level of the landfill tax. Limits are set by central Government, but, within these, the Authorities have used the powers to increase tax levels if regional recycling targets are not met. No evidence of regional issues including movements of waste could be found. The Italian Environmental agencies were contacted, but no response has been received thus far.

[26] EIONET: European Topic Centre on Resource and Waste Management (2007) *Spain Waste Factsheet*, Accessed 16th October 2008, http://waste.eionet.europa.eu/facts/factsheets_waste/Spain

[27] Personal Communication with Ignasi Puig (ENT Environmental - Spain)

The Flanders and Wallonia regions of Belgium both have differing landfill taxes. It is already known that an export tax was introduced to inhibit waste-tourism. Again the authorities have been contacted but no response has been received thus far.

Supporting Policies

Some countries resort to bans on the landfilling of specific waste streams. In the Netherlands, landfilling of municipal waste is banned other than in exceptional circumstances and most organic household waste is separately collected for composting, whilst Austria and Germany have set a maximum fermentability threshold for landfilled wastes. The interaction between landfill bans and landfill taxes is further described in Section A.3.3 below.

Given the cap on EfW in the Zero Waste Plan, it seems important to highlight that several countries also have taxes on incineration. This is set either as a dedicated tax on EfW or, including the landfill tax, as part of a more general waste-tax. If tax raising powers were devolved to the SG a tax on EfW could also be promote the shift to recycling and act as an additional means to generate revenue (as is the case in Denmark, and to a lesser extent, the Netherlands).

In Sweden a tax on waste-to-energy incineration of municipal solid waste (MSW) was introduced on July 1, 2006. The was designed to give CHP plants an advantage compared with Heat Only Boilers (HOB), but also to increase the incentive for material recycling, including biological treatment, and to effectively align the taxation of incineration with the energy taxation system, where incineration of wastes of fossil origin was not burdened with energy and CO_2 taxation as other fossil fuels are.[28] The amount of the tax is calculated based on a model of the content of fossil material in the waste.[29] The amount of the tax is dependent on whether the taxable incineration facilities produce electricity and, if so, how efficiently. For facilities without electrical production, the tax is € 49 (SEK 487) per tonne, which would then decrease with increased electricity production. At 15 per cent electricity production, the tax is approx. € 8.3 (SEK 83) per tonne, at 20 per cent approx € 7.6 (SEK 76) per tonne. Since the introduction of the tax material recycling, including biological treatment, has increased from 34.6 per cent to 48.7 per cent and waste-to-energy has increased from 38.1 to 46.4 per cent.

The incineration tax in Norway was also changed to reward operators who reduce pollution below legal limits specified in the EU's 2001 Waste Incineration Directive. This is done by changing the mechanism so that it is emissions based and focuses on pollutants such as CO_2, NO_x, SO_x, particulates and dioxins. The CO_2 charge (€4.85) is per tonne of waste delivered to an incineration plant, and all the additional 14 pollutants are taxed on the basis of the quantity of pollutant emitted. The changes were introduced in such a way that the overall revenue take would be more or less

---

[28] Swedish Ministry of Finance (2006) *Proposition 2005/06:125 Beskattning av visst hushållsavfall som förbränns, m.m. (Taxation of some household waste for incineration)*, Ministry of Finance, 2006

[29] Avfall Sverige (2008) *Swedish Waste Mangement*, http://www.avfallsverige.se/se/netset/files3/web/P01.m4n?download=true&id=2371_94867351

unchanged, and so that no major change to the balance of residual waste treatments would be occasioned by this.

Also in Catalonia, from 2008, an incineration tax has been implemented, the first of its kind in Spain. The tax rate will be €5 per tonne. However, there will be an increased tax rate of €15 per tonne for those municipalities that do not have in place separate collection of biowaste, but could have introduced it according to the regional waste strategy.

Inert Wastes

Figure 5 above indicates that the taxation mechanisms vary significantly between countries. For example, some keep the same rate as for MSW / C&I, some have separate rates for C&D wastes specifically, others differentiate the inert fraction and several do not indicate any specifics at all. Some policies also have measures to exempt material from the higher rates.

Table 7: Summary of Inert / C&D Landfill Taxes

Country	Landfill Tax	Tax Rate, £	Exemptions for Inerts?
Austria	1989	7	
Finland	1996	26	Yes
Italy	1996	9	
Denmark	1987	44	Yes
France	1992	0	
The Netherlands	1996	12	
Norway	1999	35	
Sweden	2000	38	Yes
Slovakia	1992	0.23	
United Kingdom	1996	2.50	

Inert waste taxes are also generally of a much lower level than active rate wastes because the environmental damages from landfilling are much lower. Moreover the large quantities and low disposal costs result in significant marginal changes, even at low tax rates.

Table 7 above shows a summary of the inert rates of landfill tax. Excluding the taxes which have exemptions, the range of tax levels payable on the landfilling of inert wastes is between £0.23 and £35. The UK's lower rate tax is nearer to the bottom of this scale at only £2.50.

A.3.2.4 Administration of the Tax

A limited variety of mechanisms are used to collect and administer the tax. In the UK and Finland, the Customs and Excise Authorities administer the tax. In France the tax was originally collected by ADEME (French Agency for Energy and Environment), although changes to the tax regime now mean the responsibility has moved to the Excise and Duty Directorate General, within the Ministry of Finance. In Sweden and Norway, waste taxes are paid to the National Tax Authorities.

A.3.2.5 Use of Revenue

The vast majority of waste taxes are directed straight into the general budget. Revenue usage is more closely tied to the source of revenue in Austria and Switzerland where funds are used to remediate contaminated land. In fact Austria is the only European country where revenues from a landfill tax are exclusively used for this purpose.[30] Interestingly, in Finland, the tax revenue becomes part of the general budget. However, the Ministry of Finance is understood to have made a 'gentleman's agreement' with the Ministry of Environment when the tax was introduced, so that more money would be made available to fund contaminated land remediation.

Other countries such as Flanders and France started out with innovative schemes. In Flanders, the regulations have since been modified, with money being channelled into the general budget, whilst in France, the new General Tax on Polluting Activities (TGAP) scheme, which includes the landfill tax, is revenue neutral, so that rises in the tax rate will be compensated by a reduction in VAT (5.5% VAT on waste collection and sorting services instead of 20.6%).

The revenue from the system in Catalonia is refunded back to local authorities to finance additional waste collection infrastructure. The main focus of the funds is on the management of separately collected biowastes.

[30] Umweltbundesamt (2000). *Deponieabgaben im europäischen Vergleich*. Federal Environment Agency - Austrai, Vienna.

Table 8: Use of Landfill Tax Revenues

Country	General Budget	Fund Waste Management Schemes etc.	Clean up contaminated sites	Other
Austria			✓	
Catalonia (Spain)		✓		
Denmark	✓			
Finland	✓		(✓)*	
Flanders	✓ (Now)	✓ (At the start, Environment & Nature Fund)		
France		✓ (At the start, Modernisation Fund for Waste Management)		✓ (Now, revenue neutral with reduced VAT on collection)
Ireland		✓		
Italy				n/a
Netherlands	✓			
Norway	✓			
Sweden	✓			
Switzerland			✓	
UK		✓ (ENTRUST)		✓ (NIC reductions)

** Note: Although the revenue becomes part of the general budget, the Ministry of Environment made a 'gentleman's agreement' with the Ministry of Finance when the tax was introduced that more money would be made available to fund contaminated land remediation.*

A.3.2.6 Exemptions from the Tax

In this section the various exemptions from the landfill tax are identified. Exemptions can be a useful tool to steer appropriate behaviour of waste generating actors. The structure of exemptions will cause rationale economic agents to follow the path of least cost, without strict regulation *per se*. The details of the system of exemptions in a number of countries are set out below. The main structure is then summarised in Table 9.

<u>Denmark</u>

A variety of exemptions exist in Danish law, including:

- hazardous waste, including health-care waste delivered led to incineration plants in loads containing exclusively hazardous waste;
- hospital waste;
- sewage sludge of a quality sufficient for spreading;
- fly ash;
- clean filling earth and clean soil delivered to landfills and used for daily cover or final cover;
- biomass waste (e.g. straw) that is delivered to incineration plants in loads containing exclusively this type of waste;
- compost used for final cover at landfills, which meets special requirements under Section 19 of the Environmental Protection Act;
- certain wastes removed from closed-down waste disposal facilities (including inert or mono-landfills);
- clean wood waste delivered to incinerators.[31]

Waste that is reused or recycled is not subject to the tax, nor is that which is removed from a landfill site.

<u>Finland</u>

In Finland waste tax exemptions include:

- Soil and stone;
- Biological waste and sewage sludge which are delivered to a landfill for composting;
- Waste from de-inking of waste paper;
- Fly ash and desulphurization waste from power plants;
- Hazardous waste and waste for recovery, which are stored at a landfill site on an area especially reserved for this purpose for a maximum of one year;

[31] Note that treated wood is banned from incinerators in Denmark.

- Waste resulting from industrial production which is deposited on private landfill sites run by the plants.

France

Exemptions are in place for:

- owner-operated landfill sites;
- community refuse return;
- sorting centres;
- transfer sites;
- industrial waste recovery operations.

The exemption for owner-operated sites affects the volume of mixed industrial wastes (MIW) falling under the tax, as it is not collected for disposal in a collective landfill site. Of the average MIW volume of 100Mt, about 90% is disposed of at owner-operated sites. The same is true for 90% of harmless agricultural waste (or 360 Mt), but the percentage of mixed agricultural waste is uncertain. All in all, the volume of MIW that is not taxed potentially exceeds 90Mt, which is much more than the usual HW/MW quantities (around 60 Mt).

The Netherlands

For some Dutch waste streams there are special provisions within the Act. The following wastes are exempt from the waste tax (assuming certain conditions):

- organic household wastes (i.e. vegetable, fruit and garden waste), which is collected separately for composting. This exemption was, perhaps, included, following the ban on combustible wastes, in order to allow time for infrastructure to develop.
- Private production facilities with on-site landfills.
- Non-treatable polluted dredging sludges and soils - exempt because the waste cannot neither be reduced nor prevented since it is the consequence of past polluting events. The Government also wanted to encourage the remediation of areas affected by such waste. Since there are no current techniques available for cleaning polluted dredging sludge, all polluted dredging sludge is exempt from the tax until a date to be fixed between 1 January 2000 and 1 January 2002. In the meantime, the supplier of the soil/sludge is required to obtain a statement from the Soil Purification Service Centre certifying that the soil/sludge cannot be treated.
- Asbestos – exempt in order to stimulate clean up and to ensure that the costs of responsible asbestos removal are kept as low as possible. The temporary nil tariff applies until 1 January 2002.
- De-inking residues - the rationale for exempting these wastes is that it would make paper recycling more expensive than virgin paper production. The exemption is therefore believed to stimulate the use of secondary materials. The tax can be refunded on request until 1 January 2001.

- **Waste from plastic recycling** – such wastes are eligible for a tax refund. The rationale for this is that increasing the costs of plastic recycling would make manufacturers more likely to use virgin plastic.

Sweden

In Sweden there are general exemptions for:

- waste for which landfill is currently the only alternative;
- radioactive waste;
- waste from mining;
- certain industrial waste.

Overall, exemptions are granted to about 25 different types of waste, many of which originate from special industrial processes, and for which there are currently no "environmentally acceptable alternatives to landfilling". These include:

- inert waste rock (at approx. 50 million tonnes, mining waste represents the largest exemption);
- contaminated soils from contaminated sites;
- slag and certain other wastes from metallurgical processes;
- foundry sand;
- dredging waste from the dredging of water systems;
- sludges from chemical processes involving the manufacture of dicalcium phosphate, calcium chloride and sodium phosphate;
- recycled fibre waste and de-inking sludge from the processing of recycled paper; and,
- ash from incinerated recycled fibre waste and de-inking sludge.

The Swedish Government recognises that for several types of waste, it is currently not realistic to reduce the quantities of wastes through either process changes, selection of different raw materials or similar measures. However, the Government does expect to gradually reduce these exemptions over time on the basis on new R&D and improvements in waste management practices.

Facilities that are not liable to the tax include those where, exclusively, the following kinds of waste are being deposited or stored for more than 3 years:

- waste rock;
- earth, stone, gravel, clay, shale or limestone;
- waste sand from the manufacturing process in the mining industry;
- waste derived from water purification processes;
- radioactive waste.

If any of the above wastes are deposited alongside other kinds of waste at, for example, a municipal landfill, then the tax automatically applies.

Specific exemptions apply to certain types of waste that are deposited at landfill sites as the first stage in a defined treatment or reuse process. Such wastes do not need to be accounted for in the quarterly declarations to the National Tax Board. This exemption applies to:

- waste material intended for use in essential construction work at the landfill site and for the daily operation of the facility;
- garden waste intended to be composted;
- waste intended to be made into specific types of fuels (e.g. wood waste into chips, household waste pressed into pellets);
- waste intended to be burned (e.g. used for energy recovery, heat production).

Hazardous wastes and waste destined for recycling are exempt from the tax.

The table on the following page highlights the various emphases of waste tax exemptions across European countries. There are clearly wide ranging reasons for exempting certain activities, some of which are driven more by economic than environmental arguments.

Table 9: Focus and Rationale of Landfill Tax Exemptions

	Environmental			Economic		
Country	Protect materials being used in landfills (e.g. inert)	Stimulate remediation and clean up *	Stimulate waste recycling industry	Protect unavoidable wastes **	Protect indigenous industry	Protect on-site landfills at private production facilities
Austria			✔ 1			
Denmark	✔			✔		
Finland			✔ 1, 2	✔		✔
Flanders – n/k						
France			✔ 3			
Italy – n/k						
Netherlands		✔	✔ 1,2,4			✔
Sweden	✔	✔	✔ 1,2	✔	✔ 5	
UK	✔	✔				
Norway			✔ 6	✔ 7		

Switzerland – n/k						

** e.g. contaminated land, river sludges, asbestos etc.* *** e.g. power plant ash, fly ash, clinical/hospital waste, sewage sludges, radioactive waste*

Notes

1 Various exemptions for materials destined for composting

2 Waste from deinking of waste paper

3 Industrial waste recovery facilities and community waste return

4 Waste from plastic recycling

5 Metal slags, foundry sand, sludges for certain chemical manufacturing processes

6 Waste destined for recycling

7 Hazardous waste only

A.3.2.7 Perverse Effects of the Tax

The literature on waste taxes frequently speaks of the possibility for evasive behaviour. In England, Local Authorities (LAs) bear the costs of clearing up waste that is fly-tipped on public land.[32] Some claim to have experienced increases in fly-tipping in the wake of the tax. However, it is also mentioned in the Eunomia report that this could be due to a greater awareness of the problem post-tax, and that there was a poor baseline, because LAs previously defined fly-tipping in different ways.

Eunomia's household waste prevention report states that there was some concern that waste which was previously in the commercial and industrial stream might enter the household stream through being taken to civic amenity sites.[33] The effect is that municipal waste almost certainly increased as a result of the tax. This resulted in the tightening up of procedures at HWRCs to stop the switch of C&I wastes into the municipal stream. For example, the drivers of any vans now entering HWRCs in England have to produce a proof of address, copy of hire certificate, and demonstrate to the site operators what is in the vehicle on entrance. The UK also faces a major issue with respect to sham recovery, with increasing quantities of ineligible waste being sent to unlicensed sites.[34]

In England, it has been reported that, following the divergence in levels of inert and standard rate tax, there has been some increase in mis-definition of wastes in order to avoid the higher rate tax.

The issue of 'landfill evasion' through resort to recovery options is also an issue in Denmark and Austria. One loophole in Austrian Law did exist for landfill operators. Under a 1998 amendment to the waste law certain waste may cease to be legally regarded as such if it reaches certain minimum standards for pre-treatment in respect of its stability. If the waste fulfils the criteria and is therefore regarded as 'stabilised' then no tax is due on the waste. Waste that has undergone mechanical-biological treatment (MBT) for sufficient periods of time achieves these requirements. There is, consequently, a possibility for landfill operators to mix waste in order to alter the bulk characteristics of the waste and hence avoid taxation.

In Finland there are no official statistics on illegal dumping, however, newspapers have reported several major incidents of dumping in forests. However, the Ministry of Environment believes it is more a reflection of tightening landfill requirements resulting from the Landfill Directive rather than the landfill.

Waste tourism can also result from waste taxes, as experienced in both Austria and the Netherlands - although in Austria regional laws have been drawn up to try to

---

[32] Eunomia et al (2007) *Household Waste Prevention Policy Side Research Programme*, Final Report for Defra

[33] Eunomia et al (2007) *Household Waste Prevention Policy Side Research Programme*, Final Report for Defra

[34] ECOTEC (2001), *Study on the Economic and Environmental Implications of the use of Env. Taxes & Charges in the EU*

rectify this. Notably, a move from Denmark to Sweden (now relatively easy owing to bridge construction) would enable avoidance of significant taxes, and this is believed to have led to waste for recovery moving away from Danish incinerators and into Swedish ones.

A.3.3 Interaction of Landfill Taxes with Landfill Bans

The consequences of landfill bans are difficult to separate out from the effects of other instruments in place at the same time, not least, landfill and waste taxes, but also other instruments. A ban on landfill does not dictate where the material which can no longer be landfilled will be sent. Other policies, and market conditions, will dictate how this material is managed.

In the absence of alternative interventions, the effect of a ban will, most likely, be determined by the costs of the competing options for dealing with a given waste stream. In very basic terms, the ban rules out the option of landfilling for the banned waste stream. A tax might have a similar effect for given materials if it is set at such a rate that under reasonable assumptions regarding how low pre-tax gate fees could fall, landfilling is no longer, from the perspective of costs, a viable option economically.

Even so, it is questionable whether this approach should be sanctioned, particularly from the perspective of economic efficiency. As the OECD puts it:[35]

> *191. From an economic perspective, introducing a ban on landfilling is equivalent to stating that the value of the environmental harm caused by the landfilling is infinitely high. While this can be defendable for certain types of hazardous waste, it is much more difficult to see the theoretical underpinning for a ban on the landfilling of paper waste, whether or not it has been collected separately.*
>
> *192. For such waste categories, it would seem more relevant from an economic perspective to lift the ban and to set a tax on landfilling that more closely reflected the environmental externalities that actually would be caused if the waste was to be landfilled. For paper wastes, the relevant tax rate could very well be considerably lower than the current rate of the Landfill Tax.*

The Green Alliance states quite clearly that research highlights the role played by other policies:[36]

> *A message that came out of our research very strongly was that landfill bans and restrictions had been deployed as one instrument in a range of fiscal, regulatory and other interventions aimed at moving waste away from landfill: in other words, bans and restrictions were necessary, but not sufficient.*

---

[35] OECD (2005) Instrument Mixes Used to Address Household Waste: Further Analyses and Additional Case Study, ENV/EPOC/WGWPR(2005)4/REV1, Paris: OECD.

[36] Green Alliance (2009) Landfill Bans and Restrictions in the EU and US: A Green Alliance Project for Defra (ref WR1202): Summary Evidence Review, August 2009.

It is not clear whether the view, expressed in the above extract, that bans and restrictions are 'necessary' is that of the respondents or of the authors. Two points are worth making in respect of the above statement:

- If a ban can be implemented sensibly, and if the aim of the ban is to shift waste into any other management route, then equally, a ban should be sufficient. In practice, therefore, the accompanying instruments tend to reflect the relative priorities given by different countries to different outcomes, as reflected in national waste Ordinances, Plans and Strategies.
- It is not entirely clear that landfill bans are 'necessary', particularly in cases such as those of Massachusetts and Nova Scotia, where the bans are effectively prompts for the introduction of kerbside schemes at the household level, and product stewardship schemes for waste from other sectors. The same could be said of the Netherlands, where two years after the ban was announced in the Decree, a very high tax was set on landfilling of exactly those types of waste to be subject to a ban. It seems reasonable to ask whether a relatively high tax might not achieve something similar to a ban, especially where appropriate accompanying instruments are in place through, for example, Producer Responsibility. More generally, one might question whether the effects of a ban over and above increased tax rates may be justified.

An interesting feature of landfill bans is that most countries make use of them alongside landfill (or waste) taxes. In four of the cases assessed by Green Alliance – Flanders, Netherlands, Austria and Sweden – the price for treatments other than landfill is made lower than that of landfill by the taxes in place. From an economic perspective, as the quote from OECD above suggests, the effect of a landfill ban is equivalent to setting an infinite price on landfill (subject to exemptions). The comment obtained from the German Federal Environment Ministry in work by the Green Alliance suggested:

> *A tax would have to be set high enough to have any effectiveness, and yet low enough to be politically acceptable.*

To the extent that a ban is effectively an extremely high tax, this might suggest that a high tax would be less, not more, politically acceptable than a ban.

Some of the other comments which stakeholders appear to use to suggest complementarities between landfill bans and landfill levies do seem to suggest the primacy of the effect of the tax as opposed to the ban:[37]

> *"It was decided in 1999 that the tax for landfilling untreated organic waste should be dramatically increased. The tax rate was set as €87/tonne, against seven euros/tonne in previous years. <u>This meant that a landfill operator who was not yet complying with the landfill ordinance (i.e. still accepting untreated organic waste) now had low prospects of making money anyway."</u>*

[37] Green Alliance (2009) Landfill Bans and Restrictions in the EU and US: A Green Alliance Project for Defra (ref WR1202): Summary Evidence Review, August 2009.

Christian Holzer, Lebensministerium, Austria

This suggests that the tax alone would have made it difficult to operate landfills profitably given that pre-treated waste attracted a far lower gate fee, and the costs of pre-treatment would be justified by the savings on landfill tax:

> *"The tax initially played a very important role in establishing alternatives to landfill. Given that exemptions were being granted relatively freely for banned waste based on lack of alternative capacity, it was important to also have an economic driver steering waste away from landfill…. We'd now like to see a discussion about the extent to which a high landfill tax is still needed, now that landfilling has declined to a very low level."*

Anders Hedenstedt, Avfall Sverige, Sweden

This comment suggests a considerable degree of confusion. If the ban is being implemented, then the tax ought to be redundant insofar as the tax and the ban affect wastes of the same scope. Similar points can be made in respect of Austria's higher rate of tax, now being made more or less redundant by the virtual absence of landfilling of waste which has not been pre-treated to a required standard.

Finally, from Flanders:

> *"The landfill and incineration bans are flanked by a well-considered policy of levies. Their aim is to alter the costs of waste disposal and treatment in order to reflect the waste hierarchy philosophy. Since 2007, the landfilling of combustible wastes has been made more expensive than incineration. Only landfilling of residual wastes, i.e. wastes that result from incineration and recycling, get a lower tax treatment."*

Jan Verheyen, OVAM, Flanders

It is clear that where taxes are concerned, in principle, it would be possible to structure levies so as to 'rig' the waste management market and make specific options more desirable than others. Especially where a ban's primary aim has been to achieve a shift from landfill to incineration, there seems to be little reason to believe that a tax could not, or that it does not, achieve the same (or very similar) objective in a more efficient manner.

A.4.0 Stakeholder Interview Summaries

A round of interviews with a range of relevant stakeholders was undertaken. The aim being to gain some views on the need for changes to the tax and what impacts may results from such changes. Telephone interviews were held with the following people:

- Michael Tracey (William Tracey Waste Management)
- Kenny Lang (Inverclyde Council)
- George Eckton (COSLA)
- Ian Lorimer (Director of Finance - Angus Council)
- Bill Weir (Barr Industries)
- Mark Everett (JJE Contractors)
- Adrian Bond (SEPA)
- Paul Ellis (Biffa)
- Martin Cracknell (SITA)
- David Lonsdale and Iain McMillan CBE (CBI Scotland)

Written responses were received from:

- Kenny Boag (SEPA)
- Stephen Freeland (SESA)

A questionnaire was developed and sent out to each person prior to the interview. The responses have been summarised and amalgamated below under the same question headings.

A.4.1 Summary Responses from Interviews

1) What is your experience of the implementation of the existing UK landfill tax?

A) How well regulated is it?

- Fairly efficient but could be better regulated. One landfill operator didn't know of any regulators that have turned up at a landfill site. It was reported that some sites have a free reign to do what they want.
- Comes down to interpretation in some instances (WRG case). Also issues with definition of 'fines'.
- Pretty well regulated overall, but difficult because regulators can't continuously monitor sites. Overall, landfill operators do know what is required from them.
- It was indicated by one operator that some inert landfills are breaching discharge consents. The causes were identified as a) mis-declarations of waste and b) lack of inspections.

B) How efficient is the administration?

- No major concerns over current administration.
- Simple procedures.
- Easy to calculate as weighbridges are abundant. Better checks and balances now. Not as good 10-15 years ago.
- Data from site returns should match up with tax returns. If not then someone should look at this issue.

C) Are current and anticipated changes as they should be?

- Initially the rates were too low; consequently very little diversion from landfill could be seen.
- The current rates, including the escalator, are as they should be. It has created a new industry and a buoyant market for recyclates. The tax is now at a level that technologies can compete with landfill.
- A huge change will be seen after £80 per tonne. It is likely that the 5% landfilled target will be met before 2025 because of tax level, and other ambitious policies such as carbon reduction targets. The UK will be in a better position than other EU countries.
- The floor on the standard rate of tax should be extended beyond 2020.
- Lowering the tax would be a disaster. Now that it has been set out it gives confidence to industry. A large change has been seen in last 3 to 4 years.
- The highest level of tax will still not make landfill the cheapest option for all authorities.
- Several stakeholders were clearly suggesting that, in a number of cases, the level of the current escalator was not enough to make landfill more expensive than other options. It was implied that higher levels of tax might be necessary to give further financial stimulus to Local Authorities as, in current economic conditions, overall spending is being cut.
- The tax has been a good fiscal measure, not to raise revenue, but to change behaviour. This has started to effect a cultural change.
- The landfill tax arguably represents the single greatest lever available to influence the management of waste across the UK, as the landfill tax escalator continues to make viable more sustainable waste solutions that would otherwise remain undeveloped.
- The unfair element of the landfill tax is the inert part. £2.50 on top of transport and gate fee of £1 to £1.50 is a significant increase. The tax has changed the way people manage inert wastes. Alternative routes to avoid the tax have been sought out.
- The increased costs have made it more difficult to get engineering material onto the site.

- Currently there is no link to methane recovery. There is still wide variation in performance in this regard and the tax should reflect this.
- Difference between the higher and lower rates is too high. This provides a large incentive for fraudulent activities.
- The current tax levels do not help the building industry where expenditure is already low. 2% of heavy civil builds on disposal costs, but much higher when contaminated land.

2) *What changes to the existing system (UK wide first, then Scotland only) would you recommend, in terms of:*

   A) *Levels*

- If it's not broken don't fix it. General opinion is that the levels are stimulating enough change and don't need changing.
- No change, just investment in recycling is needed. Most people aren't green so the tax is needed to change behaviour.
- Concerned by measures which would allow the Scottish Parliament to set a Scottish rate of landfill tax: this would seem to suggest a fundamental misunderstanding of the dynamics of the market for waste management.
- Increase the rates as it gives a higher baseline to model procurement options. Good for waste management officers because it encourages spending in new infrastructure and mitigates risks. The cross-over from landfill to treatment is likely to occur with a disposal cost of around £100 per tonne.
- Current rates may not stimulate landfill diversion in all cases so could be increased.
- Almost a moot points as landfilled levels are limited to 5%, does it matter what the tax is when little is being landfilled?
- There needs to be a level playing field across the UK.
- Do not take away. Who would be recycling for environmental benefits alone?
- Certainty is an important factor. If the goal posts are moving it might put off investing in infrastructure.
- The escalator is happening quicker than infrastructure can develop.
- The level should be linked to the quality of the site.
- Perhaps a moratorium on the escalator in order to stimulate the economy, or a delay.

   B) *Structure (lower / standard rates)*

- Some active wastes have lower rate, for example calcium sulphate which is biodegradable. Dredging from canals is subject to the lower rate as well, but can't go to inert waste landfills. So some waste is going to active landfills at lower rate – this is wrong.

- Should the structure reflect the waste acceptance criteria?
- Should we scrap inert? Virtually no revenue, and when tax came in lots of golf courses were built and waste sent to exempt quarries etc. This has caused some illegal activity at exempt sites.
- Differential rates over different streams may cause other issues (such as cross-border movements) and be difficult to administer.
- Have a singular rate of tax which the lower and higher rate converges to at a moderated level.
- Asbestos shouldn't be taxed at the full active rate as this discourages brown-field site redevelopment.
- There is an institutionalised view that rejects from sorting plants are inert. There probably are not, and therefore should be taxed at the higher rate.
- Replicate the structure of the proposed landfill bans and increase in the years leading up to the ban. One of the biggest worries is that industry will not react to the bans and will not get infrastructure in place.
- Keep IBA classification under review. This will get more important as EfW capacity ramps up.

C) Classifying Exempt Sites

- Exempt sites should require a waste management license and SEPA should have more authority and resource to monitor these facilities. The system of exemptions before the tax came into place was noted as a cause of the current problems.
- The tax should be applied to exempt sites as well, this will drive further materials reprocessing.

D) Other

- Keep the tax system simple / transparent.
- There should be some encouragement to find an industry for fly/bottom ash recycling and recovery.
- Tax could be refunded in a similar mechanism to how the carbon reduction commitment was supposed to work. There would be some financial uncertainties and administrative burdens with this approach though.
- Quotas for use of material on landfill sites for road access etc could be used. It would be easy for operators and regulators to agree a level for each site.

3) *How do you perceive the significance of current cross-border movements of residual waste?*

- Cross-border movements are low.
- Some hazardous waste landfill capacity at Avondale but most waste goes to treatment facilities. Hazardous waste treatment facilities attract waste from England (Manchester was one example). As the cost of treatment increases waste will travel further.
- Some hazardous waste travels south for treatment rather than disposal.
- In Scotland waste can travel large distances but cross-border movements are low.
- However, large scale plant in Teesside may attract waste for treatment and therefore may increase in the future.
- Waste is not the same as other commodities that move across borders.
- 80% of waste plasterboard goes across the border (mainly to Lincolnshire) as there in limited treatment capacity. Transportation is optimised by backhauling loads.
- Carpets go to England for reprocessing.
- Small quantities of health care wastes moving from England to Scotland because of varying definitions of BAT.

4) *How do landfill gate fees vary across Scotland and national borders, and why? What is the current state of Scottish landfill void space?*

- Gate fees are somewhere between £12 and £20 for landfills to the south and in the central belt. Fees are slightly higher in the north of the country. Around Glasgow there are a number of sites including the largest landfill site in Europe so gate fees here are as low as £10-£11.
- Lots of providers for small Local Authorities allow for low gate fees to be negotiated.
- In general, gate fees are higher in England.
- The availability of void space is the most influential factor in determining gate fees. Little impact from differing gate fees in England is perceived.
- Easily 10 years of licensed void space.
- There are half a dozen big operators that control half of the waste. Most will have massive void space. Void-space lifetime may be 50 plus years and will increase as the residual stream decreases and alternative treatment capacity comes on-line.
- The last landfill got consent in 2004 but will not open. 1 or 2 have extensions that may be passed.
- Less void space in the northern Authorities.

- General view that landfill was a business that was on its way out

5) *What issues might arise if a Scottish specific landfill tax was implemented? Including:*

   A) *Change in gate fees*

- Very little scope to lower gate fees in Scotland as operators are already running on discounted costs to fill void space. Landfilling is not the industry to be in.
- If there was more pressure put on by higher taxes, and waste quantities decreased, operators might have to increases gate fees to cover costs.
- Variation between treatments plants may be of more significance than landfills.
- More regressive for northern Authorities.

   B) *Cross-border movements of waste*

- Landfill operators suggest that if the rates changed material would move from Scotland to England and vice-versa. The main driver is price. It was noted that waste should, in principle, travel the least distance for disposal, so causing significant movements of waste would be opposed to this.
- Trans-frontier waste movements to Holland and other European countries will continue to increase, and subsequently reduce when alternative capacity comes on-line in Scotland.
- Strongly advise that the cost of waste management in Scotland should be broadly the same as the rest of the UK: environmental criminals might otherwise exploit regulatory arbitrage between Scotland and England, leading to both “waste tourism” and higher levels of flytipping.
- Given the cost of landfilling it may be cheaper to move waste across the border. Down the A47 to Cumbria, for example.
- Not huge distances so may be possible with large bulkers.
- The bottom line will be very important in coming years, so people will look hard at alternatives if rates are changed.
- This depends on where the tax is administered, in Scotland or when it goes through the gate at the landfill.
- Authorities would look with interest at moving waste aboard if tax levels increased.
- If tax is reduced then there may be significant amounts of waste coming over the border. This could be politically difficult.
- Levels would need to be modestly different to see any waste moving across the border. The relationship between cost and distance may be expected to be fairly linear.

C) How far hauliers will transport waste as price differential increase

- This, as noted above, relates to price. It was suggested that a £10 increase in disposal costs could see lorries moving waste over 100 miles. In this context relatively small changes would cover a large area of Scotland and northern England.
- Not far for inert materials as the transportation costs are high.

D) Regulation and administration

- Some large businesses (such as ASDA) have UK wide contracts, so differential taxes would complicate the administration of the tax and the contractual negations for waste services.
- Concern is that in the current climate why setup another administrative system when the current policy is working well. Even if it is just an admin fee the Scottish Government would pay, why pay an additional cost for something you are getting free at the moment.
- Current level of administration is suited to UK wide.
- Requiring waste producers to pay the tax rather than the landfill operators would make the system more complicated.

E) Other

- Political concern that Authorities don't have the money and therefore would not be able to afford treatment capacity, and there is no merchant capacity.
- Penalties from scrapping long-term landfill contracts may be significant, so in some situations, and even with the escalator, the business case for landfill diversion may not be viable.
- Higher rates would not be politically acceptable unless the funds were hypothecated. The refund of tax revenue to LAs may be politically unacceptable under the current Concordat.
- Policy could be too effective and result in funding gap for Scottish Government.
- The proposed landfill bans are still likely to have more effect than any change in the tax.

Other points raised:

- As long as Scotland is still part of the UK waste policies should be harmonised.
- Some interviewees suggested that the Scottish Government should publish a 'green paper' on their proposals for the landfill tax as soon as possible to give certainty to the industry.

- Change in the recycling industry has come from SMEs. Large players have been slow to react.
- Perverse scales of efficiency in waste procurement. Larger contracts mean more risk, so more expensive, and vice-versa.
- Non-landfill operators use the tax as a baseline to structure charging tariffs. They aim to set fees just below the total landfill disposal cost.
- No doubt that landfill tax is very relevant tool when making an investment decision.
- The study must consider how changes to the landfill tax would sit in relation to the setting of carbon reduction targets. Some Authorities are waiting for the guidance before they go to procurement.
- Interesting to look at proportions of LA budgets spent on the tax, collection and disposal.
- If quantities of waste going to landfill fall gas capture will drop off to below threshold levels. Therefore, in order to maintain high enough degradation rates to enable gas capture landfilling should be strategically planned. More waste to a few sites rather than small quantities distributed widely.
- Level of recovery of inert materials is not as high as some operators are reporting. It is going into the ground but not for appropriate uses.

A.5.0 Selection of Policy Options for Assessment

The initial review and data gathering stages of the project helped provide evidence to suggest what potential policy options, for implementing a Scottish Landfill Tax, the Scottish Government could consider. During the course of the project the pros and cons of the suggested options were discussed with the steering group. The list of options and pros and cons of each are presented in the Tables below. The steering group decision and summary of the options are given in Section 4.0 of the main report.

Table 10: Potential Landfill Tax Modelling Options

Option	Supporting Evidence	Opposing Evidence
Increase Level of Active Rate Tax	➢ The range of monetised impacts from landfilling suggests that the environmental justification for the appropriate rate of landfill taxation is far from certain. However, as knowledge of the impacts on landfilling and the value of carbon increases the monetised value of the damages caused by landfilling could increase above £80 per tonne. This would provide a justification for further increases in the level of tax. ➢ The literature review suggests that, combined with the impact of additional policies, landfill taxes create waste prevention effects and support recycling initiatives. Therefore, increases in tax level could help reduce waste generation in Scotland and increase material recovery. ➢ The stakeholder interviews suggest that in some instances the level of tax is still not high enough to make alternatives to landfill cost effective. No information was given suggesting what increase could be effective, but the evidence does suggest there is support for some increase. ➢ The evidence does appear to suggest that an increase in the standard rate of tax is justified, but not by a significant amount. ➢ The existing data is of sufficient quality to model this option.	➢ Considering the tax rates in other European countries suggests that the currently planned UK rate (£80 per tonne) will be one of the highest in Europe. One could suggest that based upon this evidence there would be no justification to raising the tax level beyond £80. However, comparing rates with other countries is only useful to a limited extent. Differing economic, policy and political conditions mean that national contexts do not necessarily make economic ceilings comparable. ➢ Evidence from stakeholders suggested that some people believed the current rate to be significantly driving the recycling industry, and in fact the current escalator would lead to high levels of recycling and minimal landfill (the cap of EfW steering waste towards recycling rather than thermal treatment). ➢ Disparities in levels of tax with England may stimulate greater cross-border movements of waste and fly-tipping ➢ Other policies dedicated to increasing recycling may be more efficient than increasing the landfill tax.

Option	Supporting Evidence	Opposing Evidence
Delay increases in escalator until 2014 (£80 per tonne)	➢ Some countries (Denmark, the Netherlands and France) have seen dramatic increases in tax but over relatively short periods. Suppressing the increase in escalator in the intermediate years until 2014 could reduce the burden on business and still have the same behavioural changing effect, because of the certainty that the tax will still increase to £80 in 2014.	➢ Change in policy may provide uncertainty to businesses in policy implementation. ➢ Potential for some waste movements from England to Scotland in the short-term.
Increase Level of Inert Rate Tax	➢ Some countries have higher rates for inert wastes and construction and demolition wastes (Austria and Italy). ➢ The stakeholder interviews suggest that recovery has increased, but more could still be done to appropriately manage inert C&D wastes. Further increases could stimulate recovery, however, one key constraint to increased recovery, which could be addressed first, may be the lack of tax at exempt sites. This is discussed below. ➢ Reduces incentive to mis-declare wastes as inert.	➢ Increased levels of tax could deliver real additional burdens to the construction industry which is already suffering from a lack of contracts. As the volumes of waste increase significantly this issue would be exacerbated if the site was on contaminated land. ➢ More material could be diverted to exempt sites.
Revenue used to incentivise recycling activities	➢ The two key examples of this option are found in Catalonia and Slovakia. The tax is refunded to Local Authorities, on a cost neutral basis, to incentivise the uptake of high quality recycling services.	➢ Administrative burden. ➢ Potential difficulties with the perception of hypothecating funds in Scotland (R.E. the Concordat). However, we do not believe refunding revenues to directly fund new services the same as ring-fencing local authority budgets. ➢ Greater administrative burdens. ➢ This option would require a more complex approach to modelling.

Option	Supporting Evidence	Opposing Evidence
Lower rate for stabilised wastes	➢ The Austrian tax is structured in this manner. Residues from MBT processes are taxed at a lower rate. ➢ Evidence from existing reports by Eunomia states that the environmental damages caused by landfilling stabilised waste are much lower than active waste. Therefore, there is a strong argument, based on environmental grounds, for a having a lower rate tax for stabilised materials.[38] ➢ This split would also help drive the ban on biodegradable wastes as defined in the Zero Waste Plan.	➢ There is limited experience of the mechanism across Europe.
Bottom Ash classified as Active Rate	➢ There is growing evidence of the hazardous nature of untreated incinerator bottom ash (IBA). ➢ The IBA also contains a quantity of precious metals. The scarcity of these elements means the market price is continuing to rise. A tax on IBA, therefore, would make investing in novel recovery processes for heavy metals costs effective.	➢ The reclassification of IBA was not accepted in a recent consultation by HMRC.

[38] Eunomia (2008) *'Biostabilisation' of Wastes: Making the Case for a Differential Rate of Landfill Tax*

Option	Supporting Evidence	Opposing Evidence
Higher rate for Automotive Shredder Residue	➢ During the international literature review for the Irish Government in 2009, it was ascertained that automotive shredder residue (ASR) needed to be targeted to meet the high recycling rates for 2015 set under the ELV Directive. Germany bans ASR from landfill, but equally a tax on ASR, which is mostly landfilled, would provide an economic stimulus to the industry to invest in new technologies and help Scotland and the UK meet the 2015 targets. The cost of treating ASR is thought to be between £100 and £200 per tonne.[39]	➢ Further research as part of the Producer Responsibility study is needed to clarify the costs and impact of this option.
Define sorting residues as active	➢ During the stakeholder interviews is was suggested that there is a strong tendency to define sorting residues as inert, whereas the reality is that there is some quantity of biodegradable material in the residue. To support a fair system effort could be made to ensure that this material is defined correctly.	➢ Potentially difficult to model.
Reclassify some biodegradable materials as active e.g. dredging spoils	➢ During the stakeholder interviews it was suggested that some wastes with a biodegradable content are landfilled under the inert rate. To ensure the environmental impacts are being fully internalised, and to stimulate further recovery of these materials, they could be reclassified under the active rate. This may not be possible, however, if no alternative treatment currently exists.	➢ Potentially difficult to model.

[39] GHK & Bio Intelligence Services (2006) *A study to examine the benefits of the End of Life Vehicles Directive and the costs and benefits of a revision of the 2015 targets for recycling, re-use and recovery under the ELV Directive*, Final Report to DG Environment

Option	Supporting Evidence	Opposing Evidence
Exemptions for asbestos and waste from contaminated land	➢ During the stakeholder interviews it was suggested that, to provide support to the redevelopment of brown-field sites, asbestos and contaminated soils should be exempt from the tax. ➢ The Netherlands and Sweden, for example, have similar exemptions already in place.	➢ The removal of the tax could mean that any environmental damages are no longer internalised. ➢ Potentially difficult to model.
Re-evaluate exemptions relating to material fused or engineering purposes such as road building	➢ During the stakeholder interviews it was suggested by landfill operators and regulators that some quantity of inert wastes should be made exempt to help with the construction of onsite roads and other engineering needs. Quotas to limit the sham recovery of material could be easily derived by regulators and operators.	➢ It is important to be able to talk with HMRC about this issue as there are planned changes coming into effect from 2012 that may be counter to this suggestion from operators. ➢ Potentially difficult to model.
Decrease Level of Active Rate Tax	➢ Current monetised estimates of the damages caused by landfilling are less than the current UK landfill tax escalator. However, the research has large uncertainties. If further research suggested that the impacts were below £80 this would provide an environmental justification to lower the tax level. ➢ One comment from the stakeholder interviews suggests that the tax could be reduced to help stimulate the economy in current difficult economic times.	➢ Strong evidence from the stakeholder interviews suggests that lowering the tax would result in the policy losing all credibility. ➢ Industry and investors would see a change of policy and lose confidence. Furthermore, in the current economic climate business will be looking very closely at ways to save money and so waste recovery could stall or decrease. ➢ No other European countries have increased then decreased the level of active rate tax. ➢ Disparities in levels of tax with England may stimulate greater cross-border movements of waste and fly-tipping.

Option	Supporting Evidence	Opposing Evidence
Delay escalator	➢ Reduce the economic burden on businesses while the economy recovers, whilst still maintain the certainty of the increase in tax level for future investment decisions.	➢ There is a risk that the policy could lose credibility.
Decrease Level of / Implement a Moratorium on Inert Rate Tax	➢ The stakeholder interviews suggest that due to the current economic climate a reduction in, or moratorium of, the inert waste landfill tax could provide a helpful stimulus to the C&D sector.	➢ This could halt advances in the recovery of inert materials. ➢ This would send the wrong message to the C&D sector in terms of the strategic direction of waste management. ➢ This would also increase the incentive to mis-declare wastes are inert. ➢ No preceding case of this option.
Split rates by sector (e.g. MSW / Commercial /. Industrial / Construction)	➢ In Catalonia and Slovakia, for example, rates are differentiated by sector. This provides a greater stimulus to one, or another sector. In these examples the focus is municipal waste, but equally higher rates could be set for the commercial sector in Scotland, for example, to stimulate further recycling. The rationale here being that the municipal sector has high recycling targets whereas the commercial sector does not.	➢ Difficulties in administration. ➢ Singling out a specific sector may not be the most holistic approach. ➢ Runs counter to the general policy aims of Government to not 'balkanise' waste streams.
Combine Active and Inert Rates	➢ One comment from the stakeholder interviews was that the disparity between the higher and lower rate tax levels was a strong incentive for illegal behaviour. The suggestion was that to reduce this behaviour the two rates should be merged together (somewhere in the middle).	➢ Disposal costs in the C&D sector, for example, would see significant increases in costs. ➢ Loses and environmental rationale. ➢ Reduces the incentive to better manage active wastes. ➢ Not likely to be a preferred policy option.

Table 11: Additional Potential Modelling Options

Option	Supporting Evidence	Opposing Evidence
Introduce EfW Tax	➢ Several other countries have EfW taxes alongside landfill taxes and bans. There are 3 main reasons why this occurs: 1. To internalise the externalities associated with thermal processes; 2. To incentivise activities further up the waste hierarchy; and 3. To raise revenue for Government. ➢ Could support the 25% EfW cap for municipal waste management.	➢ Not strictly under the scope of the study, but this could be included in the modelling work.
Export tax to discourage cross-border waste movements	➢ In Belgium there is an export tax between autonomous regions to stop waste moving for disposal. In Austria an export tax was created to stop waste going to other countries for lower cost recovery options (such as incineration). ➢ An export tax could inhibit 'waste tourism' to England and abroad if differential levels of tax were set. The operation of this mechanism would have to be considered carefully.	➢ Administrative burden. ➢ Potentially difficult to regulate.

A.6.0 Baseline Mass-Flows

This appendix outlines the baseline assumptions used to calculate the mass-flows from which the costs and benefits of the policies are derived. The baselines were constructed in relation to four key waste streams:

1) Household;
2) Commercial;
3) Industrial; and
4) Construction and Demolition.

These main assumptions required for each of the sectors are outlined in the following sections. These are:

1) Waste generation;
2) Waste composition; and
3) Waste management.

For consistency a standard composition was used for each sector. Thus any data sources were adjusted to be consistent with these categories:

- Paper and card
- Dense plastic
- Plastic film
- Glass
- Ferrous metal
- Non-ferrous metal
- Textiles
- Wood
- Food waste
- Green waste
- Furniture
- WEEE
- Other
- Incinerator Ash
- Soil
- Aggregate
- Insulation & Gypsum based materials
- Hazardous site waste

A.6.1 Household Waste

The total household waste arising in Scotland in 2008/09, from SEPA Waste Data Digest 10, was reported as 2,905,584 tonnes of waste. This was the most recent data available at the time the baselines were being constructed. The household waste stream was split into two distinct parts for the modelling of recycling a) kerbside collected and b) bring sites and HWRCs. Thus compositions and estimates of the total waste generated for each sub-waste stream were required. The compositions were derived from the most recent WasteWorks and AEA compositional analysis of household waste in Scotland in 2009. However, it was not possible to breakdown the recycling and composting element of this composition for our study. Therefore, the following approach was taken:

Use the WasteWorks compositions for:

1) Kerbside residual;
2) HWRC residual;
3) Litter; and
4) Bulky waste

and add back the quantities of recycling collected at the kerbside in 2008/09 to the kerbside residual composition to obtained the Total Kerbside Composition, and the other recycling to the HWRC residual, litter and bulky composition, to obtain the Bring Composition.[40]

However, the material specific recycling data in the Waste Data Digests is aggregated (in other words is the total for Scotland only) so the data by material and source for each Local Authority was extracted from WasteDataFlow. In addition trade waste had to be removed from the figures, as this will be included under the C&I waste stream. Some assumptions were also required to translate the data into the standard composition used in the model.

Organic waste recycled from Table 11 of the Waste Data Digest 10 is 12.4% of the total waste arising, so we assume this is composed of 7% food waste and 93% garden waste to calculate the food and garden waste recycling rates. This proportion is based on our detailed understanding of the composting market in Scotland in order to calibrate the model to provide recycling rates for food and garden waste at around 5% and 80% respectively.

For mixed cans the proportions of ferrous and non-ferrous were set at 70% and 30% respectively, and for other scrap metals at 90% and 10% respectively.

The following table shows the calculations including the % recycling from the kerbside and bring for each material (taken from WasteDataFlow). Note that some secondary

[40] Note 'Bring' includes bring sites / banks and HWRCs.

recycling from incinerators, MBT and other treatments is included in the calculations, so as this is not double counted in the calculation of the compositions.

Table 12: Calculation of Material Based Recycling from Kerbside and Bring Sources

	Total Recycling: WDD 10, tonnes	Household Recycling (Less trade), tonnes	Kerbside Recycling, %	Bring Recycling, %	Secondary Recycling, %	Kerbside Recycling, tonnes	Bring Recycling, tonnes
Paper and card	259,961	244,825	74%	26%	0%	181,520	63,305
Dense plastic	16,996	16,006	70%	30%	0%	11,252	4,755
Plastic film	0	0	70%	30%	0%	-	-
Glass	102,102	96,157	31%	69%	0%	29,908	66,249
Ferrous metal	37,988	35,777	20%	80%	0%	7,044	28,732
Non-ferrous metal	6,269	5,904	45%	55%	0%	2,681	3,222
Textiles	16,957	15,970	10%	90%	0%	1,618	14,352
Wood	67,773	63,827	0%	100%	0%	164	63,663
Food waste	25,290	25,290	77%	23%	0%	19,561	5,729
Green waste	335,999	335,999	69%	31%	0%	233,099	102,899
Furniture	19,268	18,146	19%	81%	0%	3,534	14,612
WEEE	18,586	17,504	0%	100%	0%	-	17,504
Other	58,271	54,878	30%	40%	29%	16,692	22,103
Incinerator Ash	10,919	10,283	0%	0%	100%	-	-
Soil	0	0	0%	0%	0%	-	-
Aggregate	99,269	93,489	0%	100%	0%	-	93,489
Insulation & Gypsum based materials	0	0	0%	0%	0%	-	-
Hazardous site waste	0	0	0%	0%	0%	-	-
Total	1,075,648	1,034,055				507,075	500,614

The final two columns were then added back to the non-recycled material calculated from the WasteWorks compositions and the total waste generation. The resulting waste compositions for the two modelled waste streams (Kerbside and Bring (inc. HWRC)) are as follows:

Table 13: Household Waste Compositions

Waste Fraction	Kerbside Composition	Bring (inc. HWRC) Composition
Paper and card	21%	11%
Dense plastic	8%	4%
Plastic film	3%	1%
Glass	6%	9%
Ferrous metal	3%	5%
Non-ferrous metal	1%	1%
Textiles	3%	4%
Wood	1%	11%
Food waste	25%	2%
Green waste	14%	14%
Furniture	0%	8%
WEEE	1%	6%
Other	13%	10%
Incinerator Ash	0%	0%
Soil	0%	0%
Aggregate	2%	14%
Insulation & Gypsum based materials	0%	0%
Hazardous site waste	0%	0%
Total	100.00%	100.00%

The current management of household waste was taken from a couple of sources. In terms of the recycling, the material specific data was captured from WasteDataFlow (See final two columns in Table 12). For residual treatment the total figure for incineration in 2008/09 was taken from Waste Data Digest 10, Table 3. The reporting of the Dumfries and Galloway MBT plant appeared to be split across a number of categories (i.e. the outputs of the process were reported not the total input). Thus the input capacity (60,000 tpa) was added onto the quantity incinerated.

A.6.2 Commercial and Industrial Waste

Data on the generation of commercial and industrial waste in Scotland can be obtained from the Business Waste Surveys and projections made in the Waste Data Digests. The latest survey was carried out in 2009 and the report published in April 2011.[41] The data is reported in calendar years, but the model was set up to calculate based upon the financial year. Thus some adjustment from one to the other was required. The calculation used is as follows:

FYn/n+1 = 0.75 x CYn + (CYn+1 x 0.25)

where FY = Financial Year and CY = Calendar Year.

The calendar year and financial year figures are shown in the tables below. Note to calculate 2009/10 the generation of waste in 2010 was assumed to be the same as in 2009.

Table 14: C&I Waste Generation – Calendar Years, tonnes

Calendar Year	2008	2009	2010
Tonnes Industrial	2,189,993	1,818,343	1,805,614
Tonnes Commercial	5,750,161	4,747,214	4,747,214

[41] WRc plc (2011) Statistical Analysis of Scotland Business Waste Survey Data for 2009, Final Report for SEPA, March 2011, see http://www.sepa.org.uk/waste/waste_data/commercial__industrial_waste/business_waste_surveys.aspx

Table 15: C&I Waste Generation – Financial Years, tonnes

Financial Year	2008/09	2009/10
Tonnes Industrial	2,097,080	1,815,161
Tonnes Commercial	5,499,424	4,747,214

When it comes to the composition of commercial and industrial waste, especially down to useable categories (i.e. not large proportions of 'mixed waste' or the like), there is very limited data available. One of the more detailed studies was carried out in Wales in 2007.[42] However, this still had a large proportion of mixed waste landfilled. Thus missing the inclusion of various key materials in the total composition. A further study was carried out by SLR, which sought to measure the composition of mixed residual C&I waste.[43] This composition was applied to the quantity of 'mixed waste' landfilled reported in the Welsh survey in order to disaggregate it. The disaggregated tonnages were then added back to the waste reused, recycled and recovered to calculate the total composition of C&I waste.

Table 17 shows the compositions that were calculated in the manner described above. In terms of the management of C&I wastes, reuse, recycling and recovery rates, on a material specific basis, were taken from the Wales Survey (Table 18). The main residual treatment for C&I waste was assumed to be incineration. Management rates were set so that the resulting tonnage of waste treated, was equivalent to the known business waste treatment capacity in Scotland (total Scottish capacity less household treatment). Incineration rates for the C&I sectors were thus set at around 4 to 5%.

---

[42] Urban Mines (2007) Industrial and Commercial Waste Survey in Wales, Report for WAG

[43] SLR (2007) Determination of the Biodegradability of Mixed Industrial and Commercial Waste Landfilled in Wales and EA (2007) Industrial and Commercial Waste Arisings in Wales

Table 16: Composition of Mixed C&I Waste Landfilled in Wales (2007)

Waste Fraction	Industrial	Commercial
Paper and card	35%	36%
Dense plastic	10%	8%
Plastic film	8%	7%
Glass	1%	5%
Ferrous metal	5%	3%
Non-ferrous metal	1%	1%
Textiles	1%	1%
Wood	5%	5%
Food waste	11%	20%
Green waste	0%	1%
Furniture	0%	0%
WEEE	0%	1%
Other	23%	13%
Combustion Residues	0%	0%
Soil	0%	0%
Aggregate	0%	0%
Insulation & Gypsum based materials	0%	0%
Hazardous site waste	0%	0%

Source: SLR (2007) Determination of the Biodegradability of Mixed Industrial and Commercial Waste Landfilled in Wales and EA (2007) Industrial and Commercial Waste Arisings in Wales

Table 17: Calculated Compositions for Commercial and Industrial Waste Streams

Waste Fraction	Industrial	Commercial
Paper and card	10.9%	41.1%
Dense plastic	3.7%	6.5%
Plastic film	1.2%	4.1%
Glass	1.8%	6.5%
Ferrous metal	10.5%	4.5%
Non-ferrous metal	4.3%	1.7%
Textiles	0.3%	0.9%
Wood	6.1%	4.3%
Food waste	15.0%	12.0%
Green waste	4.8%	1.8%
Furniture	0.0%	0.2%
WEEE	0.2%	1.2%
Other	16.3%	15.1%
Combustion Residues	20.4%	0.0%
Soil	0.7%	0.0%
Aggregate	3.7%	0.0%
Insulation & Gypsum based materials	0.0%	0.0%
Hazardous site waste	0.0%	0.0%

Table 18: Reuse, Recycling and Recovery Rates for Commercial and Industrial Waste Streams

Waste Fraction	Industrial	Commercial
Paper and card	49%	49%
Dense plastic	58%	32%
Plastic film	0%	0%
Glass	92%	55%
Ferrous metal	90%	62%
Non-ferrous metal	93%	70%
Textiles	28%	22%
Wood	83%	31%
Food waste	88%	4%
Green waste	97%	48%
Furniture	0%	0%
WEEE	27%	52%
Other	53%	33%
Combustion Residues	43%	0%
Soil	0%	0%
Aggregate	0%	0%
Insulation & Gypsum based materials	0%	0%
Hazardous site waste	0%	0%
Total	**63%**	**38%**

A.6.3 Construction and Demolition Waste

Data on the generation of construction and demolition wastes was taken from SEPA data supplied to Eunomia. Waste arisings are estimated by SEPA from operator data returns. Due to legislative requirements of the Revised Waste Framework Directive, C&D recycling rates must be calculated without the inclusion of hazardous waste or naturally occurring wastes. The relevant article describes the position as such:

"by 2020, the preparing for re-use, recycling and other material recovery, including backfilling operations using waste to substitute other materials, of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the list of waste shall be increased to a minimum of 70% by weight"

Therefore, the total waste generated must also be calculated accordingly. When all wastes are considered, the total generation in 2008 was 8,633,219 tonnes, and in-line with the WFD 4,340,576 tonnes.

Again, the composition or management of C&D wastes, on a material specific level, is not well understood. The most detailed national survey was carried out in Wales in 2005/06.[44] This was the study used to calculate the rates, which could be applied to the total generation figures previously discussed. However, the composition estimated in this study had to be adjusted to reflect the removal of hazardous and naturally occurring wastes. This is not a straightforward task as the category 'Aggregate' includes an unknown proportion of naturally occurring material, such as sand and stones (EWC code 17.05.04), but also manufactured aggregates such as concrete, bricks and tarmac. The process to derive the correct total C&D composition was therefore as follows:

1) Adjust categories of waste from Wales survey to match the standard composition;
2) Remove 'soils' (all naturally occurring) and 'Hazardous' wastes from the composition;
3) Factor down the proportion of 'Aggregates' so that the calculated proportion between all wastes and waste less Haz and 17.05.04, was the same as the proportion between the generation figures noted above for Scotland (circa 2:1 or waste less Haz and 17.05.04 is around 50% of the total).

The calculated composition of C&D waste (less Haz and 17.05.04) is shown in Table 19.

One can see that, notwithstanding the exclusion of a large quantity of naturally occurring inert material, there is still a large proportion of dense aggregate type material in the waste stream. Other 'active' wastes are a much less significant proportion of the C&D waste stream.

[44] Environment Agency (accessed 2010) Building the future 2005-06: A survey on the arising and management of construction and demolition waste in Wales 2005-06

Table 19: Calculated Composition and Reuse / Recycling Rates for Construction and Demolition Waste Stream

Waste Fraction	Composition	Reuse and Recycling Rate
Paper and card	1%	20%
Dense plastic	2%	18%
Plastic film	0%	0%
Glass	0%	43%
Ferrous metal	2%	86%
Non-ferrous metal	1%	86%
Textiles	0%	0%
Wood	7%	72%
Food waste	0%	0%
Green waste	2%	46%
Furniture	0%	0%
WEEE	0%	18%
Other	3%	14%
Combustion Residues	0%	0%
Soil	0%	0%
Aggregate	79%	98%
Insulation & Gypsum based materials	3%	18%
Hazardous site waste	0%	0%

The main management routes in the C&D sector are reuse (on- or off-site) recycling, treatment, incineration and landfill. However, the use of treatment and incineration is small (less than 1%). Thus most of the non-landfill management is reuse and recycling. Reuse and recycling rates were taken from the Welsh study and factored down so that the calculated landfill quantities were benchmarked against the quantities landfilled reported by site operators under EWC Chapter 17 (Construction and demolition wastes). The final reuse and recycling rates are also shown in Table 19.

A.6.4 Quantities Landfilled

From the data and analysis undertaken for each waste stream it is possible, by material, calculate the total quantity landfilled. This is simply performed by multiplying the total waste generation by the total composition, subtracting the amount reused, recycled and recovered – to calculate the composition of residual waste – and subtracting the proportion of non-landfill treatment (such as incineration). To estimate the quantities of inert and active waste landfilled, each fraction, in the standard composition, was assigned to either type.

Table 20: Apportionment of Waste Types to Landfill Categories

Waste Fraction	Landfill
Aggregate	Inert
Dense plastic	Active
Ferrous metal	Active
Food waste	Active
Furniture	Active
Glass	Active
Green waste	Active
Hazardous site waste	Hazardous
Incinerator Ash	Inert
Insulation & Gypsum based materials	Inert
Non-ferrous metal	Active
Other	Active
Paper and card	Active
Plastic film	Active
Soil	Inert
Textiles	Active
WEEE	Active
Wood	Active

A.6.5 Maximum Recycling Rates under ZWP

These maximum capture rates were based upon high technical potentials of capture of a range of recyclables. The analysis was undertaken as part of a CBA of landfill bans in the UK.[45]

Table 21: Maximum Household Recycling Rates under ZWP

Weight Based Recycling Rate	Recycling Rate under ZWP
Paper and card	85%
Dense plastic	45%
Plastic film	15%
Glass	90%
Ferrous metal	75%
Non-ferrous metal	75%
Textiles	60%
Food waste	55%

[45] Eunomia (2010) *Feasibility of Landfill Bans Research*, Final Report for WRAP, March 2010

Table 22: Maximum Commercial Recycling Rates under ZWP

Weight Based Recycling Rate	Recycling Rate under ZWP
Paper and card	92%
Dense plastic	67%
Plastic film	57%
Glass	90%
Ferrous metal	90%
Non-ferrous metal	90%
Textiles	81%
Food waste	70%

Table 23: Maximum Industrial Recycling Rates under ZWP

Weight Based Recycling Rate	Recycling Rate under ZWP
Paper and card	90%
Dense plastic	80%
Plastic film	50%
Glass	95%
Ferrous metal	92%
Non-ferrous metal	95%
Textiles	80%
Food waste	95%

Table 24: Maximum C&D Recycling Rates under ZWP

Weight Based Recycling Rate	Recycling Rate under ZWP
Paper and card	95%
Dense plastic	75%
Glass	90%
Ferrous metal	90%
Non-ferrous metal	95%

A.6.6 Baseline Projections

The following tables present the headline baseline mass-flows under both baselines. These are as calculated in the Scottish Landfill Model provided to the Scottish Government.

Table 25: Baseline Mass-flows – Household Waste, thousand tonnes

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
BaU	**Total Generated**	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906
	Total Recycling / Reuse / Recovery	1,163	1,240	1,317	1,395	1,472	1,472	1,472	1,472	1,472	1,472	1,472	1,472	1,472	1,472	1,472	1,472
	Total Incineration Operational (2010)	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
	Total Incineration Proposed	0	0	0	0	451	451	451	451	451	451	451	451	451	451	451	451
	Total Other Non-Landfill Treatment	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
	Total Landfill	1,628	1,550	1,473	1,396	867	867	867	867	867	867	867	867	867	867	867	867
ZWP	**Total Generated**	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906	2,906
	Total Recycling / Reuse / Recovery	1,163	1,358	1,553	1,748	1,760	1,766	1,772	1,778	1,784	1,790	1,796	1,802	1,808	1,814	1,820	1,826
	Total Incineration Operational (2010)	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
	Total Incineration Proposed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Other Non-Landfill Treatment	60	60	60	60	60	368	676	1,031	1,025	1,019	1,013	1,007	1,001	995	989	983
	Total Landfill	1,628	1,433	1,237	1,042	1,030	717	403	41	41	41	41	41	41	41	41	41

Table 26: Baseline Mass-flows – Commercial Waste, thousand tonnes

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
BaU	**Total Generated**	4,747	4,795	4,891	5,037	5,088	5,088	5,088	5,088	5,088	5,088	5,088	5,088	5,088	5,088	5,088	5,088
	Total Recycling / Reuse / Recovery	2,141	2,270	2,425	2,610	2,750	2,769	2,788	2,807	2,826	2,845	2,864	2,883	2,902	2,920	2,939	2,958
	Total Incineration Operational (2010)	182	184	188	193	195	195	195	195	195	195	195	195	195	195	195	195
	Total Incineration Proposed	0	0	0	0	159	159	159	159	159	159	159	159	159	159	159	159
	Total Other Non-Landfill Treatment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Landfill	2,424	2,341	2,278	2,234	1,983	1,964	1,945	1,926	1,907	1,888	1,869	1,850	1,832	1,813	1,794	1,775
ZWP	**Total Generated**	4,747	4,795	4,891	5,037	5,088	5,088	5,088	5,088	5,088	5,088	5,088	5,088	5,088	5,088	5,088	5,088
	Total Recycling / Reuse / Recovery	2,141	2,673	3,246	3,880	3,952	3,952	3,952	3,952	3,952	3,952	3,952	3,952	3,952	3,952	3,952	3,952
	Total Incineration Operational (2010)	182	184	188	193	195	195	195	195	195	195	195	195	195	195	195	195
	Total Incineration Proposed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Other Non-Landfill Treatment	0	0	0	0	159	335	510	686	686	686	686	686	686	686	686	686
	Total Landfill	2,424	1,938	1,457	964	781	605	430	254	254	254	254	254	254	254	254	254

Table 27: Baseline Mass-flows – Industrial Waste, thousand tonnes

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
BaU	**Total Generated**	1,815	1,833	1,870	1,926	1,965	1,951	1,937	1,924	1,910	1,897	1,884	1,870	1,857	1,844	1,831	1,819
	Total Recycling / Reuse / Recovery	1,172	1,191	1,223	1,269	1,303	1,294	1,284	1,275	1,267	1,258	1,249	1,240	1,231	1,223	1,214	1,206
	Total Incineration Operational (2010)	90	91	93	96	98	97	96	96	95	94	94	93	92	92	91	90
	Total Incineration Proposed	0	0	0	0	60	60	59	59	59	58	58	57	57	57	56	56
	Total Other Non-Landfill Treatment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Landfill	553	551	554	562	504	501	497	494	490	487	483	480	477	473	470	467
ZWP	**Total Generated**	1,815	1,833	1,870	1,926	1,965	1,951	1,937	1,924	1,910	1,897	1,884	1,870	1,857	1,844	1,831	1,819
	Total Recycling / Reuse / Recovery	1,172	1,226	1,294	1,378	1,408	1,398	1,389	1,379	1,369	1,360	1,350	1,341	1,331	1,322	1,313	1,304
	Total Incineration Operational (2010)	90	91	93	96	98	97	96	96	95	94	94	93	92	92	91	90
	Total Incineration Proposed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Other Non-Landfill Treatment	0	0	0	0	60	159	257	353	350	348	346	343	341	338	336	334
	Total Landfill	553	516	483	452	398	296	195	96	96	95	94	94	93	92	92	91

Table 28: Baseline Mass-flows – C&D Waste (excluding Haz and 17.05.04), thousand tonnes

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
BaU	**Total Generated**	4,256	4,227	4,197	4,168	4,138	4,109	4,081	4,052	4,024	3,996	3,968	3,940	3,912	3,885	3,858	3,831
	Total Recycling / Reuse / Recovery	3,773	3,763	3,752	3,742	3,732	3,705	3,679	3,654	3,628	3,603	3,578	3,552	3,528	3,503	3,478	3,454
	Total Incineration Operational (2010)	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	6
	Total Incineration Proposed	0	0	0	0	31	31	31	31	31	30	30	30	30	30	29	29
	Total Other Non-Landfill Treatment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Landfill	476	457	437	419	368	366	363	361	358	356	353	351	348	346	343	341
ZWP	**Total Generated**	4,256	4,227	4,197	4,168	4,138	4,109	4,081	4,052	4,024	3,996	3,968	3,940	3,912	3,885	3,858	3,831
	Total Recycling / Reuse / Recovery	3,773	3,791	3,808	3,824	3,811	3,785	3,758	3,732	3,706	3,680	3,654	3,628	3,603	3,578	3,553	3,528
	Total Incineration Operational (2010)	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	6
	Total Incineration Proposed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Other Non-Landfill Treatment	0	0	0	0	31	58	85	111	110	109	108	108	107	106	105	105
	Total Landfill	476	429	382	336	289	260	231	203	201	200	198	197	196	194	193	192

Table 29: Baseline Mass-flows – Total Waste, thousand tonnes

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
BaU	**Total Generated**	13,724	13,760	13,863	14,037	14,096	14,054	14,011	13,969	13,927	13,886	13,844	13,803	13,763	13,722	13,682	13,642
	Total Recycling / Reuse / Recovery	8,248	8,464	8,718	9,016	9,256	9,240	9,224	9,208	9,193	9,177	9,162	9,147	9,133	9,118	9,104	9,090
	Total Incineration Operational (2010)	335	337	343	351	355	354	353	353	352	351	351	350	349	349	348	347
	Total Incineration Proposed	0	0	0	0	702	702	701	700	700	699	698	698	697	697	696	695
	Total Other Non-Landfill Treatment	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
	Total Landfill	5,081	4,899	4,743	4,610	3,723	3,698	3,673	3,648	3,623	3,598	3,573	3,548	3,524	3,499	3,474	3,450
ZWP	**Total Generated**	13,724	13,760	13,863	14,037	14,096	14,054	14,011	13,969	13,927	13,886	13,844	13,803	13,763	13,722	13,682	13,642
	Total Recycling / Reuse / Recovery	8,248	9,047	9,901	10,830	10,932	10,902	10,871	10,841	10,811	10,782	10,753	10,724	10,695	10,666	10,638	10,610
	Total Incineration Operational (2010)	335	337	343	351	355	354	353	353	352	351	351	350	349	349	348	347
	Total Incineration Proposed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Other Non-Landfill Treatment	60	60	60	60	311	920	1,527	2,181	2,172	2,162	2,153	2,144	2,135	2,126	2,117	2,108
	Total Landfill	5,081	4,316	3,559	2,796	2,498	1,878	1,259	594	592	590	588	586	584	582	580	578

A.7.0 Description of 'Local Authority' Collection Cost Model

A.7.1 Overview

Eunomia Research & Consulting's Proprietary Waste Collection Cost Model, Hermes, is a sophisticated spreadsheet based tool that allows a wide range of variables to be accounted for, and which enables the optimisation of scenarios to accurately reflect local circumstances.

The recycling performance of each collection system scenario is built up by specifying a range of performance parameters for each component of the system. Performance parameters include weight and volume of material collected by current systems, residual composition, the materials targeted by each collection service, the number of households of each type (e.g. detached, semi-detached, terrace etc) that the service is available to, the participation rate of those households and the recognition rate achieved from those households for the materials targeted.

Costs are built up automatically by the model using unit cost data extracted from the database. The model calculates the numbers of vehicles, containers, and crew required and multiplies these by their unit costs. Disposal costs, net cost/income from material sales, are also calculated and included in the costings. Finally the model adds overheads for management and administration, depot costs, and insurances and financing. Although capital requirements are shown in the model, annual costs are based on the amortised cost of capital using depreciation periods and interest rates entered by the user.

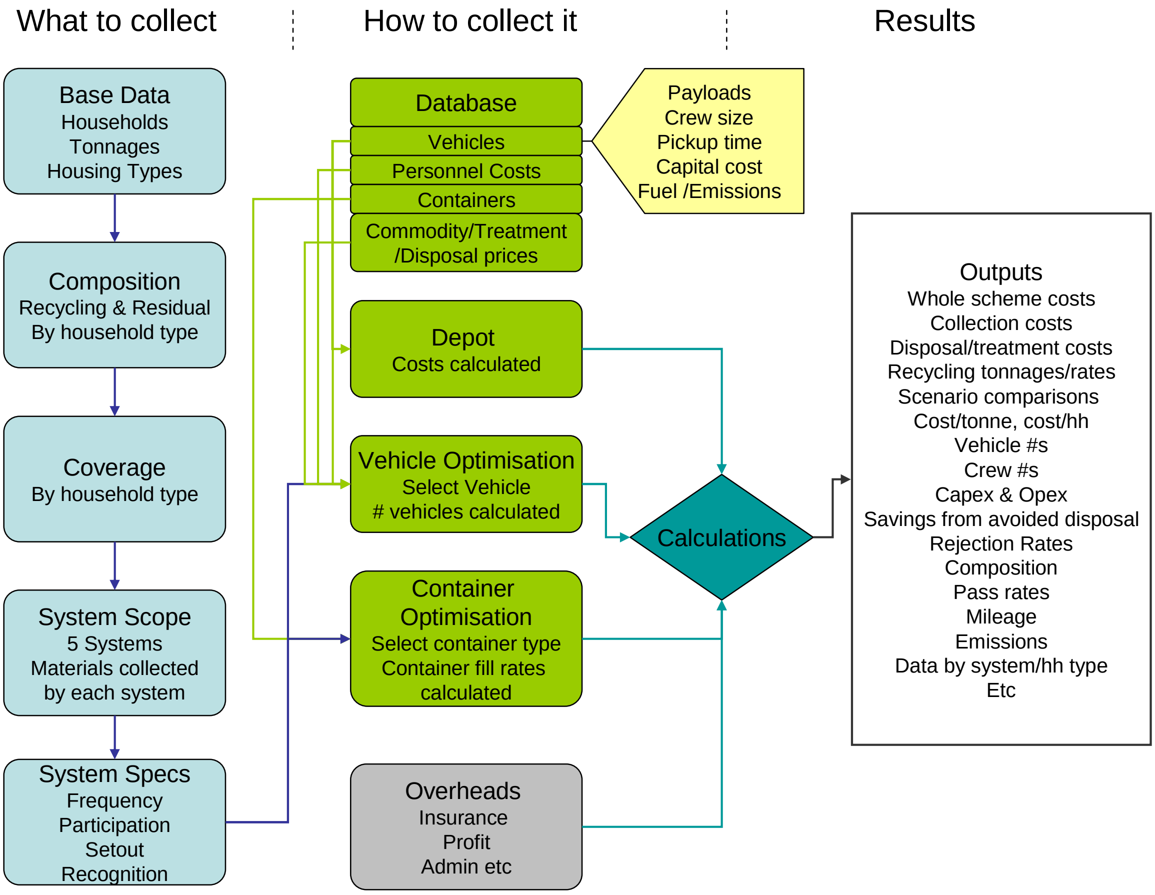
A.7.2 Model Detail

Figure 9 presents a simplified schematic of how the Eunomia Local Authority model calculates collection cost figures. This representation of the model divides the modelling into 3 key phases:

1) Determining what material is to be collected through what systems (blue boxes);
2) Determining the types of physical systems that will be used to undertake the collection (green boxes); and
3) Calculations and outputs.

A brief description of each of the modules in these three phases follows. Where the values used in the modelling are ubiquitous across all scenarios these are presented below.

Figure 9: Eunomia Collection Cost Model Schematic



A.7.3 Phase 1: Defining what to collect

A.7.3.1 Base Data

In this module key data related to the characteristics of the collection area to be modelled is entered. This includes the number of households to be collected from, the types of households (e.g. terraced, semi detached etc) and number of households of each type, and the total tonnages of material that will be handled by the collection system being modelled. This includes all collected residual material as well as the tonnages of material recycled and composted in the baseline system.

A.7.3.2 Composition

The proportion of each type of material that is in the waste stream and that can potentially be separately collected for recycling or composting is crucial data, as it determines the ultimate potential performance of systems being modelled. This module allows tailored composition information for up to 20 different material streams to be entered. In addition adjustment can be made for variations in composition by household type – for example flats will produce negligible quantities of garden waste while detached households will produce above average quantities. Composition data is then used in this module to determine quantities of each material available from each type of household.

A.7.3.3 Coverage

The proportion of each type of household covered by each element of the collection system (e.g. dry recycling, garden waste, residual waste) is then specified. This module then calculates the number of households that need to be serviced by each element of the collection system. Within this module travel distances for collection vehicles are also calculated based on the numbers of each type of household.

A.7.3.4 System Scope

Up to five different types of collection system (e.g. dry recycling, food waste, garden waste, residual waste etc) can be modelled simultaneously as an integrated system, with variations possible for each housing type (for example the dry recycling system for flats may collect different materials than for detached households), giving a total of 30 possible system combinations. In this module the types of material collected by each system combination is specified. This module then calculates the potential of each type of material that can be separately collected for recycling or composting.

A.7.3.5 System Specification

In this module the user specifies the frequency of each collection system, the participation rate of households (how many household use the service), the set-out rate (the proportion of household putting out material for collection each collection day), and the recognition rate for each type of material (how much of the recyclable material in each household actually gets put out for collection). This is then used to calculate how much material will actually be required to be collected by each of the separate systems (and hence the performance in terms of recycling rates etc, of each of the systems). These are key calculations and the assumptions behind them are based on a set of rules based on the performance of known system configurations.

Once this data has been calculated it is then possible to determine the best way to collect the available material.

A.7.4 Phase 2: Determining Collection Systems

A.7.4.1 Database

The database contains equipment specifications and cost and performance information, which is used in the model to calculate costs. Four key areas of information are contained in the model:

Vehicles & Crew

The database contains information on actual vehicles, their typical staffing configurations and their performance parameters including, payloads, capital costs, fuel use, emissions, running costs (e.g. maintenance, Road User Charges, insurance etc) and pickup times for each household. This information is used in the 'Vehicle Optimisation' module to calculate the numbers of vehicles required and the cost of those vehicles. The capital cost of vehicles is converted to annualised costs based on a vehicle replacement period, and finance costs.

Personnel Costs

Personnel costs for each grade of operative including supervisors and management are specified here. Once crew numbers and supervisor ratios etc are determined this information is used to calculate personnel costs of each system and total personnel costs.

Containers

A database of container types is maintained with key performance data including capacity, lifespan/replacement rate, and capital cost. This data is based on manufacturers' specifications and market prices for bulk purchasing.

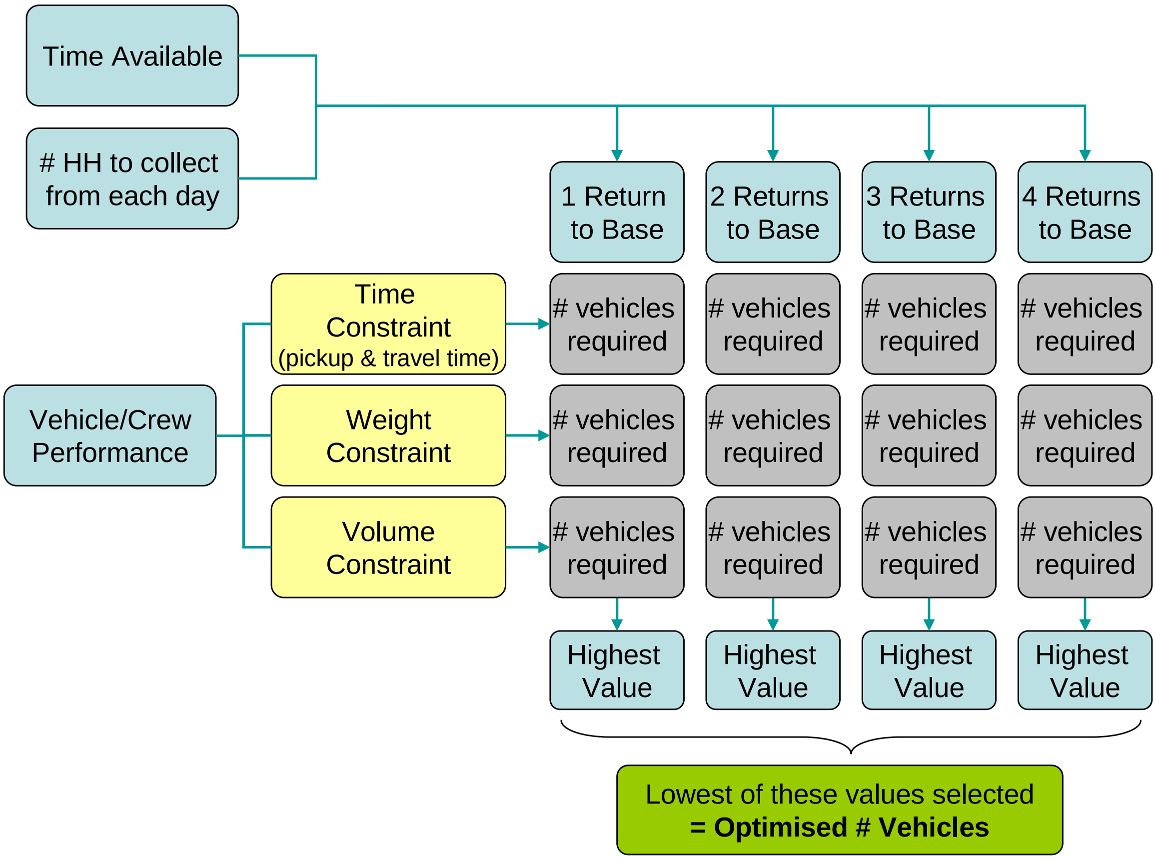
Commodity/Treatment/Disposal prices

The costs or income from collection of each material type is contained in the database. Costs can be updated to reflect actual contractual situations in a given authority. Costs are calculated as net costs after bulking and transport. Once the total quantity of each type of material separately collected is known this can be multiplied by the cost of processing that material (e.g. in the case of organic waste) or income from sale of that material (e.g. for dry recyclable commodities).

A.7.4.2 Vehicle Optimisation

This module is the heart of the collection cost model as it is here that the numbers of vehicles & crew required are calculated, which are the most significant elements of the total system cost. For the purposes of illustration Figure 10 below shows the basis of the how vehicle numbers are calculated.

Figure 10: Vehicle Optimisation Schematic



There are 3 basic parameters that are used to determine the numbers of vehicles required: the time that is available to undertake collections, the number of households that need to be collected from, and the performance characteristics of the vehicles and crew.

1) The time available for actual collection is influenced by the number of times a vehicle must return to base to empty its load – the more times it has to return to base the less time it has available to be picking up from households.

2) Similarly the vehicle/crew performance is a function of how quickly they can pick up from each household (and travel time between households on a round), how quickly the vehicle reaches its weight limit, and how quickly it fills up in terms of volume. These factors will be influenced by the types of materials that are being collected.

3) For each vehicle configuration the model calculated the number of vehicles required if they were to return to base only once. It does this for the time constraint factor, the weight constraint factor and the volume constraint factor. The highest of these values (i.e. the most trucks) represents the constraining factor for the 1 return to base scenario. This is repeated for 2,3 & 4 returns to base yielding 4 values (i.e. numbers of trucks). The lowest of these 4 values is the optimum number of vehicles needed to collect the specified amount of material from the number of households in the time available.

The Vehicle Optimisation module calculates fractions of vehicles, as this captures the incremental changes between different types of systems. In practice fractions of vehicles would obviously not be used but this would be accounted for by using smaller vehicles and/or building in spare capacity. In addition it should be noted that the modelling is based average loads rather than peak loads. A slight redundancy factor is built into the model therefore to account for the effect of peak loads.

A.7.4.3 Container Optimisation

The container optimisation module calculates the number of containers required and their costs based on coverage of the systems and lifespan/replacement rates. It also provides a check on container volumes and fill ratios to ensure that sufficient containment capacity is being provided to householders.

A.7.4.4 Depot

A 'depot builder' is included where the configuration of the relevant depot or transfer stations can be specified. This is generally a fixed cost (i.e. it will not necessarily vary between systems). The depot builder takes account of personnel, maintenance, site based vehicles and machinery, as well as any site works and rentals that may be applicable.

A.7.4.5 Overheads

Overheads such as insurance costs, profit levels, management and administration, finance costs etc can be specified. In the local authority modelling the following values were specified:

- Overheads for all systems combined were set at approximately £350,000 per annum;
- Profit margins were set at 5% of contract costs.

A.7.4.6 Outputs

The model is extremely flexible in the outputs that are possible to be generated. Key output parameters include:

- Whole scheme costs
- Collection costs
- Disposal/treatment costs
- Recycling tonnages/rates
- Scenario comparisons
- Cost/tonne, cost/hh
- Vehicle numbers
- Crew numbers
- Capex & Opex

- Savings from avoided disposal
- Rejection Rates
- Composition
- Pass rates
- Mileage
- Emissions
- Data by system/hh type

A.8.0 Landfill Tax in Catalonia

Catalonia is one of three autonomous regions in Spain and as such still defines its own laws and regulations under EU Directives. The region comprised of 944 municipalities and has a population of approximately 7.5 million.

Efforts to promote source separation of biowastes go back to 1993 with the Catalan Parliament voting in Law 6/93. This law was updated in 2003 with the publication of Law 15/2003 on regulating wastes, which enabled household and industrial waste to be managed independently and more effectively. Law 16/2003 was published at the same time and covered the financing of waste treatment infrastructure and provided details on a landfill tax system. Landfill tax was set to take effect from 1st January 2004 and was originally set at €10 per tonne of municipal solid waste sent to landfill (to be paid in addition to gate fees).[46] In 2008 the landfill tax was expanded to include a tax on incineration (€5) and the landfilling of construction and demolition wastes. Since their implementation the rates have remained unchanged.

The definition of municipal solid waste in Catalan is very broad. According to the Legislative Decree 1/2009 municipal solid waste includes waste arisings from households, shops, offices, and municipal services (e.g. wastes from cleaning public areas). Animal carcases, furniture and construction wastes from small operations are also considered to be municipal waste as well as industrial waste arisings with similar composition.

The funds generated from the landfill tax are transferred into an environmental fund (Fons de Gestió de Residus) which is used to finance waste diversion activities (e.g. separate waste collections, recycling, composting). This fund is managed by the Waste Agency of Catalonia (Agència de Residus de Catalunya) who receive the taxes from the local municipalities and industries producing waste which is similar to municipal solid waste. With approximately 3 million tonnes of waste being landfilled annually in 2008 this gave rise to an annual fund of approximately €30 million. With the subsequent inclusion of the incinerator tax at the start of 2009 the fund remains largely unchanged despite reduced landfilling. In 2011 the fund is expected to generate €27.4 million from the disposal of approximately 2,400,000 tonnes of waste and the incineration of a further 680,000 tonnes.[47] At least 50% of the funds

---

[46] ECN (2003) *Situation of the Source Separated Collection of Biowaste in Catalunya. A Balance of one decade (1993 – 2003)*, a paper presented at the Source Separation Workshop 2003, 15th /16th December 2003, http://mie.esab.upc.es/ms/informacio/residus_urbans/Situacio%20recollida%20selectiva%20catalunya.pdf.

[47] Agnuència de Residus de Catalunya (2010) *Revisió de Retorn Del Cánon Pel 2011*, published 25th October 2010, accessed on 7th February 2011, www20.gencat.cat/docs/arc/Home/Ambits%20dactuacio/Tipus%20de%20residu/Residus%20municipals/Canons%20sobre%20la%20disposicio%20del%20rebuig%20dels%20residus%20municipals/Guies%20i%20balancos/canon_prev2011.pdf.

have to go to improving the separation and treatment of organic wastes, while the remainder is used for separate collection infrastructure, recovery, pre-treatment and educational activities.[48] In this way the tax system is completely revenue neutral: all taxes are refunded to promote recycling activities within the region and are adjusted annually to account for changes in landfilling, incineration and recycling rates (approximately 4% of revenues are used to cover administrative costs).

The landfill tax in Catalonia is levied on all municipal waste being sent to public or private landfills in Catalonia. The tax is paid by the local authorities that operate, or contract out the operation of the municipal waste management service and the municipal waste producers. The tax is paid when the waste holder delivers the waste to the landfill operator or incinerator plant.

At present the landfill tax rate remains set at €10 (£8.75) per tonne of waste sent to landfill for municipalities that operate separate biowaste collection services and €20 (£17.50) per tonne for those that fail to do so (at present only two municipalities pay these higher levies). (According to the Confederation of European Waste-to-Energy Plants (CEWEP) the average net fee for landfilling in Catalonia was €40 in the autumn of 2010[49]). The same logic applies to municipalities which incinerate waste: €5 per tonne incinerated is charged if a separate biowaste collection service is offered and €15 per tonne if not.

The tax refund rates are adjusted annually by the Catalan Waste Agency. Municipalities receive refunds for diverting biowaste from landfill, for pre-treating refuse destined for landfill and for delivering source separated materials to recycling facilities. An example of the annual changes in the tax can be observed in

---

[48] EC (2008) Organisation of Awareness-raising Events Concerning the Application and Enforcement of Community Legislation on Shipments of Waste and on Landfills, Report Extract: Spain, a report by BiRPO for the European Commission, November 2008, www.bipro.de/waste-events/doc/events08/Report%20Extract%20Landfill%20ES.pdf.

[49] CEWEP (2010) *Landfill Taxes and Bans*, reported by the Confederation of European Waste-to-Energy Plants, September 2010, www.cewep.com/storage/med/media/data/taxes/375_CEWEP_-_Landfill_Taxes_and_Bans_7September2010_web.pdf?fCMS=6c2ef3f2cb6c445ea07daad07f073613.

Table 30, which shows the refund rates for 2008, 2010 and 2011.[50]

[50] Agencia de Residus de Catalunya (Catalan Waste Agency) (2010) *Documents Aprovats per la Junta de Govern per als Residus Municipals*, accessed on7th February 2011, www20.gencat.cat/portal/site/arc/menuitem.60fb2478680e61fd624a1d25b0c0e1a0/?vgnextoid=1bb661b0d62b6210VgnVCM1000008d0c1e0aRCRDandvgnextchannel=1bb661b0d62b6210VgnVCM1000008d0c1e0aRCRDandvgnextfmt=default.

Table 30: Refund Rates (€ Per Tonne) Used as Part of Catalonia's Landfill Tax System

Activities receiving refunds	2008	2010	2011
1. Biowaste treatment and collection	33.50	33.50	33.50
2. Treatments to reduce the quantity or improve the quality of refuse destined for landfill	5	2.50	2.50
3. Treatments to reduce the quantity or improve the quality of refuse destined for incineration	-	1.25	1.25
4. Biowaste separate collection[1]	12	8.50	8.60
5. Paper/cardboard separate collection	21	3.80	-
6. Active recycling centre in the municipality			
6.1 Per inhabitant[2]	0.32	-	-
6.2 Per tonne received by recycling centre:			
Wood	12	-	-
Flat glass	12	-	-
Batteries	160	-	-
Vegetable oil	80	-	-
7. Delivery of special wastes to recycling centers[3]	-	500	500

Notes: 1. Quantities are considered net of impurities, with the refund rate being dependent on the level of impurities in the collected biowaste; 2. A correction factor is applied in municipalities which have high seasonal fluctuations in population; 3. Price paid for special waste collection and delivery, up to 0.38kg per inhabitant.

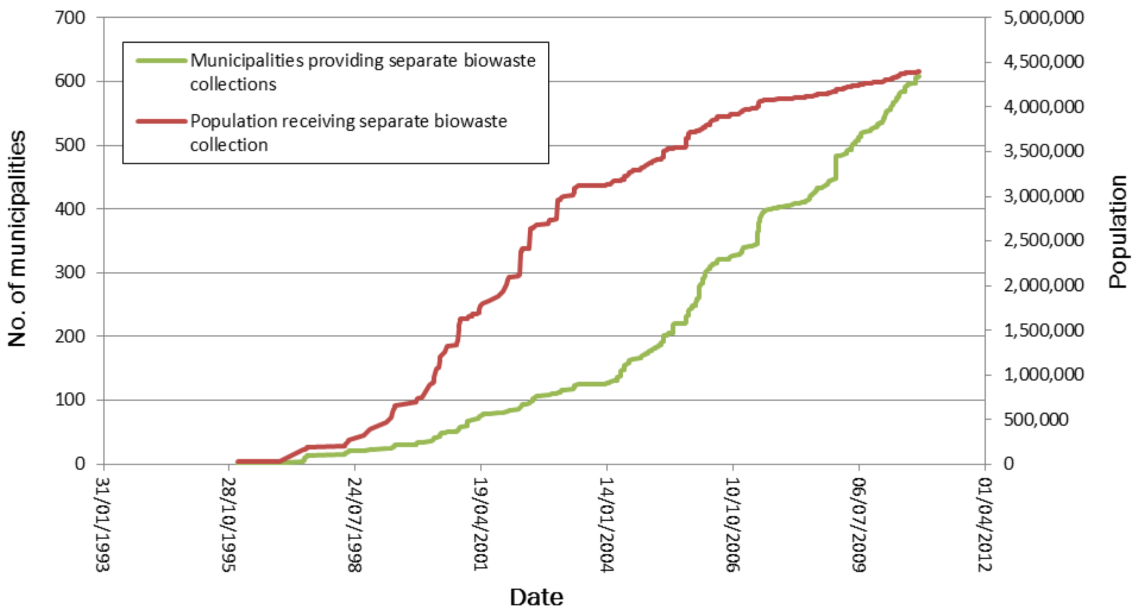
Source: Catalan Waste Agency (2010)

All refund rates are revised annually to account for changes in the amount of revenue generated from the landfill tax as waste sent to landfill decreases and recycling increases. The rates for Activities 4, 5 and 6.1 in

Table 30 are adjusted according to the size of the municipality by applying a correction factor: 1 for urban municipalities (population > 50,000); 1.28 for semi-urban municipalities (5,000 to 50,000 inhabitants); and 1.5 for rural municipalities (<5,000 inhabitants). A correction factor is also applied to the purity of organic waste collected. This value ranges from 2 for biowaste with less than 5% impurities to zero for waste with more than 25% contamination (a factor of 1 is applied for biowaste with 15% to 20% impurities).

The Catalan Municipal Waste Management Programme (PROGREMIC) obligates municipalities with more than 5,000 inhabitants to provide separate collection facilities for biodegradable municipal waste. The European Topic Centre on Resource and Waste Management (ETCRWM) report that by the end of 2003 a total of 144 municipalities had introduced separate biodegradable municipal waste collection systems, covering approximately 2.2 million inhabitants. At this point 15 composting plants had been developed and one facility for anaerobic digestion, which together processed some 150,336 tonnes of waste.[51] By October 2010 a total of 609 municipalities were providing a food waste collection service to a total population of 4.4 million people (Figure 11).

Figure 11: Increase in the Number of Municipalities Providing Separate Biowaste Collection Services Since 1996 and the Cumulative Population Receiving this Service



Source: Personal communication with Ignasi Puig, Catalan Waste Agency, on 22nd February 2011.

[51] ETCRWM (2006) *Country Fact Sheet: Spain*, report by the European Topic Centre on Resource and Waste Management, September 2006, http://eea.eionet.europa.eu/Public/irc/eionet-circle/etc_waste/library?l=/country_fact_sheets/spainpdf/_EN_1.0_anda=d.

Early targets for the collection of biodegradable municipal waste were set at 40% by the end of 2003 and 55% three years later.[52] These targets were not achieved and thus in 2007 the 55% target was extended to 2012.

There are no impact studies at present which have assessed the full effects and impact of the waste taxes in Catalonia; however, waste statistics for the region suggest that separate collection of materials has greatly improved. The clear focus on organic wastes has had a positive impact and it has been reported that the collection of separated biowaste increased by 7.9% between 2008 and 2009 alone (Table 31). Collectively separate collection increased by 7.1% between 2008 and 2009, while refuse sent for landfilling decreased by 6.8%.

[52] ETCRWM (2006) *Country Fact Sheet: Spain*, report by the European Topic Centre on Resource and Waste Management, September 2006, http://eea.eionet.europa.eu/Public/irc/eionet-circle/etc_waste/library?l=/country_fact_sheets/spainpdf/_EN_1.0_anda=d.

Table 31: Trends in the Separate Collection of Recyclables in Catalonia

Material	Growth rate for 2008 to 2009 (%)	Quantity collected in 2009 (tonnes)	Long-term trend
Biowastes	7.9	340,670	Separate collection increasing since 2001
Glass	-6.23	191,645	Separate collection increasing since 2001, pleated at in 2007/8
Paper and Cardboard	4.2	427,988	Separate collection increasing since 1995, but has remained more or less constant since 2005
Packaging	10.1	127,624	An upward trend since 1996 has recorded
Source: Catalan Waste Agency Statistics (2010)			

A.9.0 Environmental Impacts from Combustion Processes

Incineration and combustion processes have received widespread attention because of the environmental and health impacts associated with these activities. When raw materials (e.g. coal, biomass) and wastes (e.g. municipal solid waste, clinical, commercial and industrial waste) are burned potentially harmful substances in these materials can be volatilised or remain bound to the ash by-products. The fate of potentially toxic contaminants contained in incinerated primary materials can take three forms:

1) remain as part of the ash;
2) partition off into the volatile phase and be removed by scrubbers/precipitators; or
3) escape into the atmosphere.

The two chief concerns associated with incineration are thus a) the emission of contaminants to the atmosphere, and b) the production of potentially hazardous ash/filter materials. This section will outline the scientific views, relevant to the latter concern, on the following areas:

- The hazardous nature of IBA from municipal incinerators
- The composition of ash (IBA) from municipal waste incinerators
- The chemical composition of Municipal Waste
- Partitioning factors
- The hazardous nature of furnace bottom ash and pulverised fuel ash from power stations and other industrial processes
- The loss of Valuable Precious Metals with Disposal of PFA, FBA and IBA

To provide some context to the discussion, the evidence is followed by an assessment of the quantities of ash materials arising in Scotland, and what level of taxation is appropriate given the evidence presented.

A.9.1 The Hazardous Nature of Bottom Ash

Legally, municipal waste incineration ashes can be classified as being either hazardous or non-hazardous, depending on their chemical composition and ecotoxicity. Hazardous Waste is defined by European Council Directive 91/689/EEC (the Hazardous Waste Directive).[53] Residues from the incineration of municipal solid waste appear under Section 19 01 of the revised European Waste Catalogue as one of the following entries:

[53] Directive 91/689/EEC.

- **Absolute** entries are <u>always</u> considered hazardous and include both solid waste from gas treatment and spent activated carbon from flue-gas treatment.
- **Mirror** wastes, on the other hand, can be classified as <u>either</u> hazardous or non-hazardous.

The UK Technical Guidance WM2 on Hazardous Waste outlines the procedures to be followed with regards to determining the hazardous nature of waste materials.[54] Incinerator Bottom ash and fly ash are defined as '**mirror**' substances and this guidance specifies that the following hazard properties must be assessed for these materials:

- H5 – Harmful
- H6 – Toxic
- H7 – Carcinogenic
- H10 – Toxic for reproduction
- H11 – Mutagenic
- H14 – Ecotoxic

After consultation with the Environment Agency the Environmental Services Association report that the *'hazard property of most concern with respect to IBA is H14 (aquatic toxicity only), due to both the additive nature of the hazard and the very low threshold concentration (0.25% w/w) with respect to "very toxic to aquatic organisms and may cause long term effects in the aquatic environment"'*.[55] It is thus suggested that a sampling protocol to determine the hazardous nature of IBA could be limited to an H14 assessment. However, it is mentioned that *'those operators that have not yet undertaken a reasonable Level 1 IBA characterisation and a full hazard assessment, will need to demonstrate that H14 is the only hazard property of relevance'*.[56] Furthermore, according to Römbke *et al 'the hazard assessment of [IBA] waste according to the H14 criterion of the European Waste List can only be completed by a combination of chemical and biological test methods'*.[57] It is therefore essential that waste incinerators have a rigorous sampling procedure in

---

[54] SEPA, EHA, and EA (2008) Technical Guidance WM2 on Hazardous Waste, second edition report (version 2.2) by the Scottish Environmental Protection Agency, Environment and Heritage Service and the Environment Agency, March 2008, http://publications.environment-agency.gov.uk/pdf/GEHO0603BIRB-e-e.pdf.

[55] ESA (2009) *Sampling and Testing Protocol (with Justification) for the Assessment of Hazardous Status of Incinerator Bottom Ash*, a report by WRc for the Environmental Services Association, August 2009. The EA was contacted, without success, to obtain further details on the progress of the Waste Protocol for IBA.

[56] *Ibid.*

[57] Römbke, J., Moser, T. and Moser, H. (2009) Ecotoxicological Characterisation of 12 Incineration Ashes using 6 Laboratory Tests, *Waste Management*, Vol.29, pp.2475-2482.

place and fully justify their choice of laboratory techniques used to define their ash materials as inert, non-hazardous, or hazardous.

More recently the Environmental Services Association has provided technical guidance on the sampling procedure to be followed in order to determine the hazardous nature of IBA. [58] The material will be classified as hazardous if, in the first year of analysis, seven or more of a total of 24 samples collected over the period (two per month) are found to exceed the H14 hazard threshold. As stated above, it will be necessary to prove that H14 is the only hazardous property that needs to be assessed and there is no sign that industry's testing protocols will improve as a result. At present it would seem that these tests are not being applied rigorously as Veolia has been reported as saying that they estimated that about 40% of their ash would *fail* these tests in the UK if they were to be applied properly.[59] In addition, due to variance in incinerator operating performances and input materials it would seem prudent to treat all ash arisings independently and update hazard ratings each time input materials are changed.

Concerns about the environmental impacts associated with the disposal and management of ash have been widely documented due to its potentially hazardous characteristics. The following points summarise some of the key research:

1) In a detailed review of the disposal, use and treatment of combustion ashes Reijnders identifies numerous studies which have demonstrated the release of both inorganic and organic contaminants from these materials.[60] <u>A range of potentially harmful inorganic compounds have been shown to leach easily from these materials</u>; for example, relatively high concentrations of arsenic, barium, bromine, cadmium, chlorine, cobalt, chromium, copper, fluoride, iron, manganese, molybdenum, nickel, lead, selenium, vanadium and zinc have been mobilised from ash materials in neutral aqueous solutions. According to Reijnders '<u>*it is [also] clear that ashes commonly contain persistent hazardous organic compounds'*</u>. Persistent organic pollutants, as they are also known, include elements such as polycyclic aromatic hydrocarbons, polychlorinated bifenyls, methyl sulphates, polychlorinated dibenzodioxins (PCDDs) and dibenzoflurans (PCDFs).

2) A study on ash derived from the combustion of municipal solid waste in five west European countries (including the UK) showed marked variation between samples and <u>concerns over ecotoxicity were raised in all but one case</u>. Writing in 2002 the authors report that:

---

[58] ESA (2010) *Sampling and Testing Protocol for the Assessment of Hazardous Status of Incinerator Bottom Ash*, a report by WRc for the Environmental Services Association, October 2010, http://www.esauk.org/publications/reports/ESA_IBA_Sampling_and_Testing_Protocol.pdf.

[59] ENDS (2009) *Confusion Over status of Incinerator Bottom Ash*, Environmental Data Services (ENDS), Vol.410, pp.23-24.

[60] Reijnders, L. (2005) Disposal, Uses and Treatments of Combustion Ashes: A Review, *Resources, Conservation and Recycling*, Vol.43, No.3, pp.313-336.

i) *'the bottom ashes resulting from the incineration of MSW are not considered as hazardous wastes [in Europe]. However, as it is demonstrated in this work, the criteria of different European countries point out for the classification of this type of materials as ecotoxic/hazardous. A clarification on this point seems to be necessary and urgent'*.[61]

3) Concerns over ecotoxicity have been raised in a number of biological[62,63], leaching[64,65,66,67] and ring[68,69] experiments. Donatello *et al*, for example, investigated the ecotoxicity of seven UK ash samples from incinerated sewage sludge.[70] They found that two of the materials would have to be classified as hazardous waste under the EU Hazardous Waste Directive and that leaching experiments showed that all of the materials [ashes] tested could '*not be considered as inert'*.

4) A series of ring tests for ecotoxicity methods have been carried out in Europe.[71] These included sampling and testing of highly alkaline (pH 10.5) incinerator

---

[61] Lapa, N., Barbosa, R., Morais, J., Mendes, B., Mehu, J. and Santos Oliveira, J. F. (2002) Ecotoxicological Assessment of Leachates from MSWI Bottom Ashes, *Waste Management*, Vol.22, No.6, *pp.583-593.*

[62] Römbke, J., Moser, T. and Moser, H. (2009) Ecotoxicological Characterisation of 12 Incineration Ashes using 6 Laboratory Tests, *Waste Management*, Vol.29, pp.2475-2482.

[63] Ferrari, B., Radetski, C. M., Vebber, A. and Ferard, J. (1999). Ecotoxicological Assessment of Solid Wastes: A Combined Liquid and Solid Phase Testing Approach Using a Battery of Bioassays and Biomarkers, *Environmental Toxicology and Chemistry*, Vol.18, No.6, pp.1195-1202.

[64] Feng, S., Wang, X., Wei, G., Peng, P., Yang, Y. and Cao, Z. (2007) Leachates of Municipal Solid Waste Incineration Bottom Ash from Macao: Heavy Metal Concentrations and Genotoxicity, *Chemosphere,* Vol.67, pp.1133-1137.

[65] Hu, Y., Bakker, M., Brem, G. and Chen, G. (2011) Controlled Combustion Tests and Bottom Ash Analysis Using Household Waste with Varying Composition, *Waste Management*, Vol.31, No.2, pp.259-266.

[66] Lapa, N., Barbosa, R., Morais, J., Mendes, B., Mehu, J. and Santos Oliveira, J. F. (2002) Ecotoxicological Assessment of Leachates from MSWI Bottom Ashes, *Waste Management*, Vol.22, No.6, pp.583-593.

[67] Ibanex, R., Andres, A., Viguri, J. R., Oritz, I. and Irabien, J. A. (2000) Characterisation and Management of Incinerator Wastes, *Journal of Hazardous Materials*, Vol.79, No.3, pp.215-227.

[68] Becker, R. Donnevert, G. et al. (2007) Biological Test Methods for the Ecotoxicological Characterization of Wastes, November 2007, Umweltbundesamt, Postfach 1406, D-06813 Dessau.

[69] H. Moser (2008) Ecotoxicological Characterization of Waste. German Federal Environment Agency (UBA). Dessau. For full results, see H. Moser and J. Römbke (Eds.) (2009) *Ecotoxicological Characterization of Waste: Results and Experiences of an International Ring Test*, Springer.

[70] Donatello, S., Tyrer, M. and Cheeseman, C. R. (2010) EU Landfill Waste Acceptance Criteria and EU Hazardous Waste Directive Compliance Testing on Incinerated Sewage Sludge Ash, *Waste Management*, Vol.30, pp.63-71.

[71] R. Becker, G. Donnevert, et al. (2007) Biological test methods for the ecotoxicological characterization of wastes 30.11.2007 Umweltbundesamt, Postfach 1406, D-06813 Dessau; H.

bottom ash from a Dutch incinerator. The results of these tests *clearly indicated that the bottom ash was ecotoxic*.

5) Römbke *et al* used six laboratory test methods to assess 12 incineration ashes of varying ages and found a *'clear ecotoxicological hazard potential for some of the MWI ashes'*. Toxicity was not directly related to age and experiments demonstrated further that *'there is no correlation between the biological effects and the analysed chemical compounds of the ash samples'*.[72] This could suggest that extrapolating ecotoxicity from the chemical composition of the ash may not be possible.

6) In another study Ferrari *et al* analysed the ecotoxicity of municipal waste incineration bottom ash in both the leachate and solid phase.[73] Their results clearly demonstrated '*a significant increase in all antioxidant stress enzyme activity levels across all plant tests even at the lowest test concentrations (solid phase and leachate)*'. Feng *et al* found that high concentrations of lead were leached from their bottom ash (BA) samples, which led them to conclude that *'both chemical and biological approaches are necessary to evaluate the environmental impacts and risks of BA before sound decisions can be made on its utilization, treatment or disposal'*.[74]

7) Stiernström *et al* tested seven ash types from various energy plants and recommended that (sub)chronic tests were best suited for assessing the ecotoxicity of ash materials under the H14 criterion. These authors showed that '*high concentrations of non-hazardous components (Ca, K) influenced the toxicity of almost all ash eluates, whereas hazardous components (e.g. Zn, Pb) only influenced the toxicity of the eluates ranked as most hazardous*.'[75] There thus appears to be concerns around not only heavy metals, but also what are assumed to be less innocuous compounds. It is possibly unsurprising that Ca should have been found to cause ecotoxicity due to the fact that it is found in relatively high concentrations in many materials (Table 35).

Moser (2008) Ecotoxicological characterization of waste. German Federal Environment Agency (UBA). Dessau. For full results, see H. Moser and J. Römbke (Eds.) (2009) *Ecotoxicological Characterization of Waste: Results and Experiences of an International Ring Test*, Springer.

[72] Römbke, J., Moser, T. and Moser, H. (2009) Ecotoxicological Characterisation of 12 Incineration Ashes using 6 Laboratory Tests, *Waste Management*, Vol.29, pp.2475-2482.

[73] Ferrari, B., Radetski, C. M., Vebber, A. and Ferard, J. (1999). Ecotoxicological Assessment of Solid Wastes: A Combined Liquid and Solid Phase Testing Approach Using a Battery of Bioassays and Biomarkers, *Environmental Toxicology and Chemistry*, Vol.18, No.6, pp.1195-1202.

[74] Feng, S., Wang, X., Wei, G., Peng, P., Yang, Y. and Cao, Z. (2007) Leachates of Municipal Solid Waste Incineration Bottom Ash from Macao: Heavy Metal Concentrations and Genotoxicity, *Chemosphere,* Vol.67, pp.1133-1137.

[75] Stiernström, S., Hemström, K., Wik, O., Carlsson, G. Bengtsson, B. E. and Breitholtz, M. (2011) An Ecotoxicological approach for Hazard Identification of Energy Ash, *Waste Management*, Vol. 31, No.2, pp.342-352.

In the UK, tests on incinerator bottom ash have effectively led to clear questions over the assumptions that bottom ash could be inert. In 2009 ENDS reported that:

> *'The Environment Agency has admitted it does not "have 100% confidence"' in its classification of incinerator bottom ash (IBA) as non-hazardous waste.*
>
> *Concern over its ecotoxicity dates from October 2005 when the Health and Safety Executive reclassified zinc oxide, a potential compound in ash, as ecotoxic, joining zinc chloride and all lead compounds. At the same time, the Agency drafted new guidelines for testing ecotoxicity. These said ecotoxic compounds could not make up more than 0.25% of wastes. If a laboratory cannot determine what compounds are present or it is unclear from scientific literature, the "worst case" should be assumed'.*

An official from the UK Environment Agency was reported as saying:

> *'"The operators of incinerators [may] have to go to councils and ask where these hazardous components are coming from. Where is the zinc coming from? Where is the lead coming from? Let's get the feedstock right so we don't have this problem"'.*

The reference above to zinc oxide being reclassified is a significant change in the assessment of the ecotoxicity of incinerator bottom ash. Commission Directive 2004/73/EC of 29 April 2004 [76] (*adapting to technical progress for the twenty-ninth time Council Directive 67/548/EEC on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances)* reclassified zinc oxide and zinc chloride as R50/53 – '*very toxic to aquatic organisms, may cause long term effects in the aquatic environment*'.

This classification of zinc oxide and zinc chloride is particularly concerning as the evidence presented in the sections above suggests that the zinc required to produce the oxides and chlorides during combustion is readily present in the waste stream. Thus it is very likely that some elements in IBA are, indeed, very toxic to aquatic organisms and may cause long term effects in the aquatic environment. 'Moreover, other heavy metals, which leach out of the ash and cause ecological damage, are pervasive in the waste stream and also transfer at high rates to the ash, almost ensuring that they will be present in the ash with a mixed municipal waste stream input. Along with the uncertainty that current test methods are being performed 'rigorously', so that some ashes are not being classified as hazardous when they should, there is a large body of evidence stating that; some bottom ashes are ecotoxic; there is a high level of uncertainty in the composition of the ash material; and that there are serious concerns in the UK about the classification of IBA. Thus taking a precautionary approach in the face of uncertainty, it is very likely that there will be some hazardous material in IBA, so all of this material should be classed as

[76] European Commission (2004). "Commission Directive 2004/73/EC of 29 April 2004 adapting to technical progress for the twenty-ninth time Council Directive 67/548/EEC on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances (Text with EEA relevance) " Official Journal of the European Communities, **L 152**(30.4.2004): 1–311.

such unless proven otherwise, and due to the changing nature of the input waste stream reclassification should be constantly assessed.

A.9.2 Composition of Ash from Municipal Waste Incinerators

From the partitioning factors presented above it should be clear that the majority of the metals will partition into the bottom ash and, to a lesser extent, the fly ash. This is confirmed by Zhang who found that the amounts of cadmium, copper, lead and zinc in municipal waste incineration residues were 2.27–4.00 times, 1.90–3.77 times, 2.25–3.51 times, and 2.98–4.06 times greater, respectively, than that in the waste itself when analyzing the flow of heavy metals in MSW incinerators.[77] According to the evaluation, more than 56–75% of Cd, 47–74% of Cu, 56–72% of Pb, and 66–75% of Zn in the MSW were present in the ash, along with other minor hazardous components.

Other authors also state that ash is known to contain numerous organic and inorganic pollutants, the composition of which depends on the inputted material and the type of combustion or incineration processing being undertaken.[78,79] Hu *et al* agree that the chemical composition of municipal solid waste varies widely and strongly influences the composition of the resulting ash.[80] The compositional variance of incinerator ash derived from the incineration of municipal solid waste is shown in Table 32. These data were compiled in the mid-1990s and as such the composition of 'typical' IBA ash may have changed slightly due to improved recycling rates, new technologies, and changing waste streams. Nevertheless, these data provide a good indication of the wide range of concentrations which are found in these materials and the presence of elevated concentrations of numerous potentially toxic substances.

Moreover, poor controls over the content of household waste, which often includes PVC and waste electrical and electronic equipment (WEEE), can often impact negatively upon the quality of the ash produced from the incineration of municipal waste.[81] Thus, importantly, the physical and chemical composition of incinerator ash will vary from site to site, depending on combustion methods and material inputs.

Hu *et al* examined how co-combusting household waste with sewage sludge, shredder fluff, electrical and electronic waste, or PVC affected the chemical

---

[77] H. Zhang, P.-J. He, and L.-M. Shao (2008) Flow Analysis of Heavy Metals in MSW Incinerators for Investigating Contamination of Hazardous Components. *Environ. Sci. Technol.*, 2008

[78] Hjelmar, O. (1996) Disposal Strategies for Municipal Solid Waste Incineration Residues, *Journal of Hazardous Materials*, Vol.47, No.1-3, pp.345–368.

[79] Reijnders, L. (2005) Disposal, Uses and Treatments of Combustion Ashes: A Review, *Resources, Conservation and Recycling*, Vol.43, No.3, pp.313-336.

[80] Hu, Y., Bakker, M., Brem, G. and Chen, G. (2011) Controlled Combustion Tests and Bottom Ash Analysis Using Household Waste with Varying Composition, *Waste Management*, Vol.31, No.2, pp.259-266.

[81] Ibid.

composition of ashes outputs. The authors state that: *'Positive correlations were found between the target elements contents in the bottom ash and their contents in the input materials, and between the increased levels of Cl, Cu and Mo in the input waste due to the special wastes and their leaching in bottom ashes'*.[82] This clearly suggests that incinerator bottom ashes cannot be considered to be homogenous, especially when different materials are being incinerated or co-incinerated – as is widely the case.

---

[82] Hu, Y., Bakker, M., Brem, G. and Chen, G. (2011) Controlled Combustion Tests and Bottom Ash Analysis Using Household Waste with Varying Composition, *Waste Management*, Vol.31, No.2, pp.259-266.

Table 32: Ranges in the Composition of Municipal Solid Waste Incineration Ash (Excluding Scrap Metal Portion and the Size Fraction > 45mm)

Component	Unit	Incinerator bottom ash	Fly ash
Si	g/kg	210–290	95–190
Al	g/kg	47–72	49–78
Fe	g/kg	27–150	18–35
Ca	g/kg	65–97	74–130
Mg	g/kg	7.7–19	11–19
K	g/kg	9.2–22	23–47
Na	g/kg	22–41	22–57
Ti	g/kg	3.2–7.2	7.5–12
S	g/kg	1.3–8	11–32
Cl	g/kg	1.2–3.2	45–101
P	g/kg	2.9–13	4.8–9.6
Mn	g/kg	<0.7–1.7	0.8–1.7
Ag	mg/kg	4.1–14	31–95
As	mg/kg	19–80	49–320
Ba	mg/kg	900–2700	920–1800
Be	mg/kg	nd	nd
Cd	mg/kg	1.4–40	250–450
Co	mg/kg	<10–40	29–69
Cr	mg/kg	230–600	140–530
Cu	mg/kg	900–4800	860–1400
Hg	mg/kg	<0.01–3	0.8–7
Mo	mg/kg	2.5–40	15–49
Ni	mg/kg	60–190	92–240
Pb	mg/kg	1300–5400	7400–19000
Se	mg/kg	0.6–8	6.1–31
Sn	mg/kg	<100–1300	1400–1900
Sr	mg/kg	170–350	<80–250
V	mg/kg	36–90	32–150
W	mg/kg	<20–50	nd
Zn	mg/kg	1800–6200	19000–41000
PAH	mg/kg	0.23–2200	30–110
CB	mg/kg	6.7–45	50–890
PCB	mg/kg	<40	<40
CP	mg/kg	16–34	120–1800
PCDD	mg/kg	0.2–10	115–140
PCDF	mg/kg	0.44–4.5	48–69
TCDD	mg/kg	0.02–0.22	1.5–2.5
TOC	g/kg	4.8–13	4.9–17
LOI	g/kg	5.9–50	11–45

Notes: TCDD: toxicity equivalents determined according to Eadon's method; nd: no data available; PAH: polycyclic aromatic hydrocarbons; CB: chlorobenzenes; CP: chlorophenols; PCDD: polychlorinated dibenzop-dioxins; PCDF: polychlorinated dibenzofurans; TOC: total organic Carbon; LOI: loss on ignition at 550 ^{0}C.

Source: Hjelmar, O. (1996) Disposal Strategies for Municipal Solid Waste Incineration Residues, Journal of Hazardous Materials, Vol.47, No.1-3, pp.345–368.

It is evident from Table 32 that IBA can contain high concentrations of various heavy metals, such as arsenic, barium, chromium, cadmium, copper, lead, nickel, mercury, silver and zinc. In addition a number of persistent organic pollutants are also frequently found, including PCDD and PCDF. The concentration of metals in the ash will naturally have significant impacts on the recorded toxicity of these materials. In addition, the varying nature of MSW results in a potentially wide range of these pollutants in the ash, so, therefore, the composition of pollutants in the ash is likely to vary significantly from site to site.

A.9.3 Chemical Composition of Municipal Waste

Burnley has reviewed the chemical composition of UK municipal waste and reported a range of values for the waste components containing some key heavy metals (see Table 33).[83]

[83] Burnley, S. J. (2007) The use of Chemical Composition Data in Waste Management Planning - A Case Study. *Waste Management*, Vol.27, No.3, pp. 327-336.

Table 33: Concentration of Heavy Metals (on a Dry Basis) in Key Waste Streams[84]

Category	As (ppm)			Cd (ppm)			Cr (ppm)			Hg (ppm)			Pb (ppm)		
	UK	NI	D	UK	NI	D	UK	NI	D	UK	NI	D	UK	NI	D
Paper/card	2	2	<5	1	11	1	20	67	10	0.1	<0.1	0.2	42	127	23
Organic waste	5	67	30	1	5	1	25	310	55	0.1	<0.1	0.5	76	188	90
Total plastics		3			388			853			<0.1			302	
Dense plastics	2			32			181			0.1			879		
Film plastics	4			4			195			0.1			1595		
PVC			<5			66			29			0.2			50
Wood		6	<5		12	<1		231	5		1	<0.1		277	21
Textiles	2	2	<5	1	16	1	25	934	17	0.1	<0.1	<0.1	35	30	35
Glass	6	287	0	1	<1	0	454	253	1	<0.1	<0.1	0	168	381	329
Miscellaneous non-combustible	11			3			118			<0.1			999		
Stone/ceramics		91	10		341	1		822	80		<0.1	0		1967	50
Total metals			20			21			156			nd			582
Ferrous metal	32	539		15	<1		1571	1730		nd	nd		1300	520	
Non-Fe metal	4	48		16	19		221	331		nd	nd		4000	11,635	
Batteries			12			53			18			127			10,800
Electrical goods			71			361			1304			17			11,000
Fines	16			1			97			0.2			706		

There are a number of doubts about the lead and cadmium contents of the coloured dense plastic bottles. The 1994 UK data reported lead concentrations of 390 ppm and 36 ppm for the 1992 and 1993 samples, respectively, and corresponding values of 160 ppm and 250 ppm for cadmium. This wide variation suggests that the samples were either not representative or contaminated and amply demonstrate the need for further data. Furthermore, these results pre-date the European Directive on Packaging and Packaging Wastes[85], which called for a reduction in the sum of lead, cadmium, mercury and hexavalent chromium to a maximum value of 600 ppm by June 1998, 250 ppm by June 1999 and 100 ppm by June 2001. Therefore, even if

[84] Based on data from 1) Environment Agency (1994a) National household waste analysis project phase 2: Report on composition and weight data, Volume 1, CWM 082/94, The Environment Agency for England and Wales, Bristol, UK (note that whilst Burnley attributes this to the Environment Agency it should be The Department of the Environment Wastes Technical Division – The Environment Agency was not formed until 1st April 1996); 2) B. Herring, M. Herring and E. Gruneklee (1999) Schwermetallentfrachtung durch das trockenstabilatverfahren, *Wasser und Abfall* 4 (1999), pp. 20–23; and 3) P. Otte (1995) *Analysis of metals and calorific value in components from household waste 1988–1992*. National Institute of Public Health and Environmental Protection, Report 776201024, Bilthoven, Netherlands.

[85] Official Journal of the European Communities (1994) *Directive on Packaging and Packaging Wastes*, L365, 31/12/1994, 010-023, Brussels, Belgium.

the reported values are accurate, current concentrations should be much lower than those from the early 1990s.

It can be seen from Figure 12 that lead is widely distributed among a number of fractions (mainly metals, miscellaneous and plastics), but is less prevalent in the materials that would form the bulk of an intensive recycling or compost collection scheme and would thus tend to concentrate in the residual wastes that might be incinerated. Glass has no calorific value and as far as possible, should not be incinerated, not least because some glass contains a high percentage of lead oxide (it can be seen that 8% of the lead is in glass) which is an avoidable addition to the toxicity of the bottom and fly ash residues.

Figure 12: Distribution of Key Pollutants of Concern Across Waste Materials

Source: Burnley, S. J. (2007) The Use of Chemical Composition Data in Waste Management Planning - A Case Study. Waste Management, Vol.3, pp. 327-336

Certain specific waste streams are also major sources of these heavy metals. A report for Environment Canada, for example, highlighted waste PCs and monitors which were estimated to contain c. 6.3% lead, 0.01% cadmium, 2.2% zinc and 0.002% mercury.[86]

A Dutch study has suggested that zinc was present in residual household waste in the Netherlands in quantities between 180 and 542 mg/kg.[87] Table 34 shows the concentration of zinc for specific components of the waste stream taken from the same study. This Table also shows the proportion of zinc in residual household waste associated with each component. What is clear is that zinc is quite widely distributed across different waste materials. Biodegradable wastes account for much of the zinc in residual household waste. Leather and rubber do also. It does seem, however, that carpets, leather, textiles and non-ferrous metals might be materials worthy of targeting on the input side. In addition, sanitary products are likely to contain high levels of zinc, partly owing to the use of various creams containing zinc. Even if the materials with highest concentrations of zinc – leather, rubber, carpets, sanitary products, textiles and non-ferrous metals - were eliminated from household waste being incinerated, however, the loading of zinc would still be of the order 70% of current levels because zinc is widely present in waste components.

Table 34: Concentration of Zinc in Waste Components

Material	Concentration of Zinc mg/kg dry matter	Contribution of Material to Total Zinc in Residual Waste (%)
Biowaste, sub 3 mm	570	10
Biowaste, 3-8 mm	270	6
Biowaste, 8-20 mm	340	4
Biowaste, >20 mm	130	5
Paper / card	83	10
Plastic	310	16
Glass	140	3
Ferrous	20	0
Non-ferrous	850	2
Textiles	260	3
Ceramics	480	7
Carpets and rugs	1,800	5
Leather / rubber	3,300	26
Wood	150	1

Source: D. Beker and A. A. J. Cornelissen (1999) Chemische Analyse von Huishoudelijk Restafval: Resultaten 1994 en 1995, RIVM Report No 776221002.

[86] Enviros RIS (2000). *Information Technology (IT) and Telecommunication (Telecom) Waste in Canada October 2000*, Report for Environment Canada; also cited in R. B. Gordon, T. E. Graedel, et al. (2003). The characterization of technological zinc cycles, *Resources, Conservation and Recycling* 39(2): 107-135.

[87] D. Beker and A. A. J. Cornelissen (1999) *Chemische Analyse von Huishoudelijk Restafval: Resultaten 1994 en 1995*, RIVM Report No 776221002.

Calcium's presence in the waste stream may also be difficult to avoid. As discussed later in the document high concentrations of this element can increase the toxicity of the ash material.

Table 35: Concentration of Calcium in Waste Components

Material	Concentration of calcium mg/kg dry matter
Carpet Waste	21
Plastics from waste from electrical and electronic equipment (WEEE) material, mix 1	9,980
Plastics from waste from electrical and electronic equipment (WEEE) material, mix 2	1,260
Building and demolition residue	1,980
Coffee grounds	900
Organic waste, 0-150mm	6,100
Shuttering wood	4,940
Demolition wood pellets	2,290
Clean wood	5,900
Painted wood	3,200
Painted wood, fine fraction	13,000

Sources: S.A.H.Moorman et al: Emissies uit bijstoken, verbranden en vergassen van niet-gevaarlijke afvalstromen in vergelijking tot BLA en AVI. Hoofdrapport, Delft (Netherlands), Centrum voor Energiebesparing en schone technologie, CE--00.5713.01, 69 p. (2000); European brominated flame retardant industry panel (EBFRIP); H.A.van der Sloot and P.A.J.P.Cnubben: Verkennende evaluatie kwaliteitsbeinvloeding poederkoolvliegas, ECN-report ECN-C-00-058, 88 p. (2000).

In summary the literature suggests that metals such as lead, cadmium, zinc, mercury, and chromium are present in municipal waste. In fact, zinc especially, is present in high concentrations. Thus it is evident that significant quantities of these metals maybe inputted into incinerators as part of the residual waste stream.

A.9.4 Partitioning Factors: Metal flows Through Incinerators

In order to understand the implications for the management of incineration ash it is important to set out some basis for the understanding of how materials flow through the incineration process. In doing so, it is worth considering that different modellers of incineration processes characterize the process, and the resulting emissions, in rather different ways. In essence, however, waste can be broken down into chemical constituents, including heavy metals, and estimates can be made of the way that these partition through the incineration process.

Assessment of metals and inorganic compounds is more straightforward than that of organic compounds. The mass of metals entering the incineration process (including in the form of auxiliary inputs) must equal the mass of metal exiting the process (at least, excluding what may be small amounts of material retained – unintentionally - within the plant on a semi-permanent basis). In other words, the mass of elemental metal inputs should balance the mass of elemental metal outputs.

The way in which metals are dealt with in incineration processes depends upon a range of different factors, amongst others these include:

- The volatility of the metal (this determines how much remains on the grate as ash, and how much partitions to the raw, or uncleaned, flue gas stream);

- The nature of the flue gas cleaning process (determining the extent to which the raw flue gas is cleansed of the heavy metal content, and through what means – that which is removed from flue gas will be found, in some form, in air pollution control residues or in the scrubber liquor of wet systems); and
- The degree to which there is post treatment of ash residues, for example, in order to extract useful metals for recovery.

Several modelers have built models of incineration processes based on the application of 'transfer factors'. These factors effectively determine, for a given metal, the degree to which they are partitioned into one or other stream. Typically, for an incinerator, these streams will include:

1) Grate / bottom ash;
2) Fly ash and air pollution control residues (sometimes sub-divided into fractions to reflect the nature of the gas cleaning configuration);
3) The flue gas leaving the stack; and
4) The metals recovered from the process.

For a given metal, reflecting its characteristics, transfer factors are used to determine what proportion of the metal is likely to be found in which output stream. The issue is which output they will be discharged in, in what proportions, and in what form.

Examples of typical partitioning factors are given below for an incinerator in Wurzburg, Germany (Table 36). This shows that volatile metals, such as mercury, are apt to escape into the flue gas, whilst metals such as copper and nickel are found mainly in grate (bottom) ash. Some metals – notably cadmium and thallium – are assumed to be volatilised, but to a large extent captured through the flue gas cleaning system (unlike mercury).

Another example, from work by Lahl, is given in Table 37, showing only transfer into the cleaned flue gas, the recycled fraction and other ashes. [88] The plants examined in the work by Lahl were more modern German and Austrian plants than the Wurzburg plant from which the transfer factors in Table 36 were taken. It will be noted that the percentages transferred to the ash residues are very high, reflecting the efficacy of the flue gas treatment assumed at the facility. The consequence of efficient flue gas treatment and the fact there is a greater propensity for metals to remain associated with the solid phase, means that atmospheric emissions may be reduced at the cost of producing metal rich ash materials.

Table 36: Transfer Co-efficients for Heavy Metals in Grate Firing, Wurzburg MSW Incinerator

Path	As	Cd	Co	Cr	Cu	Hg	Mn
Flue gas	0.2	16.2	0.3	2.8	0.2	92.8	0.2

[88] Uwe Lahl (2001) Ecodumping by Energy Recovery: A Report on Distortions of Environmental Standards Between Disposal and Recovery and Approaches to Overcome Them, Report to the European Environmental Bureau, January 2001.

Filter dust	5.5	56.2	3.8	4.3	2.6	0.8	8
Boiler ash	2.1	1.4	2.1	2	0.3	0.4	1.5
Grate ash	92.3	26.2	93.8	90.9	96.9	6	90.3
Path	Ni	Pb	Sb	Sn	Tl	V	Zn
Flue gas	1.7	20.1	2.9	11.3	0	0.1	12.1
Filter dust	2.8	14.4	33.8	26.5	70.2	9	22.8
Boiler ash	1.2	0.7	1.2	1.4	0.6	2	1.4
Grate ash	94.3	64.8	62.1	60.8	29.2	88.9	63.7

Source: M. Kremer, G. Goldhan and M. Heyde (1998) Waste Treatment in Product Specific Life Cycle Inventories: An Approach to Material-related Modelling: Part 1, Incineration, International Journal of LCA, Vol. ***3, No. 1, pp.*** *1 47-55*

Table 37: Transfer Co-efficients for Heavy Metals in 'State-of-the-art' Incinerator

	Flue Gas	Ferrous / non ferrous	Other ashes
As	0 %		100.00%
Cd	0.05%	5.00%	94.95%
Co	0.01%		100.00%
Cr	0.01%	10.00%	90.00%
Cu	0.01%	10.00%	90.00%
Hg	5.00%		95.00%
Mn	0.01%		100.00%
Ni	0.01%	10.00%	90.00%
Pb	0.01%	10.00%	90.00%
Sb	0.00%		100.00%
Sn	0.01%		100.00%
Tl	0.07%		99.94%
V	0.01%		100.00%
Zn	0 %		100.00%

Source: Uwe Lahl (2001) Ecodumping by Energy Recovery: A Report on Distortions of Environmental Standards Between Disposal and Recovery and Approaches to Overcome Them, Report to the European Environmental Bureau, January 2001.

From the partitioning factors presented in both Table 36 and Table 37 it is evident that the majority of metals, other than mercury, end up remaining behind as part of the bottom ash or fly ash. These partitioning coefficients have clear implications for the chemical composition of ash materials which are being derived from the incineration of municipal solid waste.

A.9.5 Pulverised Fuel Ash and Furnace Bottom Ash

Pulverised fuel ash, sometimes referred to as fly ash, is the fine power released into the flue after the combustion of coal. Furnace bottom ash (FBA), usually accounting for 10 to 20 per cent of the total ash produced, is the coarser fraction of ash which falls to the base of the furnace.[89] PFA has received much attention in the academic literature and a number of authors have shown that high concentrations of heavy metals can potentially be leached from these materials or cause environmental harm.[90,91,92,93]

Based on total elemental concentrations it can be seen that the upper ranges reported in Table 38 are typically lower than those cited in Table 32 for incinerator bottom ash. Total elemental concentrations, however, provide a poor prediction of the actual ecotoxicity of a material and a direct correlation should not be assumed.[94] It is therefore necessary to assess the ecotoxicity of ash materials in addition to total the elemental composition.

Table 38: Typical Chemical Composition of PFA and FBA

Chemical	Units	PFA[1]		FBA[1]	
		Min	Max	Min	Max
Aluminium	% w/w	24	26		
Aluminium	mg/kg			2,000	123,000
Aluminium Oxide	% w/w			18.9	26.1
Antinomy	mg/kg	1	325	0.3	4
Arsenic	mg/kg	4	128	<3	33
Barium	mg/kg	0	36,000	32	3,100
Barium Oxide	% w/w			0.12	0.32
Beryllium	mg/kg	0.2	9.1		
Boron	mg/kg	5	310	0.5	145
Cadmium	mg/kg	<0.1	4	0.06	0.6
Calcium	% w/w	5.3	5.7		
Calcium	mg/kg			1,610	33,800
Calcium Oxide	% w/w			4.57	33,800
Carbon	mg/kg			23,000	23,000
Chloride	mg/kg	0	2,990	3,000	3,000
Chromium	mg/kg	16	220	16	950

[89] WRAP and EA (2008) *A Technical Report on the Manufacture of Products from Pulverised Fuel Ash (PFA) and Furnace Bottom Ash (FBA),* a report by The Waste and Resources Action Programme and the Environmental Agency for the Department for Environment, Food and Rural Affairs, August 2008, pp.54, www.environment-agency.gov.uk/business/topics/waste/114443.aspx.

[90] Reijnders, L. (2005) Disposal, Uses and Treatments of Combustion Ashes: A Review, *Resources, Conservation and Recycling*, Vol.43, No.3, pp,313-336.

[91] Lee, S. and Spears, D. A. (1998) Potential Contamination of Groundwater by Pulverised Fuel Ash, *Geological Society of London*, Vol.128, pp.51-61.

[92] Lohner, T. M., Reash, R. J., Willet, V. E. and Fletcher, J. (2001) Assessment of Tolerant Sunfish Populations (*Lepomis sp.*) Inhabiting Selenium-Laden Coal Ash Effluents: 3. Serum Chemistry and Fish Health Indicators*, Ecotoxicology and Environmental Safety*, Vol.50, No.3, pp.225-232.

[93] Haynes, R. J. (2009) Reclamation and Revegetation of Fly Ash Disposal Sites – Challenges and Research Needs, *Journal of Environmental Management*, Vol.90, No.1, pp.43-53.

[94] Gupta, S.K., Vollmer, M.K. and Krebs, R. (1996) The Importance of Mobile, Mobilisable and Pseudo Total Heavy Metal Fractions in Soil for Three-Level Risk Assessment and Risk Management, *Science of the Total Environment*, Vol.178, No.1-3, pp.11-20.

Chemical	Units	PFA[1]		FBA[1]	
		Min	Max	Min	Max
Cobalt	mg/kg	2	115	4	73
Copper	mg/kg	10	474	7	310
Fluoride	mg/kg	0	230	<5	145
Fluorine	mg/kg			<5	69
Gold	mg/kg			<5	<5
Iron	% w/w	7.7	9.5		
Iron	mg/kg			7,630	119,000
Iron Oxide	% w/w			12	22
Lead	mg/kg	<1	976	<5	100
Magnesium	% w/w	2.1	2.6		
Magnesium	mg/kg			299	15,000
Magnesium Oxide	% w/w			1.83	2.92
Manganese	mg/kg	0.27	1,600	31	2,223
Manganese Oxide	% w/w			0.17	0.31
Mercury	mg/kg	<0.01	1.3	<0.01	0.06
Molybdenum	mg/kg	<2	81	4	23
Nickel	mg/kg	8.3	583	40	620
Phosphorus	mg/kg	262	2,818	220	270
Phosphorus	% w/w	262	2,818	220	270
Phosphorus Pentoxide	% w/w			0.23	0.7
Potassium	%w/w	1.8	3.4		
Potassium	mg/kg			166	10,000
Potassium Oxide	% w/w			1.31	2.17
Selenium	mg/kg	<1	162	0.3	<1
Silica	% w/w			39	53
Silicon	% w/w	48	56		
Silicon	mg/kg			325	187,000
Silver	mg/kg	0.13	0.13		
Sodium	% w/w	0.7	1.1		
Sodium	mg/kg			126	5,000
Sodium Oxide	% w/w			0.3	0.9
Sulphur	% w/w	0.9	1.1		
Sulphur	mg/kg			4,500	4,500
Sulphur Trioxide	% w/w			0.08	1.39
Thallium	mg/kg	0.37	0.37		
Tin	mg/kg	<2	1,847	1.2	1.2
Titanium	% w/w	1	1.1		
Titanium	mg/kg			124	5,100
Titanium Dioxide	% w/w			0.76	1.05
Total Sulphate	mg/kg	1,600	4,240		
Uranium	mg/kg	3.65	3.65		
Vanadium	mg/kg	44	1,339	11	540
Zinc	mg/kg	43	918	20	230

Note: 1. PFA and FBA taken from coal fired power stations, coal and petcoke and biomass co-firing, and from a power station using ammonia injection technologies.

Source: WRAP and EA (2008) A Technical Report on the Manufacture of Products from Pulverised Fuel Ash (PFA) and Furnace Bottom Ash (FBA), a report by The Waste & Resources Action Programme and the Environmental Agency for the Department for Environment, Food and Rural Affairs, August 2008, www.environment-agency.gov.uk/business/topics/waste/114443.aspx.

The practice of co-firing biomass materials in coal fired power stations is becoming increasingly popular as the EU looks to move towards 'renewable' energy sources. In analysing the effect of co-firing on the composition of coal fly ash Izquierdo *et al* concluded that: *'The most significant differences were determined in sewage sludge fly ash, mainly enriched in P, Zn, Cu, Sb and Pb and in petcoke fly ash, characterized by higher contents of V, Ni and Mo. Wood pellets, palm pit, olive stone and olive pulp do not provide significant amounts of potentially harmful elements or induce changes in the fly ash'*.[95] In relation to changes in leaching potential the authors conclude by saying: *'Some metals traditionally considered environmentally relevant such as Cd, Ni, Pb, Hg, Cu or Zn showed markedly low extractable levels and revealed an extremely low mobility under moderately alkaline conditions. The main concern of the (co)-firing fly ash of this study (based on leaching potential) arises from elements such as Se, Sb, Mo, Cr, As or* SO_4^{-2}*, behaving as oxyanions in an alkaline environment and showing a significant mobility'.*

A.9.6 Loss of Valuable Precious Metals with Disposal of PFA, FBA and IBA

It is well known that electrical and electronic equipment contain relatively high levels of precious metals such as gold and silver.[96] Hu *et al* highlighted the possible economic value of trace elements and precious metals in the finer fractions of IBA in which the input materials contained small amounts of WEEE. These authors state that *'the precious metals content represents an economically interesting intrinsic value, even when the observed peak values are properly averaged over a larger volume of ashes'*.[97] (Compositional analysis of Scottish household waste suggests that electrical items comprise 1.5% of the waste stream by weight, a value similar to that used by Hu *et al*).[98]

In addition, Reijnders states that *'bottom ash from municipal incinerators tends to contain significant amounts of iron and non-ferro metals such as Ag, Cu, Pb, Sn and Zn as small pieces of metal'*. It is suggested that *'these can be separated from the rest of the ash by eddy current and magnetic techniques in a profitable way'*. He also suggests that in the future *'increased prices, increased interest in self sufficiency and*

---

[95] Izquierdo, M., Moreno, N., Font, O., Querol, X., Alvarez, E., Antenucci, D., Nugteren, H., Luna, Y. and Pereira, C. F. (2008) Influence of the Co-firing on the Leaching of Trace Pollutants from Coal Fly Ash, *Fuel*, Vol.87, No.10-11, pp.1958-1966.

[96] Geyer, R. and Blass, V. 2010. The Economics of Cell Phone Reuse and Recycling, *The International Journal of Advanced Manufacturing Technology*, Vol.47, No.5-8, pp.515-525.

[97] Hu, Y., Bakker, M., Brem, G. and Chen, G. (2011) Controlled combustion tests and bottom ash analysis using household waste with varying composition, *Waste Management*, Vol.31, No.2, pp.259-266.

[98] WasteWork and AEA (2010) *The Composition of Municipal Solid Waste in Scotland*, final report for Zero Waste Scotland, April 2010, www.wrap.org.uk/downloads/Scotland_MSW_report_final.63e6617d.8938.pdf.

growing uneasiness about the environmental implications of ore mining may raise the prospects for forced extraction to recover useful elements from ashes' (the potential recovery metals from ash will be discussed in more detail in the next section).

We live on a finite planet with fixed sources of raw materials and limited capacity for absorbing pollution.[99] Given the predicted global shortages of precious metals in the coming decades, their recovery is becoming increasingly important. It has been estimated, for example, that if gold and silver continue to be used at current rates, known reserves will be depleted within 45 and 29 years, respectively.[100] It is further reported that other important metals vital to industry are also in limited supply, such as copper (61 years at current rates), zinc (46 years) and tin (40 years).

The EC has recently produced a list of 'critical' raw materials for the EU, based on the availability, economic importance and environmental risk of a range of materials.[101] They produced the following list, in alphabetical order:

- antimony
- beryllium
- cobalt
- fluorspar
- gallium
- germanium
- graphite
- indium
- magnesium
- niobium
- platinum group metals
- rare earth metals
- tantalum
- tungsten

---

[99] Environmental limits are grouped into 'source' and 'sink' limits, which refer to the earth's ability to provide natural resources and absorb pollution, respectively.

[100] Turner, R. K., Morse-Jones, S. and Fisher, B. (2007) *Perspectives on the 'Environmental Limits' Concept*, a report to the Department for Environment, Food and Rural Affairs. CSERGE, Norwich, Defra, London, http://randd.defra.gov.uk/Default.aspx?Menu=MenuandModule=MoreandLocation=NoneandCompleted=0andProjectID=15471.

[101] EC (2010) *Critical Raw Materials for the EU*, a report by the Ad-hoc Working Group on Defining Critical Raw Materials for the European Commission, July 2010, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/report-b_en.pdf.

In a similar vein to this EU wide study a report has recently been published by SEPA outlining raw materials which are critical to the Scottish economy.[102] The following materials were identified as being critical:

- aggregates
- cobalt
- copper
- fish
- indium
- lead
- lithium
- palm oil
- phosphorous
- rare earth elements
- timber
- tin

Copper and lead were listed as critical resources, but in the overall assessment of the report the future access to these two metals was ranked as being of 'low risk' compared to cobalt, lithium, indium and rare earth metals which were all ranked as 'high risk'. The repost concludes that the *'scarcity of certain resources particularly rare earth elements and other metals has the potential to substantially reduce opportunities for low and zero carbon growth'*.

The report highlighted a number of strategies / options that the Scottish Government and local business would have to consider if risks of resource shortages are to be adequately addressed. Key opportunities for businesses included recommendations to develop the following areas:

Alternative resources – research and development is required to promote the substitution of materials in various processes and technologies;

Preserving primary resources – through improved extraction methods and developing the use of recycled material in products;

Closed loop systems – develop 'cradle to cradle' processes more fully;

Process efficiencies – through improved efficiencies across the entire life cycle of a product; and

Reducing waste to landfill – through a clear focus on improved efficiency, design and recycling.

---

[102] SEPA (2011). *Raw Materials Critical to the Scottish Economy*, a report by the Scotland and Northern Island Forum for Environmental Research (SNIFFER) and the Scottish Environment Protection Agency, January 2011, www.sepa.org.uk/science_and_research/publications.aspx.

In both the Scottish and the European study the group of rare earth metals were identified as being most critical and already predicted shortages of these metals are causing political turmoil.[103, 104] China has come to dominate the global market and is in the process of reducing exports in order to retain these metals for its own high-tech industry.[105, 106, 107] The largest US rare earth metal mine at Mountain Pass in California was closed after China flooded the market in the early 1990s; however, due to clear shortages and a changing political environment the mine is being reopened by Molycorp Minerals.[108]

A recent study on rare earth metals and their recycling have stated that, *'even if China imposes no export restrictions it is to be expected that the increasing demand up to 2014 can only be met if further mines in addition to the two planned mines in Australia and USA are opened.'* Rare earth metals are critically important because little opportunity exists for substituting them with other materials without the radical redesign of products which are critically important to the technologically advanced European economies.[109]

Recent scares about adequate supplies of rare earth metals have driven up prices significantly (

Figure 13). China's reduced exports and the increasing costs will force greater levels of self-sufficiency and will likely help to stimulate and drive forward improved recycling of WEEE and recovery of precious metals and other valuables from waste

---

[103] EC (2010) *Critical Raw Materials for the EU*, a report by the Ad-hoc Working Group on Defining Critical Raw Materials for the European Commission, July 2010, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/report-b_en.pdf.

[104] SEPA (2011). *Raw Materials Critical to the Scottish Economy*, a report by the Scotland and Northern Island Forum for Environmental Research (SNIFFER) and the Scottish Environment Protection Agency, January 2011, www.sepa.org.uk/science_and_research/publications.aspx.

[105] The Telegraph (2010) *Hot Political Summer as China Throttles Rare Metal Supply and Claims South China Sea*, accessed on 11th January 2011 http://www.telegraph.co.uk/finance/comment/ambroseevans_pritchard/7921209/Hot-political-summer-as-China-throttles-rare-metal-supply-and-claims-South-China-Sea.html.

[106] The Telegraph (2010) *World faces hi-tech crunch as China eyes ban on rare metal exports*, accessed on 11th January 2011, http://www.telegraph.co.uk/finance/comment/ambroseevans_pritchard/6082464/World-faces-hi-tech-crunch-as-China-eyes-ban-on-rare-metal-exports.html.

[107] Bloomberg (2010) *Rare Earth Prices Soar Even as China Pledges Supply*, accessed on 20th January 2011, http://www.bloomberg.com/news/2010-10-20/china-pledges-to-maintain-rare-earth-sales-official-says-exports-may-rise.html.

[108] The Telegraph (2010) *World faces hi-tech crunch as China eyes ban on rare metal exports*, accessed on 11th January 2011, http://www.telegraph.co.uk/finance/comment/ambroseevans_pritchard/6082464/World-faces-hi-tech-crunch-as-China-eyes-ban-on-rare-metal-exports.html.

[109] Öko-Institute e.V. (2011) *Study on Rare Earths and Their Recycling*, a report by Öko-Institute e.V. for The Greens European Free Alliance in the European Parliament, January 2011, http://reinhardbuetikofer.eu/wp-content/uploads/2011/01/Rare-earths-study_Oeko-Institut_Jan-2011.pdf.

materials. On the 10th November 2010 the Science and Technology Select Committee of the House of Commons announced an inquiry into the importance of strategic metals to the UK.[110] The chair of the committee stated that: *"This inquiry has the potential to be wide-ranging, from concerns about the availability of rare earth elements to how metals are recycled from discarded technological devices"*. This demonstrates a clear political concern that is likely to intensify in coming years.[111]

Figure 13: Changes in the Rare-earths Price Index Since 2002 (January 2002 = 100)*

Source: The Economist (2nd September 2010) Digging In: China Restricts Exports of Some Obscure but Important Commodities, accessed on 12th January 2011, www.economist.com/node/16944034

From Table 32 and Table 38 it is evident that fairly high concentrations of metals – for example, copper, lead and zinc – can be found in ash arising from the incineration of municipal solid waste and coal. According to the London Metal Exchange a cash buyer will pay $8,849, $2,485, and $2,279 per tonne of copper, lead and zinc, respectively.[112] It is clear that rare earth metals fetch much higher prices, for example, molybdenum will fetch in the region of $36,600 a tonne and cobalt as much as $38,500.[113]

Taking these prices from the London Metal Exchange and from other Metal Pricing websites, and applying to the composition of IBA and FBA one can imply a potential

---

[110] UK Parliament (2010) *Strategically Important Metals*, accessed on 20th January 2011, www.parliament.uk/business/committees/committees-a-z/commons-select/science-and-technology-committee/inquiries/strategically-important-metals/

[111] PlanetArc (2011) *EU Watching Rare Earths Closely: Trade Chief*, accessed on 31st January 2011, http://planetark.org/wen/61018.

[112] London Metal Exchange (2011) *Non-ferrous Metals*, prices viewed on 20th January 2011, www.lme.com/non-ferrous/index.asp.

[113] London Metal Exchange (2011) *Minor Metals*, prices viewed on 27th January 2011, [113] London Metal Exchange (2011) *Non-ferrous metals*, prices viewed on 20th January 2011, www.lme.com/non-ferrous/index.asp.

revenue stream from each tonne of ash material.[114] This is caveated by the fact that the level of extraction of the different elements varies with price, thus the figures are do not include the cost of extraction, but it is simply to show the potential value of the metals in ash which is currently being disposed of. It seems also important to note, given the preceding discussion, that the price of these metals is likely to increase over time due to the finite nature of the resources.

So for IBA the value of the metals could be somewhere between around £140 and £340 per tonne, and for fly ash, £230 to £400 per tonne. For furnace bottom ash the estimated range is between £8 and £340 per tonne.

Given these costs and the critical nature of some of these elements for the Scottish economy it would seem prudent to follow the recommendation of the SNIFFER report, and encourage the diversion of waste from landfill through improved, recovery, recycling, and the development of innovative technologies and processes to enable the recovery of valuable metals from ash materials. [115]

The recovery of rare earth metals at present is a complex process, often requiring high energy physical and chemical treatment. A recent study states that *'apart from a few specialised industries and applications, the know-how in rare earth processing is quite low… The building up of know-how in recycling will widen the competency of enterprises and scientific institutions in Europe concerning rare earth processing*'.[116]

Recovery of metals from various slags and incineration bottom ash is technically feasible and has been covered in some detail.[117, 118, 119, 120] It is likely that greater political and economic incentives in the future will continue to drive research and development, and promote commercial applications for the recovery of metals from

---

114 Metal Prices.com (2011) *Metal Prices and News on the Internet*, Accessed 19th May 2010, http://www.metalprices.com/index.asp

115 SEPA (2011). *Raw Materials Critical to the Scottish Economy*, a report by the Scotland and Northern Island Forum for Environmental Research (SNIFFER) and the Scottish Environment Protection Agency, January 2011, www.sepa.org.uk/science_and_research/publications.aspx.

116 116 Öko-Institute e.V. (2011) *Study on Rare Earths and Their Recycling*, a report by Öko-Institute e.V. for The Greens European Free Alliance in the European Parliament, January 2011, http://reinhardbuetikofer.eu/wp-content/uploads/2011/01/Rare-earths-study_Oeko-Institut_Jan-2011.pdf.

117 Shen, H. and Forssberg, E. (2003) An Overview of Recovery of Metals from Slags, *Waste Management*, Vol.23, pp.933-949.

118 Nagib, S. and Inoue, K. (2000) Recovery of Lead and Zinc from Fly Ash Generated from Municipal Incineration Plants by Means of Acid and/or Alkaline Leaching, *Hydrometallurgy*, Vol.56, No.3, pp.269-292.

119 Zhang, F-S. and Itoh, H. (2006) Extraction of Metals from Municipal Solid Waste Incinerator Fly Ash by Hydrothermal Process, *Journal of Hazardous Materials*, Vol. 136, No. 3, pp.663-670.

120 Krebs, W., Brombacher, C., Bosshard, P. P., Bachofen, R. and Brandl, H. (1997) Microbial Recovery of Metals from Solids, *Microbiology Reviews*, Vol.20, No. 3-4, pp.605-617.

wastes. A number of companies already exist in the UK to undertake such operations, for example, Tetronics Ltd[121] and JBR Recovery Ltd[122].

Tetronics specialises in waste recovery plants that can eliminate / extract the hazardous elements within waste ash materials and thereby generate an inert building aggregate with the remaining material. Tetronics' patented Direct Current (DC) Plasma Arc plant technology is used to recover metals and produce an environmentally stable aggregate patented as Plasmarok.[123] Personal communication with the company indicated that relatively high levels of extraction, and capture of metals, could be costs effective with an avoided disposal cost of around £80 to £120 per tonne.

JBR Recovery use blast furnace technology and focus more specifically on the recovery of silver, but also recover gold, lead and other precious metals. They process a large variety of low and high grade wastes and can reportedly recover silver from wastes containing as little as $0.1\%_{wt}$ to $0.15\%_{wt}$ (90% to 99% silver purity is achieved). JBR Recovery operations can reportedly process fairly large volumes and operate a toll processing fee, whereby their customers pay by weight to have the silver removed from the waste materials they provide (the silver is then owned by the client). The fee varies depending on the type and quantity of material requiring processing (JBR was unwilling to provide cost estimates without specific details on materials and quantities).[124]

A.9.7 Treatment of IBA

The section describes some of the potential options for treating IBA which could be made more cost effective if the material was not taxed under the standard rate.

In order to promote secondary markets for incinerator bottom ash (IBA) in England, Wales and Northern Ireland the Environment Agency and WRAP are in the process of considering whether it is feasible to develop a Waste Protocol for the material. With the aim of removing the waste classification of a material the Waste Protocol Programme looks to gather *'evidence on standards the material meets, markets it may be able to exploit, and most importantly any potential impacts on human health and the environment'.* It is estimated that the introduction of such a protocol could potentially help to divert approximately 469,000 tonnes of IBA from landfill annually.[125] It is worth noting, however, that the proposal to develop this Waste Protocol was put forward by the Environmental Services Association (ESA), an industry representative of the UK's waste sector, who was also asked to propose suitable

---

121 Tetronics Ltd (2011) *About Us*, viewed on 20th January 2011, www.tetronics.com/about-us.aspx.

122 JBR Recovery Ltd (2011) *About Us*, viewed on 20th January 2011, www.jbr.co.uk/index.htm.

123 Tetronics (2010) Explained: Plasmarok™ Generated from Waste Recovery, accessed on 3rd February 2011, www.tetronics.com/img//pdf/Plasmarok%20Datasheet.pdf.

124 Personal communication with Richard Punt of JBR Recovery on the 3rd February 2011.

125 Environmental Agency (2010) *Waste Protocols Project: Incinerator Bottom Ash (IBA)*, accessed 10 January 2011, www.environment-agCarbonency.gov.uk/business/topics/waste/114416.aspx.

candidates for the Technical Advisory Group.[126] Eunomia contacted the Waste Protocols Project and it was reported that the Waste Protocol for IBA was still under consideration, and that the decision to go ahead with developing a protocol would depend on a detailed risk assessment due to be completed later this year (if developed the Waste Protocol would only apply to England, Wales and Northern Ireland).[127]

In order for IBA to be used as a resource or to be classified as non-hazardous, hazardous elements need to be immobilised or made safe. A number of options have been developed and these include diluting materials with blast furnace slag, washing, solidification with binders, vitrification, thermal treatment, and forced extraction of mobile compounds such as heavy metals (e.g. through using eelectrodialysis, pyrometallurgy, hydrometallurgy, biohydrometallurg techniques).[128]

Recently it has been reported that Italian researchers have developed a low-cost method for removing / immobilising the hazardous elements in municipal solid waste incineration ashes.[129] Their research demonstrated that treating these ash materials with colloidal silica significantly reduced the leachability of zinc, and virtually immobilised lead, vanadium, arsenic and selenium.[130] Once the metals have been stabilised the soluble salts can then be washed out and the resulting product, known as COSMOS, used as an inert aggregate. The promising outcomes of this initial research has led to funding being granted by the European Commission for an initial demonstration project.[131]

Gerven *et al* report that in Europe *'all countries consider bottom ash as non-hazardous waste whereas fly ash and APC residue are considered hazardous'*.[132] This is reflected in the UK too, where it appears as if the practice of recycling IBA is widespread despite the concerns highlighted above. Before being screened into varying particle size fractions raw IBA is processed to segregate off metals and a

---

[126] ESA (2007) *IBA Success*, Environmental Services Association, accessed on 25th February 2011, www.esauk.org/070524_iba_success.asp.

[127] Personal e-mail communication with Nick Boase, Environmental and Business Officer, from the Environment Agency's Waste Protocols Project, 6 April 2011.

[128] Reijnders, L. (2005) Disposal, Uses and Treatments of Combustion Ashes: A Review, *Resources, Conservation and Recycling*, Vol.43, No.3, pp.313-336.

[129] DG Environmental News Alert Service (2011) *Science for Environment Policy: Waste Incineration Ash Could Prove a Valuable Resource*, 27 January 2011, accessed on the 2nd February 2011, http://ec.europa.eu/environment/integration/research/newsalert/pdf/226na4.pdf.

[130] Bontempi, E., Zacco, A., Borgese, L., et al (2010) A New Method for Municipal Solid Waste Incinerator (MSWI) Fly Ash Inertization, Based on Colloidal Silica, *Journal of Environmental Monitoring*, Vol.12, pp.2093-2099.

[131] COSMOS (2010) *COlloidal Silica Medium to Obtain Safe inert*, project LIFE08 ENV/IT/000434, accessed on 2nd February 2011, www.cosmos.csmt.eu.

[132] Van Gerven, T., Geysen, D., Stoffels, L., Jaspers, M., Wauters, G., and Vandecasteele, C. (2005) Management of Incinerator Residues in Flanders (Belgium) and in Neighbouring Countries: A Comparison, *Wastes Management*, Vol.25, No.1, pp.75-87.

small amount of unusable materials. Once sorted and graded the incinerator bottom ash aggregate has a number of commercial uses (provided it meets specific quality requirements[133, 134]). The main uses include the material's incorporation in bitumen bound materials (e.g. road surfaces), concrete blocks, pipe bedding, and land works (e.g. fill, capping layers, and embankment construction).[135, 136, 137, 138] However, it should be noted that the use of IBA in these applications has not been without criticism by environmental groups.[139, 140]

A.9.8 Arisings of Combustion Residues

In 2008 approximately 336,000 tonnes of waste were incinerated or co-incinerated across Scotland (Table 39). Energy was recovered from 35% (119,274 tonnes) of this waste, while the remainder was managed in this way for disposal purposes (Table 40).

Table 39: Waste Arisings (tonnes) Sent for Incineration and Co-incineration in Scotland (2004 to 2008)

	2004	2005	2006	2007	2008
Municipal	93,142	102,333	85,279	97,928	88,145
Commercial & Industrial[1]	228,790	177,598	188,314	156,225	247,968
Total	*321,932*	*279,931*	*273,593*	*254,153*	*336,113*

[133] SEPA, EHA, and EA (2008) Technical Guidance WM2 on Hazardous Waste, second edition report (version 2.2) by the Scottish Environmental Protection Agency, Environment and Heritage Service and the Environment Agency, March 2008, http://publications.environment-agency.gov.uk/pdf/GEHO0603BIRB-e-e.pdf.

[134] ESA (2010) *Sampling and Testing Protocol for the Assessment of Hazardous Status of Incinerator Bottom Ash*, a report by WRc for the Environmental Services Association, October 2010, http://www.esauk.org/publications/reports/ESA_IBA_Sampling_and_Testing_Protocol.pdf.

[135] DCLG (2007) *Survey of Arisings and Use of Alternatives to Primary Aggregates in England, 2005 - Other Materials*, final report by Capita Symonds Ltd and WRc for Department for Communities and Local Government, February 2007, www.communities.gov.uk/documents/planningandbuilding/pdf/surveyother2005.pdf.

[136] WRAP (2010*) Incinerator Bottom Ash*, accessed on 11th January 2011, http://aggregain.wrap.org.uk/specifier/materials/incinerator.html; and: WRAP (2003) Performance of Processed Incinerator Bottom Ash with both Recycled Asphalt and Recycled Concrete Aggregate as a 50:50 Blend in a Foamed Bitumen Mixture in a Perimeter Road at a Landfill Site, accessed on 11th January 2011, http://aggregain.wrap.org.uk/case_studies/2691_performance.html.

[137] Pera, J., Coutaz, L., Ambroise, J., and Chababbet, M. (1997) Use of Incinerator Bottom Ash in Concrete, *Cement and Concrete research*, Vol.27, No.1, pp.1-5.

[138] EA (2002) *Solid Residues from Municipal Waste Incinerators in England and Wales*, a report by the Environment Agency, May 2002, www.seas.columbia.edu/earth/wtert/sofos/UK-env-agency_incin-residue_2002.pdf.

[139] Friends of the Earth (2002) The Safety of Incinerator Ash, a briefing note by Friends of the Erath, Novemebr 2002, www.foe.co.uk/resource/briefings/safety_incinerator_ash.pdf.

[140] Greenpeace (2004) *The Problem*, accessed on 11th January 2011, www.greenpeace.org/international/en/campaigns/toxics/incineration/the-problem/.

Note: 1. These figures do not include any waste collected as part of municipal waste collections. *Source: SEPA (2010) Waste Data Digest 10: Key Facts and Trends, Scottish Environmental Protection Agency final report,www.sepa.org.uk/waste/waste_data/waste_data_digest.aspx*

Table 40: Breakdown of Waste Incinerated (tonnes) for Either Energy Recovery or Disposal (2004 to 2008)

	2004	2005	2006	2007	2008
Energy recovery	37,104	35,000	66,903	71,297	119,274
Disposal	284,828	244,931	206,690	182,856	216,839
Total	*321,932*	*279,931*	*273,593*	*254,153*	*336,113*
Source: SEPA (2010) Waste Data Digest 10: Key Facts and Trends, Scottish Environmental Protection Agency final report,www.sepa.org.uk/waste/waste_data/waste_data_digest.aspx					

Energy was recovered from the incineration of chemical wastes, sewage sludge, shredded tires and wood, while animal remains/litter and household waste were the two main waste streams incinerated for disposal purposes (Table 41).

Table 41: Breakdown (tonnes) of Waste Inputs for Incineration and Co-incineration and Estimated Ash Arisings (2008)

Waste type	Incineration and co-incineration with energy recovery	Incineration and co-incineration for disposal	Range and average ash content[1] (%)	Estimated ash arisings[2]
Animal remains/litter	0	121,810	7 – 64 (35.5)	43,243
Chemical wastes	11,056	16	-	-
Healthcare wastes	0	1,016	44 – 55 (48)[3]	488
Household and similar	0	77,537	27 (27)	20,935
Oil sludges	0	749	-	-
Paper and card	0	123	1 – 22 (11.5)	14
Refuse derived fuel	0	13,017	9 – 25 (17)	2,213
Sewage sludge	48,652	0	31 – 32 (31.5)[4]	15,325
Shredded tyres	16,310	0	(17)[5]	2,773
Sorting residues	0	2,000	-	-
Wood	43,256	0	1 – 10 (5.5)	2,379
Other	0	572[6]	-	-
Total	*119,274*	*216,839[7]*		*87,369[8]*
Notes: 1. Data from ECN Phyllis Database – ash values vary according to contents of waste inputs and thus vary from study to study, range in values given with average of the two in parenthesis; 2. Product of the average ash percentage and mass of waste incinerated; 3.Range from four samples analysed by Gidarakos et al[141]; 4. Untreated sewage sludge; 5.				

[141] Gidarakos, E., Petrantonaki, M., Anastasiadou, K. and Schramm, K-W. (2009) Characterization and hazard evaluation of bottom ash produced from incinerated hospital waste, *Journal of Hazardous Materials*, Vol.172, No.2-3, pp.935-942.

Value reported by Juma et al[142]; 6. Includes textiles and mixed packaging; 7. 88,145 tonnes of the total inputs came from municipal sources; 8. Approximate total ignoring the likely small additions which would be made by the incineration of chemical wastes, oil sludges and 'other' materials.

Source: Incineration data obtained SEPA (2010) Waste Data Digest 10: Online Excel Tables, 15th April 2010, data accessed on 7th January 2011, www.sepa.org.uk/waste/waste_data/waste_data_digest.aspx

Eight energy from waste/waste incinerator plants were in operation across Scotland in 2008 (Table 42). These plants received approximately 260,000 tonnes of waste in 2008, just under half of the total licensed capacity (this figure is lower than the total reported in Table 39, most likely because some waste was diverted for incineration in other commercial incinerators, such as cement kilns[143] and coal fired power stations).

Table 42: Waste Inputs to Energy from Waste (EfW) and Incineration Plants in Scotland (2008)

Operator organisation	Local authority	Licenced capacity (tpa)	Total waste handled (t)	
			Waste inputs	Output from site
Sacone Environmental (Glasgow) Ltd[1]	Angus	47,952	6,469	0
E.ON UK Renewables Limited	Dumfries & Galloway	150,000	43,256	265
Dundee Energy Recycling Ltd	Dundee	150,000	72,543	n/a
Inveresk Research International Ltd	East Lothian	2,160	449	n/a
EPR Scotland Limited	Fife	135,000	103,361	n/a
North East Incineration Services	Moray	24,400	12,137	0
Borders General Hospital NHS Trust	Scottish Borders	1,000	414	n/a
Shetland Islands Council	Shetland	26,000	21,715	5,489
Scottish Leather Group Ltd[2]	Renfrewshire	30,000	-	-
Joseph Mitchell (Letham) Ltd[2]	Angus	14,000	-	-
Total		*536,512*	*260,344*	*5,754*

Notes: 1. Taken over by JP Jess Environmental Ltd and closed in April 2010; 2. These operators were not in operation by the end of 2008

Source: SEPA, National Capacity Project 2008, data accessed 11th January 2011, www.sepa.org.uk/waste/waste_data/site_capacity__infrastructure/national_capacity_reports.aspx)

---

[142] Juma, M., Korenova, Z., Jelemensky, L. and Bafrnec (2007) Experimental Study of Pyrolysis and Combustion of Scrap Tire, *Polymers for Advanced Technologies*, Vol.18, No.2, pp.144-148.

[143] The company Lafarge, operating Scotland's only cement plant in Dunbar, claim to obtain 12% of their energy requirements from burning alternative fuels; see: Lafarge (2011) *Cement: Industry Ecology*, accessed on 12th January 2011, www.lafarge.com/wps/portal/4_3_6-Ecologie_industrielle. In 2009 the company reported obtaining 22% of its energy from the incineration of waste materials such as shredded tires, meat and bone meal, processed sewage pellets, waste derived liquid fuel, recovered fuel oil, and solid recovered fuel, this amounted to the incineration of 83,000 tonnes of waste across the UK - see Lafarge (2009) *2009 Sustainability Report*, report by Lafarge Cement UK, www.sustainablelafarge.co.uk/downloads/2009_sustainability_report.pdf.

Table 43: Waste Inputs to Incinerators and Co-incinerators in Scotland (2009)

Site Name	Licence Local Authority	Inputted waste (tonnes)[1]	Total ash arisings (tonnes)[2]	Waste incinerated
Borders General Hospital	Borders	460	n/a	Medical and mixed municipal waste
Charles River	East Lothian	158	n/a	Medical and mixed packaging waste
Dargavel EfW Facility	Dumfries and Galloway	562	83[3]	Mixed municipal waste, waste marked as hazardous, absorbents, and filter materials
Dundee Energy Recycling Ltd	Dundee	79,200	17,941[4]	Biomass, refuse derived fuel, medicines, fuel oils and diesel, paper and cardboard
EPR Westfield Biomass Plant	Fife	99,127	70,000[5]	Animal wastes and tissue
E.ON UK Plc, Stevens Croft	Dumfries and Galloway	45,423	n/a[6]	Biomass
Lafarge Cement UK Ltd	East Lothian	21,582	0[7]	End-of-life tyres, solvents and other mixtures
Lerwick Energy Recovery Plant	Shetland	22,061	4,180[8]	Mixed municipal waste, medical and animal tissue
Longannet Power Station	Fife	45,000	348,502[9]	Sewage sludge
North East Incineration Services	Moray	2,990	n/a[10]	Animal-tissue waste
Pet Crematorium	North Ayrshire	128	4.8[11]	Animal-tissue waste
SAC (Vet Science Division)	Highland	13	0.64[12]	Animal-tissue waste
Sacone Environmental Ltd	Angus	3,551	n/a[13]	Unspecified waste, animal-tissue waste
UPM Kymmene (UK) Ltd	North Ayrshire	27,075	23,000[14]	Waste wood, fibres and sewage sludge
Total		*≈ 347,329*	*≈463,711*	

Notes:

1. *Waste data obtained from SEPA, personal communication with Cindy Lee on 11th February 2011. Note also that this is waste inputs only, so the tonnage of coal combusted at Longannet Power Station is not included in this column but the ash arising from the combustion of the coal is included in the Total Ash Arisings column;*
2. *Total ash arisings includes ash derived from the incineration/combustion of non-waste materials (e.g. ash from the combustion of coal at the Longannet Power Station);*
3. *Value excludes 1.3 tonnes of ferrous metals removed from bottom ash (data provided by SEPA on 14th February 2011);*
4. *In 2009/10 Dundee Energy Recycling Ltd (DERL) produced 12,075 tonnes of incinerator bottom ash which was recycled into road aggregate; a further 3,832 and 2,034 tonnes of cyclone and filter ash, respectively, were landfilled (personal communication with Janet Weed of Dundee City Council on 21st February 2011);*
5. *All ash material is sold to Fibrophos for use as an agricultural fertiliser. In 2005/6 the reported 70,000 tonnes of product was sold. Reported that 85% of input materials sourced from a single long term provider (EPR (2011) Westfield Overview, accessed on10th February 2011, www.eprl.co.uk/assets/westfield/overview.html).*
6. *Not willing to provide data on ash arisings;*

7. *All ash materials are incorporated into cement products: personal communication with Lafarge's Environment Officer, Sharon Gardner, on 14th February 2011 and reported in: Lafarge (2009) 2009 Sustainability Report, report by Lafarge Cement UK, www.sustainablelafarge.co.uk/downloads/2009_sustainability_report.pdf;*
8. *Excludes 1,423 tonnes of ferrous metals removed from bottom ash (data provided by SEPA on 14th February 2011);*
9. *All PFA and FBA arisings in 2009: Scottish Power (2010) Longannet Power Station EMAS Statement 2009, EMAS report published by Longannet Power Station, www.spenergywholesale.com/userfiles/file/LongannetEMAS09.pdf). A large proportion of this material is used by ScotAsh for the production of construction materials. Note also that the input is waste only, so the tonnage of coal combusted at Longannet Power Station is not included but the ash arising from the combustion of the coal is included in the Total Ash Arisings column;*
10. *Company not willing to provide data on ash arisings;*
11. *Data provided by SEPA on 14th February 2011;*
12. *Data provided by SEPA on 14th February 2011;*
13. *Sacone Environmental Ltd was taken over by JP Jess Environmental Ltd and according to Green Alternatives to Incineration in Scotland (www.gainscotland.org.uk/facilities.shtml) the site was closed in April 2010;*
14. *Approximately 300,000 tonnes of biomass are incinerated annually with ±7,000 tonnes fly ash and ±16,000 tonnes bottom ash arising from these activities. The former is processed through liquid fermentation and the latter is used for engineering aggregates (personal communication with Eddie Reilly of UPM Caledonian Paper on 14th February 2011).*

A.9.9 Appropriate Levels of Taxation for Combustion Residues

Despite concerns raised about the treatment and disposal of ash wastes HM Treasury (HMT) and HM Revenue & Customs (HMRC) recently rejected a move to charge the standard landfill tax rate for various ash materials after a 2009 consultation with interested and affected parties.[144] Reporting on the outcome of the consultation it was stated that:

> *'The list of wastes that qualify for the lower rate will remain broadly the same as at present. This means, for example, that pulverised fuel ash landfilled in a mono-fill, incinerator bottom ash, used foundry sand, furnace slags and aluminium/ferric hydroxide wastes will all remain lower rated'.*[145]

According to David Fitzgerald of HMRC *'this group [of materials] was left largely untouched because existing/anticipated policy drivers weren't strong enough to force a significant change at this time'*. This would seem somewhat surprising given the contentious nature of incineration and the polarised arguments that have

[144] HMT and HMRC (2010) *Government Response to Modernising Landfill Tax Legislation*, report published by HM Revenue and Customs and the Treasury, March 2010, http://webarchive.nationalarchives.gov.uk/+/http:/www.hm-treasury.gov.uk/d/consult_landfill_tax_govt_response.pdf.

[145] *Ibid.*

developed around the subject. The only envisaged changes cover the criteria governing PFA disposal, which has reportedly been altered slightly to include materials arising from co-combustion with biomass and a requirement to dispose of the material in monocell landfills after 2012. According to David Fitzgerald, '*The monofill criterion is designed to encourage recovery – although, arguably, it will be of limited real impact because storage and recovery are now common practice in the sector'*.[146] This will certainly be true in Scotland where Scottish Power's two coal fired power stations already dispose of their un-recycled ash into onsite monocell sludge ponds.

The final outcome of the Treasury's consultation was published in April 2011 in a HMRC public notice *A General Guide to Landfill Tax.*[147] In this report it is stated that the *'lower rate [of tax] applies to those less polluting wastes'*. According to the consultation draft *'the overall purpose of the changes is to improve the [landfill] tax's environmental effectiveness and ensure that decisions about what to include in the lower rate are more transparent'*.[148]

Give the above discussions on the hazardous nature of bottom ash it would appear that the Treasury has not followed through with the aims of the consultation and have chosen to assume, contrary to the overwhelming evidence described above, that the material is inert. The argument developed here has explicitly shown that municipal waste streams contain significant amounts of organic and inorganic contaminants which after incineration remain associated with the residual ash materials. The accumulation of these elements in ash materials has led to numerous studies which have shown these materials to be hazardous. Indeed, what seems clear from the above discussion is that as the composition of residual waste changes, then obviously, so will the composition of bottom ash. Thus, it is believed that the best way to proceed is to assume that incinerator bottom ash is hazardous until it has been shown to be otherwise and that the rate of landfill tax reflects this. However, if there are uncertainties about the 'hazardous' nature of IBA, it is even more clear that the material is not inert, and again supports the argument that bottom ash from municipal incinerators should not be subject to the lower rate of tax.

With respect to furnace bottom ash, there are comparable levels of metals and other inorganic pollutants in the ash material, but no significant evidence was found with regards to the ecotoxicity of the material. Thus without further testing regimes it is not conclusive whether the material is hazardous, but the very presence of some heavy

[146] Personal communication with David Fitzgerald of HM Revenue and Customs (HMRC) on 16th February 2011.

[147] HM Revenue and Customs and HM Treasury (2011) *A General Guide to Landfill Tax*, April 2011, http://customs.hmrc.gov.uk/channelsPortalWebApp/channelsPortalWebApp.portal?_nfpb=true&_pageLabel=pageExcise_ShowContent&propertyType=document&id=HMCE_CL_000509#P1107_110788

[148] HM Treasury. (2010) *Landfill Tax: Criteria for Determining Material to be Subject to Lower Rate*, Draft Explanatory Note, Finance (No.2) Bill 2010, www.hm-treasury.gov.uk/d/consult_finbill_landfill_tax_criteria_for_determining_material_to_be_subject_to_lower_rate.pdf

metals, suggests that it is probably not inert. There is more evidence with regards to the presence of potentially ecotoxic pollutants in pulverised fuel (or fly) ash, especially when co-firing occurs, however, further research would be required in this area being suggesting a change to the classification of these materials as falling under the lower or standard rates.

The secondary benefits to increasing the costs of disposal of bottom ashes, especially IBA, include providing the economic stimulus for investment in recovery, as opposed to disposal, of the material. This is increasingly important as the composition of mixed waste streams includes many precious and rare earth metals, and as we have demonstrated, a significant proportion of these metals will transfer to the bottom ash. This aspect is further discussed in the following Section.