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EXIOPOL

A NEW ENVIRONMENTAL ACCOUNTING FRAMEWORK USING EXTERNALITY DATA AND INPUT-OUTPUT TOOLS FOR POLICY ANALYSIS

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Final report on waste management externalities in EU25 and report on disamenity impacts in the UK

Report of the EXIOPOL project

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Executive Summary

Overview

This report is the report of the EXIOPOL named “Final report on externalities associated with waste types and waste management practices and technologies used in the EU and selected non-EU countries”. The project has started in March 2007 and will run until March 2011.

This preliminary report is divided to seven distinctive chapters. In first part report explains implementation of IPA (Impact pathway approach) for waste management sector. In second, third and fourth chapter we have evaluated and compared the damage costs (“external costs”) of landfill, incineration and MBT of MSW, based on the latest results of ExternE [2004] and taking into account the relevant life cycle impacts, especially emissions avoided by recovery of energy and materials. The damage cost of incineration ranges from about 4 to +21 €/t waste, depending on the assumptions about energy recovery. The damage cost of landfills, around 10 to 13 €/t waste, is mostly due to greenhouse gases, evaluated here with a unit cost of 19 €/tCO_2 according to ExternE [2004]. In addition there may be amenity costs on the order of one €/t waste (highly variable with site and imposed only on the local population, thus to be internalized differently from air pollution). Unlike incinerators, the damage cost of landfill does not vary as much with type of energy recovery because in any case the amount recovered is relatively small.

The benefits of energy recovery from incinerators are largest if the heat can be used directly for process heat or district heating systems with sufficiently large constant load. Electricity production brings far lower benefits than heat because of the poor conversion efficiency of incinerator heat (compared to central station power plants).

The MBT techniques permits to cut sensibly the direct emissions by controlling the methane emissions in case of methanisation and by avoiding to burn fossil carbon. Depending on the technology, results can be negative external cost of 5.77 €/twaste in case of methanisation with energy recovery replacing gas and oil for heat and coal and oil for electricity. For composting, with energy consumption produced by gas and oil for heat and coal and oil for electricity, the external cost is evaluated to 3 €/ twaste.

The calculations are also performed for sewage sludge elimination by drying and co incineration. The results show that the drying phase is very important and the energy recovery option is very important in term of shifting the damage cost of this phase.

In fifth chapter we aggregate all damage from waste sector using GHG emissions and emissions of classical air polutants. Aggregation of impacts of waste management shows that waste sector is not to be omitted. Lookin on industrial sectors assessed in WP II.5.a results are very well comparable. Whole waste management sector in the EU in 2005 produced external costs totalling 2.7 bil. € (using scenario 21 €per ton of CO2ekv.). For example chemical industry in EU 27 produced in same year 3.6 bil. € of external costs.

Significant categories for the waste management are connected with methane emissions. This is where possibilities for improvement are readily available. Reducing methane emissions would reduce total external costs and as second benefit it would provide additional source of energy and therefore reduce external cost even more due to avoided external cost from classical fuels.

Chapter six focused on comparison between China and the EU. The burdens of waste in China and the EU are significant. China national municipal solid waste production takes a fast-growing trend, with the average annual growth rate of 4%. Appropriate management of the MSW has become more urgent. However, China's waste disposal still has a lot of serious problems, like the backward technologies, failure to meet the environmental standards, secondary pollutions, and etc. In fact, the existing waste disposal methods have caused serious pollutions on the surrounding soil, the groundwater and the surface water. In particular, the main waste disposal methods of China's most small cities are the simple landfill with little treatment or without any treatment, resulting in huge harmful gases and sewages as the secondary pollution, which has become a constraint for the local socio-economic development.

China and the EU both have significant amounts of legislation on waste management. The need for an appropriate waste hierarchy, founded on sound evaluation of waste management options is clear. The evidence shows that China still has significant environmental burdens from municipal solid waste management.

Last chapter of this report seeks to analyse the impact of two waste management facilities on the local inhabitants of Dudley in the UK by employing a choice experiment methodology. This methodology was conducted so as to assess any disamenity effects that may have been incurred as a result of four externalities – Noise, Smell, Traffic and Visual. Choice experiments have not previously been employed in this context and few stated preference studies exist on this type of impact.

The findings of this study suggest that the amenity impacts of the incinerator in Dudley may not be that large. The four attributes assessed do not seem to influence the choice patterns of individuals and the ASC was consistently negative and significant. These results appear positive for both waste management operators and waste policy makers – that incineration bears lower amenity effects than may be the case with e.g. landfill.

The study is able to identify certain levels of WTP when people are annoyed by attributes of the site. For instance those that are annoyed by the height of the chimney are willing to pay £3.69 for a 50% reduction. However, these people are relatively few in number in the sample in question. Overall most of the sample reported very low annoyance and exposure levels.

However whether these results are robust enough to infer similar results for other incinerators is as yet undecided. It should be noted that the site in question is a very small incinerator, the fifth smallest in the UK, in a rather industrial setting; therefore its marginal impact is further diminished, so the transferability of the results is questionable. Also, an incinerator has been present on the site for over 70 years; any habituation effect is likely to be strong.

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1 Impact Pathway Analysis

In this report the impact pathway analysis based on the latest update of ExternE project [2004] is presented and used to evaluate the external cost of the municipal solid waste elimination using either incineration, landfill or MBT (mechanical and biological treatment). Furthermore, first results are presented for sewage sludge elimination by drying and co incineration with municipal solid waste.

To calculate the damage costs one needs to carry out an impact pathway analysis (IPA), tracing the passage of a pollutant from where it is emitted to the affected receptors (population, crops, forests, buildings, etc.). The principal steps of an IPA can be grouped as follows:

- Emission: specification of the relevant technologies and pollutants, e. g. kg of NOx per tonne of waste emitted by an incinerator;
- Dispersion: calculation of increased pollutant concentrations in all affected regions, e. g. incremental concentration of ozone, using models of atmospheric dispersion and chemistry for ozone formation due to NOx (this step is also called environmental fate analysis, especially when it involves more complex pathways that pass through the food chain);
- Impact: calculation of the dose from the increased concentration and calculation of impacts (damage in physical units) from this dose, using a dose-response function, e. g. cases of asthma due to this increase in ozone;
- Cost: monetary valuation of these impacts, e. g. multiplication by the cost of a case of asthma.

The impacts and costs are summed over all receptors of concern; for the numbers presented here this includes the entire European continent. The result of an IPA is the damage cost per kg of emitted pollutant; multiplication by the emissions per tonne of waste yields the damage cost per tonne of waste. The steps of the IPA are described in the following section. The work involves a multidisciplinary system analysis, with inputs from engineers, dispersion modelers, epidemiologists, ecologists, and economists. The present report is based on the results of the ExternE project series of the EC [ExternE 2004], plus more recent updates for Hg and Pb.

The uncertainties are large [Rabl & Spadaro 1999, Spadaro & Rabl 2007a] and not all impacts can be quantified adequately. For example, the impacts of leachates from landfill are problematic because they involve scenarios about the future management of the site, more than 30 years after closure (the time limit for the responsibility of the owner under current EU legislation). However, current regulations for leachates are very strict and their impacts are more or less confined to the local zone of a few km; they are unlikely to make a significant contribution to the damage cost (unless a large aquifer can be contaminated). On the other hand, greenhouse gas emissions, especially CH4, from landfills are appreciable and their cost is comparable to the damage costs of incineration. The comparison turns out to hinge on the emissions avoided by recovery of energy and materials.

1.1 Dispersion of Pollutants and Exposure

The principal greenhouse gases, CO2, CH4 and N2O, stay in the atmosphere long enough to mix uniformly over the entire globe. No specific dispersion calculation is needed but the estimation of impacts is extraordinarily complex. Here we refer merely to the main authority, the Intergovernmental Panel on Climate Change [IPCC http://www.ipcc.ch]. For most other air pollutants, in particular PM10, NOx and SO2, atmospheric dispersion is significant over hundreds to thousands of km, so both local and regional effects are important. ExternE uses therefore a combination of local and regional dispersion models to account for all significant damages. The main model for the local range (< 50 km from the source) has been the gaussian plume model ISC [Brode & Wang 1992].

At the regional scale one needs to take into account the chemical reactions that lead to the transformation of primary pollutants (i.e. the pollutants as they are emitted) to secondary pollutants, for example the creation of sulfates from SO2. Here ExternE uses the Windrose Trajectory Model (WTM) [Trukenmüller and Friedrich 1995] to estimate the concentration and deposition of acid species. WTM is a user-configurable Lagrangian trajectory model, derived from the Harwell Trajectory model [Derwent and Nodop 1986]. The modeling of ozone is based on the EMEP MSC-W oxidant model [Simpson et al. 1992, Simpson and Eliassen 1997]. EMEP is the official model used for policy decisions about transboundary air pollution in Europe [http://www.emep.int].

The calculation of damage costs is carried out by means of the EcoSense software package [Krewitt et al 1995], an integrated impact assessment model that combines these atmospheric models with databases for receptors (population, land use, agricultural production, buildings and materials, etc.), dose-response functions and monetary values. There is also a simplified analysis tool, called RiskPoll (actually a package of several models with different input requirements), developed by J. Spadaro and freely available from www.arirabl.org or www.externe.info. It is based on the interpolation of EcoSense dispersion calculations, and with its simplest version yields damage costs that are typically within a factor of two to three of detailed EcoSense calculations for stack heights above 50 m. RiskPoll includes a module for the multimedia pathways of Fig.1.

Several tests have been carried out to confirm the accuracy of the EcoSense dispersion calculations. For example, we have verified the consistency between the Gaussian plume models ISC and ROADPOL [Vossiniotis et al 1996], and we have compared the concentrations predicted by EcoSense with measured data and with calculations of the EMEP program.

Whereas only the inhalation dose matters for PM10, NOx, SO2 and O3, toxic metals and persistent organic pollutants affect us also through food and drink. For these a much more complex IPA is required to calculate ingestion doses. Spadaro & Rabl [2004] have developed a model for the assessment of external costs due to the emission of the most toxic metals (As, Cd, Cr, Hg, Ni and Pb), as well as certain organic pollutants, in particular dioxins. It takes into account the pathways in Fig.1. This model is a generalization of the UWM described in Section 3.3. It is based mostly on transfer factors published by EPA [1998], with some supplemental data of IAEA [1994 and 2001]. These transfer factors account in a simple manner for the transport of a pollutant between different environmental compartments, for example the uptake by agricultural crops of a pollutant from the soil. The uncertainties are large, but at least one has approximate values for the pollutants of concern here.

A general result of this analysis is that when these pollutants are emitted into the air, the collective ingestion dose can be about two orders of magnitude larger than the collective dose by inhalation. Because nowadays most food is transported over very large distances, the total dose varies little with the site where these pollutants are emitted into the air (except due to the variation of agricultural crops with emission site). As far as damages are concerned, one has to note that the same dose can have a very different effect on the body depending on whether it is inhaled or ingested. Cd, CrVI and Ni, for instance, are according to current knowledge carcinogenic only through inhalation. The impact of metals also depends on the chemical speciation; for example methyl-Hg is far more toxic than Hg vapor.

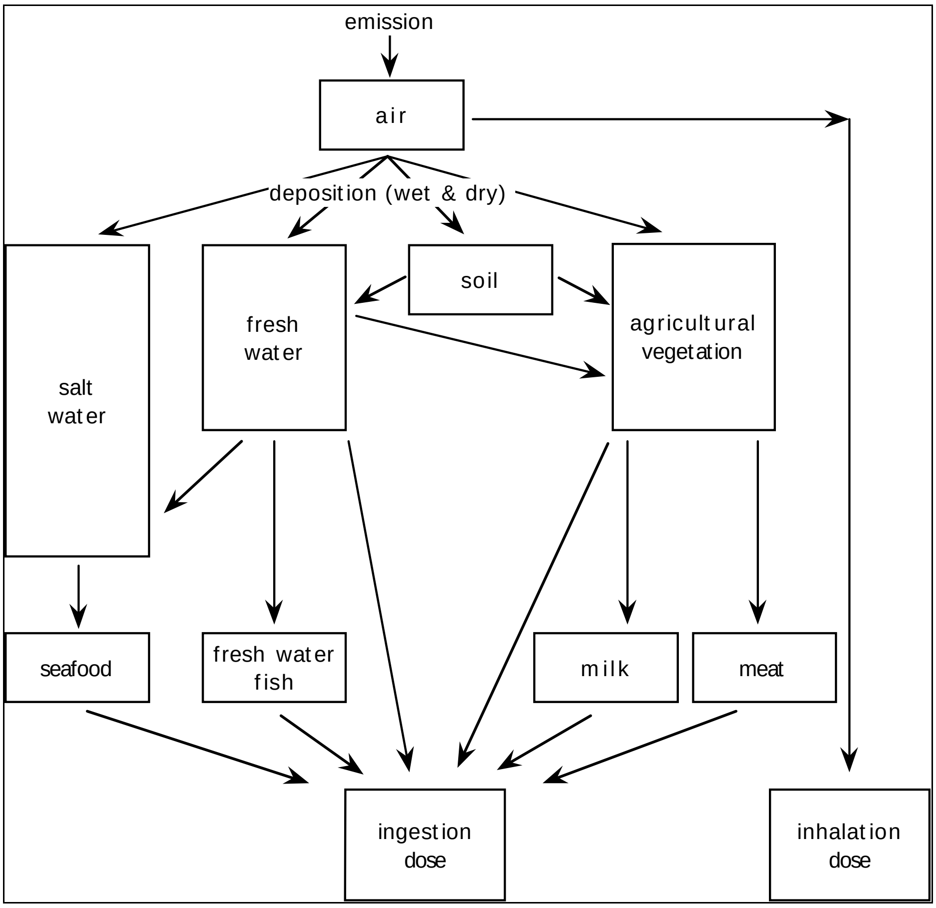


Figure 1: Pathways taken into account for health impacts of air pollutants. Direct emissions to soil or water are a special case where the analysis begins at the respective "soil" and "water" boxes.

1.2 Dose-response functions

1.2.1 General considerations

The dose-response function (DRF) relates the quantity of a pollutant that affects a receptor (e.g. population) to the physical impact on this receptor (e.g. incremental number of hospitalizations). In the narrow sense of the term, it should be based on the dose actually absorbed by a receptor. However, the term dose-response function is often used in a wider sense where it is formulated directly in terms of the concentration of a pollutant in the ambient air, accounting implicitly for the absorption of the pollutant from the air into the body. The functions for the classical air pollutants (NOx, SO2, O3, and particulates) are typically of the that kind, and the terms exposure-response function or concentration-response function (CRF) are often used.

The DRF is a central ingredient in the impact pathway analysis and merits special attention. A damage can be quantified only if the corresponding DRF is known. Such functions are available for many of the impacts on human health, building materials and crops, that can be caused by a range of pollutants, in particular primary and secondary (i.e. nitrates, sulfates) particles, ozone, CO, SO2, NOx, Benzene, benzo(a)pyrene, formaldehyde, dioxins, As, Cd, Cr, Hg, Ni and Pb. The most comprehensive reference for health impacts is the IRIS database of EPA [http://www.epa.gov/iriswebp/iris/index.html]. For the application in an IPA that information often has to be expressed in somewhat different form, including additional factors such as the background incidence rate [ExternE 1998, Spadaro & Rabl 2004]. Unfortunately, for many pollutants and many impacts the DRFs are very uncertain or not even known at all. For most substances and non-cancer impacts the only available information covers thresholds, typically the NOAEL (no observed adverse effect level) or LOAEL (lowest observed adverse effect level). Knowing thresholds is not sufficient for quantifying impacts; it only provides an answer to the question whether or not there is a risk. The principal exceptions are carcinogens and the classical air pollutants, for which explicit DRFs are known (often on the assumption of linearity and no threshold).

ExternE assumes that all DRFs for health impacts, including neurotoxic effects of Hg and Pb and cancers, are linear at the population level, in view of the lack of evidence for thresholds at current ambient concentrations (however, for Hg we assume a threshold equal to the RfD of EPA [Spadaro & Rabl 2007b]). By contrast to the homogeneous populations of cloned animals studied by toxicologists, the absence of a no-effect threshold is plausible for real human populations because they always contain individuals with widely differing sensitivities (for example, at any moment about 1% is within the last nine months of life and thus extremely frail). Note that for the calculation of incremental damage costs there is no difference between the linear and the hockey stick function (with the same slope), if the background concentration is everywhere above this threshold; only the slope sDR of the DRF matters. For the particles, NOx, SO2, O3 and CO the background in most industrialized countries is above the level where effects are known to occur. Thus the precise form of the DRF at extremely low doses is irrelevant for these pollutants; if there is a no-effects threshold, it is below the background concentrations of interest.

1.2.2 Health Impacts

In terms of costs, health impacts contribute the largest part of the damage estimates of ExternE. A consensus has been emerging among public health experts that air pollution, even at current ambient levels, aggravates morbidity (especially respiratory and cardiovascular diseases) and leads to premature mortality [e.g. Wilson & Spengler 1996, WHO 2003]. There is less certainty about specific causes, but most recent studies have identified fine particles (PM10 or PM2.5) as a prime culprit; ozone has also been implicated directly. The most important cost comes from chronic mortality due to particles, calculated on the basis of Pope et al [2002] (this term, chosen by analogy with acute and chronic morbidity impacts, indicates that the total or long term effects of pollution on mortality have been included, by contrast to acute mortality impacts that are observed within a few days of exposure to pollution). Another important contribution comes from chronic bronchitis due to particles [Abbey et al 1995]. In addition there may be significant direct health impacts of SO2, but for direct impacts of NOx the evidence is less convincing.

In ExternE the working hypothesis has been to use the CRFs for particles and for O3 as basis. Effects of NOx and SO2 are assumed to arise indirectly from the particulate nature of nitrate and sulfate aerosols, and they are calculated by applying the particle CRFs to these aerosol concentrations. But the uncertainties are large because there is insufficient evidence for the health impacts of the individual components or characteristics (acidity, solubility …) of particulate air pollution. In particular there is a lack of epidemiological studies of nitrate aerosols because until recently this pollutant has not been monitored by air pollution monitoring stations.

Among the toxic metals the following are considered carcinogenic: arsenic (As), cadmium (Cd), chrome (Cr, in oxidation state VI) and nickel (Ni). We use the DRFs published by the IRIS data base of EPA [http://www.epa.gov/iriswebp/iris/index.html]. For Pb we cite the damage cost due to IQ decrement as calculated by Spadaro & Rabl [2004]. More recently Spadaro & Rabl [2007b] have estimated the global contribution of IQ loss to the damage cost of Hg (the real damage for a specific site can be different because of local and regional variations that are much more difficult to estimate). Hg has a long residence time in the atmosphere, on the order of two years, and is therefore a globally dispersing pollutant; most of its health impacts arise after its transformation by aquatic organisms to methyl-mercury and its ingestion via seafood. We also consider dioxin, a pollutant emitted from the incineration of municipal solid waste. The calculation is documented in Rabl, Spadaro & McGavran [1998]. Note that the damage costs in the present paper are somewhat different from that reference, from Rabl & Spadaro [2002] and from Spadaro & Rabl [2004] because some of the DRFs (e.g. for dioxins) and monetary values have been updated.

1.3 Monetary Valuation

The goal of the monetary valuation of damages is to account for all costs, market and non-market. For example, the valuation of an asthma attack should include not only the cost of the medical treatment but also the willingness-to-pay (WTP) to avoid the residual suffering. It turns out that damage costs of air pollution are dominated by non-market goods, especially mortality. If the WTP for a non-market good has been determined correctly, it is like a price, consistent with prices paid for market goods. Economists have developed several tools for determining non-market costs. Of these tools contingent valuation (CV) has enjoyed increasing popularity in recent years [Mitchell & Carson 1989]. The results of well conducted studies are considered sufficiently reliable for informing public policy.

For the valuation of mortality a crucial parameter is the “value of a prevented fatality” VPF (which has usually been called “value of statistical life”, an unfortunate terminology for what is really the “willingness to pay for reducing the risk of an anonymous premature death”). In ExternE [1998], a European-wide value of 3.1 M€ was chosen for VPF, somewhat lower than similar studies in the USA; this value was chosen as average of the VPF studies that had been carried out in Europe. The uncertainty is large and one could argue for other values in the range of 1 to 5 M€. Currently ExternE uses 1 M€, based on a recent CV study by the ExternE team [Markandya et al 2004]; that is also the value recommended for air pollution deaths by the DG Environment of the European Commission [EC 2000b].

A key question for air pollution mortality is whether one should simply multiply the number of premature deaths by VPF, or whether one should take into account the years of life lost (YOLL) per death. The difference is very important because premature deaths from air pollution tend to involve far fewer YOLL per death than accidents (on which VPF is based) [Rabl 2003]. The ExternE [2004] numbers, used here, are based on YOLL, by contrast to most previous external cost studies (studies in the USA continue to use VPF, exclusively or in parallel with YOLL). There is considerable uncertainty about the relation between VPF (which has been determined for accidents) and the value of a life year (VOLY) appropriate for air pollution, because it involves the period at the end of life about which valuation studies are only just beginning. In ExternE [1998] the value of a YOLL had therefore been calculated on theoretical grounds by considering VPF as the net present value of a series of discounted annual values. The ratio of VPF and the value of a YOLL thus obtained depends on the discount rate; it is typically in the range of 20 to 40. More recently a CV study by ExternE found a VOLY of 50,000 € and that has been used for the current damage cost estimates [ExternE 2004].

For cancers the loss of life per premature death is intermediate between accidents and air pollution. But economists also assume a premium because cancers are feared as an especially dreadful form of death. Here we assume a value of 2.0 M€, averaged over fatal and non-fatal cancers. For neurotoxic impacts we take the value of an IQ point to be 10,000 €.

1.4 Global Warming

The valuation of global warming damages is extremely complex, see for example Tol et al [2001]. Not only is the task difficult because of the large number of different impacts in all countries of the world that should be taken into account, but as these impacts will occur in future decades and centuries one needs to estimate how these costs will evolve into the distant future. On top of the resulting uncertainties there are controversial ethical issues related to the valuation of mortality in developing countries (where most of the impacts will occur) and the choice of the discount rate for intergenerational costs.

Several major studies have been published with estimates of the damage cost per tonne of CO2eq; the subscript eq indicates that the result can also be used for other greenhouse gases if their masses are multiplied by their global warming potential (GWP). Most of the results are in the range of 1 to 50 €/tCO2eq, the range being so wide because of the large uncertainties. The ExternE team carried out two valuation efforts, the first, in 1998, yielded a range of values with a geometric mean of 29 □/tCO2eq, the second, in 2000, obtained a much lower value of 2.4 □/tCO2eq because of more optimistic assumptions and a better accounting for benefits such as increased agricultural production in cold countries. Because of the difficulty of determining the damage cost of CO2, the current phase of ExternE uses as proxy the abatement cost in the EU implied by the commitment to the Kyoto protocol, 19 □/tCO2eq. It thus represents an implicit valuation by decision makers of the EU. It is also in effect the cost imposed on the EU by incremental emissions of CO2 in the EU. Even though this is not the damage cost, the choice appears reasonable in view of the damage cost estimates published in the literature [Tol 2005].

1.5 Results per kg of Pollutant

1.5.1 Cost per kg of Pollutant

The impacts quantified by ExternE so far are global warming, health, damage to buildings and materials, and loss of agricultural production. Apart from global warming due to CO2, CH4 and N2O, more than 95% of the costs is due to health impacts, especially mortality. Morbidity (above all chronic bronchitis, but also asthma, work days lost, hospital admissions etc) account for almost 30% of the damage cost of PM10, NOx and SO2. The impacts evaluated and the key assumptions are listed in Table 1.

Table 1: Impacts evaluated and key assumptions. [ExternE 2004].

Atmospheric dispersion models	
Local range	Gaussian plume models ISC (point sources) or ROADPOL (emissions from transport)
Regional range (Europe)	Harwell Trajectory Model as implemented in ECOSENSE software of ExternE O_3 concentrations based on EMEP model
Physical impacts	
Impacts on health	
Form of dose-response functions	Linearity without threshold, with slope s_{CR}
Chronic mortality, YOLL (years of life lost)	s_{CR} = 3.9E-4 YOLL per person per year per μg/m^3 PM_{10}, derived from increase in age-specific mortality [Pope et al 2002] by integrating over age distribution
Acute mortality	For SO_2 and O_3, assume 0.75 YOLL per premature death
Nitrate and sulfate aerosols	Dose response function for sulfates same as for PM_{10} ($s_{CR,sulfate} = s_{CR,PM10} = 0.6\ s_{CR,PM2.5}$) Dose response function for nitrates: toxicity 50% of PM_{10} ($s_{CR,nitrate} = 0.5\ s_{CR,PM10}$)

Micropollutants	Cancers due to As, Cd, Cr, Ni, and dioxins DRF for dioxins according to EPA [2000] IQ decrement due to Hg and Pb
Impacts on plants	Loss of crops due to SO_2 and O_3
Impacts on buildings and materials	Corrosion and erosion due to SO_2 Soiling due to particles
Impacts not quantified but potentially significant	Reduced visibility due to air pollution Eutrophication and acidification Disposal of residues from fossil fuels or incineration
Monetary valuation	
Valuation of premature death	Proportional to reduction of life expectancy, with value of a of life year (VOLY) = 50,000 □
Valuation of cancers	2 M□ per cancer
Valuation of neurotoxicity	10,000 □ per IQ point lost
Global warming damage cost	0.019 □/kg_{CO2eq}

The resulting damage costs in □/kg of pollutant are shown in Table 2 for typical sources with stack height h above 40 m in Central Europe, as well as for road transport in France. The uncertainty is also indicated. Note that the damage costs are somewhat different from those published by previous phases of ExternE, because the methodology has been evolving.

Table 2: Damage cost and most important health impact (end point) per kg of pollutant. For PM, NOx and SO2 morbidity impacts account for about 30% of the damage cost. h = stack height.

Pollutant	□/kg [range]	% due to end point	□/end point	Impact/kg
Traffic, h=0m				
PM2.5, rural	1.52E+01 [2.8E+00, 2.5E+01]	68%	50000	2.1E-04 YOLL/kg
PM2.5, highway	1.15E+02 [2.1E+01, 1.9E+02]	68%	50000	1.6E-03 YOLL/kg
PM2.5, Paris	1.58E+03 [2.9E+02, 2.6E+03]	68%	50000	2.1E-02 YOLL/kg
Stacks, h=100m				
PM10, rural	5.2E+00	68%	50000	7.1E-05 YOLL/kg

	[9.5E-01, 8.5E+00]			
PM10, urban	1.2E+01 [2.1E+00, 1.9E+01]	68%	50000	1.6E-04 YOLL/kg
PM10, Paris	6.2E+01 [1.1E+01, 1.0E+02]	68%	50000	8.5E-04 YOLL
Cd	3.9E+01 [7.1E+00, 6.4E+01]	100%	2000000	2.0E-05 cancers/kg
CrVI	2.0E+02 [3.7E+01, 3.3E+02]	100%	2000000	1.0E-04 cancers/kg
Ni	3.8E+00 [6.9E-01, 6.2E+00]	100%	2000000	1.9E-06 cancers/kg
Little h dependence				
SO2, via sulfates	3.5E+00 [6.4E-00, 5.7E-00]	68%	50000	4.8E-05 YOLL/kg
NO2, via nitrates	3.4E+00 [6.1E-01, 5.5E+00]	68%	50000	4.6E-05 YOLL/kg
As	8.0E+01 [7.7E+00, 1.2E+02]	100%	2000000	4.0E-05 cancers/kg
Pb	6.0E+02 [5.7E+01, 9.2E+02]	100%	10000	6.0E-02 IQ points/kg
Hg	8.0E+03 [7.7E+02, 1.2E+04]	100%	10000	8.0E-01 IQ points/kg
Dioxins	1.85E+08 [1.0E+07, 2.5E+08]	100%	2000000	9.3E+01 cancers/kg
No h dependence				
CO2	1.9E-02 [6.4E-04, 2.3E-02]			

To estimate results for other regions, simply rescale the numbers in proportion to the regional average receptor density ρ (within 1000 km) and the cost per case (if different). As for variation with site and stack height, the following can be said:

- There is no dependence on site or stack height for globally dispersing pollutants such as CO2. For As, Hg, Pb and dioxins the variation with site, for a given ρ, is in the range of about 0.5 to 2.0, small because non-inhalation pathways dominate. Variation with site, for a given ρ, is also small for secondary pollutants, a range of about 0.5 to 2.0 because the formation of the secondary pollutants is slow and occurs mostly far from the source. Variation with stack height is negligible for non-inhalation pathways and for secondary particles (nitrates and sulfates).

- For primary air pollutants the variation with site and stack height is strong and the result of Duni (see Section 3.3) can be improved by using the following correction factors:

0.5 to 5 for site (higher if near big city),

0.6 to 3 for stack conditions (higher for low stacks, up to 15 for ground level emissions in big city).

These correction factors have been derived by evaluating the results of more than a hundred detailed EcoSense calculations. Of course, such rules can only yield rough estimates; site-specific calculations should be carried out when more precise results are needed.

1.5.2 Health Risks per kg of Pollutant

Sometimes a decision maker may prefer to see results in terms of YOLL (years of life lost) rather than costs in order to make risk-risk comparisons which avoid the uncertainties of monetary valuation. Therefore we also show in Table 2 the dominant health impacts in physical units per kg of pollutant.

1.6 UWM: a Simple Model for Damage Cost Estimation

A simple and convenient tool for the development of typical values is the "uniform world model" (UWM), first presented by Curtiss & Rabl [1996] and further developed, with detailed validation studies, by Spadaro [1999], Spadaro and Rabl [1999] and Spadaro & Rabl [2002]. More recently Spadaro & Rabl [2004] have extended it to toxic metals and their pathways through the food chain. The UWM is a product of a few factors; it is simple and transparent, showing at a glance the role of the most important parameters of the impact pathway analysis. It is exact for tall stacks in the limit where the distribution of either the sources or the receptors is uniform and the ratio of surface concentration and deposition (and/or transformation) rate does not vary with location. In practice the agreement with detailed models is usually within a factor of two for stack heights above 50 m. For policy applications one needs typical values and the UWM is more relevant than a detailed analysis for a specific site.

The UWM for the damage cost Duni in □/kg of a particular impact due to the inhalation of a primary pollutant is shown in Eq.1

$$\text{Duni} = p \ \text{sCR} \ \rho/\text{vdep} \qquad (1)$$

where

p = cost per case ("price") [□/case],

sCR = CRF slope [(cases/yr)/(person•(υg/m3))],

ρ = population density [person/km2] averaged over land and water within approximately 1000 km of source, and

vdep = deposition velocity of pollutant (dry + wet) [m/s].

For secondary pollutants the equation has the same form, but with an effective deposition velocity that includes the transformation rate of the primary into the secondary pollutant. With this model it is easy to transfer to the results from one region to another (assuming that CRF and deposition velocity are the same): simply rescale the result in proportion to the receptor density and the cost per case.

2 Comparison Landfill vs. Incineration

2.1 Assumptions

Since a comparison of different waste treatment options necessitates an LCA, the work begins by choosing the boundaries of the analysis. The most appropriate choice is to start at the point where the waste has been collected and sorted. From here the waste must be transported to the landfill or incinerator; we have included the emissions due to transport by showing a hypothetical round trip distance of 100 km, for the purpose of illustration. In addition to the emission of pollutants from the landfill or incinerator, the emissions avoided by recovery of energy and materials are also taken into account, based on the LCA data of ADEME [2000]. The main assumptions of the analysis are summarized in Table 3.

Table 3: Assumptions of the analysis of incineration and landfill ofMSW.

Stages taken into account	Construction of landfill or incinerator (negligible); Transport of waste (negligible); Emissions from landfill or incinerator; Avoided emissions due to energy recovery; Avoided emissions due to materials recovery.
Emissions from incinerator	Equal to limit values of Directive EC [2000a] [a]
Avoided emissions due to energy recovery	Equal to limit values of Large Combustion Plant Directive [EC 2001] [a]
Impact pathway analysis	Assumptions and results of ExternE [2004], see Tables 1 and 2.
Impacts that have been quantified	Human health; Crops; Materials and buildings; Global warming; Amenity impacts (very site specific, not included in results, only order of magnitude is indicated in text, based

	on Walton et al [2006]).
Impacts that have <u>not</u> been quantified	Effects of air pollutants on ecosystems; Reduction of visibility due to air pollution; Soil and water pollution due to leachates (but shown not to be of concern, see Section 4.2); Impacts from residues of incineration.

[a] in reality the average emissions are usually lower.

We have explicitly quantified the impacts of the stages in Table 3, with the exception of the construction of the landfill or incinerator. For the latter we merely refer to the LCA of power plants carried out by ExternE, where the emissions from construction (due to materials production) were found to be about three orders of magnitude smaller than those during operation. That holds also for other combustion equipment that is used full time, in particular for waste incinerators. With landfills the impacts of construction are also negligible compared to the utilization stage.

We assume that the incinerator emissions are equal to limit values of Directive EC [2000a]; in reality the average emissions are usually lower if compliance is enforced but representative data are difficult to obtain. Our assumptions for the emissions from incinerators are listed in Table 4.

Table 4: Assumptions for the emissions from incineration of MSW[1].

Pollutant	**mg/Nm³**	**g/t$_{waste}$**	**□/kg$_{polluant}$**	**□/t$_{waste}$**
PM_{10}	10	51.5	12	0.62
SO_2	50	258	3.5	0.88
NO_2	200	1030	3.4	3.61
CO_2		861800	0.019	15.33
As (2.8% of 0.5mg/Nm^3)	0.014	0.072	80	0.01
Cd (81.2% of 0.05mg/Nm^3)	0.0406	0.21	39	0.01
Cr^{VI} (6.5% of 0.2*0.05mg/Nm^3) [a]	0.00065	0.0033	200	0.00
Hg (0.05mg/Nm^3)	0.05	0.26	8000	2.06
Ni (33.8% of 0.5mg/Nm^3)	0.169	0.87	3.8	0.00
Pb (22% of 0.5mg/Nm^3)	0.11	0.57	600	0.34

[1] They are taken as the limit values of the flue gas concentrations, in Directive EC [2000a], assuming 5150 Nm3/twaste. For metals the directive specifies only 0.5mg/Nm3 for the sum of As+Co+Cr+Cu+Mn+Ni+Pb+Sn+Sb+V, and 0.05mg/Nm3 for the sum of Cd+Tl; for the % within these sums we follow ETSU [1996].

Dioxins	1.00E-07	5.15E-07	185000000	0.10

[a] assuming that 20% of Cr from incinerators is CrVI

Part of municipal solid waste is of biological origin and its combustion emits CO2. In the LCA community a special convention has been established according to which such CO2 emission should not be counted. The accounting framework of ExternE, by contrast, assigns the same damage cost per kg of emitted CO2, regardless of its origin. We follow ExternE, arguing that the convention of current LCA practice is inappropriate because it fails to distinguish different options for reducing the emission of such CO2. The logic of such a practice would imply absurd conclusions, for instance that the burning of tropical forests be counted the same way as their preservation, and that adding carbon capture and sequestration to a biomass fueled power plant would have no benefit for global warming.

The principal emissions from landfill are CH4 and CO2. Fig.2 shows the total greenhouse gas emissions of a municipal solid waste landfill versus time. CH4 is expressed as equivalent CO2, using a GWP (global warming potential) of 23 [IPCC 2001]. Note that a modern landfill is divided into a large number of individual compartments; they are filled one after another and sealed when full. The data of ADEME [2003] are plotted in Fig.2, where the time is measured from the date that a compartment is sealed. In practice it is impossible to capture all of the CH4, and capture rates around 70% are commonly assumed (although measured data seem to be difficult to find). Here we assume a capture rate of 70% for the first 45 years, on average, after closure of a compartment; after 45 years we assume that all the remaining CH4 escapes to the atmosphere.

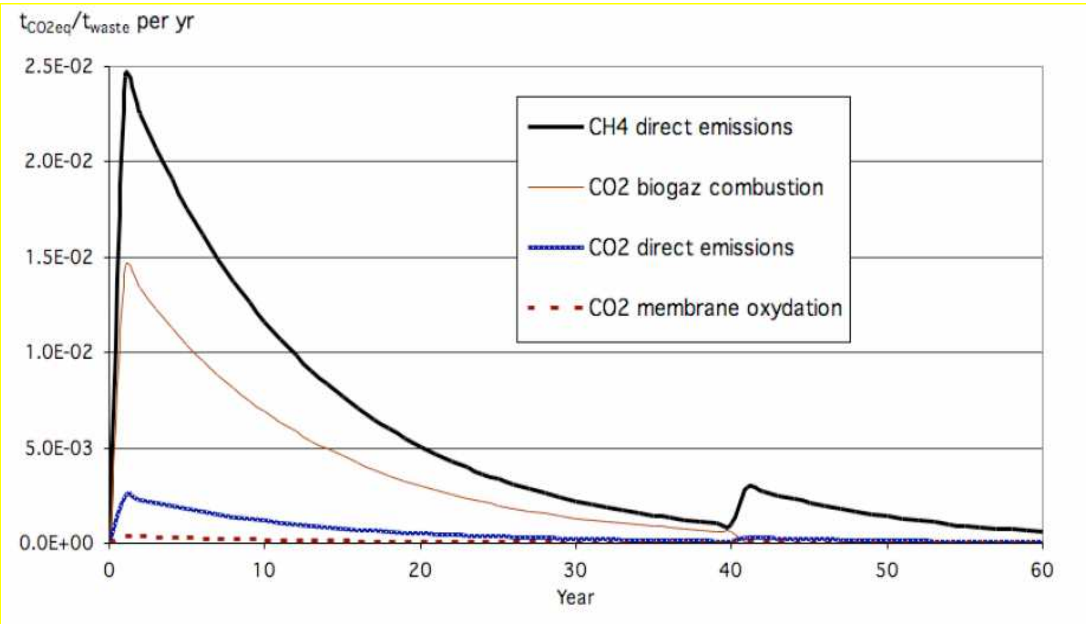


Figure 2: Greenhouse gas emissions from a municipal solid waste landfill versus time, tCO2eq/twaste if 70% of the CH4 is captured. Based on ADEME [2003].

2.2 Results for Damage Cost per Tonne of Waste

A summary of the total damage cost for all the options is shown in Fig.3. More detailed results for some of the options can be found in Fig.4, showing the contribution of each stage and of the major pollutants (dioxins and toxic metals are shown as “Trace”). The benefits of materials recovery make a small or negligible contribution to the total damage cost. The damage costs of waste transport, illustrated with an arbitrary choice of 100 km roundtrip by a 16 tonne truck, are also negligible. The only significant contributions come from direct emissions (of the landfill or incinerator) and energy recovery.

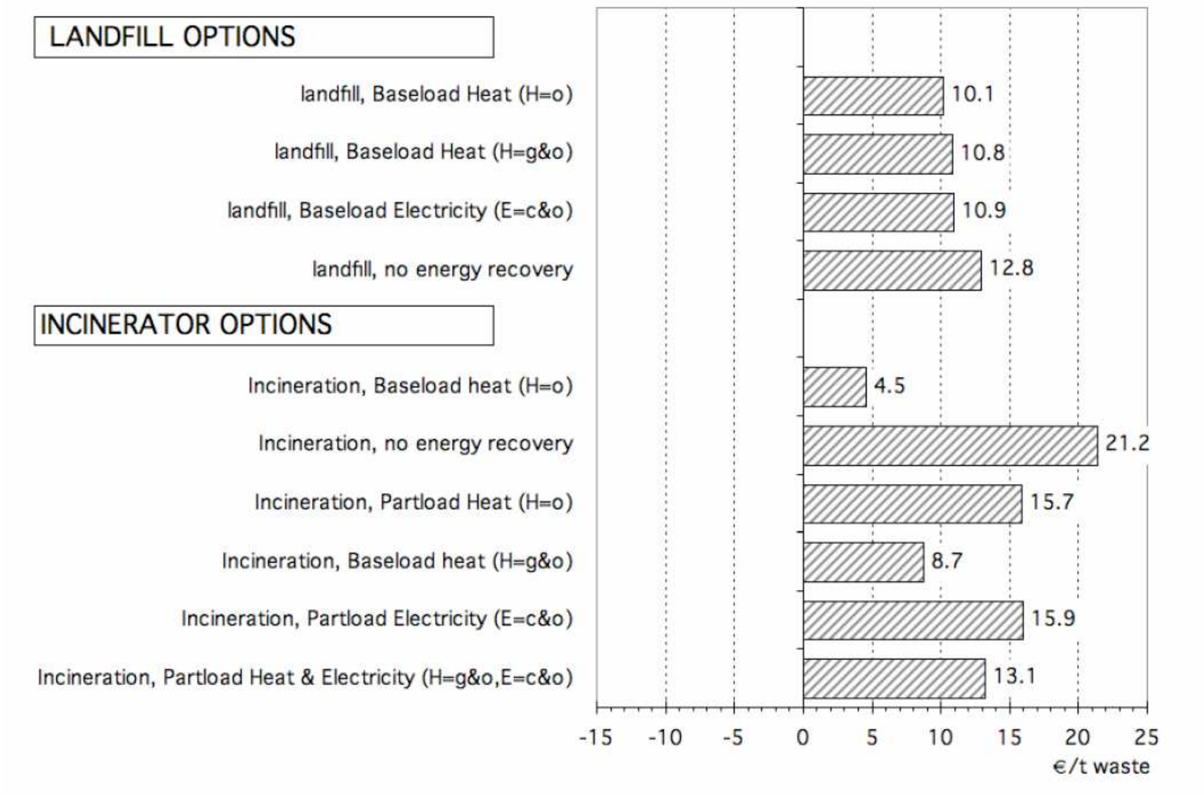


Figure 3: Results for total damage cost for all options. If electricity displaces nuclear, damage costs are essentially the same as for the case without energy recovery. Amenity costs are not included; they are very site-specific and could make a contribution on the order of one €/t waste.

The total cost of incinerator emissions is 22.9 €/twaste as can be seen by adding the last column of Table 4. Most of that is due to PM, NOx, SO2 and CO2. Toxic metals and dioxins, shown in Fig.4 as “Trace”, contribute only 2.5 €/twaste, mostly because of Hg and Pb. The contribution of dioxins is negligible, only 0.1 €/twaste, thanks to the low emission limit of the Directive EC [2000a].

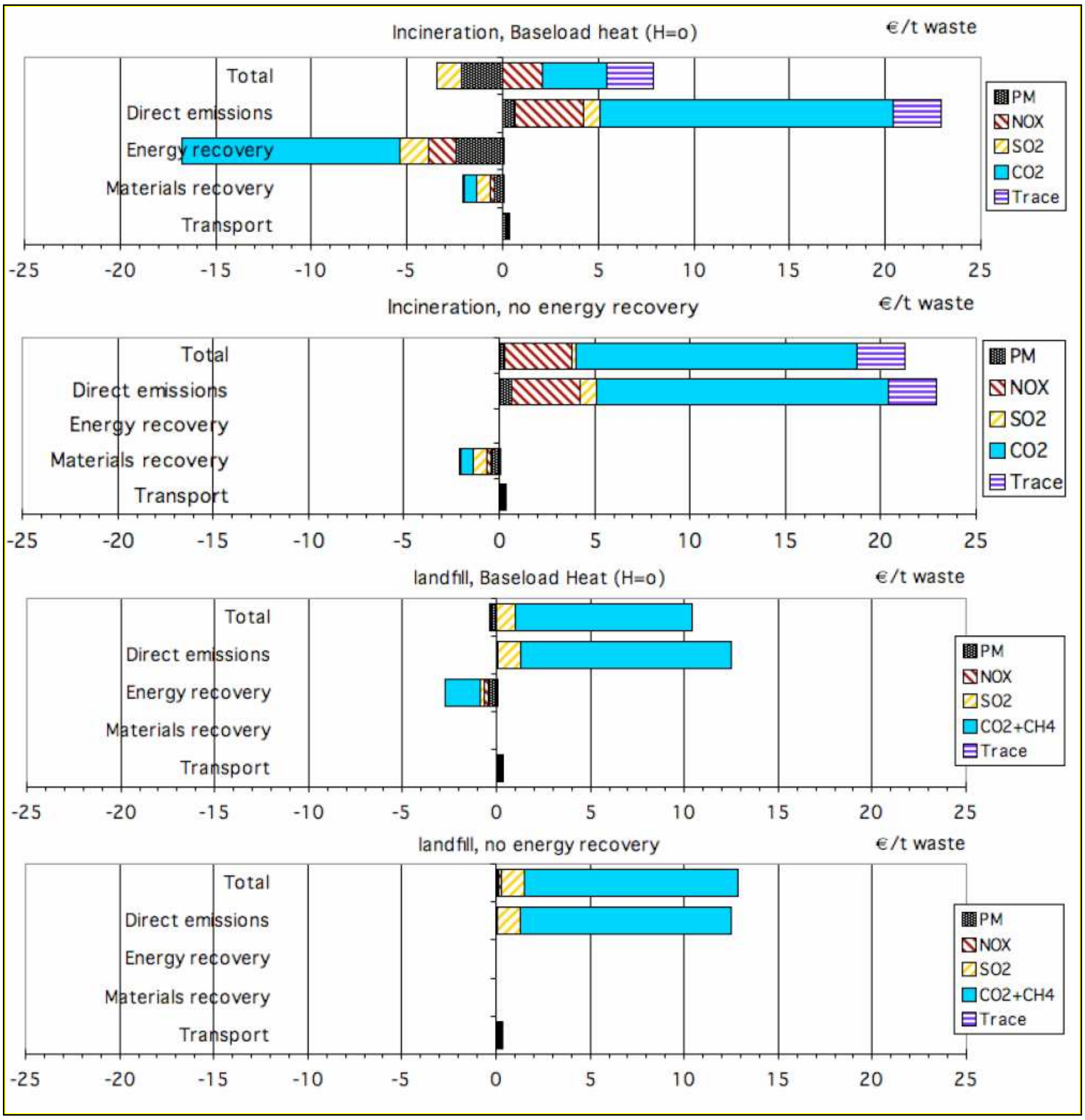


Figure 4: Some detailed results, by stage and pollutant. "Trace" = dioxins and toxic metals.

For landfill the cost is dominated by greenhouse gas emissions because only about 70% the CH4 can be captured. Energy recovery from a landfill is not very significant (and because of NOx from the electricity production, this option increases the damage cost if the electricity displaces nuclear). By contrast, energy recovery is crucial for the damage cost of incineration. Under favorable conditions (all heat produced by incinerator displaces coal and oil) the total external cost can even be negative, i.e. a net benefit. By contrast to most other countries, in France recovery of electricity does not bring significant benefits, because it is base load power and all the base load power is produced by nuclear; the options where it displaces coal or oil are not realistic in France (except near the border where the power can be exported) because these fuels are used only during the heating season. In any case, electricity production brings far lower benefits than heat because of the poor conversion efficiency of incinerator heat (compared to central station power plants).

3 Sewage sludge treatment by drying and MSW co incineration

3.1 Assumptions

The work begins by choosing the boundaries of the analysis. The most appropriate choice is to start at the point where the sludge has been produced and mechanically dewatered at the water treatment plant. From here the humid sludge is dried in a gas fired drier from where it is transported to the MSW incinerator; we have included the emissions due to transport by showing a hypothetical round trip distance of 40 km, for the purpose of illustration. At the incinerator level, it is assumed that the co incineration does not imply any modification of the emissions which correspond to the standard level ones. In addition to the emission of pollutants from the incinerator, the emissions avoided by recovery of energy and materials are also taken into account, based on the LCA data of ADEME [2000]. The main assumptions of the analysis are summarized in Table 5.

Table 5: Assumptions of the analysis of co incineration of dried sewage sludge.

Stages taken into account	Transport of sludge (negligible); Emissions from drier and incinerator; Avoided emissions due to energy recovery; Avoided emissions due to materials recovery.
Emissions from gas drier	Equal to limit values of Large Combustion Plant Directive [EC 2001] [a]
Emissions from incinerator	Equal to limit values of Directive EC [2000a] [a]
Avoided emissions due to energy recovery	Equal to limit values of Large Combustion Plant Directive [EC 2001] [a]
Impact pathway analysis	Assumptions and results of ExternE [2004], see Tables 1 and 2.
Impacts that have been quantified	Human health; Crops; Materials and buildings; Global warming; Amenity impacts (very site specific, not included in results, only order of magnitude is indicated in text, based on Walton et al [2006]).
Impacts that have <u>not</u> been quantified	Effects of air pollutants on ecosystems; Reduction of visibility due to air pollution; Impacts from residues of incineration.

[a] in reality the average emissions are usually lower.

We assume that the sewage sludge heavy metal contents and pathogens concentrations are equal to limit values of Directive EC [2005].

3.2 Results for Damage Cost per Tonne of dry sewage sludge

A summary of the total damage cost for all the options is shown in Fig.5. More detailed results for some of the options can be found in Fig.6, showing the contribution of each stage and of the major pollutants (dioxins and toxic metals are shown as “Trace”). The damage costs of sludge transport, illustrated with an arbitrary choice of 40 km roundtrip by a 16 tonne truck, are also negligible. The only significant contributions come from direct emissions (of the drier and incinerator) and energy recovery.

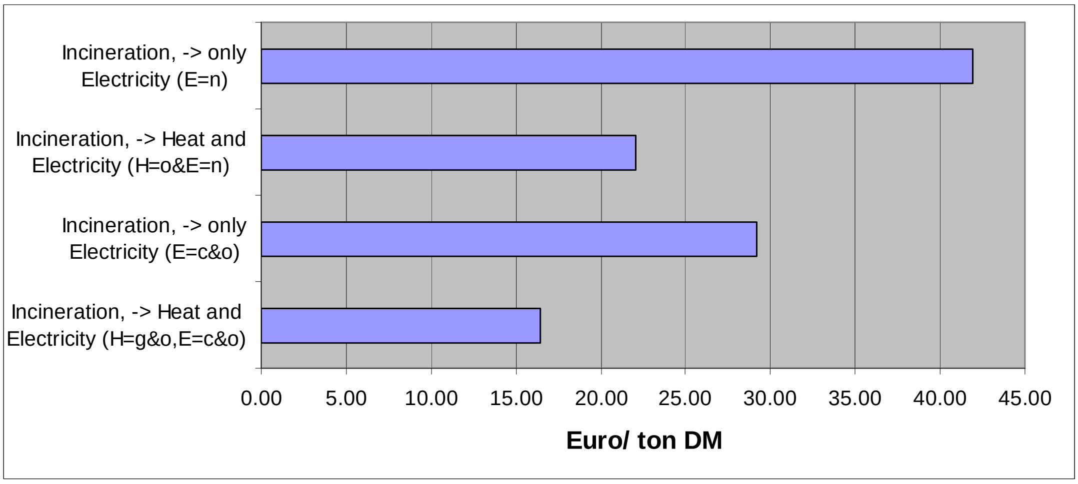


Figure 5: Results for total damage cost for all options. If electricity displaces nuclear, damage costs are essentially the same as for the case without energy recovery. Amenity costs are not included; they are very site-specific and could make a contribution on the order of one □/tsludge.

The total cost of sewage sludge elimination ranges from 16 to 41 □/tDM as it can be seen in figure 5. Most of that is due to PM, NOx, SO2 and CO2. Energy recovery option is a key point for shifting the drying emissions as shown in figure 6.

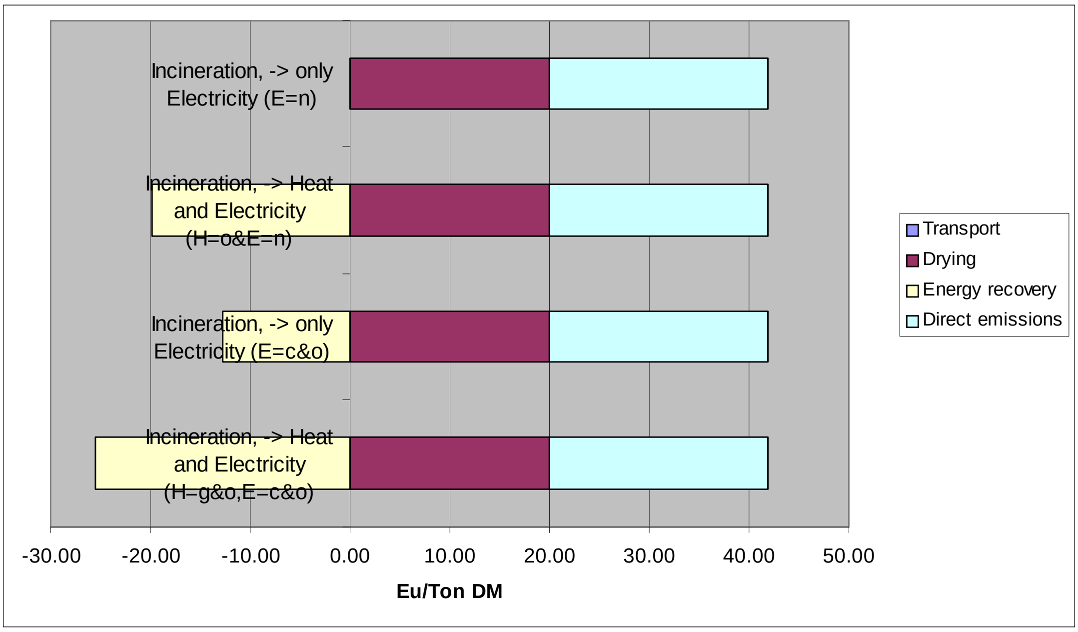


Figure 6: Detailed results for total damage cost for all options. If electricity displaces nuclear, damage costs are essentially the same as for the case without energy recovery. Amenity costs are not included; they are very site-specific and could make a contribution on the order of one □/tsludge.

4 MBT (mechanical and biological treatment): methanisation and composting

4.1 Assumptions

The MBT (mechanical and biological treatment) technique is a general concept were integrated operations helps to improve both the energy and material performance of waste treatment. Many variants exists were differences are linked to economy (e.g. difference between methanisation and composting) or to the end use of the treated waste (e.g. soil organic amendment or landfill).

Figure 7 shows the steps followed by MBT treatment techniques as considered in this work.

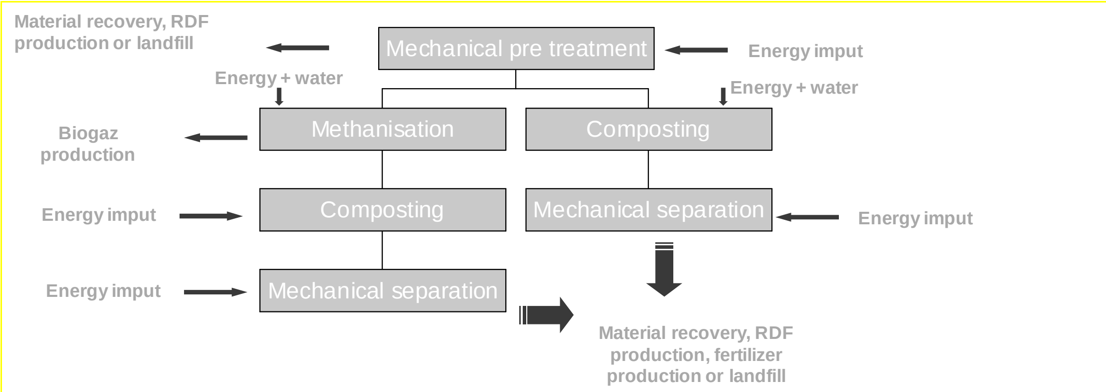


Figure 7: Steps taken into account for the evaluation of MBT techniques

In this work, two possible paths are considered. The first one were two biological steps are present: anaerobic phase with biogas production followed by an aerobic with compost production. The second path has only an aerobic phase producing compost.

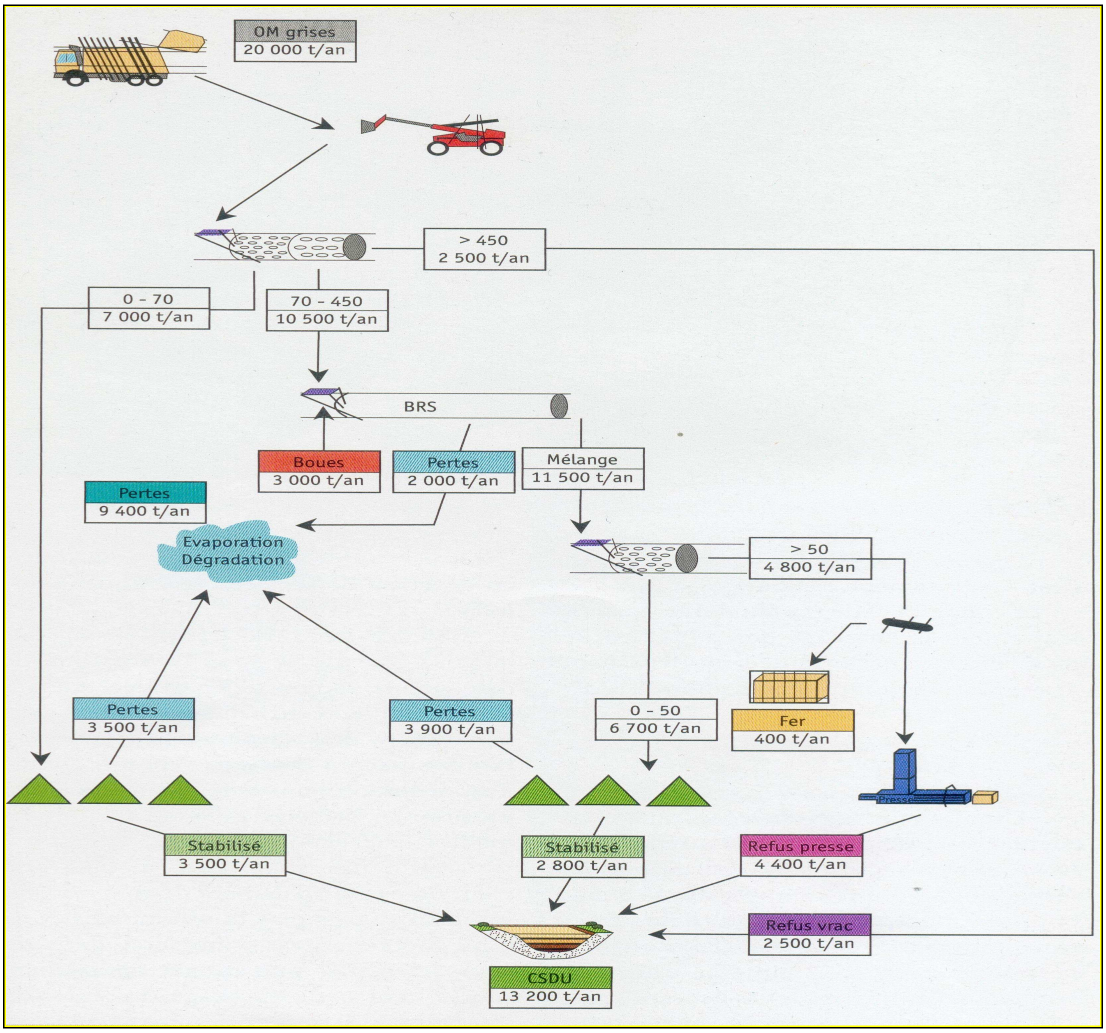


Figure 8: Mass balance of the Mende site in France

Depending on the second mechanical separation quality and on the need for fertilizer for green spaces, the final destination of the residual compost can be either green spaces or landfill. Metals are recovered both on the first mechanical separation step and on the second one. Plastics can be recovered as RDF also in both mechanical separation steps.

Figure 8 shows the mass balance for the site of Mende in France. This site is designed to operate a single aerobic biological step. The mechanical separation steps, before and after the composting process, permit to recover metals. The plastics and the compost coming out of this process are sent to landfill.

Diaz and Warith (2006), established an LCA for the composting process. Data for the biological evolution of waste and reactor electricity and fuel consumption are given in the table 6.

Table 6: LCA of the composting process. (Diaz and Warith, 2006)

	Parameter	Unit	Reference
Degradable organic carbon[a]	17	%	IPCC (1996)
Conversion[b]	400	kg/tonne waste	Woodrising Inc. (1999)
Residue	5	% total waste	Baky and Eriksson (2003)
Carbon storage	0.183	Tonne CO_2/tonne waste	EPA (2002)
NH_3emissions	0.38	kg/tonne waste	Baky and Eriksson (2003)
VOC emissions	1.7	kg/tonne waste	Baky and Eriksson (2003)
CH_4 emissions	0	% total DOC	Baky and Eriksson (2003)
Open windrow compost			
Electricity consumption	0	MJ/tonne waste	Baky and Eriksson (2003)
Diesel consumption	1.51	MJ/tonne waste	Baky and Eriksson (2003)
Compost gas cleaning	No		Baky and Eriksson (2003)
Reduction of NH_3	0	%	Baky and Eriksson (2003)
Reduction of NO_x	0	%	Baky and Eriksson (2003)
Reduction of CH_4	0	%	Baky and Eriksson (2003)
Reactor compost			
Electricity consumption	180.1	MJ/tonne waste	Baky and Eriksson (2003)
Diesel consumption	75.51	MJ/tonne waste	Baky and Eriksson (2003)
Compost gas cleaning	Yes		Baky and Eriksson (2003)
Reduction of NH_3	99.1	%	Baky and Eriksson (2003)
Reduction of NO_x	90	%	Baky and Eriksson (2003)
Reduction of CH_4	50	%	Baky and Eriksson (2003)

[a] Degradable carbon content in the organic waste fraction.
[b] Compost yield per tonne of waste composted.

Even though in the case of incineration the materials recovery impact was found negligible compared to direct emissions impact, the reduction of direct emissions in the case of MBT will lead to a more important weight for that impact. For the evaluation of its impact, LCA data of recovered materials (metals and glass) are taken from (Haight, 2004) and are given in table 7.

Table 7: LCA of metal and glass recycling. (Haight, 2004)

Parameter	Aluminium		Ferrous metal		Glass	
	Virgin	Recycled	Virgin	Recycled	Virgin	Recycled
Energy (GJ)	140.00	11.70	25.20	9.43	14.10	9.23
Air emissions						
CO_2	2900.00	4.36	1820.00	595.00	632.00	278.00
PFC (CO_2 eq.)	2226.00	0.00	0.00	0.00	0.00	0.00
CH_4	6.53	2.71	0.0097	1.29	1.11	0.83
NO_x	17.30	0.62	2.76	1.77	2.73	1.69
VOCs	24.50	0.30	0.23	0.02	0.24	0.17
SO_x	47.60	2.88	5.11	2.98	4.37	3.11
PM	10.00	0.00	1.31	7.22	0.89	0.43
Pb	1.93×10^{-3}	0.38	7.60×10^{-4}	6.59×10^{-4}	5.01×10^{-6}	1.15×10^{-6}
Hg	n/a	n/a	n/a	n/a	1.30×10^{-6}	3.00×10^{-7}
Cd	n/a	4.37×10^{-5}	n/a	n/a	1.35×10^{-5}	2.95×10^{-6}
HCl	0.81	5.81×10^{2}	8.57×10^{-2}	0.10	5.96×10^{-2}	0.98
TCDD Eq.	n/a	n/a	n/a	n/a	n/a	n/a
Water emissions						
Pb water	1.47×10^{-7}	0.00	2.92×10^{-2}	2.90×10^{-2}	3.60×10^{-8}	1.90×10^{-8}
Hg water	0.00	0.00	n/a	n/a	2.55×10^{-8}	1.95×10^{-8}
Cd water	0.24	0.06	9.75×10^{-5}	9.38×10^{-5}	2.20×10^{-4}	2.55×10^{-4}
TCDD Eq. W	1.20×10^{-6}	4.42×10^{-8}	n/a	n/a	n/a	n/a
BOD	n/a	n/a	n/a	n/a	6.9×10^{-3}	5.1×10^{-3}

For options, composting or methanisation, the LCA data permitted to calculate per Ton of waste the energy consumption and production. The tables 8 and 9 summarize these results and give the assumptions that permitted to reach these values.

Table 8: Mass balance, energy consumption and energy production of the methanisation process

Screened %	48%
Biodegradable%	53%
Methane fraction (Nm3/t waste)	63
Biogenic CO2 (Nm3/t waste)	42
PCI (MJ/Nm3)	35,8
Energy content (MJ/t waste)	2254,4
Electrical efficiency %	33
Heat recovery %	52
Electricity production (kWh/t waste)	206,7
Heat produced (kwh/t waste)	325,6
Consumed electricity (kWh/t)	26,3
Consumed heat (kWh/t)	93,9

Table 9: Mass balance and energy consumption of the composting process

Screened %	48%

Biodegradable%	53%
Methane fraction (Nm3/t waste)	0
Biogenic CO2 (Nm3/t waste)	105
Consumed electricity (kWh/t)	26,3
Consumed heat (kWh/t)	11,0

4.2 Results for Damage Cost per Tonne waste

The same scenarios, as in the case of the landfill and incineration, for the electricity and heat production mix are considered A summary of the total damage cost, with the different contributions, for all the options are shown in Fig.9 and 10.

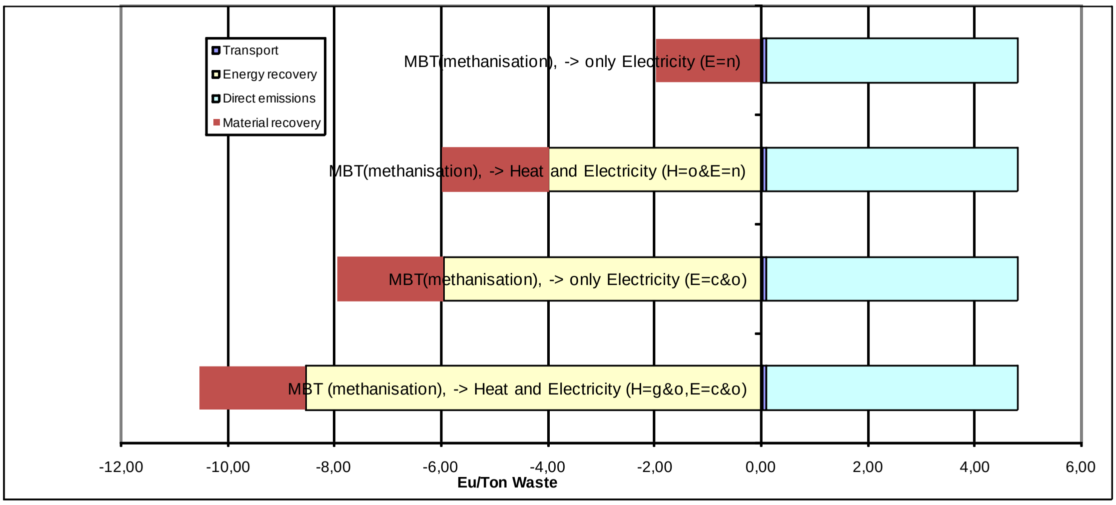


Figure 9: Detailed results for total damage cost of MBT with methanisation for all options. If electricity displaces nuclear, damage costs are essentially the same as for the case without energy recovery.

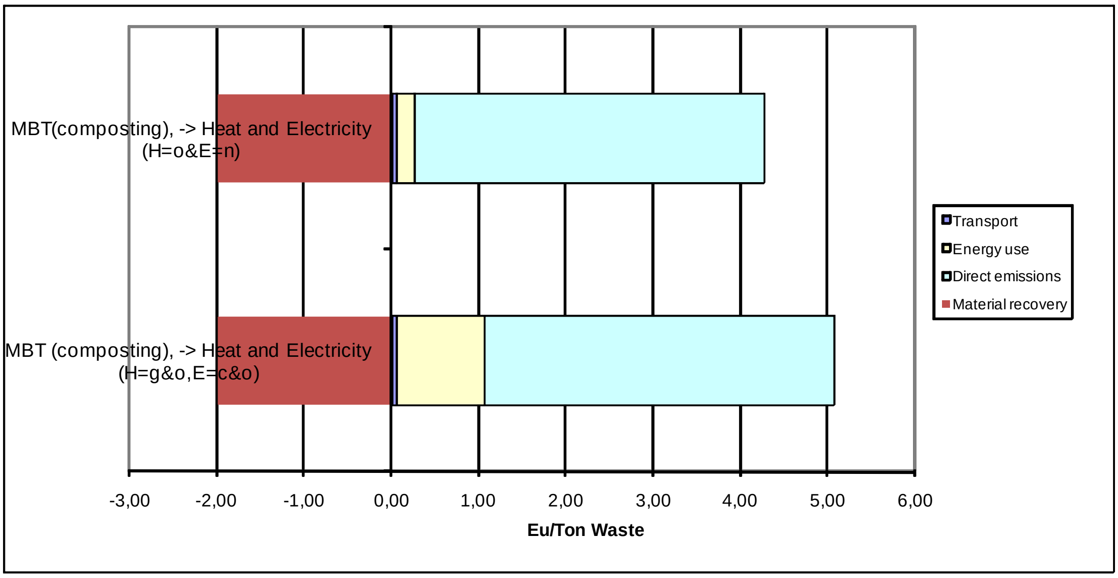


Figure 10: Detailed results for total damage cost of MBT with composting for all options Since there is no energy production, only two scenarios are considered.

Figures 9 and 10 show that, in the case of MBT, the direct emissions are sensibly reduced. The only emission that accounts is the biogenic CO2. In the case of methanisation, the assumption of no methane leak has to be evaluated. The reactor is of course easier to control than the landfill. However, more detailed investigations are needed to confirm this assumption.

For the material recovery impact, as expected, its weight is more important in that case.

Comparing both techniques, methanisation and composting, it is clear that methanisation permits to achieve, in most of the cases, negative external costs. It is interesting to perform a cost benefit analysis to see the impact of the private costs.

4.3 Conclusions

We have evaluated and compared the damage costs ("external costs") of landfill, incineration and MBT of MSW, based on the latest results of ExternE [2004] and taking into account the relevant life cycle impacts, especially emissions avoided by recovery of energy and materials. The damage cost of incineration ranges from about 4 to +21 €/twaste, depending on the assumptions about energy recovery. The damage cost of landfills, around 10 to 13 €/twaste, is mostly due to greenhouse gases, evaluated here with a unit cost of 19 €/tCO2 according to ExternE [2004]. In addition there may be amenity costs on the order of one €/twaste (highly variable with site and imposed only on the local population, thus to be internalized differently from air pollution). Unlike incinerators, the damage cost of landfill does not vary as much with type of energy recovery because in any case the amount recovered is relatively small.

The benefits of energy recovery from incinerators are largest if the heat can be used directly for process heat or district heating systems with sufficiently large constant load. Electricity production brings far lower benefits than heat because of the poor conversion efficiency of incinerator heat (compared to central station power plants).

The MBT techniques permits to cut sensibly the direct emissions by controlling the methane emissions in case of methanisation and by avoiding to burn fossil carbon. Depending on the technology, results can be negative external cost of 5.77 □/twaste in case of methanisation with energy recovery replacing gas and oil for heat and coal and oil for electricity. For composting, with energy consumption produced by gas and oil for heat and coal and oil for electricity, the external cost is evaluated to 3 □/ twaste.

The calculations are also performed for sewage sludge elimination by drying and co incineration. The results show that the drying phase is very important and the energy recovery option is very important in term of shifting the damage cost of this phase.

5 Aggregation of externalities from waste management practices and technologies

In this particular task we are gathered relevant data for Europe wide aggregation of waste management technologies, and use the data to estimate extent of environmental burden that is waste management carrying. Categories of waste treatment that we were able to cover were: landfilling, incineration, waste water treatment, waste water sludge treatment and composting.

5.1 Greenhouse gasses

Based on work in previous ExternE projects Sustools and MethodEx CH_4 emissions from SWDS (Solid waste disposal sites) are the largest source of greenhouse gas emissions in the waste management. Emissions from wastewater treatment and discharge seem to be also important (IPCC, 2006).

Incineration and open burning of waste containing fossil carbon, e.g., plastics, are the most important sources of CO_2 emissions in the waste management sector. CO_2 is also produced in SWDS, wastewater treatment and burning of non-fossil waste, but this CO_2 is of biogenic origin and is therefore not viewed as a burden (however it is accounted so full LCA could be done to confirm its carbon neutrality).

The importance of the N_2O emissions varies much depending on the type of treatment and conditions during the treatment, but generally it is important for treatment of waste water.

5.2 Classical pollutants

Above mentioned GHGs there are also other pollutants produced by waste treatment. Waste and wastewater treatment and discharge can also produce emissions of non-methane volatile organic compounds (NMVOCs), nitrogen oxides (NOx), and carbon monoxide (CO) as well as of ammonia (NH_3). (EMEP/CORINAIR Guidebook, EEA, 2005; U.S.EPA, 1995). The NOx and NH_3 emissions from the Waste Sector can cause indirect N_2O emissions. NOx is produced mainly in burning of waste, while NH_3 in composting. Overall, the indirect N_2O from the treatment are likely to be insignificant (IPCC,2006).

5.3 Emission data

For this report we have used data mainly from UNFCCC emission database. UNFCCC database contains data reported by parties of the conference. Data have several steps of QA/QC and can be considered very reliable in terms of reporting mistakes. Emissions in the database are based on unified methodology of IPCC (IPCC, 2006) and therefore they are comparable across the countries. Data from waste sector contains several subcategories:

- emissions from landfills,
- emissions from domestic and commercial waste water treatment

- emissions from industrial wastewater
- municipal solid waste incineration
- clinical waste incineration
- hazardous waste incineration.
- composting (if occurring is reported in category other – see Annex 1)
- mechanical biol. treatment (if occurring is reported in category other – see Annex 1)

Thou comparability of the data is guaranteed by unified methodology and central controlling mechanisms uncertainty in this sector is quite high (reported uncertainties are about 40% for methane and 80% for N2O).

5.4 Monetary data for classical pollutants

In this part we use identical data as we used in the industry WP (see WP II.5.a final report). In order to estimate the external costs resulting from the emission of the above-mentioned substances, monetary valuation factors have to be applied. For NH3, NMVOC, NOx, SOx, PM and dioxins the factors were taken from the results of research within the NEEDS project, an integrated project of the 6th Framework Programme of the European Commission. These factors have been calculated and generalized by a number of runs of the EcoSenseWeb applications. Detailed Information on the estimated Euro per ton values for damages to human health can be found in Desaigues et al. (2007), for losses of biodiversity in Ott et al. (2006) and for damages to crops in ExternE (1999) and ExternE (2005). For the heavy metals – As, Cd, Cr, Ni and Pb – the applied monetary factors are the results of projects of NEEDS and ESPREME, both within the 6th Framework Programme of the European Commission. The results were estimated with WATSON, an integrated water and soil environmental fate, exposure and impact assessment model of noxious substances, which provides Euro per ton values for damages following the ingestion. Additionally OMEGA, an integrated assessment of heavy metal releases in Europe, covers the damages resulting from inhalation of substances. For mercury (Hg) the estimations of Spadaro and Rabl (2007) were applied. Finally, monetary valuation factors for Dioxins were extracted from MethodEx (2006).

An overview of the monetary valuation factors used in this part of the case study is provided in the table 10. There, the factors for damages to human health, the loss of biodiversity and damages to crops by nitrate deposition and ozone are shown for all substance that valuation factors are provided for the above-mentioned literature. All values are given in Euros per ton of the emitted substance. As can be seen, the monetary factors for heavy metals only cover damages to human health. Unfortunately, there is no information on the external costs for heavy metals resulting from damages to the ecosystem provided by the data sources applied in this analysis.

Table 10: Cost per ton of pollutant (□/ton) of airborne pollutants, 2005

Country	NH_3	NMVOC	NO_X	SO_X	CO_2ekv. Option 1	CO_2ekv. Option 2	CO_2ekv. Option 3
Austria	11 711	1 015	9 533	7 719	7	16	21
Belgium	21 871	1 569	6 373	8 543	7	16	21
Bulgaria	5 647	-52	5 382	4 865	7	16	21
Cyprus	4 298	-39	3 890	7 555	7	16	21
Czech Republic	16 783	584	7 302	7 235	7	16	21
Denmark	7 130	570	3 409	4 226	7	16	21
Estonia	5 103	163	1 481	3 392	7	16	21
Finland	3 160	175	1 121	2 298	7	16	21
France	8 595	702	7 264	7 844	7	16	21
Germany	13 070	831	8 947	8 318	7	16	21
Greece	4 260	154	1 875	4 696	7	16	21
Hungary	13 672	483	8 965	6 985	7	16	21
Ireland	1 804	512	3 101	4 299	7	16	21
Italy	10 037	511	6 541	7 049	7	16	21
Latvia	4 825	296	2 590	3 854	7	16	21
Lithuania	6 667	689	4 364	4 628	7	16	21
Malta	6 961	696	2 277	4 555	7	16	21
Netherlands	16 804	1 215	6 612	10 262	7	16	21
Poland	9 651	452	5 344	6 451	7	16	21
Portugal	2 955	310	897	2 997	7	16	21
Romania	6 579	292	7 543	5 855	7	16	21
Slovakia	15 094	389	7 856	6 696	7	16	21
Slovenia	13 155	834	7 569	6 737	7	16	21
Spain	3 590	325	2 300	4 136	7	16	21
Sweden	6 093	288	2 198	2 719	7	16	21
United Kingdom	12 871	652	3 826	5 807	7	16	21
EU-27	9482	584	5591	6070	7	16	21

5.5 Monetary data for greenhouse gasses

Impacts due to climate change may be monetized by considering two different conceptual approaches. First, the costs of carbon might be based on abatement costs of reaching certain (arbitrary set) goal. This approach would be correct if one was sure the agreed policy target was also socially optimal. Estimate of abatement costs to reach Kyoto target by the EU15 countries were just used to value damage of carbon emissions last years in the ExternE project series. Methodologically more correct – at least following welfare economics ground – approach is, however, to estimate marginal damage costs of carbon, commonly referred to as the Social Costs of Carbon. Although, as noted by Anthoff (2007), the marginal damage figures are not the only measure used to quantify impacts from climate change , their estimates have been appearing more often in the literature.

Magnitude of social costs of carbon estimates do, however, significantly vary. Scope and structure of the assessment model present the first reason of variations; value of the estimate would then depend on number of impacts being covered, time horizon of impacts considered, or climate sensitivity assumed in given model (see Watkiss 2007). Next, there are also two key parameters of modelling that certainly will influence magnitude of the estimates: it is discounting and equity weighting. As a meta-analysis of IAM studies by Richard Tol (2005) shows weighting impacts due to equity and giving higher weight to future outcomes, i.e. by applying lower discount rates might indeed result in more than one order larger value of the MSC.

To provide comprehensive picture on MSC, several runs by FUND model were performed within the NEEDS project. Anthoff (2007) reports a range of MSC estimated based on using several pure rates of time preference (such as 0%, 1%, and 3%) plus declining rates over time, without equity weighting (No_EqW)or equity weighted by world average (Aver_EqW) or EU income average (EU_EqW), including reporting a statistical inference for probabilistic MSC estimates. Values of MSC for given various assumptions of two key model parameters are displayed in table 11 (all in 2000 Euro prices).

Table 11: MSC of CO2 estimates based on FUND model v. 3.0.

'deterministic'	0%	1%	3%
No_EqW	16.4 €	2.1 €	-1.4 €
Aver_EqW	41.4 €	7.7 €	-1.4 €
EU_EqW	197.3 €	36.7 €	-6.8 €

1% trimmean	0%	1%	3%
No_EqW	31.5 €	7.0 €	-0.5 €
Aver_EqW	75.8 €	20.3 €	1.7 €
EU_EqW	360.9 €	96.8 €	8.1 €

average	0%	1%	3%
No_EqW	39.8 €	8.9 €	-0.1 €
Aver_EqW	91.5 €	24.3 €	2.4 €
EU_EqW	435.6 €	115.9 €	11.6 €

median	0%	1%	3%
No_EqW	8.6 €	0.3 €	-1.8 €
Aver_EqW	27.2 €	5.4 €	-1.5 €
EU_EqW	129.5 €	25.9 €	-6.9 €

Note: based on NEEDS project cit. in Anthoff 2005; all values are in 2000 Euros.

MSC estimates depends on assumption where world-wide outcomes are weighted by the EU average. Differences are about one order higher than without weighting, for instance, almost 97 € for 1% PRTP and 1% trim mean. Median MSC values are smaller than 1%, 5% and 10% trimmed mean values, while mean values of MSC are the lowest ones. The highest discount rate, the smaller MSC of carbon is. Applying declining discount rate in deterministic model runs, MSC per ton of CO2 would be 3.8 €. Best guess MSC of CO2 estimate based on deterministic runs, 1% PRTP and without equity weighting yields a value of 2.1 € per tonne CO2.

It is just a nature of damage estimation of climate change that the one (say true) value of MSC of carbon can't exist. Any decision about the parameters will have to be just arbitrary based on normative notion followed by the decision maker. Due to the fact that modelling exercise requires having one unique number or distribution of the variables NEEDS coordination research team has widely discussed what a central value of parameters for discounting and weighting the MSC of carbon estimate should be based on. As a result, a probabilistic estimate based on 1% PRTP, without equity weighting and taking 1% trimmed mean has been considered as the central MSC of carbon value; this yields 6.96 € per tonne of CO2 released in decade 2000-2010. Option 1 just also uses the value of 7 € per tonne of CO2 in our damage aggregation. Next two options follow NEEDS discussions on valuing damage due to climate change; these values – being thought by NEEDS consortium – might better reflect actual policy targets as well as value of abatement costs estimates. Therefore, our Option 2 assumes 15.7 € and Option 3 takes 21.1 € per tonne of CO2.

5.6 Emissions data

We based aggregation on data from UNFCCC database. As mentioned previously data are weighted by high uncertainty. While we were gathering emissions data we were able to get additional (quantitative and qualitative) data about particular waste management systems.

- Methane recovery from landfills – recovered methane provide net benefit in terms of avoided external costs and greatly reduces impact of landfills
- Industrial waste – in Exiopol we wanted to add external costs from additional waste stream and industrial waste is one of them
- Waste incineration – Waste incineration is waste management practice where various waste stream are treated. Data gathered can consist from clinical, municipal and hazardous waste incineration. It is important to see what are particular countries reporting

These remarks to the data seems to be important for further research on waste management sector aggregation so we included them in Appendix I. Remarks are based on review of National Greenhouse Gas Inventory Reports submitted to UNFCCC by particular countries and/or country aggregates (EU15).

Table 12: Emissions of CO_2 (Gg) from waste management practices in the EU, 1990-2005

	1990	1995	2000	2005
Austria	26.9	11.0	12.3	12.3
Belgium	337.3	112.0	146.3	114.6
Bulgaria				
Czech Republic	357.0	357.0	357.0	358.5
Denmark		0.4	3.4	1.8
Estonia				
European Community (EU15)	5 435.3	4 020.1	3 253.4	3 022.1
Finland				
France	2 295.4	2 257.4	1 794.0	1 647.6
Germany				
Greece	0.2	0.2	0.2	
Hungary	62.9	136.9	144.5	297.2
Ireland				
Italy	536.9	483.0	201.6	165.5
Latvia			1.2	0.4
Lithuania	4.0	4.1	1.8	5.8
Luxembourg	10.0	10.0	10.0	10.0
Netherlands				
Poland	458.7	396.0	448.0	543.0
Portugal	10.1	10.1	360.9	383.2
Romania	85.0	87.0	91.6	89.0
Slovakia			156.1	145.6
Slovenia				
Spain	968.8	222.3	210.5	136.8
Sweden	43.9	42.7	44.4	91.2
United Kingdom of Great Britain and Northern Ireland	1 206.5	871.7	470.5	458.9

Source: UNFCCC,2008

Table 13: Emissions of CH_4 (Gg CO_{2ekv}) from waste management practices in the EU, 1990-2005

	1990	1995	2000	2005
Austria	3 489.4	3 003.8	2 385.2	1 953.0
Belgium	2 721.6	2 493.9	1 790.7	929.8
Bulgaria	12 075.9	10 060.7	7 380.7	6 328.4
Czech Republic	2 782.7	2 647.5	2 136.5	2 352.2
Denmark	1 460.8	1 478.2	1 432.5	1 312.0
Estonia	535.9	715.9	760.7	494.7
European Community (15)	160 710.8	155 448.3	125 799.8	95 566.0
Finland	3 813.9	3 747.6	3 116.4	2 271.9
France	12 170.1	15 007.0	13 103.8	10 946.1
Germany	38 186.0	31 903.5	19 457.3	11 053.5
Greece	4 119.9	4 079.6	3 563.4	
Hungary	3 076.9	3 319.2	3 485.2	3 432.1
Ireland	1 346.7	1 577.3	1 513.8	1 643.4
Italy	15 427.1	18 219.5	19 358.9	17 059.9
Latvia	625.8	591.3	691.3	708.7
Lithuania	1 916.4	1 552.8	1 494.3	1 463.0
Luxembourg	32.6	27.5	29.4	23.9
Netherlands	12 301.3	10 814.6	8 397.8	6 203.7
Poland	11 192.5	10 769.6	10 250.9	10 305.5
Portugal	6 581.5	7 655.8	7 408.9	5 469.9
Romania	4 745.6	5 546.2	6 540.6	6 675.0
Slovakia	1 481.8	1 495.8	1 736.0	1 936.2
Slovenia	532.4	487.0	537.2	588.3
Spain	5 650.8	7 861.3	10 130.6	11 570.4
Sweden	2 874.2	2 696.9	2 414.5	1 922.6
United Kingdom of Great Britain and Northern Ireland	50 616.6	45 016.9	31 804.4	20 358.1

Source: UNFCCC,2008

Table 14: Emissions of N_2O (Gg CO_{2ekv}) from waste management practices in the EU, 1990-2005

	1990	1995	2000	2005
Austria	132.41	169.73	258.61	317.20
Belgium	292.56	288.78	274.13	287.16
Bulgaria	223.66	168.88	155.57	147.08
Czech Republic	161.54	161.05	200.37	203.86
Denmark	87.63	85.15	65.42	61.00
Estonia	40.21	38.52	36.31	35.91
European Community (15)	9 494.51	9 636.12	10 266.16	10 515.49
Finland	164.21	162.46	158.34	163.61
France	1 603.89	1 624.77	1 714.56	1 634.48
Germany	2 237.51	2 307.44	2 538.98	2 640.17
Greece	325.05	353.84	367.63	
Hungary	214.27	193.04	193.10	212.46
Ireland	114.00	111.26	126.70	134.20
Italy	1 951.52	1 943.15	2 077.96	2 104.48
Latvia	56.98	53.69	50.69	49.81
Lithuania	80.04	78.17	76.59	75.52
Luxembourg				
Netherlands	514.06	505.10	473.04	440.70
Poland	1 112.38	1 088.92	1 107.27	1 356.84
Portugal	470.83	508.53	587.55	613.71
Romania	686.62	671.06	663.79	639.79
Slovakia	20.02	11.99	12.11	29.37
Slovenia	59.52	54.96	59.28	62.57
Spain	1 143.06	1 071.47	1 156.33	1 254.50
Sweden	195.40	185.94	146.11	137.63
United Kingdom of Great Britain and Northern Ireland	1 081.54	1 081.89	1 229.24	1 263.99

Source: UNFCCC,2008

Table 15: Emissions of CO (Gg) from waste management practices in the EU, 1990-2005

	1990	1995	2000	2005
Austria	11.37	9.71	7.73	6.31
Belgium	1.22	1.00	0.40	0.36
Bulgaria				
Czech Republic				0.06
Denmark		0.00	0.00	0.00
Estonia				
European Community (15)	524.13	638.96	634.75	685.89
Finland				
France	227.79	244.97	275.78	273.17
Germany				
Greece				
Hungary				
Ireland				
Italy	159.19	269.30	249.23	295.70
Latvia		0.00	0.00	0.00
Lithuania				
Luxembourg				
Netherlands	1.93	0.40	0.01	0.02
Poland				764.99
Portugal	1.03	1.13	0.66	2.03
Romania				
Slovakia				
Slovenia				
Spain	98.28	90.16	77.44	84.92
Sweden				0.02
United Kingdom of Great Britain and Northern Ireland	23.32	22.30	23.50	23.37

Source: UNFCCC, 2008

Table 16: Emissions of NOx (Gg) from waste management practices in the EU, 1990-2005

	1990	1995	2000	2005
Austria	0.10	0.05	0.05	0.05
Belgium	1.95	2.47	2.61	2.26
Bulgaria				
Czech Republic				0.51
Denmark		0.00	0.00	0.00
Estonia				
European Community (15)	33.18	34.63	27.11	28.63
Finland				
France	8.10	8.17	6.38	5.37
Germany	0.05	0.06	0.10	0.12
Greece				
Hungary				
Ireland				
Italy	8.44	13.69	12.25	14.40
Latvia		0.00	0.00	0.00
Lithuania				
Luxembourg				
Netherlands	3.91	2.38	0.01	0.01
Poland				
Portugal	0.09	0.10	0.72	0.85
Romania				
Slovakia				
Slovenia				
Spain	4.38	3.57	3.13	3.58
Sweden	0.02	0.05	0.04	0.12
United Kingdom of Great Britain and Northern Ireland	6.14	4.09	1.82	1.87

Source: UNFCCC, 2008

Table 17: Emissions of NMVOC (Gg) from waste management practices in the EU, 1990-2005

	1990	1995	2000	2005
Austria	0.16	0.13	0.10	0.09
Belgium	2.00	1.67	1.25	0.69
Bulgaria				
Czech Republic				0.03
Denmark		0.00	0.00	0.00
Estonia				
European Community (15)	96.93	105.79	97.32	97.22
Finland	0.52	0.50	0.46	0.44
France	16.67	18.26	17.80	16.72
Germany				
Greece				
Hungary				
Ireland				
Italy	18.74	25.44	23.67	24.48
Latvia		0.00	0.01	0.00
Lithuania				
Luxembourg				
Netherlands	1.56	1.76	1.05	0.81
Poland			2.11	4.22
Portugal	5.85	7.17	7.12	7.59
Romania				
Slovakia	4.54	0.26	0.21	0.23
Slovenia				
Spain	21.23	23.32	24.55	30.41
Sweden	0.00	0.00	0.00	0.00
United Kingdom of Great Britain and Northern Ireland	30.24	27.61	21.38	16.04

Source: UNFCCC, 2008

Table 18: Emissions of SO_2 (Gg) from waste management practices in the EU, 1990-2005

	1990	1995	2000	2005
Austria	0.07	0.05	0.06	0.06
Belgium	2.28	1.79	1.26	1.35
Bulgaria				
Czech Republic				0.03
Denmark		0.00	0.00	0.00
Estonia				
European Community (15)	20.78	11.89	5.81	5.11
Finland				
France	4.45	3.92	2.14	1.63
Germany	0.01	0.01	0.02	0.02
Greece				
Hungary				
Ireland				
Italy	0.50	0.43	0.22	0.17
Latvia		0.00	0.00	0.00
Lithuania				
Luxembourg				
Netherlands	4.17	0.26	0.00	0.00
Poland				
Portugal	0.03	0.03	0.04	0.05
Romania				
Slovakia				
Slovenia				
Spain	1.93	1.15	0.88	0.91
Sweden	0.05	0.08	0.02	0.00
United Kingdom of Great Britain and Northern Ireland	7.29	4.17	1.18	0.91

Source: UNFCCC, 2008

5.7 Results for EU 27

Aggregation of impacts of waste management shows that waste sector is not to be omitted. Lookin on industrial sectors assessed in WP II.5.a results are very well comparable. Whole waste management sector in the EU in 2005 produced external costs totaling 2.7 bil. □ (using 21 □per ton of CO2ekv.). Chemical industry in EU 27 produced in same year 3.6 bil. □ of external costs.

Significant categories for the waste management are connected with methane emissions. This is where possibilities for improvement are readily available. Reducing methane emissions would reduce total external costs and as second benefit it would provide additional source of energy and therefore reduce cost even more (see section 3-4 of this report) .

Table 19: Damage caused by waste management in the EU, (Mil. □), 2005

	NO_X	SO_2	NMVOC	GHG (7□)	GHG (16□)	GHG (21□)
Austria	0.5	0.4	0.0	18.1	41.4	54.3
Belgium	14.4	11.5	0.0	10.5	24.1	31.6
Bulgaria	0.0	0.0	0.0	46.4	106.0	139.1
Czech Republic	3.7	0.2	0.0	19.3	44.2	58.0
Denmark	0.0	0.0	0.0	10.0	22.9	30.1
Estonia	0.0	0.0	0.0	4.0	9.1	11.9
EU 15	0.0	0.0	0.0	0.0	0.0	0.0
Finland	0.0	0.0	0.0	18.2	41.6	54.6
France	39.0	12.8	0.0	99.5	227.4	298.5
Germany	1.1	0.2	0.0	114.3	261.3	343.0
Greece	0.0	0.0	0.0	0.0	0.0	0.0
Hungary	0.0	0.0	0.0	27.0	61.7	81.0
Ireland	0.0	0.0	0.0	13.4	30.6	40.1
Italy	94.2	1.2	0.0	148.9	340.3	446.6
Latvia	0.0	0.0	0.0	5.7	12.9	17.0
Lithuania	0.0	0.0	0.0	11.3	25.8	33.9
Luxembourg	0.0	0.0	0.0	0.0	0.0	0.0
Netherlands	0.0	0.0	0.0	49.6	113.4	148.8
Poland	0.0	0.0	0.0	91.1	208.3	273.4
Portugal	0.8	0.1	0.0	46.9	107.2	140.6
Romania	0.0	0.0	0.0	55.7	127.3	167.0
Slovakia	0.0	0.0	0.0	14.0	31.9	41.9
Slovenia	0.0	0.0	0.0	5.0	11.4	15.0
Spain	8.2	3.8	0.0	98.6	225.3	295.7
Sweden	0.3	0.0	0.0	15.4	35.2	46.2
United Kingdom	7.1	5.3	0.0	160.2	366.2	480.6
EU-27	169.4	35.6	0.1	1083.0	2475.4	3248.9

6 Comparative Assessment of the Waste Management in China and the EU

6.1 Introduction

The waste sector is coming under increasing attention in both China and the EU. Assessment of the burdens of waste management requires an understanding of the policy framework in each case, the technologies employed and volumes of waste – as well as the associated environmental impacts. This paper provides a comparison of waste policy and the impacts in China and the EU and the highlights the need for further action.

6.2 Policy Framework

6.2.1 Europe

European actions on waste date back to the 14th Century at least, when the first waste management law was introduced in the United Kingdom. However, it was not until the 1840s that a code of protection was adopted in the UK with the 1848 Public Health Act. In 1862, a Committee on the investigation into the Amelioration of Invisible Gaseous Pollution was established under Lord Derby, and the 1863 Alkali Act lead to the introduction of the concept of best practical means, forcing producers to reduce emissions of gases – the forefather of the BAT regulations. This evolution in waste policy was driven by both prosperity and a greater desire to protect individual health, as well as the need for more regulation to meet the challenges posed by the Industrial Revolution. Box 1 gives an overview of some of the early waste management laws in England and Wales.

In 1972 the member states approached the European Commission (EC) asking them to draw up an environmental policy. This policy was approved in 1973.

The first statue regulating the disposal of waste to land was The Control of Pollution Act (1974). This Act also supplied the working definition of waste 'anything which is discarded or otherwise dealt with as if it were waste shall be presumed to be waste unless the contrary was proved', is still used today. This act also was the inspiration for the European 75/442 Waste Framework Directive, which will be discussed below.

Box 1: A brief history of the evolution of waste management law in England and Wales

1306 - Royal Proclamation Against Using Sea Coal in London – first form of legalisation on air in UK

1380s – Act of Richard II: removal of refuse on pain of forfeits – first waste management law

1848 - The Public Health Act gave the public a code of protection. This allowed the people the ability to harness control over the activities of others depositing waste.

1862- Lord Derby was asked to chair the committee on the investigation into the Amelioration of Invisible Gaseous Pollution. The profiteers of the industrial revolution did not like the idea of government passing environmental legislation that could bear antagonistic effects on their business. Industry was seen as the bases of wealth creation that ultimately drove national prosperity.

1863 – Alkali Act passed. Partly due to an odour event affecting Whitehall. Introduced and advocated the concept of Best Practical Means (BPM) which forced producers to reduce their emissions of gasses to the minimum level. This idea still stands firm now with section 3 of the Pollution Prevention and Control Regulations 2000 SI 1973 explicitly demanding that producers use the Best Available Technique (BAT) to reduce their emissions.

1875 - The Public Health Act gave added strength to the public and was the precursor of the Environmental Act 1995, which empowers the Environment Agency.

1936 - Public Health Act demanded local authorities police and inspect their jurisdictions for statutory nuisances e.g. foul smells.

1969 – Aberfan disaster - 40 school children killed due to a coal tip landslide. This led to the Mines and Quarries (Tips Act) 1969.

1972 - The Deposit of Poisonous Waste Act introduced a law whereby it was illegal to dump noxious hazardous waste on land where it could cause environmental problems, i.e. death to either wildlife or humans.

1972 - UK signed the Treaty of Accessions in Brussels, the European Communities Act 1972, and from here on UK laws became an amalgamation of UK initiatives and EU directives.

In 1986 the Single European Act amended the treaty of Rome to include the Environmental Protection Article 130r(2). Following this, in 1989 the first EC waste management strategy was developed, which was later revised in 1996. It contained five key environmental points:

- Prevention is preferred to corrective measures
- Any environmental damage should be corrected for at source

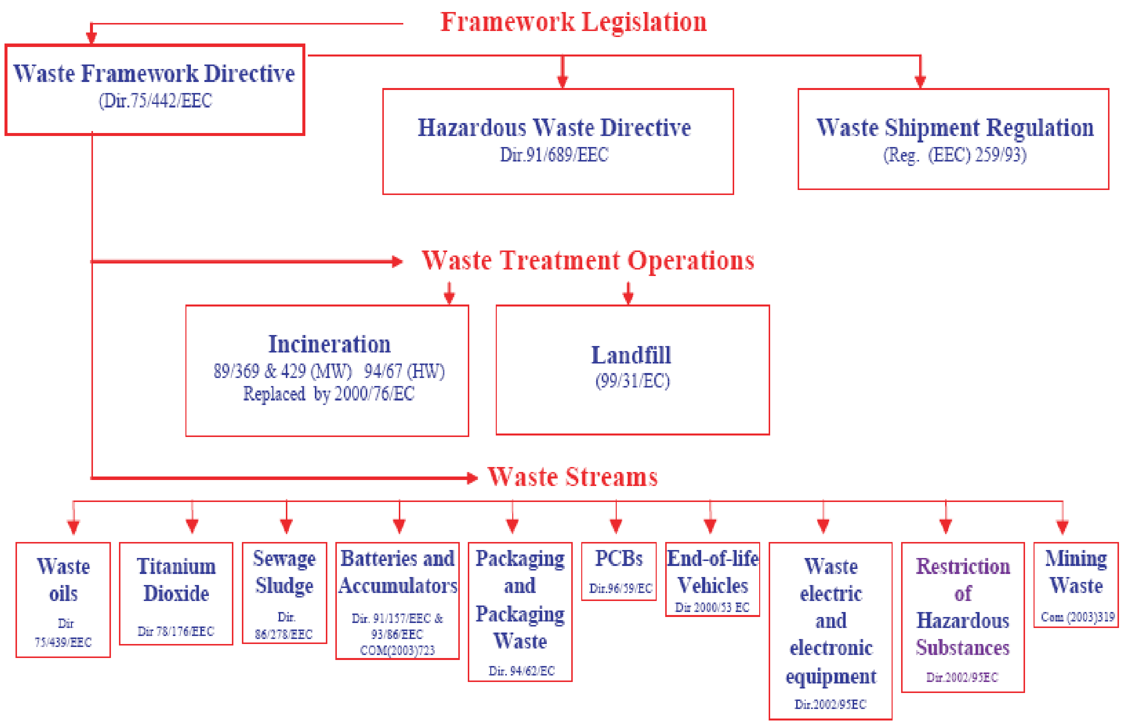
- The polluter is the one to pay
- Environmental policies must be present in other EC policies
- The proximity principle should be acknowledged.

The EC 1989 Waste Management Strategy also espoused waste disposal self-sufficiency. Once the EC has formulated its plan and passed the according legislation each member state must then implement these plans through legislation, command and control policies, economic incentives, education and assessment.

6.2.1.1 Waste Frameworks

The EU has focused and developed its policy on waste in a number of ways over the last 25 years. Its perspective has shifted over this time, from being very definition focused and concerned with controlling dangerous waste to becoming more focused on sustainability and reducing the environmental impact of waste schemes. This drive has led to a much more preventative approach to waste management. Figure 11 shows how the EU breaks waste management down into its respective arms.

Figure 11: EU Waste Framework



In 1975 the Waste Framework Directive (75/442/EEC), considered the overall umbrella framework of EU regulation, was implemented to bring together all the varying Member States approaches to waste management. It was also designed to provide a clear definition of waste, a framework for waste management policy to follow and also to provide accountability with regards to who should pay, establishing the Polluter-Pays Principle (Art. 15 of

Directive). This article was subsequently revised in 1991 modifying it to become the Directive 91/156/EEC.

A similar directive was set up in dealing specifically with hazardous waste. The Directive on Hazardous Waste (91/689/EEC) was designed to establish a framework on dealing with all waste that is considered 'hazardous'. These two directives plus additional legislation concerning the movement of waste, Waste Shipment Regulation (EEC 259/93), provide the core on waste legislation within the EC. These form the top three boxes in Figure 11.

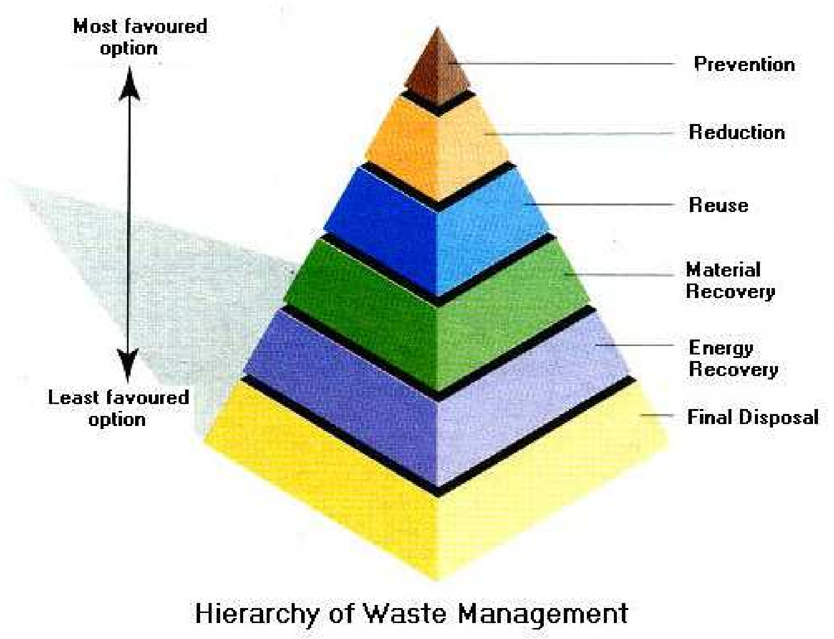
Other directives have been formed to tackle specific issues e.g. in 1994 the Packaging Waste Directive (94/62/EC) was enforced. This focuses on the management of packaging waste, which aims to reduce the effects of packaging waste on the environment by controlling the amount going to final disposal. This is achieved through directing more into reuse and recovery. The directive considers all products that are used to 'protect, handle, deliver and present goods' (Article 3) regardless of the material it is composed of.

The objective of the Landfill Directive (99/31/EC) is to encourage reuse, recycling and recovery by both constraining the amount that can be sent to landfill and by monitoring the quality of waste that is sent there. It aims to protect the health of both humans and the environment. As proclaimed by Article 4 landfills must be categorised in one of three classifications: hazardous waste, non-hazardous waste (municipal waste) and inert waste. This act also explicitly wishes to reduce methane gas emissions by producing target reductions on the quantity of biodegradable waste allowed to go to landfills (Art. 5).

This was designed not only to reduce methane emissions but also to encourage the uptake of other waste disposal alternatives such as recycling.

The European Commission has developed a waste hierarchy in categorising and ordering its programs based on sustainability. This framework was first set out in the Waste Framework Directive (75/442/EEC) and now features in all the waste directives. Its guiding principle is to follow the Best Practicable Environmental Option, whereby both social and economic costs are taken into account. The hierarchy is presented in Figure 12. It can be seen from the diagram that the prevention of waste is considered the most important form of waste management, followed naturally by reduction. Final disposal is the last action, considered only if failure to make use of a higher action. The directive has set targets for both recovery and recycling rates at five year intervals and subsequently updates these upon maturity (Article 6). These are reported in Table 20.

Figure 12: Hierarchy of waste management in Europe



Source: Hansen et al. (2002)

Table 20: Recovery and Recycling Targets.

	2001	2008*
Overall Recovery Targets	50-65%	min 60%
Overall Recycling Targets	25-45%	50-80%
Glass Recycling Target	15%	60%
Paper/Cardboard Recycling Targets	15%	60%
Metals Recycling Targets	15%	50%
Plastics Recycling Targets	15%	22.5%
Wood Recycling Targets	15%	15%

Figures not official until the proposed amendments have passed. Source: Hansen et al. (2002)

The EU has also compiled the 'European Waste Catalogue', in order to standardise waste classification and reporting. From 2006 the EU has now demanded that each nation forward on their national waste management statistics to aid monitoring and comparisons across nations. The data is specifically categorised into two parts: waste that is generated and waste that is recovered and is to occur every 2 years.

6.2.2 China

In 1986, the State Council issued the "Report on handling the municipal solid waste and improving the environmental Sanitation", which marked the official beginning of pollution control and harmless treatment (hazard-free treatment) targeting at the MSW. In 1996, the "Law of The People's Republic of China on Prevention of Environmental Pollution Caused by Solid Waste" was promulgated (amended in 2005), clarifying the basic requirements for the dumping, cleaning, collection, recycling and disposal of MSW. China's main laws and policies on waste management are listed clearly in table 5 since 1980s.

In China the Ministry of Housing and Urban-Rural Development (previously as the Ministry of Construction) is responsible for the MSW collection and removal, and the its branch, the Bureau of City Appearance and Environment & Sanitation, Department of Urban Construction is in charge of the ordinary work. The Ministry of Environmental Protection (previously as the State Environmental Protection Administration) is responsible for the supervision and management on pollution prevention and treatment caused by MSW.

Table 5 Overview of Main Legislation and Policies on MSW Control since the 1980s in China

Date	Department	Name of Legislation or Policy Document	Subject
1986	State Council	Report on handling the municipal solid waste and improving the environmental sanitation	Urban environmental sanitation and the collection and removal of MSW
1987	State Council	Notice of strengthening *comprehensive* urban environmental improvement	Urban environmental sanitation and the collection and removal of MSW
1991	Ministry of Construction	Implementation of industrial policy for urban environmental sanitation	Urban environmental sanitation and the collection and removal of MSW
1992	State Council	Notice of addressing the issue of China's municipal solid waste	Urban environmental sanitation, the collection and removal of MSW, and waste disposal industrialization
1992	State Council	Regulations for city appearance and environmental sanitation	Urban environmental sanitation and the collection and removal of MSW
1993	Ministry of Construction	Measures for *Municipal Solid Waste Management*	Urban environmental sanitation and the collection and removal of MSW
1994	Ministry of Construction	Measures for the cleaning work of urban road&street and public space	Urban environmental sanitation and the collection and removal of MSW
1996	Standing Committee of National People's Congress	Law of the People's Republic of China on Prevention of Environmental Pollution Caused by Solid Waste	Urban environmental sanitation and the collection and removal of MSW

Date	Department	Name of Legislation or Policy Document	Subject
1997	Ministry of Transportation, Ministry of Construction and State Environmental Protection Adminstration	Regulations for prevention and control of the marine *waste and* longshore solid waste pollution on the Yangtze River	Urban environmental sanitation
1997	Ministry of Transportation, Ministry of Construction and State Environmental Protection Adminstration	Several suggestions for strengthening marine *waste and* longshore solid waste management of the Yangtze River	Urban environmental sanitation
1998	State Environmental Protection Adminstration, Ministry of Construction, Ministry of Railways, Ministry of Transportation, China National Tourism Administration,	Several suggestions for strengthening the plastics packaging waste management at the main transportation *lines, river* basin and tourist spots	Urban environmental sanitation
1999	National Development and Reform Commission	Temporary management measures on recycling packaging resources	Recycling
2000	Ministry of Construction	Notice on pilot cities for the municipal solid waste classification and collection	*Waste* sorting and collecting
2000	Ministry of Construction	Municipal Solid Waste Treatment and Pollution Control Technology Policy	Waste disposal, reduction, and comprehensive utilization
2001	State *Economic and Trade Commission*	Emergency notice for immediately stopping the plastic disposable tableware production	Waste source control

Date	Department	Name of Legislation or Policy Document	Subject
2001	State *Economic and Trade Commission*	Notice on the requirement for stopping the use of plastic disposable tablewares by food and beverage companies	Waste source control
2001	State *Economic and Trade Commission,* Administration For *Industry* And Commerce, State General Administration of the People's Republic of China for Quality Supervision and Inspection and Quarantine, State Environmental Protection Administration	Notice for strenthening enforcement and supervision of phase outing plastic disposable tablewares	Waste source control
2002	Ministry of Construction, the State Environmental Protection Administration	Views on the promotion of urban sewage, and waste disposal and industrialization	Waste disposal industrialization
2002	Ministry of Finance, the Ministry of Construction, State Environmental Protection Administration	Notice on the implementation of municipal solid waste disposal fee system to promote the waste industrialization	Waste fees and charges, and waste disposal industrialization
2003	Ministry of Construction	Labels for municipal solid waste sorting	*Waste* sorting and collecting
2003	Ministry of Construction	Notice for the summary report on the key watershed, urban sewage, waste disposal project	Waste disposal industrialization
2004	Ministry of Construction	Municipal solid waste sorting and evaluation criteria	*Waste* sorting and collecting
2004	Ministry of Construction	Notice on the model text of the Franchise *Operation for* urban	Waste disposal industrialization

Date	Department	Name of Legislation or Policy Document	Subject
		water supply, gas pipeline, and municipal solid waste disposal	
2005	Standing Committee of National People's Congress	Law of the People's Republic of China on Prevention of Environmental Pollution Caused by Solid Waste (revised edition)	Waste disposal, reduction, and recycling
2006	State Council	Several suggestions for accelerating the circular economy development	Waste disposal, reduction, and recycling
2006	Ministry of Construction	China's urban and rural environmental sanitation system	*City appearance* and environmental sanitation
2006	Ministry of Information Industry, National Development and Reform Commission, Ministry of Commerce, General Administration of Customs, Administration For *Industry* And Commerce, State General Administration of the People's Republic of China for Quality Supervision and Inspection and Quarantine, State Environmental Protection Administration	Management measures for Electronic Information Products Pollution Control	Waste source control, and pollution treatment
2006	State Environmental Protection Administration	Management measures for prevention of environmental pollution caused by E-waste	Waste re-use, and pollution control
2007	Ministry of Construction	Measures for municipal solid *waste management*	Environmental sanitation, and waste collection and transportation
2007	Ministry of Commerce, National Development and Reform Commission, Ministry of Public Security,	*Management* regulations secondary resources *recycling*	Recycling

Date	Department	Name of Legislation or Policy Document	Subject
	Ministry of Construction, Administration For *Industry* And Commerce, the State Environmental Protection Administration		

6.3 Comparative assessment

The EU has a highly developed framework for waste management. However, the implementation of the policies do range from nation state to nation state. The setting of targets for reducing waste going to landfill has had some impact – as have the increased use of levies for waste going to such sites. The development of the waste hierarchy has given a good basis for effective policy making.

However, the effectiveness of these policies may be questioned. The OECD estimates that by 2020 the EU will be producing 45% more waste than in 1995. This is an alarming increase and one that must be countered. The EU's Sixth Environmental Action Program recognises the severity of the problem and resultantly places prevention and management as top priorities. The programmes main aim is to try and decouple waste generation from economic growth. The two main methods of waste disposal are incinerators and landfill, however these methods are not without their problems. The EU is determined to provide new waste prevention initiatives to cut the amount of waste generated and thus the amount of waste that must be disposed of.

China has a number of measures to encourage appropriate waste management measures including policies to help reduce the burdens of waste management and the amount of waste going to landfill. Waste management is seen as being a priority area for the promotion of sustainable development in China.

6.4 Waste Burdens

6.4.1 Europe

The amount of waste produced in the EU is estimated to be approximately 2 billion tones per annum (Eurostat). The main contributors are from manufacturing, energy production, construction and municipal waste. Table 21 gives a breakdown of total waste in the EU. Germany and the UK are by far the largest producers of waste producing 339 million and 323 million respectively.

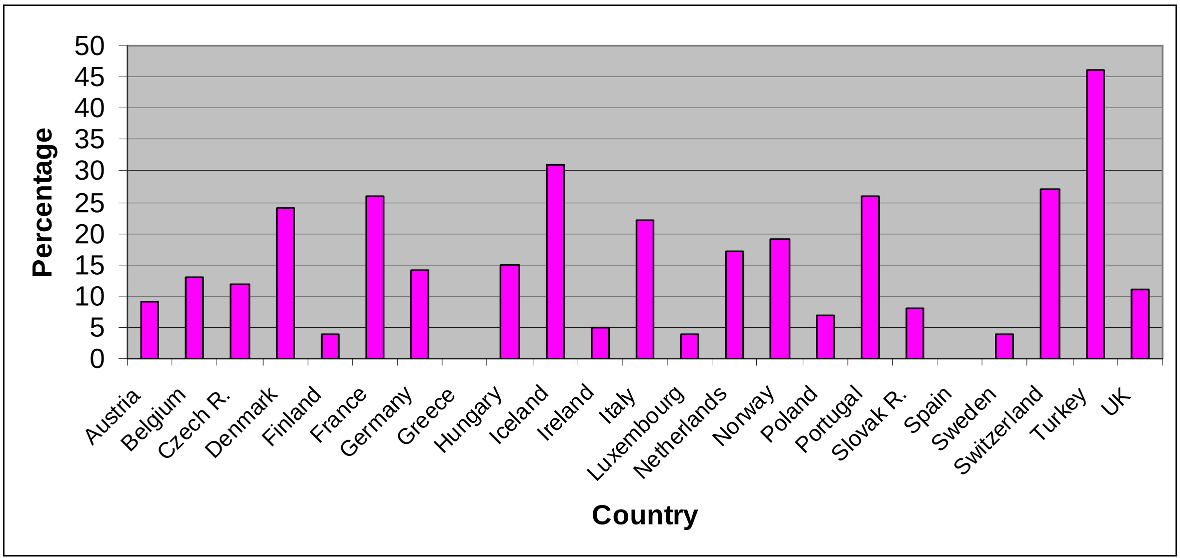
Figure 11 uses the results from Table 21 and represents municipal waste as a percentage of total waste for each country in graphical form. As can be seen Turkey has the largest ratio of municipal waste to total waste; nearly half of its national waste is municipal waste. Finland, Luxembourg and Sweden all have a much smaller municipal contribution to total waste, only around 4 per cent.

Table 21: Amounts of waste generated by sector – per 1,000 tonnes

Country	Agriculture & forestry	Mining & quarrying	Manufacturing	Energy Prod	Water Purification	Construct.	Other	**Municipal**	Total
Austria	-	-	-	-	1 910	28 600	18 900	4 590	54 000
Belgium	1 150	120	13 650	850	200	10 490	6 300	4 750	36 360
Czech R.	460	650	6 040	2 310	650	9 110	2 770	2 950	24 940
Denmark	-	-	1 850	1 080	820	5 270	1 850	3 340	14 210
Finland	860	23 820	15 710	1 570	510	20 840	100	2 370	65 790
France	-	-	90 000	-	960	-	-	33 780	128 610
Germany	-	50 450	53 010	-	-	187 480	-	48 430	339 370
Greece	-	-	-	-	-	5 000	-	4 710	-
Hungary	-	13 080	5 200	3 330	-	1 740	2 050	4 590	29 990
Iceland	50	-	50	-	-	20	230	150	490
Ireland	60 170	4 050	5 300	290	60	2 680	-	3 000	57 160
Italy	440	900	37 780	2 800	13 550	46 460	5 530	31 150	138 620
Luxembourg	-	50	730	-	130	6 980	90	310	8 300
Netherlands	2 390	90	16 900	1 430	170	24 000	6 150	10 160	61 290
Norway	160	190	3 800	40	-	1 500	2 260	1 840	9 790
Poland	-	39 620	58 440	19 840	3 280	240	2 740	9 350	133 960
Portugal	-	3 630	8 980	320	50	-	110	4 620	17 710
Slovak R.	4 490	-	8 680	-	260	1 690	-	1 400	16 590
Spain	-	21 780	28 510	5 940	-	-	9 510	27 590	-
Sweden	-	58 640	29 470	1 250	920	11 270	-	4 170	105 710
Switzerland	-	-	1 130	-	210	11 900	-	4 910	18 140
Turkey	-	-	17 500	13 890	3 240	-	-	29 740	64 350
UK	540	96 390	45 000	6 180	1 390	109 000	30 320	36 120	323 430

Source: OECD

Figure 13: Municipal waste as a percentage of total waste in selected European states



Source: OECD

Table 22 shows the amount of municipal waste per 1,000 tonnes for each country in 5 year integers from 1980-2005. Unfortunately some data is missing but enough is present to evaluate how much municipal waste has increased over the past 25 years. Most countries have seen a near doubling in the amount of municipal waste they produce. The most significant increase is in Ireland, which has increased from 640,000 to 3 million tons almost a five-fold increase. Turkey has also seen a significant increase from 12 million to 31 million tonnes.

Table 23 tries to put these figures into a social context by considering respective populations. The increases are approximately the same, roughly doubling over the last 25 years - population change is only one element, attitudes to waste and consumption have also been significant.

Table 22: Generation of municipal waste 1980-2005 – quantities in 1000 tonnes

	Generation of municipal waste					
Country	1980	1985	1990	1995	2000	2005
Austria	-	-	3204	3476	4250	4588
Belgium	2763	3055	3436	4615	4783	4847
Czech Rep.	..	2600	-	3200	3434	2954
Denmark	2046	2430	-	2960	3546	3990
Finland	-	-	-	2109	2600	2450
France	-	-	26220	28253	31232	33963
Germany	-	-	-	44390	50132	49563
Greece	2500	3000	3000	3200	4447	4853
Hungary	-	-	5500	4752	4552	4632
Iceland	-	-	-	114	130	153

Ireland	640	1100	-	1848	2279	3050
Italy	14041	15000	20000	25780	28959	31677
Luxembourg	128	131	224	240	285	321
Netherlands	7050	6933	7430	8469	9769	10180
Norway	1700	1968	2000	2722	2755	3498
Poland	10055	11087	11098	10985	12226	9354
Portugal	1980	2350	3000	3855	4531	5009
Slovak Rep.	-	1901	1600	1620	1707	1468
Spain	-	-	-	20076	26505	27593
Sweden	2510	2650	3200	3555	3796	4347
Switzerland	2790	3398	4101	4200	4728	4855
Turkey	12000	18000	22315	27234	30617	31352
UK	-	-	27100	28900	33954	35077

Source: OECD

Table 23:Per capita generation of municipal waste measured in kg per capita

Country	Amounts per capita (kg/capita / kg/habitant) Municipal waste					
	1980	1985	1990	1995	2000	2005
Austria	-	-	420	430	520	560
Belgium	280	310	340	460	470	460
Czech Rep.	..	250	-	310	330	290
Denmark	400	480	-	570	660	740
Finland	-	-	-	410	500	470
France	-	-	450	480	510	540
Germany	-	-	-	540	610	600
Greece	260	300	300	300	410	440
Hungary	-	-	530	460	450	460
Iceland	-	-	-	430	460	520
Ireland	190	310	..	510	600	740
Italy	250	270	350	450	510	540
Luxembourg	350	360	580	580	650	710
Netherlands	490	480	500	550	610	620
Norway	550	590	550	640	620	760
Poland	280	300	290	280	320	250
Portugal	200	230	300	390	440	470
Slovak Rep.	-	360	300	300	320	270
Spain	-	-	-	510	660	650
Sweden	300	320	370	400	430	480
Switzerland	440	530	610	600	660	650
Turkey	270	360	390	440	450	440
UK	-	-	470	500	580	580

Source: OECD

Table 24 breaks down municipal waste into its major components. Paper, organic material and textiles are the largest contributors to municipal waste. Organic material is represented particularly high in Spain, 49%, Luxembourg, 45%, and Belgium, 39%. Table 25 shows a comparison across time for organic material, for the years 1995-2005. Belgium, Germany, Hungary, Ireland, Netherlands and Switzerland all show a reduction in organic composition, with Germany showing the largest reduction of all.

Table 24: Composition of municipal waste for the year 2005 as percentage of total

Country	As % of total					
	paper and paperboard	organic material	plastic	glass	metals	textiles and others
Austria	22	35	11	8	5	19
Belgium	17	39	5	7	3	29
Denmark	27	29	0.8	5	6	32
France	20	32	9	10	3	26
Germany	34	14	22	12	5	12
Hungary	15	29	17	2	2	35
Iceland	26	26	17	4	3	24
Ireland	31	25	11	5	4	23
Italy	28	29	5	13	2	22
Luxembourg	22	45	0.8	12	4	16
Netherlands	26	35	19	4	4	12
Norway	33	30	9	4	4	20
Portugal	21	34	11	7	4	23
Slovak R.	13	38	7	8	3	31
Spain	21	49	12	8	4	7
Sweden	68	..	2	11	2	17
Switzerland	20	29	15	4	3	29

Source: OECD

Table 25: Comparison of organic composition of municipal waste across time

	Year		
Country	1995	2000	2005
Austria	30	23	35
Belgium	41	39	39
Denmark	26	33	29
Finland	33	33	..
France	30	31	32
Germany	23	18	14
Greece	49	47	..
Hungary	35	41	29
Iceland	..	29	26
Ireland	29	22	25
Italy	15	28	29
Luxembourg	35	40	45
Netherlands	38	32	35
Norway	30	30	30
Portugal	35	36	34
Slovak R.	28	38	38
Spain	44	49	49
Switzerland	38	..	29
UK	21	40	..

Source: OECD

Trends around the world have shown that the more affluent the society is, the higher its consumption growth rate. The economic prosperity inevitably brings about the increase of the volume of MSW. Table 26 shows the *Urban Domestic Waste (UDW)*[2] *per* capita per day for 12 Western developed countries in 1980 and 1990. *The average UDW in* these countries in 1980 was only 1.06 kg/day, while that in 1990 increasing to 1.23 kg/day. Table 27 shows the *UDW per* capita per day for selected Asian cities like Singapore, Seoul, Osaka, Tokyo and Hong Kong during the 1990s. These are lower than the US but higher than most of the European states.

Table 26: ***Urban Domestic Waste (UDW)*** **Production Per capita in Selected Developed Countries (kg/day)**

	1980	1990		1980	1990
Denmark	1.09	1.30	United Kingdom	0.95	0.85

[2] UDW is different from MSW. The former is one element of the latter.

France	0.79	0.90	Finland	1.71	1.40
West Germany	0.95	0.91	Sweden	1.02	0.83
Austria	0.61	0.89	Japan	1.13	1.03
Italy	0.69	0.95	United States	1.98	1.65
Netherlands	1.36	1.36	Canada	1.65	1.44
Average	**1.06**	**1.23**			

Source: Wang Hao, Wu Ke, and etc., 2007, Research on Prediction of Municipal Solid Waste Output in Hefei, Technology Economics, Vol.26, No.2, pp96-98.

Table 27: ***Urban Domestic Waste (UDW)*** **Production per capita in Selected Asia Cities (kg/day)**

	Singapore	Seoul	Osaka	Tokyo	Hong Kong
1990s	1.1	1.33	1.33	1.41	1.0

6.4.2 China

Since the 1980s, China's urbanization process has accelerated resulting in the increasing number and the expanding scale of cities. With the rapid growth of the urban non-agricultural population and the urban area, the volume of *UDW production* has increased significantly. Currently, China's total MSW ranks one of the world's high-yield countries, accounting for more than one quarter of the world's annual total, and its growth rate ranks the top one of the world. The statistics for 661 cities in 2005 shows that *UDW* was about 156 million tons. During the period of 1990-2005, *UDW* has an average annual growth rate of 5.7% (see Table 28), slightly higher than the average annual growth rate of urban population, close to the growth rate of the urban built-up *area*. For instance, in Tianjin and Chengdu, the annual *UDW production* per capita is about 280~350 kg, equivalent to 0.8~1.0 kg/day.

It is expected that during the next 30-50 years China's population and urbanization will reach the peak. Accordingly, the total MSW production will continue to grow sharply and severe challenges will be faced by China’s MSW collection and disposal system. It is estimated by experts that China's MSW in 2010 will reach 264 million tons, 409 million tons in 2030, and 528 million tons in 2050.

Table 28: ***UDW*** **Production and Urban Development (%)**

	The period of Eighth Five Year	The period of Ninth Five Year	The period of Tenth Five Year	1990－2005
Average annual growth rate of urban population	3.1	5.5	4.3	4.3
Average annual growth rate of built-up areas	8.4	3.1	7.9	6.3
Average annual growth rate	9.5	2.1	5.7	5.7

of UDW production				

Source: Task Force of The Development Research Center of the State Council, 2008, The status quo of China's Municipal Solid *Waste* disposal and Policy Recommendations *suggestion*, Review of Economic Research, No.25, pp15-19.

At the same time, the composition of *UDW* has experienced a great change, namely an increase in the percentage of the organic *components* while a decline in the proportion of in-organic components. In Beijing, for example, in 1995, the organic component accounts for about 70% of the total Beijing MSW; while in 2005, it dropped to 60%.

UDW in China has two characteristics. First, the kitchen waste particularly the food residues (mainly vegetables and other organic contents) is a large constituent of UDW. Second, UDW has the lower heat value and the poorer combustion effect (unfavorable *combustion* stability)(Table 29). The main reason for this is that people's living habits, the living standard, and the fuel structures have changed in recent years. According to the forecast of China's social and economic development, economic growth and living standards will increase further in the coming several decades, therefore, which leads to an increase in the share of the food residues in UDW.

Table 29: The Physical and Chemical Characteristics of Beijing Municipal Solid Waste in 2005

	Inner Eight districts in *Beijing*	Rural areas in Beijing
Kitchen waste	63.80 %	40.27 %
Paper waste	9.75 %	4.11 %
Plastic waste	11.76 %	6.03 %
Fabric waste	1.69 %	1.28 %
Glass waste	1.70 %	0.65 %
Metal waste	0.33 %	0.10 %
Grass and wood waste	1.26 %	2.62 %
Lime-soil waste	9.71 %	44.94 %
Moisture content	60.13 %	39.38 %

Note: The brick and others are not included in the lime-soil waste of this table.

Source: Task Force of The Development Research Center of the State Council (Consultant: Wang Mengkui; Team Leader: Lu Zhongyuan, Guo Xingwang; Coordinator: Zhou Hongchun, Fan Jianjun; Author of this report:Xu Haiyun, Zhou Hongchun.), 2008, The status quo of China's Municipal Solid *Waste* disposal and Policy Recommendations *suggestion*, Review of Economic Research, No.25, pp15-19.

6.5 Technologies

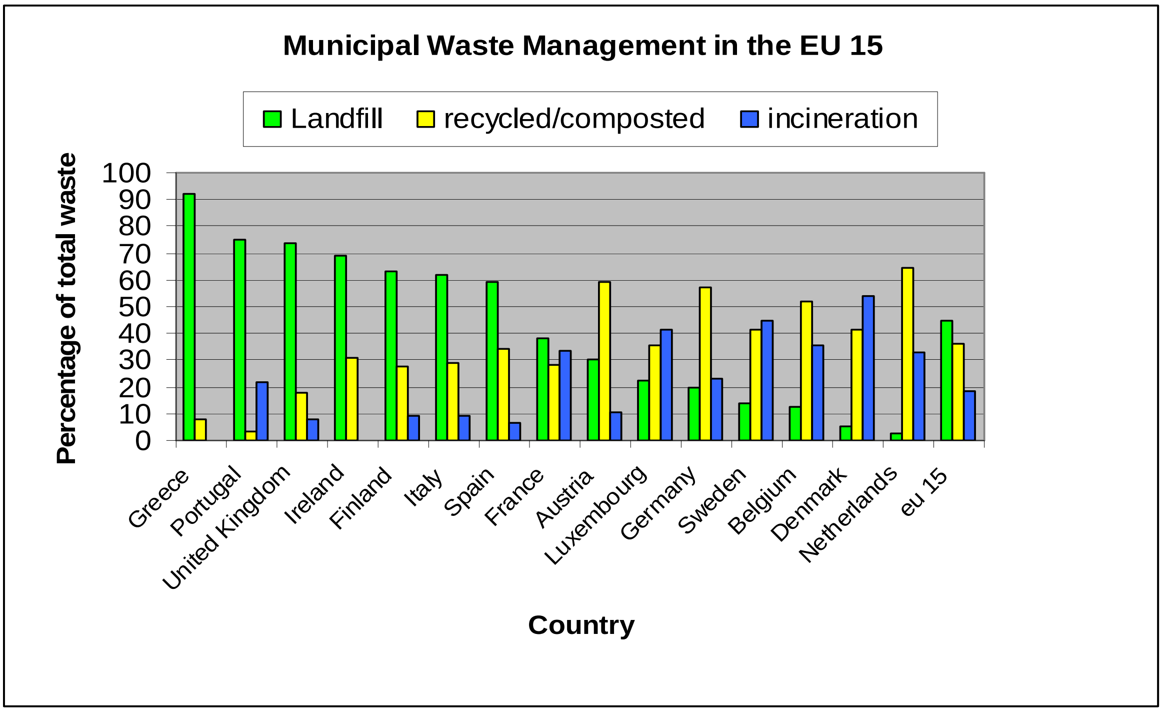
6.5.1 Europe

There are 3 main types of waste treatment method – landfill, recycling/composting and incineration. Figure 14 shows the percentage breakdown of disposal method on municipal waste as a percentage of total waste in graphical for the EU-15. Landfill is the major form of disposal for Greece, Portugal, UK, Ireland, Finland, Italy and Spain while recycling and incineration methods appear more important for Austria, Germany, Sweden, Belgium, Denmark and the Netherlands. For the EU 15 landfill makes the largest contribution closely followed by recycling/composite.

The current methods of disposal are not without their problems. Legal landfills are reaching capacity and produce toxic volatile gases and also leak heavy metals into groundwater. Incinerators, the other main form of disposal, are also guilty of producing toxins and heavy metals, despite having fitted filters.

Waste production is highly tied with consumption patterns, socio-economic characteristics and cultural influences. The EU waste policy report The Story Behind The Strategy (ec.europa.eu/environment/waste) finds that the amount of waste being produced by the 25 EU member states appears to be growing analogously with economic growth. These upward trends are predicted to increase particularly as new member states are expected to experience strong economic growth. The EU is firm in its conviction that the most effective resolution is waste prevention.

Figure 14: Municipal waste management in the European Union, represented as % of total waste



Source: Eurostat

The two tables below report the amounts of municipal waste that is incinerated and municipal waste that is sent to landfill, both measured in kg per person. Incineration on the whole has increased over the last 11 years in the EU countries. While the amount going to landfill has been ambiguous some countries have seen a reduction. Notably, Germany has reduced its amount from 225 kg per person to just 3 kg per person and others like Belgium, Netherlands, Sweden and Norway that have had significant reductions. Other countries have seen an increase in the amount they send to landfill. In particular Malta which has doubled the amount it sends. Other countries like Ireland, Spain, Portugal and Romania have all seen significant increases.

Table 30: Municipal waste that is incinerated, measured in kg per person

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Belgium	152	178	164	151	156	160	164	162	163	162	162	162
Czech Rep.	0	0	17	30	31	35	39	39	39	37	37	36
Denmark	308	315	312	315	352	374	374	363	379	397	394	427
Germany	106 (e)	111	112	125	133	135	143	137	144	160	182	192
Spain	25 (e)	35 (e)	38 (e)	36 (e)	37 (e)	37	38	42	32 (e)	44	54	58
France	170	170	167	169	169	175	182	175	193	194	184	194 (e)
Italy	27 (e)	31	34	37	41	45	48 (b)	53	61	65	67	67
Luxembourg	306	300	288	311	284	275	275	266	269	253	248 (e)	245 (e)
Hungary	32	32	35	34	34	35	28	24	15 (i)	30	39	38
Netherlands	171	219	198	203	190	199	194	197	202	202	199	200
Austria	54	56	55	57	65	65	66	73	136 (i)	153 (e)	170	180 (e)
Portugal	0	0	0	62	96	104	91 (b)	96	95	98	92	91 (e)
Slovakia	28	30	34	32	39	25	29	30	34	34	35	33
Finland	0	22	28	38	52	41	42	49	55	43	42	59
Sweden	147	150	165	163	164	169	188	212	217	242	233	240
UK	36	30	37	40	42	43	45	45	49	49	55	53
Iceland	82	82	70	62	57	53	49	45	45	37	37	49 (e)
Norway	81	84	85	92	90	99	109	120	118	133	132	132
Switzerland	285	284	279	298	320	314	350	343	337	326	354	0

Data Source: OECD

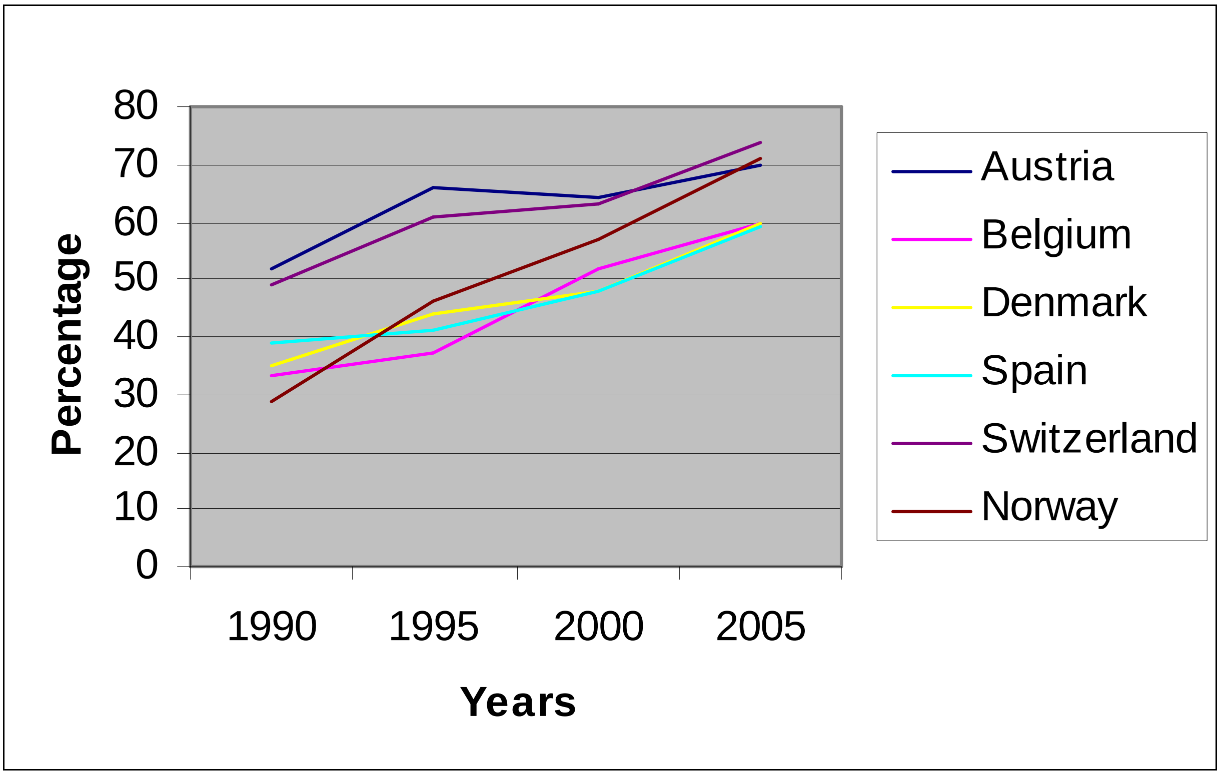
Table 31: Municipal waste that is sent to landfill, measured in kg per person

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Belgium	169	123	101	91	73	54	52	46	42	37 (e)	24 (e)	21 (e)
Bulgaria	477	433	382	388	399	392	404	407	396	405	356 (i)	388
Czech Rep.	310 (e)	318 (e)	272 (e)	277 (e)	282 (e)	214 (e)	205	201	222	209	234	243
Denmark	82	65 (i)	67	68	67	47	41	34	31	38	37	41 (e)
Germany	225 (e)	216	199	180	165	160	137	115	104	48	4	3 (e)
Estonia	396	421	399	412	438	295 (b)	308	274	283	274	278	291
Ireland	419 (e)	439 (e)	478	517 (e)	554	540	504	480	452	446	471	467
Greece	322 (e)	329	344	358	372	380	386	393	389	387	386	345
Spain	298 (e)	319 (e)	317 (e)	331 (e)	339	364	359	364	309 (e)	292	358	350 (e)
France	225	228	230	224	220	215	212	197	180	184	198	185 (e)
Italy	380	374	365	382	385	346	331	314	306	295	298	286
Cyprus	593	597	601	605	613	634	638	653	659	653	652	658
Latvia	247(e)	238 (e)	230 (e)	227 (e)	252 (e)	285	280	248	259	243	292	322
Lithuania	400	421	443	350 (b)	344	335	322 (e)	328	334	343	356	368
Luxembourg	163	145	146	140	138	131	129	129	132	130	130 (e)	130 (e)
Hungary	367	391	396	404	376 (b)	375	384	390	381	382	376	341
Malta	323 (e)	352 (e)	381 (e)	402	455	460	501	520	540	529	505	606
Netherlands	115	70	54	40	57	50	51	17	11	11	15	14
Austria	186	189	186	195	196	192	187	183	126 (i)	112 (e)	98	86 (e)
Poland	295	306	300	312	310	278	265	251	241	226	236	239
Portugal	231	269	310	303	338	355	319 (b)	293	291	278	289	297 (e)
Romania	235	263 (e)	230	261	302	272	307	277	273	296	291	284 (e)
Slovenia	465 (e)	491 (e)	512	455 (e)	402 (e)	358	357	348	313	330	362	342
Slovakia	172	177	181	185	196	209 (e)	222	233	222	228	234	240
Finland	275 (e)	281	294	280	306	284	286	278	273	282	286	267
Sweden	126	130	121	108	98	99	93 (i)	64	42	23	25	21
UK	440	461	456	469	469	474	465	440	419	376	353	324
Turkey	345	362	371	354 (e)	357 (e)	360	357	363	345 (b)	362 (e)	341	359 (s)
Iceland	328	333	338	345	351	353	359	364	365	368	390	380 (e)
Norway	425	383	417	328	336	274	274	253	243	233	245	262
Switzerland	69	67	66	66	40	40	11	8	3	1	1	0

Data Source: OECD

Figure 15 below shows the trend in waste recycling rates for paper and cardboard as a percentage of consumption for a handful of countries. This is provided to give an indication of how the amount of recycling in the EU has changed over time. All countries show a steady increasing trend towards recycling across time.

Figure 15: Waste Recycling rates for paper and cardboard as a % of consumption.



Source: Based on OECD data

6.5.2 China

Although *UDW* disposal facilities developed rapidly, they still cannot meet the needs of waste disposal in China, as a result of continuous significant *UDW* increase. At present, there are three categories for widely used methods of waste disposal: landfill, incineration and composting. According to statistics, there were 470 MSW disposal plants in 2005, with an average processing capacity of 257,000 tons/day. In 2005, 81 million tons in total were treated and the treatment rate reached 52 percent.

Specifically, there are 365 waste landfill plants in China, with a capacity of 213,000 tons/day and an annual volume of 69 million tons. Waste composting plants number 46, with the capacity of 11,800 tons/day and an annual volume of 3.45 million tons. There are 68 waste incineration plants are 68, with the capacity of 32,000 tons/day and an annual volume of 7.9 million tons.

Calculated by the processing capacity, in 2005, the proportions of landfill, incineration and composting are respectively 85.2%, 9.8% and 4.3% (see Table 32). Compared with 2001, there was a marked increase in the proportion of incineration, but the composting significantly decreased, and landfill also had a slight decrease. Over the next 10 years it is expected that the waste incineration will experience a greater development, while the waste composting will be stagnant or even in decline.

Table 32: The Proportion of *UDW* Disposal in China (%)

	Landfill	Composting	Incineration
2001	89.0	8.8	2.2
2005	85.2	4.3	9.8

Source: Task Force of The Development Research Center of the State Council (Consultant: Wang Mengkui; Team Leader: Lu Zhongyuan, Guo Xingwang; Coordinator: Zhou Hongchun, Fan Jianjun; Author of this report:Xu Haiyun, Zhou Hongchun.), 2008, The status quo of China's Municipal Solid *Waste* disposal and Policy Recommendations *suggestion*, Review of Economic Research, No.25, pp15-19.

According to the statistics *on UDW* disposal facilities made in July 2001 by the Ministry of Environmental Protection (previously as the State Environmental Protection Administration), targetting at the 30 provinces, autonomous regions and municipalities (the Tibet Autonomous Region not included), 329 cities in total, there are three phenomenons:

- From the number of cities, among those surveyed 329 cities, there are a total of 288 landfill plants (accounting for 87.5%); 21 composting plants (6.4%); and 20 incineration plants (6.1 %). It should be noted that these plants have been established with different standards. Taking landfill as an example, the landfills in line with the good sanitary requirements are only 16 in number, those in line with the basic sanitary requirements number 115 and there are 157 simple landfill plants.
- From the total volume of the waste disposal for 329 surveyed cities, the capacity of the *UDW* disposal facilities reaches 179348t/d, and the landfill, the composting and the incineration are respectively 167411t/d (93. 3%), 6017t/d (3.4%),and 5920t/d (3. 3%). It should be noted that both the composting and the incineration have the *waste* treatment capacity limit based on their original designs, with the small range of change, which makes it very difficult to increase their disposal volume so as to adapt to the rapid growth of MSW, while the landfill has the more flexible disposal capacity, which can be more easily adapted to the increasing amount of waste.
- The investments required for the waste disposal are different. Table 33 shows the original investments and the processing costs for three types of waste disposal technologies, namely the sanitary landfill, incineration and composting. Clearly, the sanitary landfill has the lowest investment and processing cost, about 8~15 yuan/ton and 20~40 yuan/ton respectively. However, the sanitary landfill usually occupies a larger disposal area. On the contrary, the use of incineration technology to deal with the waste normally occupies a smaller area, but has the higher investment and operation cost, 50~100 yuan/ton and 50~100 yuan/ton respectively. The investment and operation cost of the composting technology ranks between the former two, 15~40 yuan/tonne and 30~50 yuan/tons respectively.

Table 33: Waste Disposal Methods and their Costs

	Sanitary Landfill	Incineration	Composting
Investment (10 thousand yuan/ton)	8～15	50～100	15～40
Processing costs (yuan/ton)	20～40	50～100	30～50

Source: Wang Chunli, 2008, The Status and Solutions of the UDW in Lanzhou Lanzhou City, Science and Technology Herald, pp191.

Theoretically, the waste can be regarded as sort of new resources for cities, so-called "misplaced resources". However, from the current situation, in order to achieve the above goal there is still a long way to go. So far no city across the world can make full use of all waste. In foreign countries, most cities choose the sanitary landfill plus the incineration as the major solution to the MSW disposal. No big city takes the composting technology as the main waste disposal option. At present, the sanitary landfill, incineration and composting are three widely used approaches in China.

6.5.2.1 Landfill Technology

Landfill is currently the major way to the waste disposal for the majority of cities in China. Compared with the other waste disposal technologies, the landfill technology enjoy the advantages of less investment, lower cost, and larger capacity, which has no special requests for the heat value of the waste, and can produce methane, thus, it is widely used in China. By the end of 2003 there were 559 UDW landfill sites in total, and nearly 85% of UDW are treated by the landfill technology.

In 1988 the Ministry of Construction (currently as the ministry of Housing and Uban-Rural Development) promulgated the "Municipal Solid Waste Sanitary Landfill Technology Standards" as the basis for the improvement of the landfill planning, design, construction, operation and management. According to the engineering measures and the environmental standards, China's landfill sites are divided into three grades: simple, controlled and sanitary landfill (Table 34).

Table 34: The Main Characteristics of the Landfill Technology in China

	Engineering Measures and Environmental Standards	Characteristics	The Proportion of UDW Disposal(%)
Simple landfill (Ⅳ grade landfill)	Basically, there is no engineering measures, or only a small part of measures, nor the implementation of environmental standards.	the open system	50
Controlled landfill (Ⅲ grade landfill)	It is established with part of engineering measures; with the complete engineering measures but without any environmental standards.	The semi-closed system	30
Sanitary landfill (Ⅰ, Ⅱ grade landfill)	It is established based on a relatively complete environmental protection measures, and can meet the environmental standards.	The closed system or the eco-landfill	20

Generally speaking, the simple landfill site has the most serious externalities. At present, the simple landfill still takes a considerable proportion in China, resulting in many environment pollution incidents. A great volume of MSW are simply piled up in the suburbs, occupying a large number of farmlands. MSW sites without any treatment or strictly treatment usually have very negative impacts on farmland. Those MSW without full disposal usually contain a lot of glass, metal, broken bricks, or even some toxic components, which can damage the soil structure and change its physical and chemical properties, so as to reduce the function of the soil to keep water and fertilizer. At the same time, if MSW is only treated by the simple landfill technology, they will cause the heavily polluted surface water or groundwater. In addition, the open sites with large amount of MSW usually smell bad, with a lot of ammonia, sulfides and other pollutants released into the atmosphere, resulting in bad environmental sanitation conditions. Statistics shows that there are more than 100 kinds of volatile gases, which contains many carcinogenic and disease causing components.

Secondly, the key of the sanitary landfill is the reliable impermeable system which can effectively prevent the leakage of landfill leachates. However, the majority of landfill constructions and operations cannot fully meet the sanitary requirements or standards. In addition, due to the lack of standards on closure and follow-up management, a lack of appropriate policies and regulations, those closed landfill sites fail to meet the relevant environmental or engineering standards set for the closure and the continuous maintenance. Closed landfill sites are normally lack of ecological restoration, which poses significant damages to the environment around the landfills.

The damages of those harmful gases produced by the landfills cannot be ignored. Generally, 1 ton solid waste under anaerobic conditions can produce 300-400m3 gas emissions, among which, CH_4 and CO_2 account for 50% and 40% respectively. It is clear that the greenhouse effect of CH_4 is 22 times more than that of CO_2. At present, basically no effective measures are taken to control and recovery these gases. When the CH_4 concentration reaches a certain degree there is a risk of fire and explosion.

According to the statistics, currently CH_4 gas emissions of the landfills per year are equivalent to 7 million tons of coal as the energy, with the direct economic value of one billion yuan.

6.5.2.2 Incineration Technology

China's research and application on the UDW incineration technology started in the mid 1980s. By the end of 2003 there were 47 incineration plants in total. With the economic development of southeastern coastal areas and some large- and medium-size cities, together with the increasing heat value of UDW, many cities have attached importance to the construction of the waste incineration and started to take active actions. Currently, the incineration sites are expanding rapidly. At present, waste incineration technology in China can be divided into three categories: simple incinerator, incineration incinerator and comprehensive incinerator.

Incineration as a waste disposal method, enjoys many big advantages like recycling (that is the thermal energy recovery), reduction and harmless, namely "3R". First of all, it is helpful for the conservation of land. With the incineration technology, 80%~90% of the UDW will be burned. Compared with the direct stacking or landfills, it can greatly reduce the amount of waste. Secondly, after the burning process, the bacteria, viruses and other harmful components of UDW are well reduced or even eliminated, which is much better than the other waste disposal approaches. For example, after harmful gases with bad odours are strictly treated, those final emissions have smaller probability of polluting the surrounding environment as secondary pollution. Third, a large number of thermal power can be generated from the waste incineration. According to calculations, the waste-firing power generation is about 300 kWh per ton of waste, and at the same time the waste heat can be used for heating. There are 140 waste power plants in total in China, some of which have been completed, some are under construction and some are submitted for the construction approval. Due to the huge environmental and social benefits of waste-fired power generation (Table 35), many cities regard the incineration as the important means for the future waste disposal.

Table 35:The Comparison between Landfill and the Incineration: Chinese perspective

	Landfill	Incineration
The total volume (t/d)	1200	1200
The total occupied area (10 thousand m^2)	29.6	5.5
Initial investment (100 million yuan)	1.29	4.90
Expected service life (year)	25	50
Maintenance fees or charges (yuan/t)	40	80
The total cost for 25 years	5.67	7.20

(100 million year)		
The main investor	government	enterprises
The direct economic benefit (100 million yuan)	None	22
The environmental benefit	Good	Excellent

Source: Ceng Xiangpa, 2007, Optimism Foreground for Municipal Domestic Waste Incineration and Generating Electricity, Environmental Sanitation Engineering, Vol.15 No.4, pp35—36.

Incineration also has the disadvantage. Not all the waste can be burned well, because it requires for a certain heat value of UDW, namely the heat value must be equal to or more than 3600kj/kg. However, most cities cannot meet the above-mentioned heat value requirements. MSW in China have miscellaneous components, generally with higher water but lower heat value. Normally, their water content is over 50%, but the average heat value is only 1047 to 4187KJ/Kg (800 to 1000kcal/Kg), in particular MSW in the south has the greater water content. This situation is not favourable to combustion. At the same time, the incineration plants do not consider the waste dehydration before they are put into the furnace or incinerator. As a result, the efficiency of waste incineration is greatly reduced. According to the data on UDW incineration plants in 2001, 2/3 or more incinerators cannot work well in China. For example, Yuqiao Incineration Plant located at Pudong District in Shanghai requires for the heat value of 1200kcal/kg based on the original design, but in fact, the waste treated only has the lower heat value than 1100kcal/kg.

In addition, if the exhaust gases generated throughout burning are not properly handled, they can easily cause secondary pollutions. Statistics based on 17 incineration plants under monitoring shows that only 5 incineration plants across the country meet the standards of the "Standard for Pollution Control on the Municipal Solid *Waste* Incineration"(EWKB3-2000), namely Capital Airport Incineration Plant in Beijing, Comprehensive Environmental *Sanitation* Plant in Changzhou, Waste Power Plant in Wenzhou City, Waste Power Plant in Zhuhai and in MSW Disposal Plant in Jiangyou City. In the waste incineration process some harmful gas emissions will be produced such as HCI, SO2 and dioxins. Some studies show that these harmful substances and gases may cause the fetal malformation and the cancers.

6.5.2.3 Composting Technology

The composting technology is a bio-chemical process, which uses the micro-organisms to break down organic components of the waste, including three major categories: simple composting technology, aerobic *composting technology, and* anaerobic digestion technology. China started the development of the composting technology since the early 1980s, and has built a number of composting plants, but for various reasons the current rate of composting is not high. Most composting plants have the scale below 100t/day, only the Shijingshan Composting Plant in Beijing and the Anting Composting Plant in Shanghai have the capacity to handle the waste about 300t/day. By the end of 2003 there were 70 municipal solid waste composting plants in total in China, with the composting rate of less than 10%.

The composting technology is one of the mature application technologies, however, the composting technology has very limited development space in China. Actually, a lot of composting plants have to reduce their production or even have to stop because of economic reasons, and some of the surviving plants have to rely on government subsidies to maintain production. In other words, only a small number of composting plants can work well if measured with market economy standards, but their sizes are usually not big. The major reasons are:

- the composting has the longer cycle period, occupies a larger area, and results in poorer sanitation;
- As a result of the mixed solid waste as raw materials, it is necessary to sort out those brick, metal, plastic, and etc., which cannot be decomposited by micro-organisms. Thus, it will lead to an increase of processing costs, and accordingly higher total costs.
- the fertilizers produced by the composting technology usually have a lower fertilizer efficiency, poorer quality, and higher costs, therefore it is difficult to compete with other fertilizers, resulting in the poorer economic benefits and poorer sales.

Although the application of fertilizers originated from the waste can contribute to the yield increase and the quality improvement of the agriculture, it will have adverse environmental consequences if it is used improperly, mainly including two aspects: First, the heavy-metal contamination. The heavy metal pollution is an important problem for the fertilizers originated from the waste with the composting technology. Pang Jinhua's Shanghai case study found that if the sludge compost is applied continuously in one farmland for more than 10 years, the Cd, Zn, and Cu content of the soil will increase, which will bring serious pollutions on the rice and vegetables planted in this farmland. Second, the application of the excessive fertilizers by the compost technology possibly leads to sandy loam. Although containing a variety of nutrients, but the fertilizer by the compost, with the higher organic matter contents, lower humus *content*s, and a larger proportion of gravel composition, if used on the farmland for a long term, will lead to the sandy loam. A study by He Liyuan and others has shown that the continuous application of waste composting-fertilizers can bring several results, for example, the composition of soil changes markedly, and the clay content of less than 0.002mm lowers, while the sand and coarse sand content greater than 0.02mm significantly increase, which indicates that the soil structure changes from silty clay loam to sandy loam.

6.6 Conclusions

The burdens of waste in China and the EU are significant. According to the statistics by the Ministry of Construction (currently as the ministry of Housing and Uban-Rural Development), the national municipal solid waste production takes a fast-growing trend, with the average growth rate of 4%. Appropriate management of the MSW has become more urgent. However, China's waste disposal still has a lot of serious problems, like the backward technologies, failure to meet the environmental standards, secondary pollutions, and etc. In fact, the existing waste disposal methods have caused serious pollutions on the surrounding soil, the groundwater and the surface water. In particular, the main waste disposal methods of China's most small cities are the simple landfill with little treatment or without any treatment, resulting in huge harmful gases and sewages as the secondary pollution, which has become a constraint for the local socio-economic development.

China and the EU both have significant amounts of legislation on waste management. The need for an appropriate waste hierarchy, founded on sound evaluation of waste management options is clear. The evidence shows that China still has significant environmental burdens from municipal solid waste management.

7 Disamenity Valuation Study in the UK: The Case of Dudley

7.1 Introduction

In the economic valuation literature, amenity loss is the feeling of dissatisfaction or annoyance. It is caused by undesirable features of a local environment, such as a factory, construction project, abattoir, or any other source of noise, odour, vibration or inconvenience. If the agents responsible for such activities are not made responsible for amenity loss, for example, by paying compensation to sufferers, then amenity loss is considered an external cost or externality. In this report, we describe the economic valuation of amenity loss experienced by residents living close to a municipal solid waste incinerator.

Less is understood about the effects of waste incineration on amenity in nearby areas, compared to the case of the impacts of landfills. Indeed, we are aware of only one study in the economic valuation literature. Kiel and McClain (1995) investigated the property price effects of an incinerator located in Massachusetts, USA. However, vast improvements in incineration technologies, particularly with respect to emissions control, and pitfalls of transferring single value estimates across the Atlantic (see Ready and Navrud, 2004), limit the usefulness of this study for application in policy analysis in Europe.

Health impacts are a separate form of externality, and are the subject of other studies performed under the FP6 Framework. However, some individuals are known to associate causes of amenity loss with health impacts. A consequence is that monetary estimates of amenity loss may also include perceived health risks. Where this is true, the total cost of waste treatment and disposal is overestimated[3].

The value of amenity loss is likely to be affected by the characteristics of the local area. For example, Walton et al (2007), in a meta-analysis of hedonic price studies on the property price impact of landfills, find that impacts are higher in less densely populated areas. It is thought that this is because landfills in high-density areas are less obvious than otherwise. In a similar way, incinerator facilities that are located close to other industrial facilities may have a lower impact (Eyles et al, 1993). This variation has implications for benefits transfer; value transfers would be inaccurate if, ceteris paribus, they were transferred between dissimilar areas.

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[3] If health risks were accurately assessed by residents, it would be a simple matter of deducting (separately assessed) health costs from the monetised value of amenity loss to derive the 'true' cost of amenity loss. Unfortunately, there are at least two reasons why this is not possible. First, layperson assessments of health risk are often higher than scientific assessments, and only the latter are reliable enough to inform objective cost-benefit analysis. This inflates the 'true' cost of amenity loss under this approach. Secondly, it is likely that not all respondents perceive a link between amenity loss and health. This deflates the 'true' cost of amenity.

A recent meta-analysis of these studies (Methodex 2007) found that the size and age of a landfill and the characteristics of the surrounding area partially explain the magnitude of property price effects. Therefore, the following principle objectives apply to this research:

- To value amenity loss caused by municipal waste incineration
- To minimise the magnitude of health effects in the obtained values to help prevent double-counting;
- To investigate the effects of other industrial facilities located nearby on economic values.

We split the determinants of amenity loss into two categories: those that affect exposure to the causes of amenity loss and those that affect individual's perception of amenity loss. Exposure depends on the design characteristics of the incinerator and the geographical position of housing relative to the site. Perception is much more complex and depends on numerous psychological and social factors. Section 2 of this report uses this distinction as a framework for organising the insights gained from other studies of waste management impacts.

We use an incinerator located in the West Midlands area of the United Kingdom as a case study to value amenity loss. The Lister Road site, in the town of Dudley, is surrounded by residential properties and as such allows us to investigate the full effects of distance and direction on exposure to the causes of amenity loss. The site hosts a Mass Burn Solid Waste Incinerator that generates electricity for the national electricity network (the 'National Grid'). In addition to an incinerator, the site is also home to a green waste transfer station, which we also incorporate into the valuation exercise. The process and rationale for selecting this site is discussed in Section 3.

Complaints records were sought from the Local Authority and the Environment Agency (the competent authority responsible for regulating the site) prior to the design of the survey instrument. The Lister Road site was visited by two University of Bath Researchers to discuss the technology used at the site and potential problem areas. Findings from these exercises were discussed with two focus groups made up of local residents. These exercises identified the following priority impacts:

- *Noise from the steam release valve:* This occurs when there is an unexpected problem with the interface between the incinerator and the National Grid, causing the incinerator turbines to shut down. Steam is released at high pressure, causing an extremely loud whistling noise to occur. This can happen at any time of day or night.
- *Odour from the storage of green waste:* The Lister Road Site also acts as a transfer station for green waste, which consists of organic food waste and garden cuttings collected from households. This waste is stored in an uncovered bunker.
- *Visual Intrusion:* The incinerator chimney stack is approximately 35 metres high and visible over wide distances. The stack is white with a smaller dark section at the top. This design is fairly conventional and is considered to be unattractive by local residents.
- *Increased Vehicle Traffic:* In excess of 120 heavy vehicle movements occur at the site each day with each vehicle carrying around 20-25 tonnes of waste and by-products of the incineration process. The site entrance is located on a residential road.

The findings of this study suggest that the amenity impacts of the incinerator in Dudley may not be that large. The four attributes assessed do not seem to influence the choice patterns of individuals and the ASC was consistently negative and significant. These results appear positive for both waste management operators and waste policy makers – that incineration bears lower amenity effects than may be the case with e.g. landfill.

The study is able to identify certain levels of WTP when people are annoyed by attributes of the site. For instance those that are annoyed by the height of the chimney are willing to pay £3.69 for a 50% reduction. However, these people are relatively few in number in the sample in question. Overall most of the sample reported very low annoyance and exposure levels.

However whether these results are robust enough to infer similar results for other incinerators is as yet undecided. It should be noted that the site in question is a very small incinerator, the fifth smallest in the UK, in a rather industrial setting, therefore its marginal impact is further diminished, so the transferability of the results is questionable. Also, an incinerator has been present on the site for over 70 years; any habituation effect is likely to be strong.

7.2 Literature Review

In this review, we distinguish between factors that determine exposure to the causes of amenity loss and those that determine impact of exposure. This separation is motivated by the following observations: (i) site develops can prevent amenity loss from ever occurring by limiting exposure using the planning and design process and (ii) the relationship between impact and exposure varies depending on resident's perceptions, attitudes towards the incinerator and ability to cope to with problems they experience. Evidence is drawn from economics, psychology and epidemiology to support this review. The discussion is mainly limited to the priority impacts identified in the introduction.

7.2.1 Exposure to Causes of Amenity Loss

7.2.1.1 Incinerator Technology

Energy from Waste (EfW) is a term commonly used to describe technologies that seek to turn energy contained in waste materials into electricity, heat, or both. The most common of these technologies is incineration, where waste material is combusted in a furnace. The word 'incineration' is also commonly used to refer to pyrolysis and gasification technologies, though the correct term is Advanced Thermal Treatment (ATT). The type of incineration technology employed can in part determine exposure, though there is significant variation within each technology and no systematic observations can be made.

7.2.1.2 Odour Management Practices

Odour from waste can be prevented using a variety of approaches. The most obvious is to store the waste in covered areas. The waste can then be treated with deodorants to obscure the smell. The most effective method, however, is to trap the air in a negative pressure environment and pass it into the combustion process where the odorous compounds are destroyed by high temperatures. Other supplementary measures include measures to shield the waste from the wind and the use of trees and vegetation to absorb odours. Odour is most likely to occur when waste is stored in the open air.

7.2.1.3 Visual Impact

The visual impact is the extent to which the facility can be seen and recognised by those residents, and the extent to which it reduces the attractiveness of the nearby area. If a facility is hidden from view, for example by trees or buildings, or relatively isolated from areas utilised by residents, exposure to visual intrusion is likely to minimal. Because an incinerator normally has a tall chimney stack, it is possible that it is more difficult to hide from view than a landfill site, which in turn are often located in former quarry sites with waste buried below ground level. However, some incinerator facilities are designed to be more aesthetically pleasing. Contrasting incinerator designs are shown in Figure 16.

Conventional design ***Alternative design***

Figure 16: Examples of Chimney design

7.2.1.4 Distance Decay Effects

A common observation in the empirical literature is that amenity loss decreases with distance away from the incinerator. This is thought to be because exposure to the causes of amenity loss also falls with increasing distance. Estimates of distance decay can be drawn from hedonic property price studies, where the impact of proximity to facilities is measured as a function of distance. Kiel & McClain (1995a), in a hedonic pricing study of an incinerator in the US, assume a maximum distance of approximately 6 km. Elliott et al (1993), in an epidemiological study of an incinerator, sample all residents within 4.5 km. Walton et al (2007), in a review of hedonic price studies of US landfills, find the mean maximum distance used by researchers in 6 studies is 4.3 km. Within 800 metres from a site house prices have been observed from fall by up to 30%, although the variance is very large, with some studies estimating reductions of a little as 5% at the same distance. Overall, the results suggest a non-linear disamenity-distance function. However, the proximity of landfill sites was observed to have no significant effect on house prices at distances greater than 5 – 6.5 km. There is also widespread support for the distance decay hypothesis within applied psychology. Lima (2004) finds significantly lower differences in the impact on residents who live more than 2 km away from a Portuguese incinerator compared to those living within 2 km.

The use of distance from the site, as opposed to other measures of exposure, means that all causes of amenity loss are grouped in a single metric. This metric may also include impacts other than amenity loss, such as stigma or perceived health effect. However, it is likely that there are different distance decay functions for different causes of amenity loss. For example, noise may dissipate more quickly than odour and the chimney stack may be visible over large distances.

The use of house prices to detect distance decay also means that exposure and impact is mixed. It is very likely that the impact of amenity loss as a function of distance ceases over shorter distances than exposure[4]. This is further discussed below.

7.2.1.5 Meteorological and Topographical Conditions

Meteorological conditions, in particular wind, clearly have a role in determining the dispersion of odour and noise around the site. For a given direction of prevailing winds, we should expect some areas to be more prone to odour problems than others should. Furthermore, varying wind strength can cause a variation in the intensity of odour across different days. Rain, which has a 'scrubbing' effect on odours, and temperature both influence the intensity of odour.

The impact of meteorological conditions can be controlled by the planning process. If the majority of local residents are located upwind of the incinerator stack, then the impact of odour is likely to be lower than otherwise. Odour maps for the surrounding areas of three existing landfill sites are presented by McKendry, Looney, & McKenzie (2002) taking into account wind speed and direction. They find that for a landfill situated uphill of residents, households experience odour pollution 26.7% of the time. For a site on a plain and a site in a valley, odours were experienced 5.3% and 35.8% of the time, respectively. While landfills have different characteristics to incinerators, it is clear that exposure is highly variable.

The topography of the local area, i.e. the presence of hills, slopes, and valleys, can affect exposure. For example, a hill may shield the visual impact of a chimney stack, shelter areas from odour, and deflect or absorb noise. This serves to introduce discontinuities or truncations in the distance decay function.

7.2.1.6 Area of the site

Some studies of landfills have considered the effects of landfill size on house prices, and we would expect similar patterns to emerge for other types of site. Larger landfills typically process more waste, giving rise to higher traffic levels, and if the site covers a greater area there is greater potential for visual intrusion, odour and litter. Ready (2005) and Lim and Missios (2003) looked at these issues. The latter study found a significant difference in the external costs of two landfill sites of different sizes in Canada. Ready (2005), in a study of three landfill sites, found significant price effects for the two high volume sites, but not for the one low volume site. He therefore concluded that large landfill sites give rise to greater disamenity impacts than smaller sites. Ready (2005) further suggested that smaller landfills need not necessarily have any negative amenity effects on the local area.

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[4] On the other hand, impacts can never occur over greater distances than exposure.

7.2.1.7 Proximity to Residents

The construction of waste management facilities close to residential or other commercial areas increases the exposure of individuals to amenity loss. In many new developments, steps are taken to ensure that this is avoided. However, in some cases this is not always possible due to infrastructure restrictions and the limited supply of land. In other cases, the land surrounding a site that was once isolated from other developments is developed.

There is some evidence, referred to as the environmental justice literature, to suggest that incinerators and other facilities that pose an environmental burden on local areas are more likely to be located in relatively deprived areas. However, findings on the relationship between socioeconomic characteristics and the probability of hosting an undesirable facility are inconsistent, perhaps due to theoretical and methodological issues (Baden, Noonan, & Turaga, 2007). Of particular concern is the direction of causality between deprivation and site location. On the one hand, political forces may direct facilities to deprived areas, or the presence of facilities may lead to deprivation.

However, these issues should not detract from the high incidence of collocation. For example, Fricker & Hengartner (2001) find that deprived areas are more likely to host incinerator and landfill sites in the city of New York, and Friends of the Earth (2004) report that 50% of incinerators in the UK are located in the most deprived 10% of districts.

7.2.1.8 Temporal Effects

The causes of amenity loss may not be present all the time. For example, increased traffic may only occur on weekdays and peak during the morning when door-to-door collections occur. Odour events may be more common during warmer periods.

7.2.1.9 Volume of Traffic

Traffic can be responsible for many different impacts, including noise, vibration, reduced air quality and accidents. With respect to incineration, traffic is generated by the delivery of waste, removal of by-products, the delivery of components and staff vehicles. The amount of traffic is sensitive to the volume of waste processed.

7.2.2 Individual Perceptions of amenity loss

The last section dealt with factors governing exposure to the causes of amenity loss. This section details patterns of individual reactions to exposure that lead to an assessment of personal impact. The evidence reviewed here is largely based on two separate yet substantial research programmes examining the impact of waste disposal facilities, one based around an incinerator site in Portugal (Lima, 2004; Lima & Marques, 2005; Lima, 2006), and another focussing on various facilities in Canada (Elliott, Wakefield, Taylor, Dunn, Walter, Ostry, et al., 2004; Eyles, Taylor, Johnson, & Baxter, 1993; Elliott, Taylor, Hampson, Dunn, Eyles, Walter, et al., 1997; Elliott, Taylor, Walter, Stieb, Frank, Eyles, et al., 1993). Each uses a version of the environmental stress framework detailed in Lazarus & Folkman (1984), which describes the way in which exposure leads to impacts for individuals. The consequences of environmental stressor, in this case a waste disposal site, depend on the appraisal of the threat (mediating variables), and personal resources to deal with it (moderating variables). Figure 17 presents a schematic description of the framework. Each research programme is described in detail in Box 2.

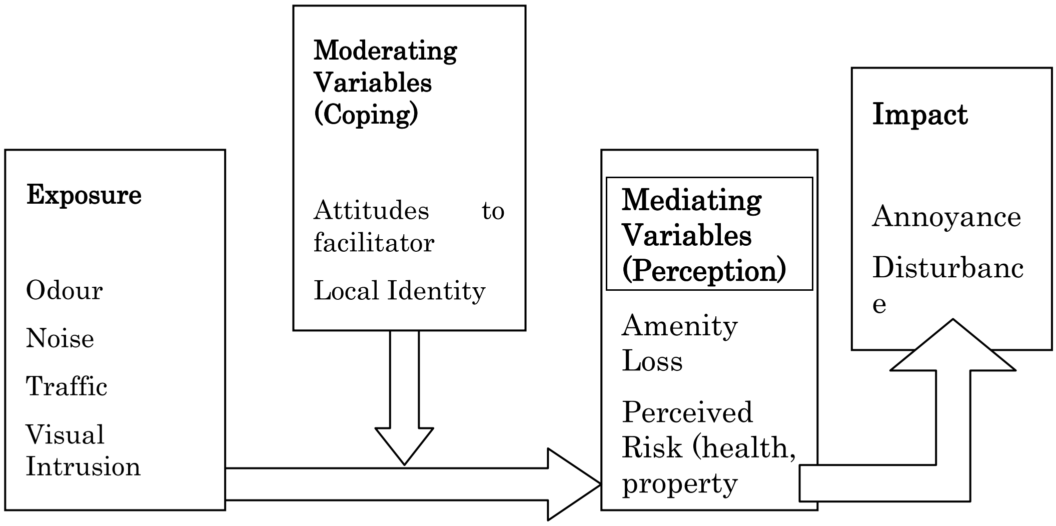


Figure 17: Typical Model of Environmental Stress (Source: Adapted from Lima & Marques, 2005)

Mediating variables reflect individual assessment of the consequences of the threat. They reflect the level of concern held by individuals for any effect as perceived by the individual. They include the perception of amenity loss and perceived risk. Perceived risk includes risks to health (discussed in more detail below), and the possibility of falling property prices reducing an individual's wealth is an important source of risk (Taylor et al, 1991).

Moderating variables reflects coping mechanisms. Inclusion of these variables in the framework acknowledges that the relationship between exposure and impact is potentially non-linear. The relationship may strengthen or weaken depending on several factors, namely attitudes, identity and perceived efficacy. Attitudes refer to the understanding of the need for an incinerator to exist. A positive attitude towards the incinerator can lower the psychological impact of mediating variables; for example, individuals have been found to less affected by a noise if they perceive the noise to derive from a necessary activity (Staples, Cornelius, and Gibbs, 1999). However, even if individuals accept the need for an incinerator, they may not accept the need for the incinerator to be placed within their community. This is also known as the 'Not in my back yard' or NIMBY effect. Thus, attitudes reflect individual acceptance of the wider needs of the society. Identity refers to the strength of individual links to their local area, perhaps represented by a measure of involvement in community activities or contact with neighbours. If identity is high, individuals are likely to be more resilient to the effects of environmental stressors. Perceived efficacy reflects the ability of individuals to react to the environmental stressor. If individuals feel they are able to influence the exposure to the stressor, perhaps via planning consultation processes or through contact with site operators, this may weaken the impact of the mediating variables. There is potential for confounding interaction effects between these variables. For example, a strong sense of identity and personal efficacy, which reduce the impact of mediating variables, may serve to strengthen opposition to the facility, causing attitudes to worsen and increase the impact of mediating variables.

Individuals become more familiar with exposure to a threat over time, perhaps leading to a lower perceived impact. However, it is likely that time impacts on perceived risk and disamenity in different ways. Elliot et al (1997) report the findings of interviews with residents who have lived near a landfill for a sustained period. They find that while levels of concern about the threat of the site fell over time, disamenity remained relatively stable.

Box 2: Key Psychological investigations into the effects of living near waste facilities

Portugal

Lima (2004) reports the results of a detailed External Environmental Monitoring study of the impact of a waste incinerator near Oporto, Portugal. Eight waves of survey were commissioned between May 1998 and February 2002. The first four occurred before the incinerator went online, two before construction and two during. In the first survey, 700 local residents were interviewed, and a random draw of 300 was made from this group for each subsequent wave. Some additional respondents were made to refresh the sample and compensate for dropouts. 906 residents provided 2797 interviews for the study. Lima asked respondents about:

- Perceived risk attributed to the incinerator, in both general terms and with respect to specific health effects (headaches, respiratory diseases, air pollution and noise pollution).
- Mental health: stress, anxiety and depression.
- Perceived environmental quality: daytime noise, night-time noise, and dust and smells.
- Attitudes towards the incinerator: general opinion of the incinerator, worries about the incinerator, and planned behavioural response (intention to move away, etc.).

Data on socioeconomic background and distance from the incinerator were also collected.

ANOVA techniques are used to compare response levels at different times - before and after incinerator operations commenced - and at two distance bands away from the facility. In general, those closest to the incinerator demonstrate higher levels of perceived risk and less favourable attitudes than those further away. This effect weakens slightly over time, with a stronger habituation effect for those closer to the incinerator. Psychological symptoms increase over time for those closer to the site, though decrease for those further away. Multiple regression analysis was used to investigate the determinants of mental health, controlling for socioeconomic differences. It was found that adding an index of annoyance to the regression increases explanatory power. Risk perception is related to psychological health before the incinerator started to work, but only for those living closer to the site. After the incinerator became operational, risk perception explains psychological health for those further away. For those closer, risk perception only explains psychological health when the term is included as an interaction term with annoyance. This shows that annoyance and perceived risk reinforce each other. Focus groups were held to help explain the results and these supported the link between annoyance and perceived risk.

Canada

Eyles et al (1993), Elliot et al (1993), and Elliot et al (2004) carried out a study into the effects of one non-hazardous waste incinerator and two non-hazardous waste landfills in various locations in Canada. They define impacts as *psychosocial effects*, which at the individual level encompass emotional, behavioural and somatic outcomes. The authors investigate prevalence and the determinants of psychosocial effects, in addition to the determinants of behavioural responses. Epidemiological surveys were administered to 254 respondents close to the incinerator, 255 for the Glanbrook landfill, and 187 for the Milton landfill. The analytical framework is designed to link external variables (socioeconomic status, exposure) to outcome variables (concern, effects and action). Mediating variables, which are thought to regulate the link between external and outcome variables, are also included. These include general mental and physical health, and membership of social networks, which is thought to indicate how well individuals are able to cope with threats and annoyances. Based on this theoretical framework, the determinants of *concern* and *health concern* are investigated using regression analysis. They found that only 62% of individuals were aware of the incinerator, which was attributed to the industrial nature of the area, meaning that it is less obvious than those in less industrial areas. 93% and 92% of respondents were aware of the landfill sites respectively. Only 28% of respondents reported c*oncern*, compared to 74% and 67% for the landfill sites. Concern fell with distance from site for all three locations. For the incinerator, air pollution was the most frequently cited problem, though mainly in terms of odour and dust annoyance. With respect to health concern, the lowest level of concern was observed for the incinerator (21%), also attributed to air pollution. Concern was highest for those who have the greatest mental and physical health, for those who have strong social network ties, and those who have lived in the area longest, though significant heterogeneity was observed across these sites. Unfortunately, little explanatory power was observed in regressions. Eyles et al report the results of a qualitative study that was run on a parallel basis and concerned the same facilities. The disparity between the landfill sites and the incinerator is probably due to differences in industrial activity surrounding the incinerator; residents are exposed to air pollution and traffic anyway, and are therefore less sensitive to the effects of individual facilities.

Elliott et al (2004) report a comparative analysis of the impact of three locations with nearby landfills and three with incinerators, spread across six locations in Ontario and British Columbia, Canada. They examine the determinants of five variables: awareness of the facility; concern about the facility; health concerns relating to the facility; number of coping responses, and; whether individuals intend to move. Awareness of the presence of an incinerator (66% on average) was low compared to locations with a nearby landfill (88% on average); while incinerators may be seen as essentially similar to other industrial facilities, for example as 'large building with a smoke stack', landfills have more unique characteristics, for example as 'a large hole in the ground'. Similarly, concern about the facility was lower for incinerators (26% on average) than landfills (58% on average). The same pattern emerges for health concerns, where just 15% for those who live near an incinerator against 39% for landfills. However, with the exception of awareness, these statistics mask wide variation across individual sites, indicating results are largely site specific. Furthermore, these findings also contrast with evidence that public acceptability of incinerators is typically much lower than that of landfill (Porteous, 2001). Logistic regression results show that awareness increases for males, with respondent age, for homeowners, and if individuals have participated with community events. Individuals are more likely to express concern if they own their own home, if they have participated in community events and if the site is relatively new. With regard to health concern, individuals are more likely to voice concerns if they have participated in community events.

7.2.2.1 Perceived Health Risk

As described above, it is the aim of the present report to augment external cost estimates with monetary values for amenity loss and to avoid double counting. It is necessary to ensure that there is no overlap between the amenity and other cost estimates. There exists potential for this to occur with respect to heath effects, particularly with respect to health risks.

Impact pathway analysis (IPA) is employed in other sections of this project in order to calculate external costs of industrial activity, including waste disposal, based on the EXTERNE methodology (Bickel & Friedrich, 2005). IPA links emissions to impacts, using the dispersion modelling and dose-response functions. The result is an estimate of the number of poor health episodes or fatalities that should be expected to occur for emissions of given pollutant in a given population. This is analogous to an estimate of risk exposure.

A frequent finding in the literature is a disparity between objective, or 'expert' analyses of the risk of mortality or illness, as embodied in IPA, and perceived health risks of laypeople. Existing scientific knowledge indicates that no health effects can be attributed to incinerators that use modern technology (DEFRA, 2004). Yet there are numerous acrimonious disputes surrounding planning decisions for waste disposal sites, particularly regarding incinerators, often centring around health. These disputes have been observed in the UK (Petts, 1992), Portugal (Lima 2005; Lima and Marques, 2006), and many other areas around the world, even leading to the formation of the Global Alliance for Incinerator Alternatives (www.no-burn.org). Explanations for this disparity vary, though most agree that risks are evaluated in a different way across the two groups. In general, evidence suggests that while experts discuss risk using terms such as probability, dispersion, and mortality, ordinary people see risk as attached to catastrophe and moral issues such as trust and fairness. Selected theories of perceived risk are summarised in Box 2.

Box 3: Selected Theories of Risk Perception

The psychometric paradigm of risk perception, attributed to the work of Paul Slovic (e.g. Slovic, Fischhoff, & Lichtenstein, 1986) finds that risks that are thought of as "dread risks" and unknown risks are thought to be more dangerous than others. Dread risks are felt when an individual has no control over exposure to the risk, when the consequences are highly dangerous or fatal, and is inequitable. Unknown risks represent those where the consequences are uncertain and delayed. For example, the consequences of genetically modified food production may fulfil this description.

Sandman (1988) describes people's perceptions of risk from industrial facilities to be driven by outrage rather than hazard. Outrage is in part determined by people's trust in institutions and governing authorities.

The Cultural Theory of Risk argues that risk is a product of, and supports, social structures. Thompson, Ellis and Wildavsky (1990) suggest that individual risk perception can be categorised according to social constraints and feeling of belonging and solidarity.

Elements of the above theories can be applied to adverse reactions to incinerators (Elliot et al, 1993, 1997; Lima and Marques, 1998; Lima, 2004). Residents who live close to proposed and existing incinerators indeed have no direct control over their exposure to emissions and annoyance. The presence of facility may well be perceived as inequitable because waste is a product of society, yet the impact of its disposal fall upon few. It is likely that individuals lack sufficient information to judge health risks, and to this extent, the consequences are unknown. Attempts by waste regulators and industry to articulate quantified risk assessments and to provide reassurance may mitigate unknown risks, though often with limited success (Petts et al, 1992). The media, as a social amplifier, can promote feeling of outrage and serve to increase the perceived risk level. Social pressure groups who promote alternative waste disposal methods portray incineration as unnecessary and pointless due to the availability of other management options (e.g., recycling), strengthening perceived risk. All of these factors act to strengthen perceived health risk.

It is likely that perceived risk and annoyance are interdependent in the minds of some individuals. For example, Lima finds several interactions between health concern and annoyance. In focus groups, she finds that residents associate every change in their health with changes in environment.

Some studies have investigated whether exposure to perceived risk can lead to psychological problems, including stress, worry and 'anxiety'. Lima (2004) finds that risk perception is a statistically significant predictor of psychological symptoms. However, this results differs for those living close to the incinerator and those living further away. For the former, risk is found to be a predictor, though for those closer it the interaction between risk and annoyance that is significant. This suggests that perceived risks compound the effects of annoyance.

Finally, some researchers have attempted to test the properties of perceived risk in applied work. In line with theories of perceived risk, McCluskey and Rausser (2001) estimate the impact of perceived risk from a hazardous waste site on house prices over a 16-year period. Perceived risk is estimated econometrically using a Generalised Maximum Entropy approach, which allows the estimation of unobservable variables under specific behavioural assumptions. The authors posit that perceived risk is determined by previous perceived risk and the media, where media coverage is measured by an index reflecting the number and prominence of newspaper articles about the facility. Unfortunately, there is likely to be collinearity between disamenities and perceived risk, and therefore the results are over-estimates of the property price impact of risk. Nevertheless, the authors find that perceived risk declines over time and is boosted by media coverage of the site.

7.2.2.2 Population density and presence of other industrial facilities

The total value of amenity loss is in part dependent on the number of exposed residents. However, the number of residents, the population density in the surrounding area and nearby industries may influence the perception of exposure itself. For example, such effects can be seen in the following:

- *Traffic:* If the area is characterised by high volumes of traffic, the impact of waste transportation to the incinerator may go largely unnoticed.
- *Visual Intrusion:* If the area has other industrial facilities located within it, the impact of the incinerator on the aesthetic quality of the area may be minimal.
- *Odour:* If the area has high levels of air pollution, again the impact of the incinerator may be marginal.

There is some support for this view in Elliott et al (1993), who use an epidemiological approach, in which 254 residents living close to an incinerator in Ontario, Canada were surveyed. Relatively few of the respondents worried about disamenity effects generated by the site due to the busy nature of the area. There is only one hedonic price study that we are aware of that considers this issue, that of Bouvier et al (2000). They examine 312 properties in six rural towns with landfills in Western Massachusetts, but fail to find significant effects on property prices, although the authors say this could be due to the small sample size. However, a meta-analysis of landfill studies by Walton, Boyd, Taylor, & Markandya (2007, forthcoming) provide further empirical support for this contention. They find that the effects of landfill sites are greater in less densely populated areas.

High population density and the presence of other industrial facilities help explain why awareness of the existence of an incinerator can often be less than 100% across nearby residents. For example, Eyles et al (1993) report that just 62% of residents are aware of an incinerator site in Canada.

7.2.2.3 Habituation Effects

One of the most well established observations in applied psychology is that the magnitude of impacts has been observed to fall over time. This is also referred to in the psychological literature as the habituation effect, a term we retain here. Impacts are often at their highest before an industrial facility is still in the planning stage, peaking during construction and then falling once the facility is online. Habituation occurs following a reassessment of moderating and mediating variables. In addition, external factors that serve to strengthen negative perceptions, for example, media scepticism, may weaken once over time.

Lima (2004) find that attitudes towards the incinerator and perceived risk both improve after the Porto incinerator began operation. Elliot et al (1993) and Taylor et al (1991) conduct quantitative and qualitative studies of psychosocial effects of three solid waste disposal sites in Canada, one landfill and two incinerators. The sample for the landfill site included all residents within 4.5 km of the landfill, which was then recently approved. 74% of residents reported concerns. This high level can be attributed to a history of acrimonious dispute surrounding the planned location of the facility. A higher level of concern was observed at 2km from the site (91%) than 4.5km (67%), supporting evidence of distance decay effect observed in economic valuation studies. The study area was revisited in 1992/3 and 1995 and the same survey repeated with the original respondents, allowing a longitudinal analysis of residents concerns. Results are reported by Elliot et al (1997). They describe a fall in concern levels over the period. Elliot et al attribute this fall to a decrease in "ambiguity, uncertainty, and lack of control" (Ibid, 1997: 238) as residents gain familiarity with the facility. However, these conclusions should be viewed in conjunction with the overall level of concern observed in 1995, which remained high at 50%.

Lima (2004) also offers an alternative explanation of the habituation effect. Reported levels of psychological wellbeing fell before and after ongoing operations began at an incinerator, in spite of the fact that attitudes improved and perceived risk fell. Lima suggests that this may be a result of a sustained cognitive effort to cope with the proximity of the incinerator, representing a significant burden on emotional and mental resources. However, there is no quantitative or qualitative evidence to support this contention.

7.3 Site Selection

7.3.1 Case Study Site Selection Approaches

At the time of writing, there are 21 operational incinerators in the United Kingdom, with several more under proposal, planning consultation, or construction. The location of operational incinerators is depicted in Figure 14.

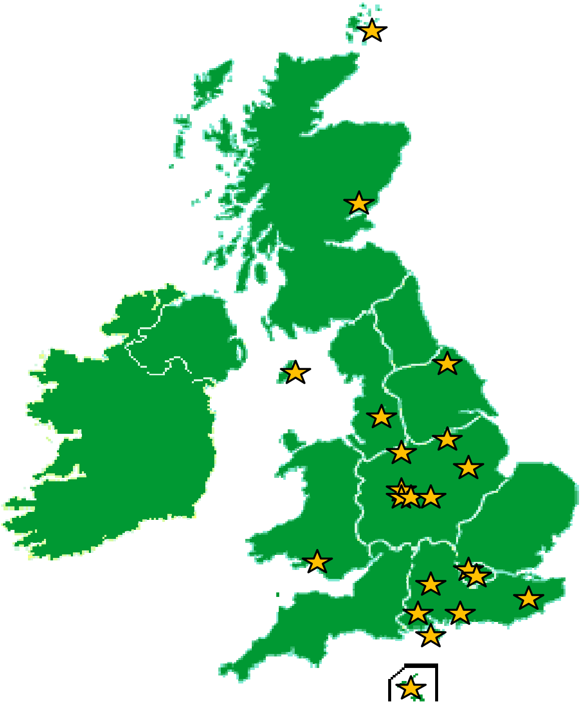
A number of possible approaches could be used in selecting a case study site. One possible approach available for selecting a case study site is to attempt to maximise the potential for accurate benefits transfer to other locations in Europe. Thus, we would attempt to identify a site with characteristics as close as possible to that as the median European incinerator, both in terms of technology and type of location. There is a multitude of characteristics available for consideration. However, the wide range characteristics to choose from, including the age of the site, the size (both in terms of throughput and land area), the type of technology, the population density and socio-demographic characteristics of the surrounding area, mean it is difficult to finding data for each one in Europe. This makes it difficult to identify the median site.

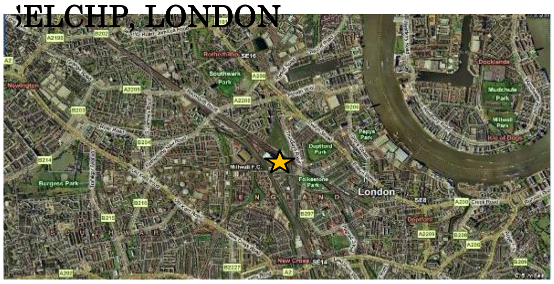
However, for illustration, we can investigate the tonnes of waste per year processed at each site in the UK. This is shown in Figure 19. Throughput ranges from less than 50,000 tonnes per year for the smallest sites and up to 585,000 tonnes for the largest sites. There is a tendency for new sites to be very large, though in contrast, some areas have instead chosen to construct a number of smaller facilities. An example of this is that of Hampshire, with the Chineham, Marchwood and Portsmouth facilities.

An alternative approach to identifying the median site is to use satellite imagery to examine the land use of the surrounding area. This is shown in **Figure 14**, where seven different UK incinerator images are provided. Close examination reveals that there is a wide variety of land-uses surrounding the sites, including agriculture, other industry, transport infrastructure, water bodies, residential uses and commercial uses. Based on the above comparison of UK sites, there is a wide variation in size and surrounding land use. For this reason, it is possible that very few sites will be similar to the median European site, regardless of the characteristics used to describe it. Ideally, a range of case studies should be carried out in order to generate a broader range of possible transfer values or functions. However, the resources available to this study mean that it is only possible to study one site.

Another alternative approach to selecting a site would be to choose one where amenity loss is potentially most likely to occur. The rationale for this approach can be described by referring to aerial images of the Allington, Chineham and Dudley sites. The Allington site is a new facility. It is located close to what appears to be residential areas to the southeast and west. There is a small industrial area to the North, a reservoir to the North West, and all other land is devoted to agricultural uses. Though it is not clear from the image, the incinerator is located in a former quarry, and as such is largely invisible from surrounding structures, all of which are at least 200 metres away. The Chineham incinerator is also a relatively new site. The site is surrounded by agricultural land except for a small community 500 metres to the west.

Figure 18: Location of UK Incinerators & Example Satellite Imagery





KM

Number and location of incinerators is correct at time of writing

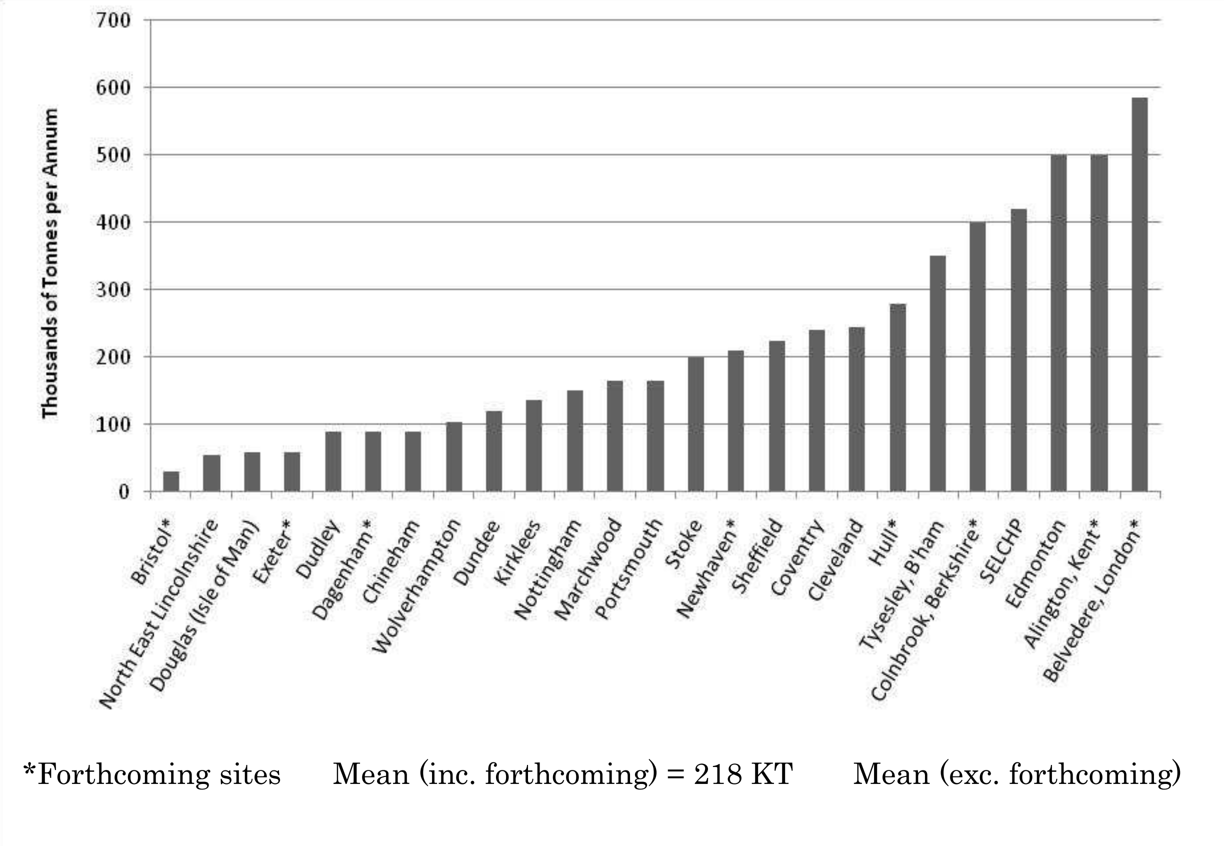


Figure 19: Incinerator Capacities in the UK

Finally, we consider the Dudley Incinerator; this is an older site and is much closer to other structures, some of which are located immediately adjacent to the site boundary. There appears to be a large park and industrial zones to the southwest, thought much of the rest of the surrounding area is apparently residential properties.

The Allington and Chineham sites are typical of new incinerator developments in that they are placed in a location chosen to minimise the impact on the public. Unfortunately, while this type of site may be described as close to the median location, little or limited information could be drawn from a case study of these facilities. Furthermore, it is likely that magnitude of amenity loss declines with increasing distance from the site. This decay may also be non-linear. If there are no properties in the case study within a given distance, for example 500 metres, though there are in the benefits transfer site, assumptions concerning the impact within 200 metres will need to be made. If there is no impact observed within 500 metres, i.e. impacts decay completely within this distance, no information will be made available at all. It is well established that noise and odour impacts are affected by the direction of prevailing winds. Therefore, similar logic can be applied to direction from the site.

The Dudley Site has residential properties located from the site boundary up to much further distances and in a majority of directions. While this site is less likely to be representative of newer developments,, a case study of this site can potentially provide information across the full range shape of the distance decay function.

In summary, the accuracy of benefits transfer using the results of this case study could be maximised by selecting a site that is representative of the median facility in Europe. On the other hand, the median site may not allow us to draw information on the impact on amenity loss over different distances and in different directions. In this case, the potential for benefits transfer is limited. For this reason, we have decided on a site with potential for observing amenity loss, namely the Dudley incinerator.

7.3.2 Overview of Case Study Site

The town of Dudley lies in the West Midlands, and with a population of almost 195,000 it is the UK's second largest town. It also represents the western fringe of a vast conurbation of almost 2.3 million people, comprising the cities of Birmingham and Wolverhampton and the towns of West Bromwich and Walsall. The town lends its name to Dudley Metropolitan Borough Council, which also includes the nearby towns of Stourbridge, Halesowen and Brierely Hill. Culturally, Dudley is part of the more loosely defined Black Country area, a name thought to follow from the highly intensive use of coal in the area during the Industrial Revolution. However, heavy industry has now gone and the service sector - including banking, finance, insurance and distribution - now dominates. The area has also become characterised by high levels of economic deprivation, with low average incomes, high levels of worklessness and low rates of business creation (Dudley MBC, 2007).

This study is primarily concerned with the effects of the incinerator located on Lister Road, which lies in the ward of Netherton and Woodside. This ward and other wards that are potentially affected by the presence of the facility[5] are amongst the poorest in the Dudley MBC area. The Lister Road Depot is owned by Dudley Metropolitan Borough Council (MBC) and is a platform for numerous local services. The site is located to the south of the Dudley central business district. Light industrial units lie immediately to the west of the site, with a major trunk road beyond. In all other directions, the site is surrounded by residential properties. An aerial view of the area is provided in Figure 5.

The Lister Road Depot is owned by Dudley Metropolitan Borough Council (MBC) and is a platform for numerous local services. An incinerator facility was first established on the site in 1938. A refurbishment was carried out in 1967, and in January 1996 Martin Environmental Services (MES), the operating arm of Dudley Waste Services (DWS), was awarded a 25 year contract in 1996 to redevelop, upgrade and operate the incinerator. The new facility began accepting waste on 14th February 1998. The incinerator burns Municipal Solid Waste (MSW), which comprises non-hazardous waste collected from residential, commercial and industrial sources. In common with most MSW incinerators in the UK (Enviros, 2007), the incinerator is based on 'moving grate' technology, a term describing the way in which the waste is passed through to the combustion chamber. The facility building has a total land take of around 3500 m^2 and a stack height of approximately 38 metres. Approximately 90,000 tonnes of MSW are burnt every year. In addition to an Energy-from-Waste (EfW) Incinerator, other services incorporated within the depot include a green waste transfer station, a dry recyclables transfer station (glass and metal), council vehicle storage and maintenance, and salt storage for use in wintry weather.

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[5] Namely St Thomas's, St Andrew's, St James and Rowley.

FIGURE 20: LISTER ROAD DEPOT: AERIAL IMAGE OF SURROUNDING AREA

☆ Location of Lister Road Depot ⋯ 2 KM from Depot

The incinerator is the primary destination for all non-recycled or non-composted waste collected from residential properties, the civic amenity site (located in Stourbridge) and swept from the streets in the Dudley MBC area. MSW is delivered to the site by vehicles in 20 to 25 tonne vehicles and dropped into one of four tipping bays. These bays have a total nominal capacity of 320 tonnes, though it is possible to store up to 1,100 tonnes by heaping the waste into a pile. From here, the waste is moved by crane into one of two combustion chambers, also known as 'lines', where the waste is burnt at temperatures in excess of 850°C. This heat is utilised in a boiler to create steam which turns a turbine to create electricity, which is fed into the national electricity grid. 7 MW is generated annually, representing an efficiency of 17 – 30% (Enviros, 2007).

For every 100 tonnes of waste going into the facility, 20 tonnes of Incinerator Bottom Ash (IBA) and 4 tonnes of fly ash are created. The rest is converted to carbon dioxide, steam and a range of other gases and substances. Thus, the waste is reduced by 76% by mass, which is equivalent to around 93% by volume. IBA can be used as construction aggregates, though it is currently to send it to landfill[6]. Fly ashes are captured by a bag house filters on the chimney stack. These ashes are hazardous and must be disposed in line with regulations.

In addition to incineration, the depot serves as a transfer station for green waste. Green waste, which comprises of garden waste and some organic food waste, is delivered by collection vehicles to the depot, where it is stored for a maximum of 48 hours before being transported to a reprocessing facility elsewhere. 6,000 tonnes of this material passes through the depot each year. There is an additional area in the depot that is a transfer station for dry recyclables, including glass bottles, tins and drinks cans made of steel or aluminium. Again, these materials are delivered by collection vehicles and subsequently transferred at a later date. 4,000 tonnes of dry recyclables pass through the depot each year.

Unusually for facilities of this type in the UK, the entrance to the site is on a residential street. Due to the wide range of activities that take place at the depot, there are no precise estimates of the number of vehicles that come and go from the site each day. However, using data on the number of domestic collection rounds, typical vehicle size and load level, and ash generation rates, we estimate that there are 120 heavy vehicle movements per day attributable to the incinerator, green waste storage and recyclable storage. Assuming that this represents around ½ of the total movements taking place at the site, total movements from all vehicles are equal to 240. This is clearly quite a large volume of traffic for a residential street.

7.3.3 Priority Impacts at the Case Study Site

The presence of a wide range of activities affords the opportunity to investigate a broad range of potential impacts on amenity levels in the local community.

Complaints made about the site are collected by the Dudley MBC Environment and Planning Department. These records are also passed to the Pollution Permit and Control Regulator, the UK Environment Agency, who also record complaints made directly to them. Other complaints may be made directly to the staff located at the site itself. Complaint data from Dudley MBC was made available to the University of Bath, though not from the other two sources. Nevertheless, the available data was used to inform the identification of causes of amenity loss. It should be remembered that complaints are typically only made by a limited number of informed individuals, and therefore this data

[6] The landfill of IBA is thought to largely result from the official classification of IBA as a waste. The associated stigma, and the fact that end users must therefore comply with waste licensing regulations if they wish to use the material, reduces the demand for its use. However, this classification is currently under review by the UK Environment Agency, and if suitable quality and processing standards can be defined and maintained, the waste classification will be removed and is likely to lead to a sharp fall in the landfill of IBA.

is not necessarily representative of the nature, intensity, and spatial distribution of any causes of annoyance. The main sources of disturbance are shown below.

7.3.3.1 Noise from the Incinerator Steam Release Valve

The heat generated by the burning of waste is used create steam, which in turn drives a turbine to generate electricity. This electricity is fed into the national grid. Occasionally, the link between the incinerator and the national grid ceases to operate. When this occurs, there must be an alternative mechanism for reducing the pressure caused by the build up of steam. At the Lister Road site, pressure is reduced by way of a steam release valve. When the valve is activated a very loud whistling noise occurs which can be heard from nearby properties, and as such, is a potential cause of disamenity. The effect of the noise may be confounded by the fact that the valve can be activated at any time of day or night and therefore has the potential to disturb sleep. The potentially intrusive and disruptive nature of the noise may increase welfare loss.

Noise from the steam release valve occurs randomly. According to records kept by the site operators, noise can be expected to occur 4-8 times per year. There were five complaints regarding the noise registered between 2003 and 2006.

7.3.3.2 Odour from the Storage of Green Waste

As described above, an area of the site acts as transfer station for municipal green waste. Green waste is stored in an open bunker close to the incinerator. This Activity occurs from February to November to coincide with demand for the service. This waste can be a cause of odour, which is described as similar to a rotting food smell.

There are only limited measures to prevent this odour causing amenity loss, namely deodorants which are sprayed on the waste. However, complaints data and anecdotal evidence suggests that this odour can still be a problem. A total of three complaints were made about odour to Dudley MBC between 2004 and 2006.

7.3.3.3 Visual Intrusion

The presence of the incinerator, particularly the chimneystack, in the landscape of the area may be a cause of welfare loss to residents. Images of the construction are shown in Figure 21.

7.3.3.4 Traffic

As described above, a large number of vehicles enter and leave the site each day. The entrance/exit to the site are located on a residential street, and therefore there is potential for annoyance to be experienced by these residents. Other residents living further away from the site may also be exposed if they live on a street that is a regular route for vehicles. However, given that collection vehicles travel to all areas of the town, disturbance is likely to be most intensively experience closer to the site. The annoyance caused by traffic can range from noise, vibration, odour, and congestion.

7.3.3.5 Health Risks

The major potential hazard to human health is emissions from the chimney, or 'flue gases'. A range of other technologies are employed to reduce the environmental and health risks of emissions to the local area. Lime injection is used to control sulphur dioxide and hydrogen chloride, ammonia injection for the control of nitrogen dioxide, and carbon injection for the capture of heavy metals. Emissions are regularly monitored to ensure that they are within limits specified by the Pollution Prevention and Control (PPC) permit. Enviros (2006), provide comparative annual emissions levels for a range of pollutants for a facility processing 230,000 tonnes per year. These comparisons have been rescaled to match the Lister Road throughput of 90,000 tonnes and reproduced below:

Oxides of Nitrogen: Emissions from a 2.7 km stretch of typical motorway;
Particulate Matter: Emissions from a 2 km stretch of typical motorway;
Dioxins and Furans: Emissions from accidental fires in a town of 72,000 people;
Cadmium: A fiftieth of the emissions from a medium sized UK coal-fired power station.

It is notable that these emissions levels are quite low. The majority of the other emissions are carbon dioxide and water vapour. These gases have no health implications (climate change effects not withstanding), though it is the moisture content of the emissions which causes the chimney to have a noticeable plume. The plume is only visible when the air surrounding the top of the chimney is cool enough to allow the water vapour to condense.

As noted elsewhere in this document a key objective of this research is to generate welfare estimates that do not include health effects.

Figure 21: Image of Lister Road Incinerator

7.4 Research Design

As described in section 2, the hedonic price model has been widely used to value impact of landfill sites on nearby residents. One study, Kiel and McClain (1995) applies this approach to the impacts of a municipal solid waste incinerator. The results of hedonic property price models reflect a broad range of effects, including amenity impacts, stigma and perceived health impact. The model typically combines the effects of these impacts into a single indicator, namely the marginal increase in house prices as a function of distance. Because an objective of this work is to generate separate estimates amenity impacts, in particular estimates that do not include perceived health impacts, the hedonic price model is not appropriate.

In order to value amenity loss we employ choice experiment methodology. A choice experiment involves choosing between different groups of options, known as choice cards. Each option consists of characteristics, or attributes, and attribute levels. With respect to amenity loss, the attributes of an option would be noise, odour, visual intrusion and traffic levels, and the attribute levels would be the amount of noise, the amount of odour, and so on. When asked to choose between different options the respondent is made to trade-offs between attribute levels. If price, or the cost to each member of the relevant population if the option were to be implemented, is included as an additional attribute then we can estimate the willingness-to-pay for improvements in the other attributes. The advantages of this approach include the ability to:

- Explore the full range of attribute levels.
- Generate different willingness-to-pay results for each attribute.
- Increase the sample size by asking each respondent to complete multiple numbers of choice cards.

In order to assist in the design of the choice experiment survey, two focus groups were carried out in February 2008. Each focus group consisted of ten participants selected from the local area. Two pilot surveys were also performed to aid the design of the final survey instrument. The first pilot survey of 50 respondents was performed in April 2008 and the second pilot of 60 respondents was performed in July/August 2008. The major influences of these exercises in the final survey design is discussed alongside the description of the survey design. More detailed descriptions of the principle findings of these exercises are contained in annexes to this document.

7.4.1 Response Format

This research focuses on annoyance or disturbance experienced by residents in the area surrounding the Lister Road Site. As such, it is necessary to ensure that respondents live close, or within a predefined distance, to the site. This, coupled with the fact that the area of interest is quite small, tends to rule out interceptions survey methods, as it could be very difficult to find enough respondents living within this area. Therefore, a response format that allows the researcher to have a high level of control where respondents live is preferred.

Postal surveys allow researchers to be highly selective about the location of households. However, the 'concealed objective' structure of the survey means that it is important that respondents are unaware of future questions when they begin the survey. This cannot be guaranteed with a postal survey, as respondents are free to browse all of the materials before they begin. Postal surveys also have a very low response rate, typically 10%.

A household door-to-door approach allows the researcher to control where respondents live and allows the interviewer to control the way in which the questions are passed to respondents. As such, this method is preferred for this research.

The survey is designed to last approximately 20 minutes. Respondents are informed that they will be given a shopping voucher at the end of the survey in exchange for their time. This is standard procedure for surveys of this duration.

7.4.2 Design of Survey Instrument

The survey instrument is designed in order to meet the following principle objectives:

- To establish the exposure of residents to amenity loss (i.e. noise, odour, visual intrusion and increased traffic levels) that can be attributed to activities on the Lister Road site. The effects of distance and direction away from the site on exposure levels are of key interest.
- To establish the welfare loss experienced by residents resulting from exposure to the causes of amenity loss that is attributable to the Lister Road Site. Welfare loss is to be measured by using choice experiment methods to estimate respondent's willingness-to-pay to reduce exposure. As far as possible, willingness-to-pay estimates should not reflect perceived health effects.
- To gather data on key background variables that might be expected to influence reported exposure to the causes of amenity loss and willingness-to-pay estimates. One such variable is the impact of other industrial facilities in the area. Other variables include moderating and mediating variables and socio-demographic variables. Analysis of the effects of these variables will aid the development of a benefits transfer approach.

The survey follows 'Concealed Objective' Approach whereby respondents are not told specific topic of the survey when it begins. This enables the interviewer to retain control over the topics of discussion and helps ensure that the respondent considers each question while drawing on the contextual information intended by the researchers. The remainder of this section describes the design of survey in more detail.

7.4.3 Section A: Opinions on local area

The purpose of this section is to make respondents begin thinking about their local area and is intended to prepare respondents for more detailed questions in later sections. However, questions on potentially significant background variables are also included.

The first three questions focus on how long the respondent has lived at their current address and if they have lived at previous addresses within the neighbourhood. The results of these questions should be used to establish the effects of habituation. Question A4 asks how often the respondent leaves the neighbourhood to go to work, go shopping, visit friends and relatives, and so on. This is potentially significant as individuals who spend time away from the neighbourhood reduce their exposure to the causes of amenity loss. Question A5 and A6 asks respondents to rate the extent of problems caused by a number of potential problems commonly related to the quality of a neighbourhood, such as antisocial behaviour, littering and potholes. Ten problems are presented in total. The design is intended to make respondents compare each problem, thereby considering each problem relative to their overall assessment of the neighbourhood.

Question A7 asks respondents to state whether they agree to a series of statements. One of these statements is “This area is industrial”. The results to this statement should be used to determine the whether welfare loss is sensitive to the presence of other industrial facilities. It is expected that marginal impact of the Lister Road site on welfare will be lower is lower if this is the case. This issue is raised in the description of work with respect to this deliverable. Ideally, one would compare the marginal impact of an additional facility in the presence of other, similar, facilities located close by. However, a lack of facilities similar to the Lister Road site in the sample area means that this is not possible. Other industrial activities in the area consist of an area of small industrial units located to the southwest of Lister Road and these are likely to have much lower impact in terms of amenity loss. Thus, in the absence of other similar causes of amenity loss, it was decided to focus on respondents perceptions of level of industry in the area.

7.4.4 Section B: Exposure to amenity loss, annoyance, perceived health effects

The focus of this section of the survey is to establish the degree of exposure to the causes of amenity loss. We also focus on the degree of annoyance or disturbance caused by exposure to noise, odour, visual intrusion and increased traffic levels. It is important to establish this for two reasons. First, this allows us to establish the impact of exposure. Secondly, the responses can be used as a validity check on the WTP estimates derived from analysis of the choice experiment results; *ceteris paribus*, we would expect greater WTP estimates for individuals who are more highly annoyed.

The design and wording for questions regarding exposure and annoyance is based on ISO Technical Specification 15666, *Acoustics – Assessment of Noise Annoyance by Means of Social and Socio-acoustic Surveys* (ISO, 2001). The use of this specification is recommended in Navrud (2002) in a discussion of state-of-the-art economic valuation of noise. The advantage of adopting this specification is that it facilitates comparison with other studies who adopt this approach (for example, Michaud et al, and the recent study as part of the NEEDS project). The wide variety of survey question designs that could be adopted can complicate this process. As such, it is important to retain the exact question wording proscribed in the specification.

Each cause of amenity loss is described to the respondent and they are told that there are reports that this is as a cause of concern in their neighbourhood. They are then asked two questions:

> B1/B5/B10/B14 *Thinking about the last 12 months or so, when you are here at home, how much does [description of problem] like the one described bother, disturb or annoy you: Not at all, Slightly, Moderately, Very, Extremely?*

> B2/B6/B11/B15 *We will now ask the same question, though this time we would like you to respond on a scale from zero to ten. If you are not at all annoyed choose zero, if you are extremely annoyed choose ten, if you are somewhere in between choose a number between one and ten.*

As can be seen, annoyance is elicited using two separate rating scales. The rationale is that the second question provides supporting evidence for the first question, where individuals might have different understandings of the word descriptors used in the survey. This is also "consistent with the most basic principles of increasing the reliability of psychometric measurements" (ISO, 2002:7). Both questions make use of direct question formats (as opposed to indirect formats such as 'how would you describe this noise?') in order to ensure that each respondent is presented with same anchoring point to communicate their response. This eases the analysis of the data. For more discussion of the precise wording of each question, see ISO (2002).

Following the two questions on annoyance, respondents are then asked about their level of exposure to each problem. It appears counter-intuitive to ask this question after the annoyance questions. Indeed, a question on exposure could serve to act as a screening question to establish whether the annoyance questions are needed. However, respondents may respond to a screening question in the way that it is intended. To illustrate this, consider a respondent who aware of a noise but is not annoyed by it. If they are asked if they notice the noise, they may say that they cannot hear it because they 'cannot *really* hear it' or they 'don't really notice it' even though the noise is actually audible. Thus, they focus on subjective reasoning (i.e. their level of annoyance) rather than the objective assessment required by the researcher. To avoid this problem, screening is avoided and questions about exposure are asked after questions about annoyance.

The Lister Road site is not specifically discussed at this stage. This is to prevent respondents who have strong concerns about the site from overstating their responses in the hope that more will be done about the issue. Instead, after each cause of amenity loss is discussed, the respondent is asked whether they know the source of the problem. An exception to this is required for questions about increased vehicle traffic, when it is necessary to discuss the site in order to describe the heavy vehicles used to transport waste material.

A final set of questions introduced in this section of the survey concerns health effects. As discussed in previous sections of this report, there is a need to avoid capturing health effects in welfare loss estimates as these are captured by other impact pathways, leading to potential for double counting. To approach this problem, it was decided to attempt to mitigate respondent's fears about health risk as far as possible. Respondents are first asked if they are concerned that the incinerator is a source of risk to the health of those living close to the incinerator. If they say yes, we ask for further details of this concern. All respondents are then read the following statement:

The incinerator located on Lister Road is a modern facility and meets strict conditions imposed by the regulator. For example:

> The waste is burned at a very high temperature to make sure the air released is as clean as possible. In fact, events such as firework displays and bonfires cause much more pollution in a single year than the incinerator.
>
> What sometimes looks like smoke coming from the top of the chimney is mostly water vapour. This turns into condensation when the air around the top of the chimney is cold, in the same way as your breath does on wintry days. There is no soot because it is collected using filters to prevent it being released into the air.
>
> Detailed reviews of scientific studies show no link between incinerators and the health of people living nearby.

Following this statement, all respondents are asked again whether they consider the incinerator to pose a threat. This is asked of all respondents to take account of the possibility that the statement could *increase* concerns about health risk. The statement itself is designed to minimise the health concerns of respondents. It should be noted that the health effects of incinerators are widely debated. For example, a report by the British Society of Ecological Medicine (2005) describes supporting evidence for a wide number of health risks associated with incineration. In contrast, the DEFRA study concludes that health risks posed are likely to be small compared to other risks.

In section D of the survey, respondents are also asked whether they considered health effects when responding to the choice questions. If respondents do not consider health, this suggests that WTP estimates exclude perceived health concerns. Any respondents who do consider health effects in the choice cards can be excluded from the sample used in statistical analysis. Alternatively, the full set of respondents can be maintained and tests performed to investigate whether there are statistically significant effects on WTP estimates. If there are no significant effects then it can be claimed that WTP estimates meet are acceptable for this task.

7.4.5 Section C: scenario description & choice cards

7.4.5.1 Scenario Description

This section of the survey introduces the scenario underlying the choice experiment. The choice experiment itself is also completed. The following discussion should be read in conjunction with the scenario description itself.

Respondents are first presented with ways in which each cause of amenity loss can be reduced:

Noise from the steam release valve Respondents are told that new equipment can be installed to warn the operators when the noise may occur such that they can take steps to prevent it from happening. Three different possibilities are presented: (i) no change in noise levels, i.e. no action is taken, (ii) 50% less chance of the noise occurring, (iii) 90% less chance of the noise occurring. Note that changes are presented in terms of the probability of the noise occurring as opposed to exact number of times. This is because focus groups showed that different residents have a different opinion about how many times per year they hear the noise. It would not make sense to say there are 10 fewer noise events per year if the respondent only hears it 4 times. Using percentages avoids this problem. Framing the proposals in terms of probabilities also reflects the fact that the noise is not something that can be completely controlled by the operators.

Odour from Green Waste Respondents are told that the air around the green waste can be captured and passed through the combustion chamber of the incinerator where the high temperature would destroy the smell. This would lead to a 100% reduction in the number of days when odour would be noticed. An alternative strategy is restrict the escape of odour by building a roof over the storage area, leading to a 50% fall in the number of days when odour would be noticed. Finally, no action could be taken and odour would remain the same. Again, percentages are used due to differences in the amount of times each respondent would notice the odour in a given period.

Traffic from Heavy vehicles Respondents are told that the operators can take steps to ensure that each vehicle entering the site carries more waste, thereby reducing the number of trips required. Three options are presented: (i) take no action, meaning 120 vehicle movements per day, (ii) reduce the number of movements to 90 per day, (iii) reduce the number of trips to 60 vehicle movements per day.

Visual intrusion Respondents are told that the height of the incinerator chimney could be reduced. In order to maintain air quality if the chimney is lower, respondents are informed that new equipment would be installed to burn the waste at a higher temperature. Participants in focus groups raised concerns about whether lowering the chimney height would lead to increased exposure to emissions. If respondents believe this it is possible that willingness-to-pay estimates for this attribute will also reflect perceived health effects. Additional text reassuring respondents that this will not be the case was inserted for this reason. A further concern is that the chimney height may not completely capture visual intrusion; the buildings and other structures associated with the site may also be a cause of concern for residents who live very close to the site. The only way of reflecting this in the survey design would be to state that the whole Lister Road site would be moved elsewhere. However, this would also imply that all other problems associated with the site would also disappear and these would subsequently be captured in the WTP estimate. For this reason, it was decided to focus on chimney height alone. Three options are presented: (i) no change in chimney height (ii) reduce chimney height by 90%, (iii) reduce chimney height by 50%

It is unknown whether the steps described to reduce amenity loss are actually possible either on a technological or practical basis. Instead, it is more important that respondents believe them to be plausible. The measures described were presented to focus groups and they stated that they found this to be the case.

7.4.5.2 Payment Vehicle

Respondents are then told that the proposed options are expensive and that this survey will be used to establish which ones would be most beneficial to residents. They are then given the following information:

> *These changes would be funded by* ***a compulsory one off payment***
>
> - *This would be made by all households in the Dudley area, not just those affected by these issues.*
> - *It would be added to your normal council tax bill. This would be for one year only.*
> - *The council have an agreement with the site operators to pay for any major changes, such as the ones described here.*
> - *The money would go directly to the site operators and is guaranteed to be used for this purpose and not for anything else.*

An optimal payment vehicle for use in economic valuation studies should be binding. This means that respondents must believe that they would have to make a payment if one were required. This ensures that respondents consider their budget constraint and any relevant tradeoffs with other expenditure categories. The payment vehicle should also be consequential, meaning that respondents must believe that the information they provide will form part to any option finally selected by policy makers (ref from Olympics). When the payment vehicle is both binding and consequential, the responses to valuation questions can be considered as reflective of the true willingness to pay function.

The Lister Road site is run as a partnership between the operators and the local authority. The local authority is responsible for financing any major changes that fall outside the terms of the contract between the two parties. Thus, council tax payments meet the consequentiality condition, as this is most realistic method for funding the proposals. However, some participants in focus groups expressed doubt about whether the money would truly go towards the changes. To attempt to mitigate these concerns we included bullet point four in the above text.

Because council tax payments are required from the majority of households in the United Kingdom, the payment vehicle is binding. An important exception is for poorer households who are entitled to full of partial exemption from payments. Thus, the payment vehicle is non-binding for respondents who meet this criterion. We include a question on this in section E of the survey to help identify such respondents in the sample.

A disadvantage of using council tax payments is that they are highly controversial in the current political climate. This may mean that some respondents will refuse to pay any additional council tax. Where this is true, their responses do not reflect their underlying willingness to pay and their response is considered as a protest vote. Debriefing questions are inserted into section D of the survey to identify when this is the case.

A voluntary payment vehicle that may lead to lower levels of protest votes was considered early on in the research design process. The initial pilot survey, which is described in more detail later on in this document, was split into two halves in order to test this alternative. One-half included council tax and the other included a voluntary mechanism. For this mechanism, respondents were told that they would be asked to contribute to a community fund. Unfortunately, the lack of precedent for this type of arrangement in the UK meant that we were unable to describe the community fund in a way acceptable to all respondents, leading to widespread rejection by respondents, leading to an insignificant difference in non-payment levels between this and the council tax vehicle. Thus, a compulsory council tax vehicle is preferred due to its superior incentive properties.

The possible cost to residents is entered as an additional attribute in the choice cards. Three values were selected: £6, £12 and £18. A value of £0 always appears in option C, the *status quo* option. Respondents are next shown an example choice card before being asked to complete eight choice cards independently. The design of the choice cards is discussed below.

7.4.5.3 Experimental Design

Each of the five attributes (four amenity plus price) has three possible levels that could occur in options A or B in each choice card. This yields 243 unique profiles and thus a full factorial design, whereby each respondent is evaluates each profile, is unpractical. A fractional factorial design is required.

If the welfare impact of one attribute is conditional on the value of another then this increases the number of degrees of freedom needed in statistical models. This was investigated using focus groups and no logical explanation for the existence of conditionality in this study was identified. Thus, a statistical design based on main effects only is sufficient. The following steps, based on Street et al (2005), were undertaken in order to generate the statistical design:

- The SPSS software program was used to generate the smallest possible Orthogonal Main Effects Plan (OMEP). This generated 16 profiles. These represent the 16 Option A profiles.
- To create the corresponding Option B profile, the contents of each profile in the OMEP are coded as 0, 1 or 2 depending on the individual attribute level. The generator 21212 is applied using modulo arithmetic to generate the new profile. This creates 16 pairs of profiles. By definition, neither of the options in each pair is dominating.

- Two sets of eight pairs are created using a random number generator. Within-set dominance is investigated and the profiles are repeatedly reassigned until within-set dominance is minimised.
- A *status quo* option is added to each pair, denoted Option C. This option features no improvements to the Lister Road site and no payment is required by residents.

Each respondent completes one set of 8 choice cards, each one comprising a pair of profiles containing unique versions of the proposal and a *status quo* option. This means that each respondent provides 8 observations that can be used in the statistical analysis.

7.4.6 SECTION D: Debriefing questions, opinions on Lister Road Site

The first question in this section is targeted at respondents who selected option c in each of the 8 choice cards. An open question is used to ask for the reasons why they always selected this option and the interviewer is instructed to tick reasons that correspond to their answer on a predetermined list. This question is crucial to identify protest votes. A respondent is considered to be a protest voter if they say they refuse if they indicate that they have rejected the terms of the choice experiment. This may be because they think the scenario is unrealistic, they reject the payment vehicle, they do not think it is their responsibility to pay, et cetera.

Next, questions are asked about the importance of each attribute and the consideration given to health in the respondent's answers to the choice cards. The responses to these questions can be used to validate a respondent answers, for example by comparing them to the annoyance levels reported by each respondent. The importance given to health in the choice card responses is intended to be used to indicate whether the welfare estimates include perceived health effects.

The rest of the section of the survey is devoted to asking questions about factors that may be important in explaining WTP. These include potential moderating variables, such as attitudes to the incinerator and the waste management process, and mediating variables, such as the strength of community relations.

7.4.7 SECTION E: Socio-demographic characteristics

Questions on household composition, marital status, occupation and employment status, education, income and council tax benefit relief are included. The age and gender of the respondent is asked at the beginning of the survey.

7.4.8 Sample Area

The sample area for the initial pilot test was constructed by selecting five locations. At each of these locations, ten interviews were carried out. The five locations and the distance of each from the Lister Road site are shown in Figure 17. The only information available to the research team about the distance over which exposure to amenity loss occurs is drawn from the Kiel & McClain (1995) study into an incinerator in North America, who suggests that effects are statistically significant at up to 3.7 miles (6km) from the site boundary. A preliminary visit to the case study area suggested that this is unlikely in

Dudley, and therefore the maximum distance of from the site of each of the five locations is 2.5 miles.

The results of the pilot test showed that 38 of 50 the respondents interviewed were unexposed to any of the causes of amenity loss included in the survey. Only respondents from one of the five groups indicated that they were exposed to any amenity loss. This limited the usefulness of this exercise as little information about the effectiveness of the choice cards could be gained. In addition, little information can be drawn about the likely shape of the distance decay functions for exposure and annoyance. Another pilot study was therefore required.

The approach taken for the second pilot study was to select a much smaller sample area. The rationale was to ensure that more respondents would be potentially familiar with the effects of the site. In order to ensure that that more respondents in the second pilot were exposed to the effects of the Lister Road Site a much smaller sample area was selected. This is depicted by the white line in Figure 17. The shape of this area is influenced by the topography of the surrounding area and is therefore not a concentric shape. The maximum distance from the site is 1500 metres.

Five zones of four streets were selected from within this area, as shown by the different coloured lines in Figure 17. Interviewers conducted 12 interviews in each zone with no more than three interviews per street. Interviewers tried to spread the interviews out as much as possible. Interviewers were instructed to keep records of which residents they interviewed and which residents declined to be interviewed. This allowed interviewers to revisit these streets for the purposes of the main sample with the knowledge that these residents would not be asked to provide an interview again.

The results of the second pilot survey are summarised as follows:

- Reported exposure to each cause of amenity loss declines with distance. In each case, the point at which reported exposure reaches zero is contained within the sample area shown selected.
- No respondent living 600 metres or more from the site reported hearing noise from the steam release valve.
- No respondent living 600 metres or more from the site reported noticing odour.
- No respondent living 1200 metres or more from the site reports that they can see the chimney from their house.
- No respondent living 600 metres or more from the site considers that they are affected by traffic associated with the Lister Road Site.

These results confirm that the distance decay rate is much higher than suggested by the Kiel & McClain Study.

Based on the pilot two findings, the area drawn by the green line in Figure 17 is used for the main sample. This is the same as the second pilot sample area, though is slightly extended to the west and south. The boundary remains the same in other directions due to the effects of surrounding hills.

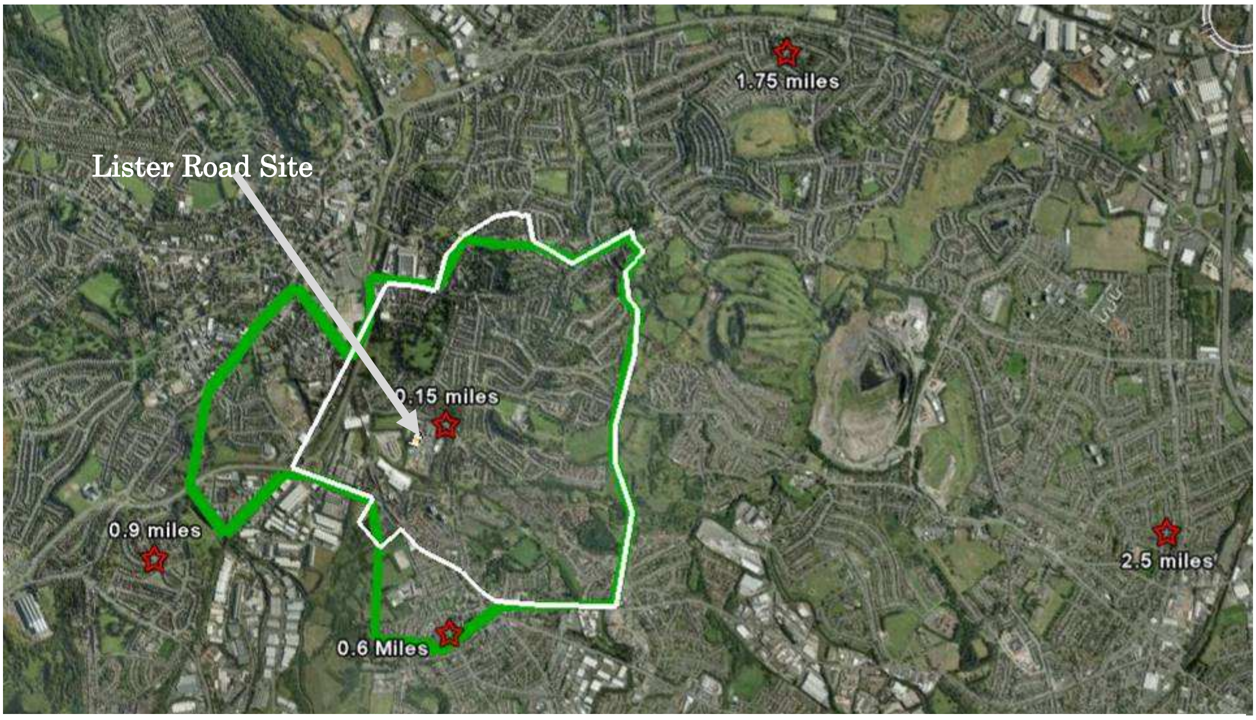


Figure 22: Sample Area

7.4.9 Other Design Conventions

The following design conventions apply in the design of the survey instrument.

- For questions that require respondents to respond to a number of statements or points, interviewers are instructed to rotate the starting point for each respondent. This is also applied to the choice card sets, whereby the interviewer ensures that the first choice card given is rotated. This helps reduce the effects of question order and fatigue.
- Direct questions with fixed response formats are preferred to indirect questions with open response formats. This makes it easier to code and compare responses.

7.5 Data Analysis and Results

7.5.1 Methodology

This study employs choice experiments to assess the values placed on disamenity from incineration. The method is designed so as to mimic a real market situation. This is achieved by allowing multiple alternative scenarios to be presented, reflecting varying levels of the attributes - of which one is price. The respondents then must make a decision, using this information, whether to 'buy' one of the alternatives or not and choose the status quo option.

As described in Section 4, in this study there are three choices/alternatives: two alternatives that advocate a change, which demand a payment in the form of a tax, and one that maintains the status quo and is costless. The two choices that require a one off payment possess improved environmental attributes by a reduction in at least one of the disamenities: Noise, Smell, Traffic or Chimney Height (a measure of visual amenity).

Data analysis is based on the Random Utility Model (RUM). This method is employed in order to obtain selection probabilities. The random part does not assume individuals make choices randomly, rather it acknowledges that important unobserved influences on choice behaviour have not been accounted for, and that these can be characterized by a distribution in the sample population. As this study is based on the RUM the welfare economic principles espoused by Hanemann (1984) can be utilized to analyse the welfare impacts accrued from a change away from the status quo.

The RUM can be described as follows; assume that G is a set of alternatives in the total choice set and S a set of measured attributes. Following this a randomly selected individual will possess an attribute vector $s \in S$ and a choice of alternatives $A \subseteq G$. Therefore the decision made by the individual can be described as a draw from a multinomial distribution with selection probabilities:

$$P(x \mid \mathrm{s}, \mathrm{A}) \, \forall \mathrm{x} \in \mathrm{A} \qquad \text{eq. 1}$$

The equation describes the probability of the individual selecting alternative x given his socio-economic background and set of alternatives A, for each and every alternative present within the choice set. Note that each alternative is defined in terms of a set of attributes. As the individual is bound to select only one alternative a discrete choice model is employed.

Having defined the selection probabilities these now need to be related to the concept of utility maximisation. By assuming that each respondent is maximising his utility function the respondent will make his selection that allows him to achieve his highest possible utility. Therefore individual i will choose alternative k if and only if:

$$U_{ik} > U_{iq} \text{ all } k \neq q \in A \qquad \text{eq. 2}$$

Where i represents the individual respondent and k represents the alternative. It is assumed that the indirect utility function is linear in its parameters. It is also assumed that it is broken down into two components: the deterministic and the random. The deterministic component, as shown in the equation below, eq. 3, is a function of the attributes of the alternatives, the socioeconomic characteristics of the individuals, and a set of unknown parameters. The random component is the error term. Hence,

$$V_{ik} = \overline{V}(\mathbf{x}_{ik}, \boldsymbol{\beta}) + \varepsilon_{ik} \qquad \text{eq. 3}$$

Where i represents the individual respondent, k represents the alternative, **x** the vector of attributes that vary across alternatives, and ε is the error term that captures the unobservable influences.

$$V_{ik} = \beta_k + x_{ik}\beta + \varepsilon_{ik} \qquad \text{eq. 4}$$

Specifically, in equation 4, β_k represents the alternative specific constant (ASC), x is a 1x5 vector comprised of the five attributes (whistling noise, smell, waste vehicle journeys, chimney height and amount to be paid) and β is a vector of unknown coefficients.

As this is a discrete model choice; using the earlier notation, the probability that alternative k is chosen against the K alternatives is:

$$\Pr(k) = \Pr(V_k > V_1, V_k > V_2, ..., V_k > V_K) = \Pr(V_k > V_j) \quad \forall j \neq k \qquad \text{eq. 5}$$

By assuming that the error terms, ε, are independently and identically distributed (iid) and they follow the type 1 extreme value distribution, formally the probability that alternative k for individual is chosen is

$$\Pi_{ik} = \Pr(k) = \frac{\exp(\theta_{ik}\beta)}{\sum_{q=1}^{K}\exp(\theta_{iq}\beta)} \qquad \text{eq. 6}$$

Where θ_{iq} is a vector of all attributes for alternative q. This equation, eq. 6, forms the basic choice model known as the multinomial logit (MNL). The log likelihood function for the multinomial logit model can be written as:

$$\ln L = \sum_{i}^{n}\sum_{k}^{K} y_{ik} \ln \Pi_{ik} \qquad \textit{eq. 7}$$

y_{ik} is a binary variable that can take either 1 or 0 depending if the alternative is chosen or not. Equation 7 can be estimated using maximum likelihood estimation with respect to β's in order to derive the respective coefficients. The model described allows us to estimate the trade off between attributes and the willingness to pay (WTP) for different policies. These are calculated by taking the ratio of their coefficients. The marginal price of attribute k can be calculated as the ratio of the negative of the respected attribute coefficient, $\hat{\beta}_k$, and the coefficient on the price/cost variable, $\hat{\beta}_p$:

$$MP_k = -\frac{\hat{\beta}_k}{\hat{\beta}_p} \qquad \textit{eq. 8}$$

Equation 8 is the monetary value of the utility coming from an extra unit of k. Also, the WTP for a certain policy can be calculated as

$$WTP_{ik} = -\frac{x_{ik}\hat{\beta}}{\hat{\beta}_p} \qquad eq.\ 9$$

Where x is the vector of the levels of attributes for alternative k given to individual i.

The iid assumption, referenced above, states that the ratio of the odds of choosing any two alternatives does not depend on the attributes of other alternatives present, therefore it only depends on the attributes of the alternatives in question. Equation 10 below shows how the addition of more alternatives does not alter the ratio of the odds between alternative k and m.

$$\frac{\Pr(k)}{\Pr(m)} = \frac{\exp(\theta_{ik}\beta)\Big/\sum_j \exp(\theta_{ij}\beta)}{\exp(\theta_{im}\beta)\Big/\sum_j \exp(\theta_{ij}\beta)} = \frac{\exp(\theta_{ik}\beta)}{\exp(\theta_{im}\beta)} \qquad eq.\ 10$$

A problem does arise if attributes are considered close substitutes. This occurs due to the necessary condition in multinomial logit estimation that the same ratio of probabilities is maintained; such that a change in the attribute of one alternative proportionally changes the probability of the other alternative (Train, 2003). A Hausman test can be used to test if the iid assumption holds. Interaction terms can also be constructed and tested.

7.6 Data description

This section is split into two subsections. The first presents the descriptive statistics for the main variables used in the analysis. These values are also compared with the actual Dudley population statistics taken from the 2001 census. (www.neighbourhood.statistics.gov.uk). The second subsection will try to develop a picture of the Dudley inhabitants by looking at the respondent's answers to the questionnaire regarding the neighbourhood and the externalities in question.

The survey was conducted by the market research company DJS Research Ltd. and was implemented by door-to-door interviews. A total of 310 responses were obtained – we were able to integrate 60 from the second pilot survey and 250 from the main survey. Eight questionnaires had to be dropped from the sample because of duplication errors and questionnaire incompletion. Due to the requirements made by Nlogit each questionnaire is represented 24 times. This occurs so the attributes and alternatives from the choice cards can be properly represented; as a result there are 7248 observations in total..

7.7 Descriptive statistics

Table 36 presents the socioeconomic attributes for the sample and the Table 37 presents the environmental attitudes. Please refer to the Appendix for variable coding.

Table 36: Descriptive statistics

Variable	Sample average	std. dev.	Min	Max	Observations	Dudley 2001 census
DISTANCE FROM CHIMNEY	719.00	335.52	236	2355	7248	
No. of FLOORS	2.05	0.93	1	14	7248	
GENDER	0.55	0.50	0	1	7224	0.51
Male	45%					
Female	55%					
AGE		1.61	1	6	7248	39.45
1) 18-24	7%					8%
2) 25-34	13%					18%
3) 35-44	22%					19%
4) 45-54	17%					18%
5) 55-64	14%					15%
6) 65+	27%					22%
Tenure (A1)	19.05	14.66	0.17	80	7248	
HOW OFTEN LEAVE NEIGHBOURHOOD	2.10	1.14	1	6	7176	
HOUSEHOLD SIZE	2.71	1.50	1	8	7248	
CHILDREN	0.40	0.49	0	1	7248	
MARITAL		0.89	1	4	7248	
1) Single	15%					41%
2) Married/living	63%					45%
3) Divorced/separated	6%					7%
4) widowed	16%					7%
OCCUPATION	4%	2.28	1	8	7224	
1) Self employed	24%					6.53%
2) full time	11%					41.83%

3) part-time 4) student 5) unemployed 6) looks after home 7) retired 8) sick/disabled	1% 6% 19% 28% 5%					12.98% 2.04% 3.94% 6.49% 15.01% 5.32%
UNEMPLOYED	0.12	0.33	0	1	7224	
EDUCATION 1) None 2) basic gcse's 3) more gcses 4) a-levels 5) degree	 49% 30% 12% 4% 5%	1.09	1	5	7224	 37% 17% 19% 6% 13%
FURTHEREDU	0.10	0.30	0	1	7224	
NOQUAL	0.47	0.49	0	1	7224	
INCOME 1) 0-5000 2) 5000-10000 3) 10000-15000 4) 15000-20000 5) 20000-30000 6) 30000-40000 7) 40000-60000 8) 60000-100000	 1% 16% 15% 22% 31% 13% 1% 0%	1.37	1	8	7224	£11,731 (for the West Midlands)
COUNTAX 1) full 2) partial 3) none	 20% 18% 61%	0.87	1	5	7224	24% (full and partial council tax claimants)
COUNTAXBI	0.62	0.49	0	1	7080	
DOUBGLAZ 1) yes 2) no	81% 11% 8%	0.59	1	3	5688	

3) partial						
BINGLAZ	0.78	0.41	0	1	5688	

Table 37: Environmental Attitudes in Sample

Variable	Sample average	std. dev.	Min	Max	Observations
WHISTLE	29.82	37.74	0	90	7248
SMELL	30.08	39.14	0	100	7248
WASTE	26.43	32.38	0	75	7248
HEIGHT	30.03	37.79	0	90	7248
WTP	7.88	6.84	0	18	7248
WHISTLE BOTHERED	1.33	0.76	1	5	7248
B1bi	0.1	0.3	0	1	7248
WHISTLE FREQUENCY (WF)	6.46	1.32	1	7	7248
B3bi	0.17	0.38	0	1	7248
SMELL BOTHERED	1.26	0.70	1	5	7224
SMELL FREQUENCY	5.69	0.81	1	6	7224
b7bi	0.15	0.36	0	1	7224
B5bi	0.07	0.26	0	1	7224
CHIMNEY BOTHERED	1.19	0.51	1	4	7224
B10BI	0.03	0.18	0	1	7224
CHIMNEY SEE	0.56	0.50	0	1	7248
TRAFFIC BOTHERED	1.26	0.65	1	4	7248
B14BI	0.07	0.25	0	1	7248
TRAFFIC PASSES	0.57	1.21	0	5	7248

A7ABI	0.47	0.5	0	1	7248

We now compare the sample to the population using the Census of 2001. It should be noted that the sample area was not the whole of Dudley and it is difficult to assess the representativeness of the sample through direct comparisons with the Census. However, the Census is the best comparison we have available. Females are represented more than males and their appearance in the sample is slightly higher then the population average of 51%. The mean age for the sample is between 45-54 year olds, which is slightly higher than the Dudley mean age of 39.45 years old. The age distribution of the sample and the population is similar, with just slightly more of those aged 65 or higher in our sample then in the population.

The average tenure (time spent at address) is very high, 19 years, this may suggest there is a strong habituation effect present and therefore a reduction in the disamenity cost experienced by the sample inhabitants. Elliot et al (1997) find there is a fall in concern levels over time which they attributed to a decrease in "ambiguity, uncertainty, and lack of control" as residents gain familiarity with the facility. Lima (2004) also finds that levels of perceived risk and less favourable attitudes towards an incinerator in Portugal reduce over time. The four variables that represent the degree in which the respondent is bothered or annoyed with each attribute (WHISBOTH, SMELLBOTH, CHIMBOTH, TRAFBOTH) are all very low. The highest average disturbance is from the whistling sound at 1.33 and the lowest is from the chimney height at 1.19, despite 44% of the sample claiming to be able to see it from their home. The frequency of experiencing either the whistling or the smell is quite small 6.46 out of 7 (7=never) and 5.69 out of 6 (6=never) respectively. Perception on the amount of traffic that passes outside respondents' houses is very low, 0.57 out of 5 (5=a lot). We may hence expect the disamenity from traffic is so low.

There is a discrepancy in marital status between the sample and Dudley's population. The percentage of single people sampled is much lower than the population percentage and the percentage of people married/living together and widowed is much higher in the sample than in the Census statistics. This can be explained by the sample area that is covered in Dudley. This area is a particularly older area; this can be seen from the descriptive stats. The average age in the sample is higher than in the population and the average length of tenure is very high, 19 years, again suggesting that this is an older area.

Similarly there is also a discrepancy between the sample occupational categories and that of the population. The percentage of full time employment in the sample is almost half of the population percentage. This again can be explained by the reasons stated above, i.e. due to an older population present in the sample area compared to Dudley at large. This is further backed up by the much higher percentage of retirees in the sample then in the population.

The fact the area sampled is an older and relatively more deprived area compared to that of Dudley at large (Dudley MBC, 2007) is also represented in its educational attainment. Out of the sample almost half, 49%, have no educational qualifications compared to a population of 37%. Also, the presence of less qualifications in the 'more GCSE's', A-levels and degree categories also reiterates the fact that this is an older neighbourhood and also that jobs demand less educational requirements. The low skilled jobs hypothesis is supported by the low mean wage of between £15-£20,000. Also 38% of the sample is either on full or partial council tax concessions. This is a much higher percentage than in comparison to Dudley, 24%, further reiterating the fact that this sample area is relatively more deprived.

The sample averages for the four disamenities show approximately a 30-33% reduction in the level of each one, with an average willingness to pay of £7.88. The maximum cost chosen on the choice cards is £18 which shows that at least someone suffers some form of disamenity from Lister Road and thus wishes to pay the largest amount to reduce this disamenity effects of the incineration site.

7.8 The Dudley Profile

This subsection summarizes the attitudes, opinions and other potential features of the Dudley neighbourhood.

Table 38 represents the views the local inhabitants have of their area and how much of a problem the negative externalities are to them. The highest percentages are highlighted in black along with the respective means.

A very large percentage of respondents, 49%, either strongly agree or agree that the area is industrial. This high percentage could have an effect on the results, as the marginal disamenity caused from the presence of one industrial organisation is likely to diminish the more there are present. This thought is in line with Eyles et al, (1993).

However 41% of the respondents either disagree or strongly disagree that the area is run down and 65% are not concerned that the Lister road site is too close to their house. Also, over a quarter of the respondents consider the incinerator to be a local landmark. This finding could also have a significant effect on lowering the visual disamenity cost experienced by respondents, as inhabitants may view the chimney as a source of identity. Over 50% of respondents felt the impact from car, heavy vehicles and van use in their neighbourhood was minimal. An even larger percentage of people though that smells and noise were not generally a problem in their area.

Table 38: Perceptions of the local environment

	% responses					
	strongly disagree (1)	disagree (2)	neither disagree nor agree (3)	agree (4)	strongly agree (5)	**Mean**
This area is	3	27	21	**43**	6	**3.21**

industrial						
This area is polluted	4	**43**	40	13	0	**2.63**
This area is well maintained	4	18	25	**49**	3	**3.28**
This area is rundown	2	**39**	34	22	2	**2.83**
I am concerned Lister Rd is too close to my house	31	**34**	24	10	1	**2.16**
I am concerned Lister Rd is too close to residential areas	10	29	**39**	20	1	**2.73**
I have actively considered moving because of the incinerator	**81**	17	2	0	0	**1.20**
the incinerator is a local landmark	17	13	**45**	25	1	**2.80**
	Not a proble m		Neutral		A proble m	**Mean**
How much are odours/smells a problem in your neighbourhood	**82**	7	6	4	2	**1.37**
How much is NOISE a problem in your neighbourhood	**72**	13	8	5	2	**1.53**
How much is LITTER a problem in your neighbourhood	**57**	22	10	7	5	**1.80**
	V. little		Mediu m		A lot	**Mean**
How much CAR	**53**	15	15	10	7	**2.03**

TRAFFIC is there in your neighbourhood						
How much HEAVY VEHICLE TRAFFIC is there in your neighbourhood	56	16	11	9	8	2.00
How much VAN TRAFFIC is there in your neighbourhood	56	16	15	8	6	1.91

An overview of the respective annoyance levels of those who always chose the status quo and those who selected alternatives A or B in some cases is given in Table 39. A large majority (71%, 108 respondents) would rather stick with the status quo and not pay for a change. Table 39 shows that 30% of those who consistently chose the status quo were annoyed by some or all the attributes of the site (i.e. traffic, noise, smell, height) and despite this they still preferred not to pay for change. Counter to this 49 respondents who did not claim to be annoyed with the situation were willing to pay for some change.

Table 39: Analysis of Status Quo Choice and Annoyance

	Annoyed	Not Annoyed	Total
All C	**63 (30%)**	151 (70%)	214
Not All C	37 (43%)	**49 (57%)**	86
Total	100	200	300

Table 40 shows the distribution of responses relative to exposure to nuisance. One reason for these results is that of protest behaviour, which will be explained below.

Table 40: Status Quo choice and Exposure

	Exposed	Not exposed	Total
All C	**111 (51%)**	103 (49%)	214
Not All C	63 (71%)	**25 (29)**	88
Total	174	128	302

There is a possibility that some of the choice of alternative was not a reflection of their actual preference but as a means of protest. As a result respondents who chose the status quo option for all choice cards were asked to answer a question as to why they made this decision. Four questions were included to discover if their choice was motivated by protest behaviour or not - as it is important to isolate these individuals and remove them from the sample. Respondents were asked if they agreed with the statements below:

- I already pay too much council tax as it is
- The issues are not my responsibility,
- The proposed changes will not work and
- The money collected would not be used for this purpose.

The results are provided in Table 41. From the 71% that selected the status quo in every case 48% of these were in response to protest behaviour.

The most popular reason for stating 'no change' is because the respondent was not affected by these issues; this reason is quite intuitive and is to be expected. The next two most popular reasons for not wishing to implement change is because the respondent feels that it is not their responsibility and that they already pay too much council tax, both these responses are protest responses.

Table 41: Reasons for All Status Quo Selection

Reasons given	Percent
Not affected by issues	28
Not my responsibility*	22
Pay too much council tax*	20
Cannot afford payments	16
Money spent better elsewhere	6
Changes are not worth it	4
Changes will not work*	2
Money would not be used for this purpose*	2
Total	100

Table 8, reasons for choosing 'no change', * Protest Vote

Table 42 shows the relationship between protesting, annoyance and council tax benefits. The results show that from the 63 peopled who claimed to be annoyed and yet still wished to maintain the status quo (table 6) over half of these, 35, were expressing protest behaviour (table 9). Also, 3 respondents in the data set, despite being on full council tax benefit, cited their reason for maintaining the status quo because they already pay too much council tax. This is slightly odd but it maybe attributed to them objecting to the concept of council tax in general, which is a problematic payment vehicle. Once the protest votes are removed the sample is reduced from 302 to 194.

Table 42: Protest Votes and Annoyance and Benefit Claimants

Protest votes	**Actual No.**	**Percent**
of which annoyed	35	32
of which not annoyed	73	68
of which full council tax claimants	18	17
of which partial council tax claimants	0	0
Of which NO council tax claimants	0	0

Table 9, break down of protest votes

Table 43 shows the level of importance each respondent placed on the 4 attributes in question and the cost of the option when deciding upon which alternative to select in the choice card experiment. The results are in percentage terms and the sample excludes protesters. It appears that few of the attributes, bar the cost of the option, seemed to have featured much in the respondent's decision. For the Chimney height attribute 96% of the respondents were either 'not at all' or only 'slightly' concerned when answering the choice cards. Similarly 94% of respondents did not think the whistle noise was very important, 88% didn't think smell was very important and 89% didn't think that waste vehicle journeys were very important.

Table 43: Importance of Attributes in Choice of Alternatives

	Not at all	Slightly	Moderately	Very	Extremely	At Least Moderately Important
Whistling Noise	77	17	3	2	1	6
Smell from Green Waste	75	13	7	4	2	13
Waste vehicle journeys	70	19	6	3	2	10
Chimney height	87	9	2	1	1	4
Cost of option	28	30	16	9	4	29

7.8.1.1 Noise

Noise pollution is concerned with the random whistling sound emitted from the incinerator. It has been described as a loud screeching sound resembling that of a high pitched kettle. Table 44 below shows the break down of how frequent respondents in the sample heard the whistling sound over the last 12 months. The overwhelming majority of respondents, 79%, have not heard this sound in this period. The two graphs below break down the noise categories into respondent distances from the Lister Road incinerator. Figure 23 is shows the percentage of people exposed to noise in the last year and then concentrates on the percentage of exposed who are either slightly or moderately annoyed. Figure 24 reflects the entire number of respondents that live in each distance category and calculating the percentage of these that are either slightly or at least moderately annoyed.

Figure 23 shows that 59% of respondents living 300 meters from the Lister Road site have been exposed to the whistling noise over the last 12 months. The percentage of respondents exposed to this noise seems to decrease with distance away from the incinerator, as would be expected, up until 900 meters where the percentage of exposures increases again. This could be because of the geographical bearing of the houses at this distance. Also, it maybe that the noise is being wrongly thought of as originating from the Lister Road site when in fact it is being generated by other sites. The second two spikes in Figure 23 represent the degree of annoyance, either slightly or moderately, felt by the respondent who was exposed to the noise. They show that for the majority of instances if the individual is exposed to the noise he is likely to be at least slightly annoyed by it. At the distances 500, 600, 900, 1100 meters everyone who is exposed is at least slightly annoyed by it.

For example out of the 59% of individuals who live 300 meters from the Lister Road incinerator that claim to have been exposed to this noise over the past 12 months over 90% of these are at least slightly annoyed by it and over 25% are moderately annoyed. The graph clearly shows that those who are exposed to the noise do find it annoying, represented by the high percentage. The last two spikes in each column represent the percentages of annoyed responses to the total number of inhabitants at that geographic distance from the Lister Road site.

Table 44: Frequency of whistling sound heard over the last 12 months

Frequency	PERCENT
>20	3
16 – 20	1
12 – 15	2
8 – 11	3
4 – 7	6
1 – 3	7
Never	79
Total	100

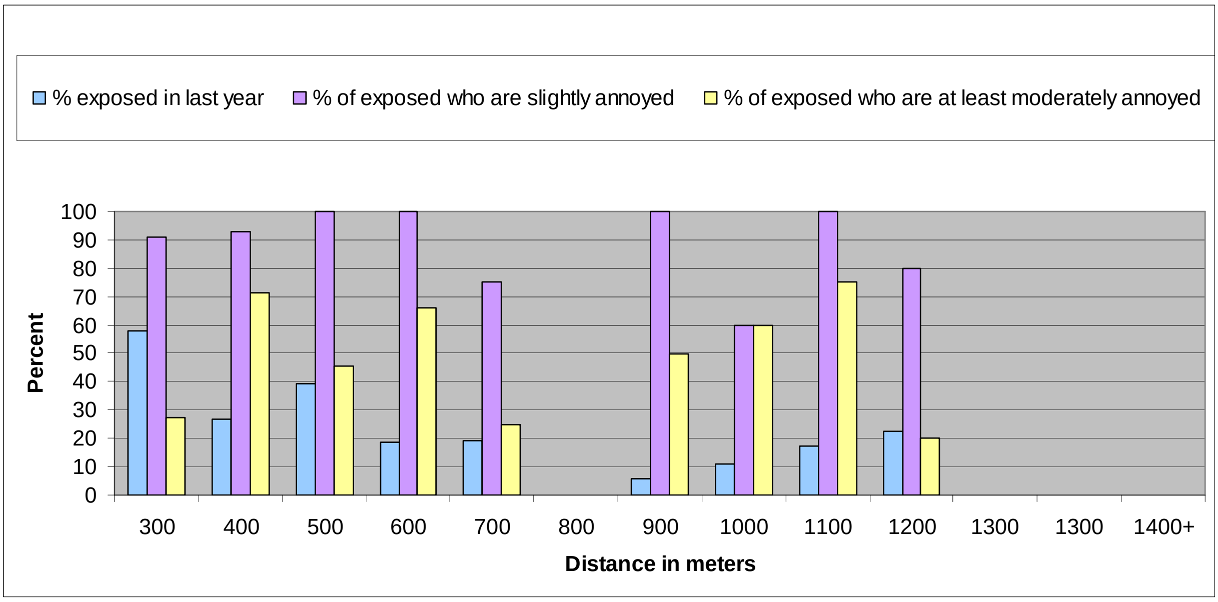


Figure 23: Percentage of people that are exposed to whistling who are either slightly or moderately annoyed

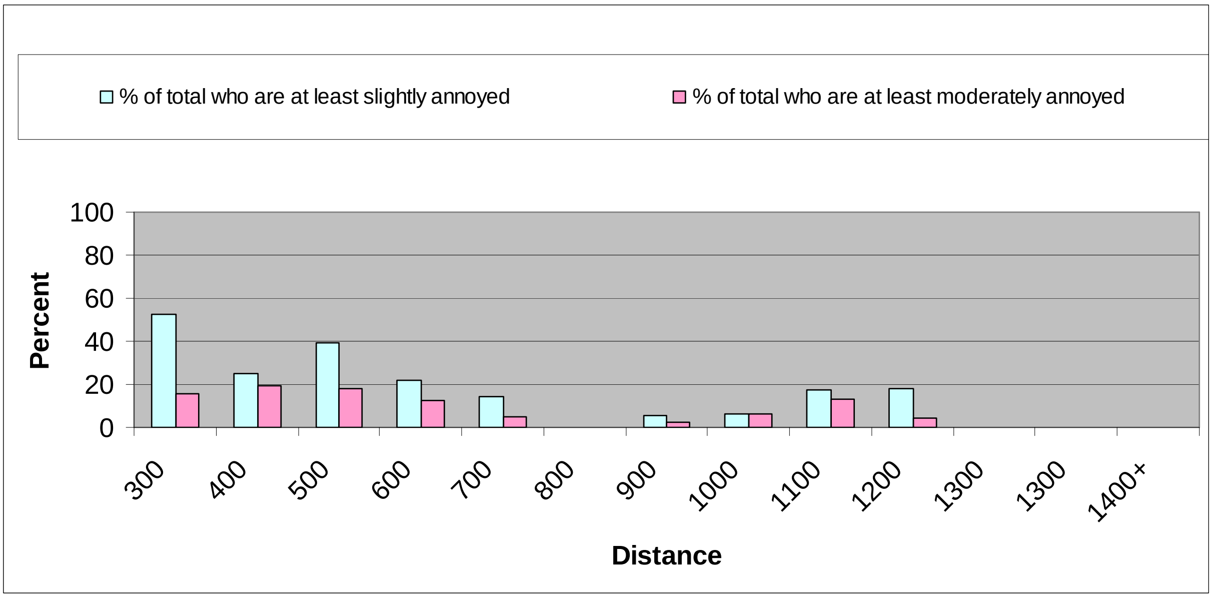


Figure 24: Percentage of those who are slightly and moderately annoyed by whistle by distance

7.8.1.2 Smell

Smell pollution is concerned with the odours emitted from the green waste storage units. It has been described as a strong odour resembling that of rotting food or compost, particularly on warm days. Table 45 below shows the breakdown of how frequently respondents in the sample noticed the smell over the last 12 months. The overwhelming majority of respondents, 85%, have not noticed the smell in this period.

Figure 25 shows a clear downward trend over distance from the Lister Road site for percentage of individuals exposed to odour in the last year. It also shows that those who are exposed to the smell are almost 100% probable to be at least slightly annoyed with it, and all those at 800 meter distance are moderately annoyed.

Interestingly, only about 36% of respondents who live 300 meters from the site have been exposed to the smell. This may be the result of household geographical bearing to the site and wind direction.

Table 45: Frequency of smell in last 12 months

Frequency	PERCENT
6 - 7 days	1
4 - 5 days	0
1 - 3 days	3
Up to 3 times monthly	7
< once a month	4
Never	85
TOTAL	100

Figure 25: Smell Exposure and Annoyance

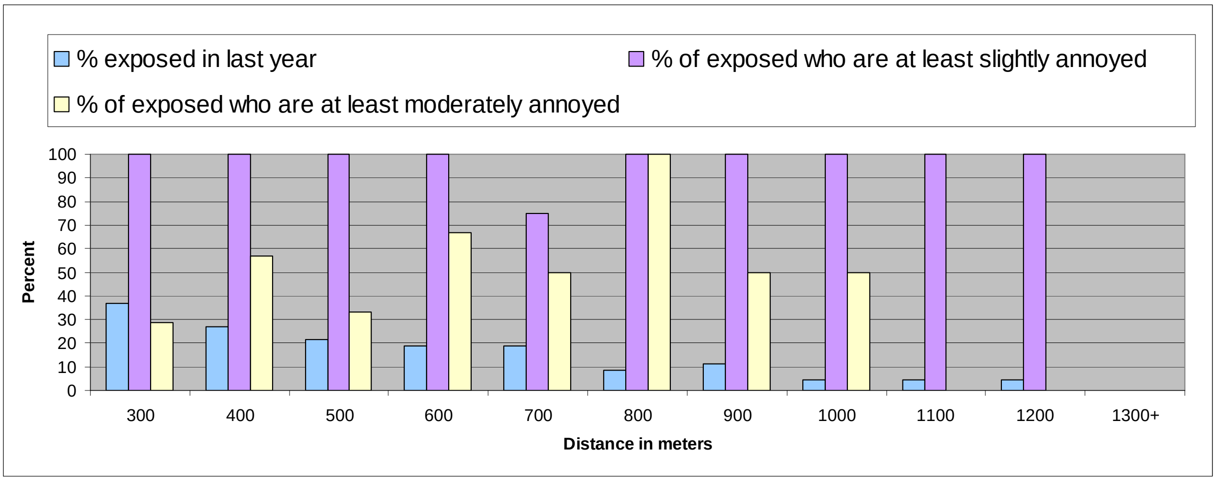
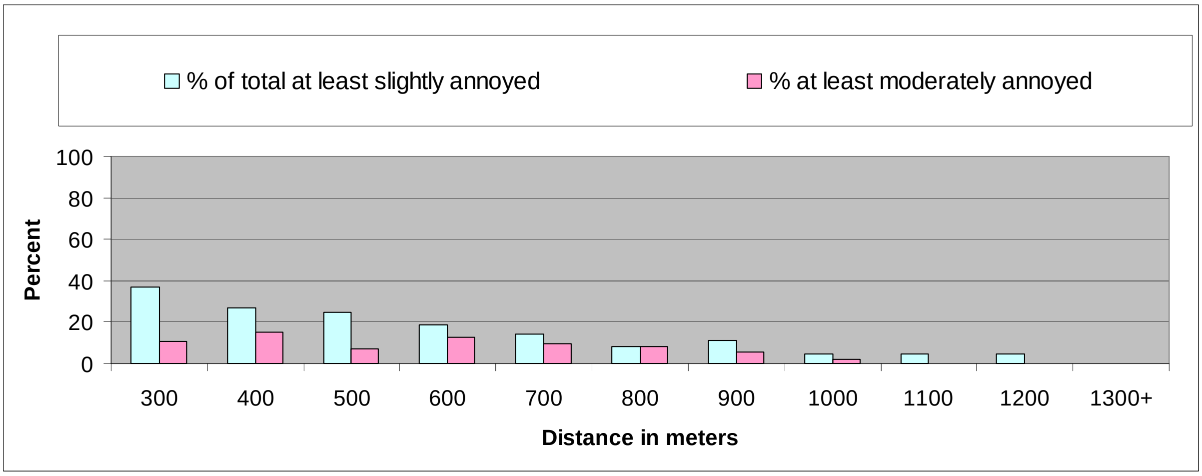


Figure 26: Annoyance by smell and distance



7.8.1.3 Chimney

Visual pollution is concerned with the height of the chimney.

Table 46 below shows the breakdown of how many respondents in the sample can see the chimney from their house and how many recognise it from a picture. The overwhelming majority of respondents, 82%, do recognise the chimney in the picture and 44% of the sample can see the chimney from their house. Figure 27 shows a general downward trend in the percentage of people who can see the chimney from their house over distance, as expected. Interestingly, the percentage of exposed who are at least moderately annoyed seems larger for those who live further away i.e. 900 and 1100m. In fact the largest spikes in percentage of people who are exposed and slightly annoyed and exposed and moderately annoyed occur at the 1100 metre distance. This maybe because at this distance from the industrial facility inhabitants may feel disconnected from the industrial character of the Lister Road area, thus inhabitants this far out are annoyed they can see the facility.

Table 46: Chimney Visibility and Recognition

Frequency		Percent
Can See from house		44
Cannot see from house		56
Recognises pictures		82
Doesn't recognise		18

Figure 27: Visibilty, Annoyance and Distance

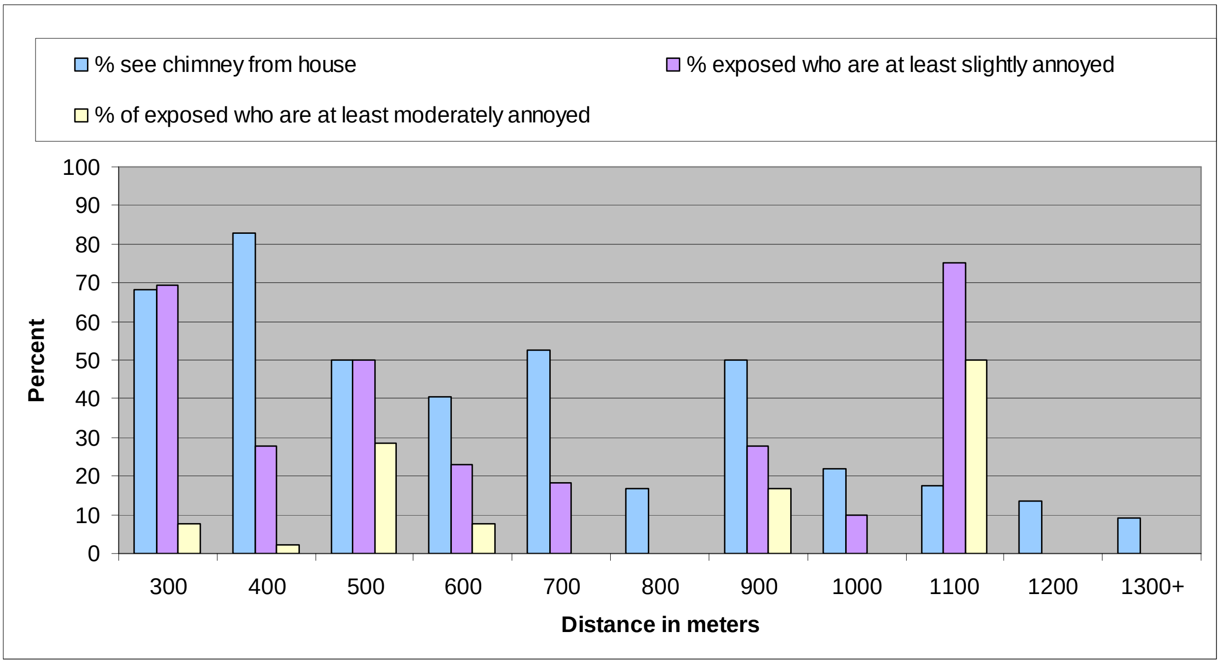
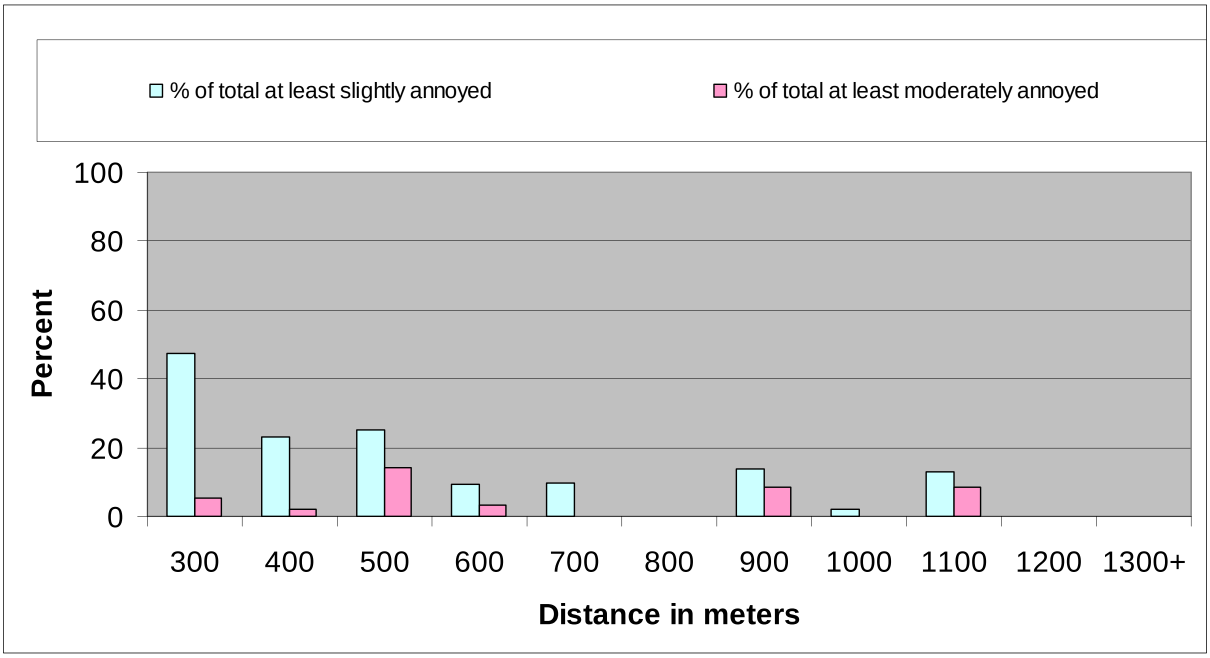


Figure 28: Visual Annoyance and Distance



7.8.1.4 Traffic

The traffic disamenity is concerned with the increase in volume of vehicles that pass near the respondent's house due to the operations at the Lister road site. Table 47 below shows the breakdown of how frequent respondents in the sample notice the amount of traffic passing by their homes over the last 12 months. The overwhelming majority of respondents, 78%, have not noticed the increase in traffic.

Figure 29 again shows a downward trend of percent exposed over distance and that of those that do notice the traffic most of them are at least slightly annoyed by it.

Table 47: Traffic Frequency

Frequency of traffic that passes your home	Percent
None = 0	78
1	5
2	6
3	7
4	3
A lot= 5	2

Figure 29: Traffic exposure and annoyance by distance

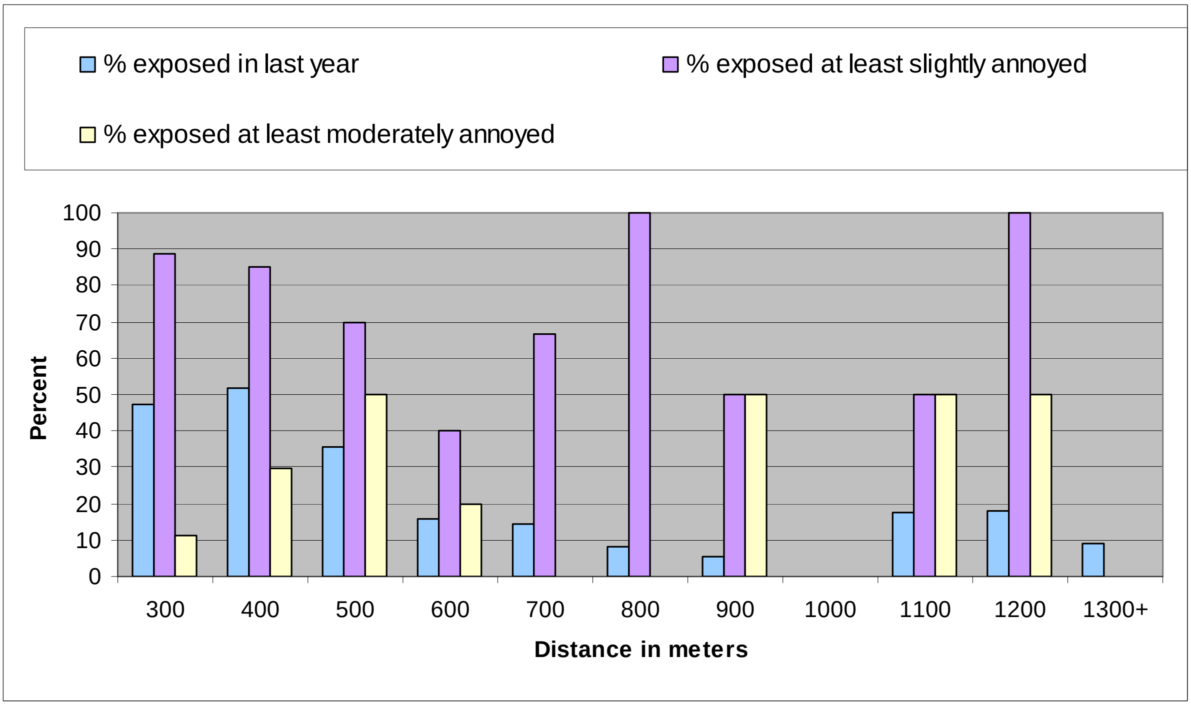
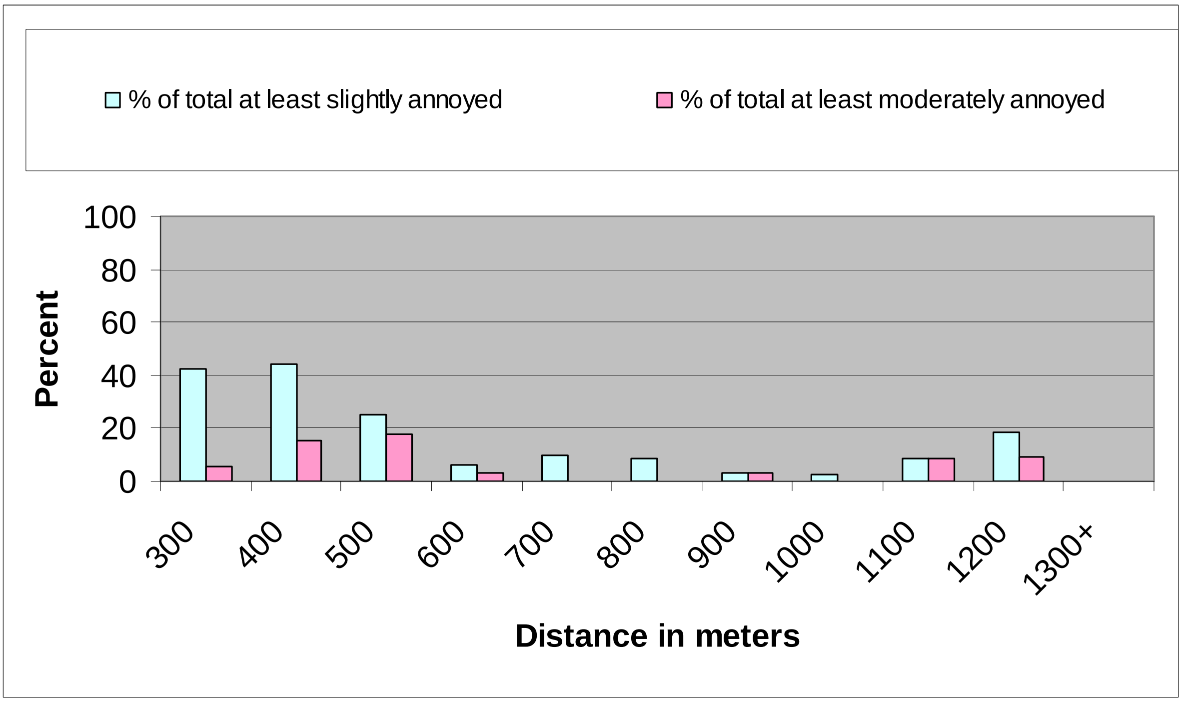


Figure 30: Traffic Annoyance and Distance



7.8.1.5 Response quality

Before moving on to the data analysis section the quality of the reponses first needs to be assessed. In section D a debriefing question was put to the respondents asking them on a scale of 1-5 how difficult was the choice exercise, 1 being not difficult 5 being extremely difficult. Approximately 90% of the respondents found the choice card exercise either not at all difficult or slightly difficult, though approximately 10% did find it moderately to very difficult. The results are presented in Table 48.

Table 48: Difficulty of the Choice Cards

How difficult did you find the choice cards?		
	Actual	Percent
not at all	222	74
Slightly	49	16
moderately	25	8
very	3	2
Extremely	0	0
Total	299	100

The respondents were also asked how important health was when filling out the choice cards. This is important for reasons discussed earlier with regards to double counting and inflated willingness to pay choices. Respondent were asked to rank on a scale of 1 to 5 the importance they attributed to health in making their responses, , 1 indicating health was not important and 5 that health was extremely important. A total of 93% of respondents thought health was either not at all or only slightly a concern when answering the choice sets. Effort was made to isolate out the effects on health as described in the earlier sections. The results suggest this method was largely successful; results are presented in Table 49.

Table 49: Health and Selection of Options

How important was health in your decision?		
	Actual	Percent
not at all	245	82
slightly	34	11
moderately	13	4
very	5	2
extremely	1	0
total	298	100

Table 50 shows that 37 people who originally stated concern over the health of those living near the Lister Road site changed their opinion after having been read the scientific evidence. However the same number of people, 37, did not change their opinion after having been read the text. Strangely there are 21 people in the sample who originally stated they were not concerned about the health of those living nearby and subsequently changed their mind, therefore becoming concerned, after having been read the scientific evidence[7].

Table 50: Before and After Level of Health Concern

	Are you concerned? **NO** (before evidence)	Are you concerned? **YES** (before evidence)	total
Are you concerned? **YES** (after evidence)	21	37	58
Are you concerned? **NO** (after evidence)	192	37	229
TOTAL	213	74	287

At the end of the questionnaire the interviewer was asked to fill in two debriefing questions: whether they thought the respondent understood the choice exercise, and on a scale of 1-5 how annoyed was the respondent by the interview, where 1 is not annoyed and 5 is very annoyed. In total the interviewer believed that 91% of the respondents understood the choice exercises and that only 1% of the respondents, 4 people, were moderately annoyed by the interview. The results are shown in the following tables.

Table 51: Understanding of Choice Exercise: Debriefing

Do you think the respondent understood the choice exercise?		
Yes	272	91%
No	27	9%
TOTAL	299	100%

[7] This perhaps merits further investigation – giving scientific evidence to respondents does not always engender trust.

Table 52: Annoyance with Questionnaire

How annoyed was the respondent?		
	Actual	Percent
not at all	259	87
slightly	35	12
moderately	4	1
very	0	0
extremely	0	0
total	298	100

7.9 Results

This section presents the results for the multinomial logistic regressions. The LIMDEP software NLOGIT was used to run the models. Before running the regressions it is important that some observations are removed from the sample. Any individual expressing protest behaviour, as already discussed in the preceding sections, and any individual who did not understand the choice experiment, as their answers are potentially spurious, were removed. In total there are 108 observations that must be deleted due to protest behaviour and 27 observations that didn't understand the choice experiment. However as 8 of the 27 observations were also protest voters, 127 observations are removed. This leaves 175 observations in the sample, which when multiplied by 8, the number of choice cards, equals 1400 observations.

The key assumption for this exercise is that the individual chooses the alternative that permits them to obtain the highest utility, and therefore obtain their highest overall welfare. In the predetermined random utility framework this is accomplished by the individual assessing the different levels of utility they would receive from each alternative by assessing the attribute levels and cost trade offs. The trade off that occurs between the cost and level of attributes can be quantified as the monetary value. A status quo option, option C, was also present in the choice sets to be consistent with the welfare measures in demand theory (Louviere et al., 2000; Bennett and Blamey, 2001; Bateman et al., 2003).

The first model specification follows that prescribed by Hensher and Greene (2003); it is composed of only the five attributes as explanatory variables plus an alternative specific constant (ASC). This model is implemented so the importance of each attribute in explaining individual choices across the three alternatives can be understood. The attributes are represented in continuous form and all the disamenity levels are represented as percentage reductions. A positive sign on the coefficient suggests that an increase in the attribute level, i.e. a reduction in its externality, will lead to an increase in a person's utility and therefore an increase in their welfare. In contrast, a negative sign would suggest a reduction in an individual's utility and therefore a lower level of welfare in response to an increase in attribute level.

Also, due to the design of the choice cards, where neither option A or B always has a greater, or lesser, reduction in disamenity or higher or lower cost, it was felt that only one alternative specific utility functions for the change option was necessary. Therefore two utility functions were designed, one for a change away from the present and one for no change. This method is in line with previous studies such as Mitiani et al. (2008), Birol et al. (2006), Birol et al. (2006). The ASC was specified so that it equalled one if either option A or B (non-status quo choices) were selected and zero if option C was chosen.

The results from this regression are reported in

Table 53. Despite three of the four disamenity attributes possessing the correct sign (smell, waste and height), which suggest that a percentage reduction in their levels will increase the individuals utility, the low Wald-statistics for all of them states that they are statistically insignificant, even at the 10% level, and thus do not contribute anything to the individual's choice. The Cost attribute also possess the expected negative sign suggesting an increase in payment of council tax reduces the individual's utility. Unfortunately, this is also insignificant at the 10% level.

What is interesting about these results is that over the entire sample none of the attributes have had any influence on which alternative was chosen, not even the cost variable. This is unlike other studies such as Garrod and Willis (1998), who assessing the disamenity cost of a landfill site by choice based analysis did find that reductions in litter, smell and cost all had significant expected effects on utility. These results may potentially support Ready's (2005) assertion that smaller waste sites (in Ready's case landfills) need not necessarily have any significant negative amenity effects on the local area: Lister Road is the 5th smallest incinerator in the UK in terms of capacity.

The ASC is included in the model to capture the impact of any omitted variables on utility. The ASC result for Model 1 is both significant, at the 1% level, and negative. Since the ASC is set up so it equals 1 if a change from the status quo is chosen (alternative 1 or 2) and 0 otherwise the negative sign indicates that the average impact of omitted variables has a negative effect on the probability of choosing a reduction in the disamenities and thus a drop in utility occurs in any move away from the status quo. Conversely it shows a positive effect on choosing the no change option (option 3) when compared with the probability of choosing the change options. This can be construed as a tendency to shy away from options that contain change.

This result can be explained by one of two things - either the significant negative sign suggests there is a status quo bias that is present, meaning respondents are reluctant to move away from the current situation (Samuelson and Zeckhauser, 1988), or it is due to a sensation of inertia the respondents feel as a result of the lack of exposure and annoyance they experience; they are not bothered by the current situation and therefore do not wish for a change.

Table 53: Model 1 results

Variables	MODEL 1	Wald-statistic
ASC	-2.186***	-7.04
WHISTLE	-0.0004	-0.20
SMELL	0.0003	0.21
WASTE	0.0024	1.15
HEIGHT	0.0016	0.96
COST	-0.0082	-0.58
N	1399	
ITERATIONS	5	
AIC	1.26	
BIC	1.29	
Loglikelihood function	-878.21	
Base comparison model	-879.76	
Pseudo-R^2	0.002	

Critical Wald-value is 1.96 at 95% confidence level, indicates: ***1%, **5%, *10%. The base comparison figure is the model run with only the ASC present.

Table 54 presents the results of a second model. In the second model, again only the five attributes are present, however this time they are no longer represented in continuous form but as dummies. The dummies are presented so as to check if any non linearity is occurring in the data. The dummies are coded as follows: whistle1 represents a 50% reduction, whistle2 a 90% reduction, smell1 a 50% reduction, smell2 a 100% reduction, waste1 a 50% reduction waste2 a 75% reduction, height1 a 50% reduction and height2 a 90% reduction and cost2 is £12 and cost3 is £18.

Table 54: Model 2 results

Variable	Model 2	Wald-statistic
ASC	-2.41***	-10.814
WHISTLE1	-0.240	-1.399
WHISTLE2	-0.005	-0.030
SMELL1	0.144	0.931
SMELL2	-0.016	-0.096
WASTE1	0.389***	2.392

WASTE2	0.149	0.873
HEIGHT1	0.354***	2.114
HEIGHT2	0.204	1.248
COST2	-0.042	0.394
COST3	-0.07	0.169
N	1399	
ITERATIONS	5	
AIC	1.26	
BIC	1.28	
Loglikelihood	-872.52	
Base comparison model	-879.76	
Pseudo-R^2	0.008	

Critical Wald-value is 1.96 at 95% confidence level, indicates: ***1%, **5%, *10%

The results from this regression are not too dissimilar to the last. Smell1, waste1 & 2 and height1 & 2 all possess a positive sign and this time both waste1 and height1 are significant, at the 1% level. This indicates that individuals would receive a positive welfare gain if both the level of traffic (waste1) and height of chimney (height1) were reduced by 50%. Both the cost variables are also negative suggesting an increase in cost reduces an individual's utility, as expected. However, both these variables are insignificant. Also, the ASC is significant and negative and the pseudo-R^2 is very low, well below the 0.2-0.4 values that Hensher and Johnson (1981) deem to be a good fit.

The data description section is consistent with the results from the two models so far. The mean values for the disamenities were all very low close to 1, not bothered (whistling sound 1.33, smell 1.26, chimney, 1.19 and traffic 1.26). These means are further supported by the lack of exposure individuals experience : – 6.46 (7 equals never), 5.69 (6 equals never), 0.56 (5 equals a lot) for whistling, smell and traffic respectively. Hence most individuals in the sample are neither disturbed nor exposed to the disamenities in question. This also adds further support for the inertia hypothesis used to explain the significant negative constant. Also, it should be remembered that 71% of the respondents did opt for the no change option.

These findings are also supported by the results in the data description section, in how minimally the attributes appear to have featured in the respondent's decision. For the Chimney height attribute 96% of the respondents were either 'not at all' or only 'slightly' concerned when filling out the chose cards. Similarly 94% of respondents did not think the whistle noise was very important, 88% didn't think smell was very important and 89% didn't think that waste vehicle journeys were very important. And also by the lack of exposure each individual has towards these disamenities: 79% claimed no to have heard the whistling sound before, 85%, have not noticed the smell, and 78%, did not notice an increase in traffic.

The incinerator has also been present at the site for a very long time, erected originally in the 1930s. This historical presence may, according to Elliott et al., (1997), lead to individuals becoming more familiar to the exposure and therefore leading to a lower perceived impact. This may particularly be the case with regards to the chimney height attribute. A recent meta-analysis of studies on landfills (Methodex 2008) found that the age of a landfill can have an impact on property price effects.

Also, as mentioned in an earlier section, the number of residents, that is the population density in the surrounding area, and the number of nearby industries may influence the perception of exposure itself. For example, if the area is characterized by high volumes of traffic, the impact of waste transportation to the incinerator may go largely unnoticed. And if the area has other industrial facilities located within it, the impact of the incinerator on the aesthetic quality of the area may be reduced. The Lister Road facility is both surrounded by light industry units, immediately to the west of the site, and has a major trunk road nearby. This can be further augmented by the fact that 49% of respondents attest that this area is industrial. This is in line with Elliott et al (1993) who attributed the relatively low number of people who worried about any disamenity effects generated by the site to the busy nature of the area.

Walton, Boyd, Taylor, & Markandya (2007) provide further empirical evidence find that the effects of landfill sites are greater in less densely populated areas. It is thought that this is because landfills in high-density areas are less obvious than otherwise. Despite it not being a landfill site Dudley does have a very populated area; it is the second largest town in the UK.

Another explanation may be found in the flow variables; that is the causes of amenity loss are not necessarily present all the time. For example, increased traffic may only occur on weekdays and peak during the morning when door-to-door collections occur. The large number of unemployed and retired represented in the sample may not be affected by this issue. Another point to consider is how infrequently the whistling sound occurs. According to records kept by the site operators, noise can be expected to occur 4-8 times per year.

In order to derive the model fit for the two models the LL function must be compared with a 'base model', in this instance the base model is the model run with only the alternative specific constant. With the $\chi^2_{(5)d.f.} = 11.07$ at the 5% level with 5 dof, model 1's -2LL function of 3.12 cannot reject the null hypothesis. Therefore model 1 is not a statistical improvement over the base model and the additional parameters do not add to the predictive power of the base model. This is not a surprising result, given that all the attributes are insignificant. Despite the fact that the R^2 of a choice model is not analogous to the R^2 of a linear regression a pseudo R^2 as low as Model 1 is still considered a poor fit.

For model two the -2LL function is 14.48, which is still below the chi squared value of 18.31 at the 5% level with 10 degrees of freedom (dof). Again Model 2 is not a statistical improvement over the base model. Because of this lack of significance in Model 2 we model the attributes in continuous form.

Table 55 presents further attempts to model the data. Model 3 expands on Model 1 by adding socio demographic variables. A problem arises when attempting to augment the model with these variables; this is due to the property of homogeneity of degree zero in the parameters. This means that any attribute which has the same value for all alternatives will withdraw from the model. This has its impact on all the individual characteristics such as age, education etc. as they are invariant across alternatives. There is a point of discrepancy in the literature concerning how to deal with this issue. Most studies resolve the issue by introducing interaction terms into the model (Garrod and Willis, 1998, Mitani et al. 2008, Birol et al. 2006a, Birol et al. 2006b, Birol and Cox, 2007, Kassie et al. 2009) while others introduce variability by adding in explanatory variable for j-1 alternatives (j is equal to the number of alternatives) (Hensher et al. 2005). This study will apply the first technique. By adding interaction terms with the attributes and individual characteristics any heterogeneity in preferences for externality reductions can be explained.

Models 3, 4 and 5 add interaction terms to explore some of the reasons as to why the attributes were insignificant. The first set of these, reported in Table 55, will look at the attitudes of the respondents. As most of the respondents do not report annoyance or exposure to the externalities connected to Lister Road site, a series of interaction terms were engineered to assess the impacts of those who do claim to be annoyed or exposed to them. Also individual's income was interacted with the cost of the program.[8] Binary dummy variables were created so that if exposed, annoyed and educated the variable equalled one and zero otherwise.

By adding in these interaction terms not only is it possible to establish the impact of exposure, it also can act as a validity check on the WTP estimates derived from analysis of the choice experiment results; ceteris paribus, it is expected that greater WTP estimates derive from individuals who are more annoyed.

Table 55: Models with Interaction Terms

Variables	Model 3	Wald-stat	Model 4	Wald-stat	Model 5	Wald-stat
ASC	-	-6.58	-	-6.52	-	-5.77

[8] The reporting of income is often problematic in surveys conducted to elicit preferences. In this case approximately 70% of the respondents failed to report their income, either because they refused to state it or because they were unsure of the amount. Due to the belief that this variable may prove to be an important explanatory variable an auxiliary regression was undertaken to predict the income of those who failed to disclose this information. Using the 86 respondents who did declare their income an OLS regression was estimated to derive the appropriate coefficients. Before using this income function to predict the values of those that refused to reveal their earnings. Its predictive power was tested on ten individuals who did reveal their income. The results were encouraging, with a 70% accuracy rate where predicted equaled actual. Of the 3 that failed to correctly predict they were all just one category out.

	2.0689***		2.0615***		1.9183***	
WHISTLE	-0.0002	-0.11	-0.0001	-0.07	-0.0018	-0.93
SMELL	-0.0002	-0.12	-0.0006	-0.37	-0.0008	-0.47
WASTE	0.0006	0.28	0.0024	1.10	0.0005	0.20
HEIGHT	0.0009	0.52	0.0016	0.91	0.0002	0.12
COST	-0.1436***	-5.43	-0.1008***	-3.30	-0.0593***	-2.77
WTPINCOM (wtp*income)	0.0289***	6.58	0.0228***	4.97	0.0087**	2.30
B5BISML (smell annoyance*smell)	0.0061*	1.72			0.0066	1.40
B10BICH (chimney annoyance*height)	0.0106**	2.34			-0.0050	-0.48
B14BITR (traffic annoyance*traffic)	0.0167***	4.34			0.0093	1.35
WTPAGE (WTP*age)			-0.0066*	-1.92	-0.0085**	2.32
EDUWTP (education*WTP)			0.0509***	3.36	0.1120***	6.25
SMELEXPO (smell*exposed)			0.0052*	1.87	0.0067*	1.73
NOISEXPO (whistle*exposed)			0.0035	1.27	0.0052*	1.69
N	1391		1383		1383	
ITERATIONS	6		6		5	
AIC	1.22		1.22		1.25	
BIC	1.25		1.26		1.30	
Loglikelihood function	-835.99		-835.35		-846.95	
Base comparison model						

Critical Wald-value is 1.96 at 95% confidence level, indicates: ***1%, **5%, *10%

Model 3 reports WTP*income, smell annoyance*smell, chimney annoyance*height and traffic annoyance*waste as interaction terms. The ASC value is still significant and negative and both waste and height have the expected signs but are insignificant. The cost variable is now significant at the 1% level and posses the correct sign, suggesting an increase in cost reduces one's utility. All four interaction terms are significant.

The first interaction term WTP*income (WTPINCOM) shows that individuals that have larger incomes are more likely to opt for a hypothetical choice that has a higher cost. This provides support for the theory that willingness to pay is correlated with ability to pay. The inclusion of this variable also makes the cost variable significant at the 1% level.

The chimney annoyance*height interaction variable (B10BICH) is positive and significant suggesting that those individuals who find the chimney height annoying are more likely to chose projects that result in a lower height of the chimney, as you would expect. This group of individuals are willing to pay £3.69 for a 50% reduction. This is calculated by applying the formula: $wtp = -1 * (\frac{\beta_{attribute}}{\beta_{\cos t}})$. Chimney height remains insignificant as an attribute suggesting that those individuals who are not annoyed by the chimney height are indifferent between options of varying levels of chimney height variation.

Smell*annoyance (B5BISML) is also statistically significant and has a positive sign suggesting that those individuals who find the smell annoying are more likely to chose projects that result in a lower reduction of the smell. This group of individuals are willing to pay £2.12 for a 50% reduction. Smell remains insignificant as an attribute suggesting that those individuals who are not annoyed by the chimney height are indifferent between options of varying levels of chimney height variation.

Traffic*annoyance (B14BITR) interactions is significant at the 1% level and has a positive sign suggesting that those individuals who find traffic annoying are more likely to chose projects that result in a lower reduction in the amount of traffic on the roads. This group of individuals are willing to pay the largest amount - £5.86 for a 50% reduction. Traffic remains insignificant as an attribute suggesting that those individuals who are not annoyed by the chimney height are indifferent between options of varying levels of chimney height variation

In model 4 four more interaction terms are introduced: WTP*age, education*WTP, smell*exposed and whistle*exposed. WTP and age (WTPAGE) is both significant at the 10% level and negative, suggesting the older the individual the less likely they are of choosing a more costly option. This can probably be explained both by the habituation effect, where age is a proxy for tenure, suggesting those that have lived near Lister road for a long time are less bothered by the situation and more likely to opt for the status quo. It may also be explained by retirement, a large proportion of the sample are retired and after retirement disposable income is reduced. A third reason for this may also be one of identity, for cultural reasons older people may wish for less change.

Education*WTP (EDUWTP) also has a significant positive effect. Education in this case is a dummy variable, 1 if they have A-levels or more. This shows that the more educated the individual the more likely they are to choose a more expensive option. This can be explained by two reasons, one the more educated an individual is the more they care about their general surroundings and also if education is correlated with individuals wealth the more educated they are the more they more they are willing to pay for change.

Smell*exposed (SMELEXPO) is positive and significant meaning those who report being exposed to the smell in the last 12 months are more likely to choose projects that result in a lower possibility of experiencing that smell, this is a fairly intuitive result. This group of individuals are willing to pay the largest amount - £1.81 for a 50% reduction. This is less than the WTP of those who are annoyed by the smell, which makes intuitive sense. The smell attribute is still insignificant suggesting that those individuals who are not exposed to the smell are indifferent between options of varying levels of smell reduction.

The final model, model 5, combines the two previous models. The signs and the coefficients remain approximately the same, bar chimney annoyance which becomes both insignificant and switches sign. Distance, both as a continuous and binary variable, and bearing to chimney, in binary form, were include in the model as interaction terms but subsequently removed due to a lack of significance.

In Table 56 socio-economic interaction terms are added to the model. These are entered in with the ASC. This methodology is common in the literature for example Mitani at al (2008).

Table 56: Models with socioeconomic interaction terms

Variables	Model 6	Wald-stat	Model 7	Wald-stat
ASC	-2.241***	-5.562	-2.3730***	-6.64
WHISTLE	-0.0005	-0.292	-0.0005	-0.30
SMELL	0.0001	0.121	0.0002	0.12
WASTE	0.0023	1.08	0.0023	1.07
HEIGHT	0.0016	0.91	0.0016	0.91
CST	-0.162***	-5.61	-0.1538***	-5.33
WTPINCOM (WTP*income)	0.031***	6.59	0.0313***	6.23
A7ABIASC (area is industrial)	-0.24***	-3.49	-0.2273***	-3.43
UNEMPLASC (unemployed)	-0.42***	-4.28	-0.4066***	-4.25
BINE4ASC (relationship status)	0.18**	2.36	0.1372**	1.98
NOQULASC (education)	-0.178**	-2.25	-0.1964**	-2.56
A1ASC (TENURE)	-0.006**	2.27	0.0045*	1.90
CHILASC (children)	0.11	1.44	-	-
DISTASC (distance)	-0.0001	-0.97		
DISBI (distance)			0.1356**	2.02
N	1391			1391
ITERATIONS	6			6
AIC	1.21			1.21
BIC	1.27			1.26
Loglikelihood function	-829.89			-829.19
Base comparison model	-879.76			
Pseudo-R^2	0.06			

Critical Wald-value is 1.96 at 95% confidence level, indicates: ***1%, **5%, *10

The ASC is still negative and significant, smell waste and height all posses the correct positive signs but still remain insignificant. The cost variable now has the correct negative sign plus it is significant at the 1% level. The interaction term WTP*income (WTPINCOM) again is positive and significant. This means that as income increases the WTP of the individuals also increases, this is no surprise as willingness to pay is correlated with ability to pay.

The interaction term area is industrial*ASC (A7ABIASC), which is a binary variable representing how industrial you perceive the area to be, is interesting. The variable is significant and negative which means if you think the area is industrial the less likely you are to choose alternative 1 or 2, the change options. This might be because the reduction on externalities from one plant will have such a minimal impact compared to the aggregate impact of all plants it does not constitute value for money. There may also be a perceived value of an industrial landscape for individuals who consider it an industrial area.

The significant negative result suggests that individual's welfare loss is sensitive to the presence of other industrial facilities. And there appears to be a lower marginal impact of the Lister Road site on welfare because of this. Note, 49% of the respondents believed the area to be industrial. Ideally, one would compare the marginal impact of an additional facility in the presence of other, similar, facilities located close by. However, a lack of facilities similar to the Lister Road site in the sample area means that this is not possible

Similarly Eyles et al, (1993) find that incinerator facilities that are located close to other industrial facilities have a lower impact. They find a disparity between the landfill sites and the incinerator and attribute this is to differences in industrial activity surrounding the incinerator; residents are exposed to air pollution and traffic anyway, and are therefore less sensitive to the effects of individual facilities. In a similar way, incinerator facilities that are located close to other industrial facilities may have a lower impact.

The interaction term whether you are unemployed*ASC (E5BIPASC), is a binary variable where unemployment is equal to one. This has a negative impact on choosing one of the change options and is significant at the 1% level. Also, education (NOQULASC) seems to have a significant negative effect on option choice, those with no education are less likely to choose an option that contains change. It should be remembered that this part of Dudley is characterised by high levels of economic deprivation, with low average incomes, high levels of unemployment, low rates of business creation and is amongst the poorest in the Dudley MBC area (Dudley MBC, 2007).

Relationship status*ASC (BINE4ASC), also a binary variable, does have a significant positive effect suggesting those who are married/living together are more likely to chose a change option than those who are single/divorced/separated. Having children (CHILASC) doesn't influence their decision.

The interaction term tenure*ASC (A1ASC) does have the expected negative effect on choosing a change alternative and adds further support to the hypothesised explanation for age having a significant negative effect elucidated to in the previous model. The longer someone has lived in the area the less likely they are to want to elicit change, due to the magnitude of impacts falling over time. This is in line with the habituation effect alluded to in the preceding chapters.

The interaction term distance*ASC (DISTASC) from the Lister Road site does lend support to the 'distance decay effect' by possessing the correct sign however it is not significant. Following the results from the second pilot study that no respondent living 600 metres or more from the site considers that they are affected by traffic associated with the Lister Road Site a dummy variable was created, where 1 equalled living less than 600 meters and 0 more than 600 meters. This variable is both significant and positive.

The log likelihood ratio test for this model compared with the base model of just the attributes and an ASC is -96.6, which is far greater than the 14.06 value for 7 dof at the 5% level and therefore convincingly rejects the null of it being inferior to the base model. Despite all this the pseudo R^2 remains very low for the model.

Other variables that were included but were then excluded by means of an F test, whose nomination was due to a lack of significance, was children interacting with the attributes, bearing of the residents to Lister Road (with regards to smell and noise, due to the potential impact wind may have in determining the dispersion of odour and noise around the site), WTP interacted with age squared, whether the individual had double glazing or not interacted with the attributes smell and noise.

Also, an attitude variable was also included to reflect individual acceptance of the wider needs of the society: incineration is needed to reduce landfill*ASC. Theoretically a positive attitude towards the incinerator can lower the psychological impact of mediating variables; for example, individuals have been found to be less affected by a noise if they perceive the noise to derive from a necessary activity (Staples, Cornelius, & Gibbs, 1999). This variable, when included, turned out to be negative but insignificant, and was ultimately rejected from the model after an F test.

7.9.1.1 Hessian test

So far the CL logit employed assumes the independence of irrelevant alternatives (IIA) property, which means that the relative probabilities of two options being chosen are unaffected by the omission or inclusion of other alternatives. This occurs if the error terms are independent of each other across the different alternatives present in the choice set. This assumption is potentially restrictive (Train 2003). If this assumption doesn't stand then the CL results will be biased. To eschew this problem an alternative model, such as a random parameter logit (RPL) model, also known as a mixed logit (ML) model, should be used.

In order to test if this property holds, and thus if the CL model is satisfactory, the Hausman and Mcfadden (1984) test is run. The IIA test is completed by running a likelihood ratio test of the unrestricted model against restricted versions that have omitted choice alternatives. If the IIA cannot be rejected then the unrestricted model, the one estimated with all choices present, should equal that of the restricted model, containing a sub-set of alternatives. The results are reported in Table 57. The results reject the IIA assumption for the model when either alternative is dropped and thus requires the employment of a less restrictive model like the ML model. Another way to circumvent this problem is by the inclusion of social and economic characteristics as interaction terms as already implemented in the above models (Revelt and Train 1998; Morey and Rossmann 2003).

Table 57: Tests for IIA

Alternative dropped	χ^2	Degrees of Freedom	Probability (C>c)
Option A	55.85	6	0.000
Option B	18.75	6	0.005

Table 24, Testing the IIA property

The ML that will now be implemented is not constrained by the IIA property. Unlike the CL model that assumes homogenous preferences the ML is able to detect and account for any unobserved heterogeneity that may be present (Garrod et al. 2002). As Birol et al. (2006) rightly suggested preferences are heterogeneous and by allowing for this will enhance the estimates and therefore present a more accurate reflection of individual preferences (Greene, 1997). This method of accounting for unobserved unconditional heterogeneity is also espoused by Kontoleon (2003) especially when dealing with pure public goods. The ML model works by allowing for taste parameters to have statistical distributions arising from different parameters for each individual (Revelt and Train 1998).

The methodology for estimation follows that prescribed by Hensher et al. (2005). First it was assumed that preferences towards the attributes, excluding the cost variable, were heterogeneous and were estimated using random parameters and the cost variable was assumed to have homogenous preferences (Morey and Rossmann, 2003; Carlsson et al., 2003, Birol, 2006). The number of random draws was set at 1000, as recommended by Bhat (2001), Birol et al. (2006) and Kosenius (2008). The results are reported in Table 58.

Table 58: ML model results (1000 draws)

Variable	Coefficient	Wald stat
Non-random parameters		
CST	-0.0069	-0.44
Mean random parameter		
ASC	-2.233***	-4.89
WHISTLE	-0.0084	-1.42
SMELL	0.0005	0.28
WASTE	0.0026	1.02
HEIGHT	0.0014	0.5
Standard deviations		
NsASC	0.3283	0.24
NsWHISTL	0.017**	2.42
NsSMELL	0.0014	0.15
NsWASTE	0.0017	0.15
NsHEIGHT	0.0045	0.53
N	1399	
ITERATIONS	28	
AIC	1.27	
BIC	1.31	
Restricted log likelihood function	-1536.959	
Loglikelihood function	-876.34	
Base comparison model		
Pseudo-R^2	0.43	

Table 25, results for mean random parameters, Critical Wald-value is 1.96 at 95% confidence level, indicates: ***1%, **5%, *10

The results show that bar whistle all the attributes posses the correct sign, unfortunately though they are all statistically insignificant and therefore unable to reject the null hypothesis that they are equal to zero. With regards to the spread, only the whistle attribute is statistically significant, at the 5% level, suggesting the existence of heterogeneity, and therefore it should not collapse into a single point representative for the entire sample. The other attributes are insignificant and therefore their derived standard deviations indicate that the dispersion around the mean is statistically equal to zero.

Following this, those parameters with insignificant standard deviations were re-estimated as non-random parameters, as shown in Table 59. The CL results from model 1 are reported again to allow for ease of comparison. As can be seen the results between the two are very similar with regards to signs, magnitudes and significance.

Table 59: Comparison of ML and CL results

	ML Model 8		CL Model 1	
Variable	Coefficient	Wald stat	Coefficient	Wald stat
Non random parameters				
ASC	-2.1912***	-6.66	-2.186***	-7.04
SMELL	0.0005	0.28	0.0003	0.21
WASTE	0.0026	1.15	0.0024	1.15
HEIGHT	0.0019	1.03	0.0016	0.96
CST	-0.0072	-0.48	-0.0082	-0.58
Whistle			-0.0004	-0.20
Mean random parameter				
WHISTLE	-0.0060 (0.0138**)	-1.12 (1.97)		
N	1399		1399	
ITERATIONS	16		5	
AIC	1.26		1.26	
BIC	1.29		1.29	
Restricted Log likelihood function	-1536.96			
Log likelihood function	-877.31		-878.21	
Base comparison model			-879.76	
Pseudo-R^2	0.43		0.002	

NsWHISTL standard deviation is reported in parenthesis, Critical Wald-value is 1.96 at 95% confidence level, indicates: ***1%, **5%, *10

Next the model is re-run with socio-economic interaction terms. This is because despite the ability of the ML model to account for unobserved heterogeneity it is unable to explain its source (Boxall and Adamowicz, 2002). The inclusion of these interaction terms allows the detection of these sources and enables the ML model to account for preference variation in terms of both random heterogeneity, that is unconditional taste heterogeneity and conditional heterogeneity, which is individual characteristics (Revelt and Train, 1998; Morey and Rossmann, 2003; Kontoleon, 2003).

The results are reported in Table 60. Only the whistle attribute was considered to have heterogeneous preferences. The CL results are reported again to ease comparison between the two models. Despite the ML being more complex the results between the two are very similar in terms of signs, coefficient magnitudes and significance levels. The log likelihood ratio test reports a figure of 1.7 which is less than the critical value of 3.8 for 1 dof at the 5% level therefore we are unable to reject the null hypothesis and the new model is not a statistical improvement on the old model.

Table 60: Models with Socioeconomic Interactions

Variables	ML Model 9		CL Model 3	
	Coefficient	Wald-stat	Coefficient	Wald-stat
ASC	-2.2733***	-5.33	-2.241***	-5.562
WHISTLE	-0.0052 (0.0128**)	-1.13 (2.02)	-0.0005	-0.292
SMELL	0.0004	0.21	0.0001	0.121
WASTE	0.0025	1.11	0.0023	1.08
HEIGHT	0.0017	0.95	0.0016	0.91
CST	-0.1678***	-5.51	-0.162***	-5.61
WTPINCOM (WTP*income)	0.0346***	6.42	0.031***	6.59
A7ABIASC (area is industrial)	-0.2515***	-3.49	-0.24***	-3.49
UNEMPLASC	-0.4345***	-4.18	-0.42***	-4.28

(unemployed)				
BINE4ASC (relationship status)	0.1804**	2.37	0.18**	2.36
CHILASC (children)	0.1119	1.42	0.11	1.44
NOQULASC (education)	-0.1721**	-2.14	-0.178**	-2.25
A1ASC (TENURE)	0.0061**	2.25	-0.006**	2.27
DISTASC (distance)	-0.0001	-0.99	-0.0001	-0.97
N	1391		1391	
ITERATIONS	24		6	
AIC	1.21		1.21	
BIC	1.27		1.27	
Loglikelihood function	-829.04		-829.89	
Base comparison model			-879.76	
Pseudo-R^2	0.46		0.06	

NsWHISTL is presented in parenthesis. Critical Wald-value is 1.96 at 95% confidence level, indicates: ***1%, **5%, *10

7.9.1.2 The models re-run but this time with observations removed

By employing the answers obtained from the debriefing questions into the analysis there are three more sets of response that were considered for removal: how annoyed was the respondent, f2, how important was health to the respondent (so as to avoid double counting), d2, and if the respondent is on full council tax benefit, e10. The results with these excluded respondents had little statistical difference to that with all of them included so the original model was maintained.

7.10 Conclusions and areas for further research

This section of report seeks to analyse the impact of two waste management facilities on the local inhabitants of Dudley in the UK by employing a choice experiment methodology. This methodology was conducted so as to assess any disamenity effects that may have been incurred as a result of four externalities – Noise, Smell, Traffic and Visual. Choice experiments have not previously been employed in this context and few stated preference studies exist on this type of impact.

The findings of this study suggest that the amenity impacts of the incinerator in Dudley may not be that large. The four attributes assessed do not seem to influence the choice patterns of individuals and the ASC was consistently negative and significant. These results appear positive for both waste management operators and waste policy makers – that incineration bears lower amenity effects than may be the case with e.g. landfill.

The study is able to identify certain levels of WTP when people are annoyed by attributes of the site. For instance those that are annoyed by the height of the chimney are willing to pay £3.69 for a 50% reduction. However, these people are relatively few in number in the sample in question. Overall most of the sample reported very low annoyance and exposure levels.

However whether these results are robust enough to infer similar results for other incinerators is as yet undecided. It should be noted that the site in question is a very small incinerator, the fifth smallest in the UK, in a rather industrial setting, therefore its marginal impact is further diminished, so the transferability of the results is questionable. Also, an incinerator has been present on the site for over 70 years; any habituation effect is likely to be strong.

Further work is required with extensions of the method to other sites to confirm if these results are anomalies or conform to the standard and thus see if they are reliable enough for transferability.

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Glossary and nomenclature

As = arsenic

CO_{2eq} = quantity of a greenhouse gas expressed as equivalent quantity of CO_2, using the GWP of the gas

Cr^{VI} = chromium in oxidation state 6

CRF = concentration-response function

CV = contingent valuation

Discount rate = rate r that allows comparison of monetary values incurred at different times, defined such that an amount P_n in year n has the same utility as an amount $P_0 = P_n (1+r)^{-n}$ in year 0.

DRF = dose-response function

ERF = exposure-response function

EC = European Commission

EPA = Environmental Protection Agency of USA

External costs = costs that arise when the social or economic activities of one group of people have an impact on another for which the first group does not fully account, e.g when a polluter does not compensate others for the damage imposed on them.

GWP = global warming potential

Hg = mercury

IPA = impact pathway analysis

ISC = Industrial Source Complex gaussian plume dispersion model

LCA = life cycle assessment

MBT=Mechanical and biological treatment

N = nitrogen

Ni = nickel

NO_x = unspecified mixture of NO and NO_2

O_3 = ozone

Pb = lead

PM_d = particulate matter with aerodynamic diameter smaller than d µm

S = sulfur

s_{CR} = slope of concentration-response function [cases/(person·yr·µg/m^3)]

UWM = uniform world model (for simplified estimation of damage costs)

v_{dep} = deposition velocity [m/s]

VOC = volatile organic compounds.

VOLY = value of a life year

VPF = value of prevented fatality

WTP = willingness to pay

YOLL = years of life lost (reduction of life expectancy)

Annex I: Appendices to the chapters

Appendix 1: Emmision data specification

Information on methane recovery

Austria

Excavated-soil landfills: 340 Construction waste landfills: 74 Residual waste landfills: 27 Mass waste landfills: 50 In 2004 the Umweltbundesamt made an investigation (ROLLAND & OLIVA 2004) and asked the operators of landfill sites to report their annual collected landfill gas. As this study considers only the amount of collected landfill gas from 1990 to 2002, the data were also used for the years 2003 to 2005. A study to update the amounts of collected landfill gas will be undertaken in 2007.

Belgium

12 (Wallonia) For Wallonia, each year all the landfills with CH4 recovery (12 in 2002) are contacted to collect data on the amount and CH4 content of the biogas recovered (flaring or energy purposes). The CH4 content is measured by landfill owners as it determines the possible use of the biogas (only "rich" biogas" is used in engines, the rest is flared). Following a 1997 legal decree, a contract with the ISSEP (Scientific institute for Public Service in Wallonia) also organises a close following of the environmental impacts of the Solid Waste Disposal Sites on Air, Water and Health. Seven main Sites are followed for the time being and the report includes biogas analysis. Details can be found on the DGRNE web site.

Denmark

26 recovering 134 not recovering Data for landfill gas plants are according to Energy Statistics from the Danish Energy Agency.

Finland

33 recovering Finnish Biogas Plant Register (Kuittinen et al. 2005)

France

88% of the solid waste disposal is landfilled on SWDS with biogas capturing.

Germany

95% is disposed to recovering sites 150 sites not recovering. For 2004 it was assumed that methane is captured on 95% of all landfills and that the corresponding capturing efficiency is 60%. The Federal Statistical Agency will consider landfill gas recovery in its survey for the next years, which allows to take the value for methane recovery from data of individual plants.

Greece

4 recovering. According to data from the Ministry for Environment, recovery and flaring of biomas constitute management practices in the 4 major managed SWDS of Greece (in the cities of Athens, Patra, Thessalonica and Larissa). For 3 of these sites (in Patra, Thessalonica and Larissa) the collection of data on the amount of biogas flared has not been possible yet. The estimation of biogas recovered in these sites was based on the assumption that for technical reasons, 60% of biogas released is finally recovered and flared. Detailed measurements data have been collected only for the SWDS of Athens, in which almost 50% of total waste going to managed sites is disposed. The quantities of waste disposed in the 3 sites for which the CH4 recovery is based on assumptions, the volume of biomas flared in the SWDS of Athens and methane that is totally recovered, are presented. For the estimation of methane recovered in the SWDS of Athens, the fraction of methane in landfill gas (F) was calculated at 0.5 and methane density at 0.7 kg CH4/m3, based on the data collected (NIR 2006).

Ireland

Annual reports on renewable energy use; top-down: the amount of CH4 captured for energy use is estimated from the reported electricity production in the national energy balance, assuming assigned percentage conversion efficiency factors; bottom-up: estimates on CH4 utilized and flared from 65 individual landfills that were producing CH4 in appreciable quantities 341 401 (1st category landfills)Landfill gas recovere data have been reconstructed on the basis of information on extraction plants (De Poli and Pasqualini, 1997; Acaia et al., 2004; Asja, 2003) and electricity production (GRTN, several years) (NIR 2006).

Luxembourg

No information available.

Netherlands

50 recovering 27 operating not recovering, few ?thousand? old sites which still are reactive The amount of waste disposed on landfill sites are mainly based on the annual survey performed by the Working Group on Waste Registration at all the landfill sites in The Netherlands. Data can be found on www.uitvoeringafvalbeheer.nl, and are documented in SenterNovem, 2005. This document contains also yearly the amount of methane recovered from landfill sites.

Portugal

In the absence of metering landfill gas recovered data, estimates on recovered CH4 for urban waste were done based on: the information of INR for each waste management system - existence of burners, and the starting year of landfill operation and on an average efficiency for the gas capture (75%) and the gas burners (97%). Industrial waste: Data on quantities of CH4 recovered and combusted are estimates based on the assumptions presented for urban waste, considering that they share the same disposal places.

Spain

21 recovering 25 not recovering landfills have been identified as having applied some system of combustion for captured biogas during between 1990-2005, whether for elimination (combustion with flares) or for energy recovery (combustion in boilers, turbines or engines). These landfills are large scale and each of them was provided with an individualized questionnaire for the collection of information.

Sweden

70 recovering 165 not recovering Information on recovered gas (in energy units) is provided by RVF and converted to use quantities by Statistic Sweden.

United Kingdom

The fraction of methane recovered was derived from a survey of statistics on gas use for power generation, and a survey of installed flare capacity. Flares (other than those used to back up power generation, which are assumed to operate only when needed) are taken to have a load factor of 85% (i.e. 15% downtime), and 7% of the flares are assumed to be replaced every year, so that the flare lifetime is 15 years. This approach was taken because suitable metering data were not available. In 2005 the estimates were that 32% of generated methane was utilised and 38% was flared.

Industrial waste

Austria

“Mixed industrial waste” is considered under "non residual waste". Several waste types with their respective waste identification numbers are described. These are not clearly referenced as industrial wastes, though.

Belgium

Emissions from industrial waste are calculated with the same model as municipal waste. The DOC value for industrial waste was estimated calculated using the detailed waste types from OWD and the IPCC Good Practice Guidance methodology (equation 5.4, page 5.9). This detailed estimation led to a complete recalculation, as the new estimated DOC were much lower than the default value previously used.

Denmark

Industrial waste is considered and data on its composition and amount deposited are used in the emission model.

Finland

Industrial solid waste and industrial sludge are considered as waste types. Activity data and several DOC values are provided in the NIR.

France

Industrial waste is neither mentioned nor considered explicitly.

Germany

The Federal Statistical Office provides detailed data about landfilling of industrial waste since 1996. In the inventory the following waste types are considered: wastes from agriculture, horticulture, forestry, fishery and food processing, wastes from wood processing, wastes from the production of cellulose, paper and cardboard, wastes from the textiles industry, packaging wastes as well as the wood fraction from construction and demolition wastes.

Greece

Industrial waste is neither mentioned nor considered explicitly (NIR 2006).

Ireland

Industrial waste is mentioned, but not considered explicitly.

Italy

Industrial waste which is landfilled in SWDS and sludge from wastewater handling plants has also been considered (NIR 2004).

Luxembourg

Industrial waste is neither mentioned nor considered explicitly (NIR 2006).

Netherlands

Industrial waste is neither mentioned nor considered explicitly.

Portugal

The fermentable part of industrial waste is considered. Historical time series are based on 1999 data which refer to annual registries relating to industrial unit declarations sent to the regional environment directorates which have been estimated on expert judgment. For the period 1960-1990 it was considered a growth rate of 1.5% per year; for the following years (1990- 1998) 2% per year. Data for the years 2000, 2002 and 2003 refer to annual registries. The years 2001, 2004 and 2005 are also estimates based on interpolation (2001) and last available data (2004-05 refer to 2003 data). All industrial waste generated was considered to be disposed in SWDS together with urban waste. However, as there is no available information concerning final industrial waste disposal, it was assumed that all estimated waste produced has followed the urban disposal pattern between uncontrolled and controlled SWDS. Except for DOC, the same parameters are used for industrial waste as for municipal waste.

Spain

Industrial waste is neither mentioned nor considered explicitly.

Sweden

Detailed description available in the NIR of how activity data and emissions of relevant industrial wastes and sludges are generated.

United Kingdom

The estimates of waste disposal quantities include industrial waste. Arisings are based on national estimates from a 1995 Survey. Waste quantities have been extrapolated to cover past years based on employment rates in the industries concerned. Commercial and industrial arisings have been scaled up to the UK, based on an England and Wales total from Environment Agency data, for 2002 and assumed constant thereafter; years 1999, 2000 and 2001 are scaled values between 1998 and 2002. In the revised LQM model, all industrial waste except for construction and demolition, blast furnace and steel slag and power station ash is assumed to have some organic content and are therefore included in the figure for MSW.

Unmanaged Solid Waste Disposal

France

The difference between managed and unmanaged MSWD is only if MSWD use compacting or not. No further information given.

Greece

Out of the existing disposal sites, it is estimated that 37 of them fulfill the criteria set by the IPCC guidelines so as to be considered as ‘managed’. The remaining waste is disposed at unmanaged disposal sites. Time series of DOC and MSW quantities disposed on unmanaged SWDS are given for 1960-2004 (NIR 2006).

Ireland

In the period 1990-1995, 40 % of DOC is assigned a MCF of 0.4, on the assumption that 40 percent of MSW is placed in unmanaged SWDS of less than 5 m depth. The MSW split between managed and unmanaged sites in 1969 is taken to be the reverse of that adopted for the years 1990-1995 and an appropriate adjustment is made for the intervening years and for the years after 1995 to reflect a gradual increase for managed landfills. The MSW split adopted for 2005 is 0.95 for managed sites and 0.05 for unmanaged sites. This represents a major change from the 0.67:0.33 division used for 2004 and it has been made following discussions with waste experts who believe that almost all landfills in Ireland could be classified in the managed category as used by IPCC.

Italy

From 2000, municipal solid wastes are disposed only into managed landfills, due to the enforcement of regulations. The share of waste disposed of into uncontrolled landfills has gradually decreased thanks to the enforcement of new regulations, and in the year 2000 it has been assumed equal to 0; emissions still occur due to the waste disposed in the past years. The unmanaged sites have been considered 50% deep and 50% shallow (NIR 2006).

Portugal

The share of final disposal destiny (inter alia uncontrolled dumping sites) for the first years of the time series was calculated having as a basis the Quercus survey. Data for recent years (mainly since 1999) refer to data collected from management systems. There have been significant efforts at national level to deactivate and close all uncontrolled dumping sites. This effort was concluded in 2002 when all uncontrolled dumping sites had been closed. Concerning uncontrolled dumping sites, it was considered that there is gas burning when a dumping site has been closed and is associated with a manager landfill having recovery of CH4. It was assumed that gas burning starts typically 2-3 years after the beginning of the landfill operation. It was assumed that all estimated industrial waste produced have followed the urban disposal pattern between uncontrolled and controlled SWDS.

Spain

With respect to unmanaged SWDS, there is no statistical information available for the characterization of the parameter of depth, so in the absence of said information it is assumed that 50% are deep and the remaining 50% are shallow. At the same time, within unmanaged SWDS, whether they are deep or shallow, burn coefficients were assumed for the reduction in volume. These coefficients have decreased during the inventory period.

Waste – Other

Austria

Emissions were estimated using a country specific methodology. To estimate the amount of composted waste it was split up into three fractions of composted waste: 1) mechanical biological treated residual waste, 2) bio waste, loppings, bio composting, 3) sewage sludge. Emissions were calculated by multiplying the quantity of waste with the corresponding emission factor (CH4 and N2O) based on national references.

Belgium

CH4 emissions from compost production are estimated using regional activity data combined with a default emission factor of 2,4 kg CH4/ton compost.

Denmark

Emission from combustion of biogas in biogas production plants is included in CRF sector 6D. The fuel consumption rate of the biogas production plants refers to the Danish energy statistics. The applied emission factors are the same as for biogas boilers (see NIR chapter 3, Energy).

Finland

Emissions from composting have been calculated using an analogous method with Draft 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Activity data are based on VAHTI database and the Water and Sewage Works Register. The activity data for composted municipal biowaste for the year 1990 are based on the estimates of the Advisory Board for Waste Management (1992) for municipal solid waste generation and treatment in Finland in 1989. Data on years 1997,2004 and 2005 are from VAHTI database and the intermediate years have been interpolated. In addition, composted solid biowaste in the years 1991-1996 has been interpolated using auxiliary information from the National Waste Plan until 2005 (Ministry of the Environment 1998).

France

CH4 and N2O emissions from composting as well as CH4 emissions from biogas production.

Germany

In Germany, yearly increasing amounts of organic waste are composted. For this purpose CH4 and N2O emissions from composting of municipal solid waste are determined using a national method. Activity data is provided by the National Statistical Agency. Emission factors stem from a national study. Composting of garden and organic waste in individual households is not considered in this category. Since 1 June 2005 landfilling of biologically degradable waste is not permitted in Germany anymore. MSW has to be treated, therefore, prior to landfilling. Mechanical-biological treatment of waste is one of the options. A national Method has been developed for the calculation of CH4 and N2O emissions in which the amount of waste treated in mechanical-biological treatment plants is multiplied with emission factors from a national study. Activity data is provided by the National Statistical Agency.

Italy

Under this source category CH_4 emissions from compost production have been reported. The composting plants are classified in plants that treat a selected waste (food, market, garden waste, sewage sludge and other organic waste, mainly from the agro-food industry) and the mechanical-biological treatment plants, that treat the unselected waste to produce compost, refuse derived fuel (RDF), and a waste with selected characteristics for landfilling or incinerating system. It is assumed that 100% of the input waste to the composting plants from selected waste is treated as compost, while in mechanical-biological treatment plants 30% of the input waste is treated as compost on the basis of national studies and references. Since no methodology is provided by the IPCC for these emissions, literature data have been used for the emission factor, 0.029 g CH_4 kg^{-1} treated waste, equivalent to compost production (NIR 2006).

Luxembourg

Sludge from waste water treatment plants and compost production sites generate CO_2 and CH_4 emissions. The CORINAIR (simple) methodology is applied. For compost production: the mass of dry compost is 33.3% of the mass of humid sludge. CO_2 emissions are accounted for, but composting is biological decomposition of organic material, so it's biogenic. CH_4 emissions for composting are missing. Activity data for sludge spreading and compost production have been taken from the Environment Agency (internal report) (NIR 2006).

Netherlands

This source category consists of the CH_4 and N_2O emissions from composting separately collected organic waste from households. A country-specific methodology for this source category is used with activity data based on the annual survey performed by the Working Group on Waste Registration at all the industrial composting sites in the Netherlands (data can be found on www.uitvoeringafvalbeheer.nl and in a background document (SenterNovem, 2005a)) and emission factors based on the average emissions (per ton composted organic waste) of some facilities in the late 1990ies (during a large scale monitoring programme in the Netherlands). Emissions from small-scale composting of garden waste and food waste by households are not estimated as this is assumed to be negligible. Since this source is not considered as a key source, the present methodology level complies with the IPCC Good Practice Guidance (IPCC, 2000).

Portugal

This category includes emissions from the open burning of industrial solid waste on land which was previously reported in the category 6C. This change relates to the in-depth review recommendation to report these emissions under category 6A. These emissions have however been reported under 6D in order to report more pollutants (SO_2) in CRF tables than was possible in category 6A. The same methodology as for category 6C Waste incineration was used, which refers to IPCC Guidelines (IPCC, 1997). Ultimate CO_2 emissions from open combustion of industrial waste on land were calculated based on data which refer to uncontrolled combustion of industrial solid waste on land and which were collected from INR. Data for the years 2000. 2002 and 2003 refer to industrial units declarations. The figure for 2001 is interpolated, and 2004-05 refer the last available data (2003). Data for the period 1990-98 are based on the same assumptions used for Industrial Solid Waste Disposed on Land: a per year growth rate of 2%. Emissions were estimated as the product of the mass of total waste combusted, and an emission factor for the pollutant emitted per unit mass of waste incinerated. Emission factors applied are either country specific, being obtained from monitoring data in incineration units, or obtained from other references (US data, EMEP/CORINAIR).

Spain

No information provided.

Waste incineration

Austria

In this category CO2 emissions from incineration of corpses and waste oil are included as well as CO2, CH4 and N2O emissions from municipal waste incineration without energy recovery. There is only one waste incineration plant without energy recovery which has been perated until 1991 with a capacity of 22 000 tons of municipal waste per year.

Belgium

N2O Emissions from domestic waste incineration are calculated using activity data known from the individual companies involved combined with the emission factor of CITEPA. CH_4 emissions are not relevant. For CO_2 emissions, each region applies its own methodology according to the available activity data. In Flanders, only the fraction of organic-synthetic waste is taken into consideration (assuming that organic waste does not give any net CO_2 emissions). For the municipal waste, the institute responsible for waste management in Flanders (OVAM) is given the analysis of the different fractions in the waste. Based on this information, the amount of non-biogenic waste (excluding the inert fraction) is determined. The karbon emission factor is based on data from literature for the different fractions involved. For industrial waste, the amount of biogenic waste is considered to be the same as in municipal waste. The remaining amount is considered to be the non-biogenic part in which no inert fraction is present. For industrial waste, it is more difficult to determine the content of C and therefore the results of a study carried out by the Vito 'Debruyn en Van Rensbergen 'Greenhouse gas emissions from municipal and industrial wastes of October 1994' are used. This study gives a content of C of the industrial waste of 65.5 %. In Wallonia, following a legal decree in 2000, the air emissions from waste incineration are measured by ISSEP and the results are validated by a Steering Committee. These results allow a crosscheck with the results of measurements directly transmitted by the incinerators to the environmental administration. There is a distinction between the emission from municipal waste incineration and hospital waste incineration. The CO2 emissions of municipal waste incineration are reported assuming that 68 % of the waste is composed of organic material. This is based on the average garbage composition in Wallonia and the use of IPCC equation on organic content of the various materials. The CO2 emissions from hospital waste incineration are measured by the Walloon incinerators and are fully reported. The emissions of CO2 from the flaring in the chemical industry in Wallonia are reported in Category 6C according to IPCC Guidelines. In Brussels, the emission factors for the incineration of hospital and municipal waste and corpses are estimated by measurements in situ in connection with EMEP/CORINAIR emission factors.

Denmark

For the CRF source category 6C. Waste Incineration the emissions are included in the energy sector since all wastes incinerated in Denmark are used in the energy production.

Finland

Emissions of greenhouse gases CO2, N2O and CH4 from Waste Incineration (CRF 6C) are reported in the energy sector (CRF 1A) in the Finnish inventory. There is no waste incineration on landfills in Finland and waste incineration for energy production is included in the energy sector. Waste incineration without energy recovery is nearly zero in combustion plants and it is also included in the energy sector. Waste incineration in households is negligibly small.

France

Carbon dioxide of biogenic origin was excluded from the emission estimates. Only waste incinerators without energy recovery are considered in this category. The incineration of special industrial waste is partially included according to the information available. Furthermore the incineration of utilized agricultural plastic films is included. Moreover, there is incineration of other non-specified waste.

Germany

Reported in the energy sector (CRF 1).

Greece

Carbon dioxide emissions from the incineration of clinical waste produced in the Attica region have been estimated. For the estimation of CO_2 emissions, the default method suggested by the IPCC Good Practice Guidance was used. CH_4 and N_2O emissions have not been estimated because there are not any available relevant emission factors. However, according to the IPCC Good Practice Guidance, these emissions are not likely to be significant. Data related to the amount of clinical waste incinerated derive from the ACMAR, which is operating the incinerator. The relevant parameters and emission factor used are the ones suggested in the IPCC Good Practice Guidance (NIR 2006).

Ireland

Not occurring

Italy

Existing incinerators in Italy are used for the disposal of municipal waste, together with some industrial waste, sanitary waste and sewage sludge for which the incineration plant has been authorized from the competent authority. Other incineration plants are used exclusively for industrial and sanitary waste, both hazardous and not, and for the combustion waste oils, whereas there are few plants that treat residual waste from waste treatments, as well as sewage sludge. Emissions from waste incineration facilities with energy recovery are reported under category 1A4a, whereas emissions from other types of waste incineration facilities are reported under category 6C. For 2004, 95% of the total amount of waste incinerated is treated in plants with energy recovery system. CH_4 emissions from biogenic, plastic and other non-biogenic wastes have been calculated. Regarding GHG emissions from incinerators, the methodology reported in the IPCC Good Practice Guidance has been applied, combined with that reported in the CORINAIR Guidebook (EMEP/CORINAIR, 2005). A single emission factor for each pollutant has been used combined with plant specific waste activity data. Emissions have been calculated for each type of waste: municipal, industrial, hospital, sewage sludge and waste oils. Different procedures were used to estimate emission factors, according to the data available for each type of waste. As regards municipal waste, a distinction was made between CO_2 from fossil fuels (generally plastics) and CO_2 from renewable organic sources. Only emissions from fossil fuels, which are equivalent to 35% of the total, were included in the inventory. On the other hand, CO_2 emissions from the incineration of sewage sludge were not included at all, while all emissions relating to the incineration of hospital and industrial waste were considered. CH_4 and N_2O emissions from agriculture residues removed, collected and burnt 'off-site', are reported in the waste incineration sub-sector. Removable residues from agriculture production are estimated for each crop type taking into account the amount of crop produced, the ratio of removable residue in the crop, the dry matter content of removable residue, the ratio of removable residue burned, the fraction of residues oxidized in burning, the carbon and nitrogen content of the residues. CO_2 emissions have been calculated but not included in the inventory as biomass. All these parameters refer both to the IPCC Guidelines and country specific values (NIR 2006).

Luxembourg

The only existing incinerator of municipal waste, SIDOR, is a major CO2 emission source in that sector. CO2 emissions were estimated at 125 kt in 1990, however a big part of those emissions result from biomass combustion. It is estimated that 10 kt of CO2 (non-biomass combustion) should be included into the national total. This value is reported every year though the quantities of refusals incinerated vary from year to year. The reason stems from the fact that the emissions are a first relatively rough estimation of the non-biogenic fraction that is burned in the sole incinerator of the country. A more precise calculation remains to be done. Also, it is worth noticing that waste incineration in Luxembourg is nowadays going with heat/energy recovery. It should then be investigated more deeply where this energy recovered is used and, consequently, whether emissions should be reported in CRF/IPCC sector 6.C or 1.A.1.a (NIR 2006).

Netherlands

The source category Waste incineration is included in source category 1A1 Energy industries since all waste incineration facilities also produce electricity or heat used for energetic purposes. According to the IPCC Guidelines (IPCC, 1997), these should be reported under category 1A1a. Total CO2 emissions – i.e. the sum of organic and fossil carbon – from waste incineration are reported per facility in the annual environmental reports. The fossil-based and organic CO2 emissions from waste incineration (e.g. plastics) are calculated from the total amount of waste incinerated. Per waste stream (residential and several others) the composition of the waste is determined. For each of these types a specific carbon content and fractions of fossil C in total C is assumed, which will yield the CO2 emissions. The method is described in detail in Joosen and De Jager (2003) and in the monitoring protocol.

Portugal

CO2 emissions from incineration are calculated according to IPCC Guidelines (IPCC, 1997), for each waste type (e.g. municipal solid waste (MSW), hazardous waste, clinical waste, and sewage sludge). Until 1999, incineration of solid wastes refers exclusively to incineration of hospital hazardous wastes. The figure for 1995 was used as an estimated for the former years. In 1999, two new incineration units, Valorsul and Lipor started to operate in an experimental regime, respectively in April and August 1999. Their industrial exploration started at the end of the same year or early January 2000. These units are exclusively dedicated to the combustion of MSW which is composed of domestic/commercial waste. Most of the organic materials in MSW are of biogenic origin (e.g. food waste, paper), and so they are not accounted for in net emissions calculations, according to the IPCC Guidelines (IPCC, 1997). However, the components of fossil origin – plastics, synthetic fibbers, and synthetic rubber – are to be accounted in the estimates. Data on clinical waste incinerated refers only to Mainland Portugal and corresponds to data declared in registry maps of public hospital units (there is no incineration in private units). The quantities of clinical waste incinerated decreased strongly in recent years. 25 incinerators were closed in recent years in Mainland. Portugal, only remaining at present one hospital incinerator. Nowadays the other clinical wastes receive alternative treatment or are treated abroad. The non-biogenic components fractions are considered to be different for MSW, and clinical waste. CH_4, N_2O and other emissions were estimated as the product of the mass of total waste combusted, and an emission factor for the pollutant emitted per unit mass of waste incinerated. Emission factors applied are either country-specific, being obtained from monitoring data in incineration units, or obtained from other references (US data, EMEP/CORINAIR).

Spain

Within this category, the emissions produced by the following activities have been estimated: the burning of gas flares at iron and steel plants, and corpse and clinical waste incinerations. Emissions deriving from industrial waste incineration have not been estimated yet. As regards the incineration of municipal waste with energy-related recovery of emissions, according to IPCC nomenclature, they are included in category 1A1a. For the burning of flares in integrated iron and steel plants, information has been gathered by means of a questionnaire. The information on burnt flows has been provided with disaggregation of fuel composition, natural gas, liquefied petroleum gas, coke gas, blast furnace gas and steelworks gas. The estimation of CO_2 emissions has been carried out by applying specific plant factors. For the incineration of human corpses at crematories, the combustion of a supporting fuel and some other material elements incinerated during the process also account for emissions. The clinical waste streams suitable for treatment by incineration are those with a low infection potential and those named "cytotoxic waste" which present a high infection potential. The estimation of the amount of this type of waste produced is calculated by considering the number of hospital beds and a waste production factor per bed and day. The main source of emission factors is the EMEP/CORINAIR Guidebook.

Sweden

Emissions from incineration of hazardous waste, and in later years also MSW and industrial waste, from one large plant are reported in CRF 6C. Reported emissions are for the whole time series obtained from the facility's Environmental report or directly from the facility on request. CO_2, SO_2 and NO_x are measured continuously in the fumes at the plant. In 2003 capacity was increased substantially at the plant by taking one new incinerator into operation. The new incinerator incinerates a mixture of MSW, industrial waste and hazardous waste. Only a minor part (less than 0.5%) of the total amount of MSW incinerated for energy purposes in Sweden are incinerated in the facility included in 6C. All other emissions from incineration of MSW are reported in CRF 1.Emissions reported are CO_2, NO_x, SO_2 and NMVOC. In the submission 2007, for the first time the CO_2 emissions are reported separately respecting the origin of the incinerated waste. According to information from the facility, occasional measurements concerning CH_4 and N_2O have been performed. The CH_4 measurement showed very low or non-detectable amounts. CH_4 is therefore reported as NE in the CRF tables. For N_2O the occasional measurements showed levels giving emissions in the approximate order of 0.2 Mg N_2O/year. N_2O is reported as NE in the CRF tables.

United Kingdom

Incineration of chemical wastes, clinical wastes, sewage sludge and animal carcasses is included here. There are approximately 70 plants incinerating chemical or clinical waste or sewage sludge and approximately 2600 animal carcass incinerators. Animal carcass incinerators are, typically, much smaller than the incinerators used to burn other forms of waste. This source category also includes emissions from crematoria. Emissions are taken from research studies or are estimated on literature-based emission factors, IPCC default values, or data reported by the Environment Agency's Pollution Inventory.

Appendix 2: Focus groups

Two focus groups, each lasting one hour, were carried out in January 2007. Each group consisted of 10 local residents recruited by DJS Research Ltd. The groups were moderated by a University of Bath Researcher.

When the groups were recruited, it was not known how far from the site amenity impacts were likely to occur, i.e. the shape of the distance decay function. In order to ensure that the participants would be able to provide useful feedback, it was decided to recruit respondents from properties relatively close to the site. All participants lived within approximately 500 metres.

The structure of the focus groups followed a 'concealed objective' approach. Under this approach, participants were not told the exact topic of the focus groups when they were recruited. Instead, they were told that the discussion would focus on the 'quality of life' in the local area. The rationale for this approach is to prevent participants pre-preparing opinions or statements regarding the site that are not reflective of their day-to-day views. Similarly, the moderator begins each group by facilitating an open-ended discussion about problems and characteristics of nearby area. The intention is to observe whether the participants themselves raise the site as a cause of disturbance without prompt from the moderator. It also helps respondents to communicate the importance of any problems caused by the site with other problems they may experience (e.g. anti-social behaviour, street lighting), thereby giving important context to the discussion. Following these discussions, the moderator addressed problems related to the Lister Road site in more detail. Finally, the preliminary survey instrument was shown to the respondents and opinions were sought on its efficacy.

The rest of this section describes the views of participants regarding the Lister Road Site and the preliminary survey instrument.

Views on the Lister Road Site

Health Effects

Only a minority of respondents perceived there to be impact on human health from the presence of the incinerator. All members of this group suggested that the incinerator could cause respiratory problems. One participant, a nurse, suggested it might cause cancer. All health concerns are related to the emissions from the chimney. None of the participants described sleep disturbance from noise, stress, or any other similar symptom, as a cause of concern.

At an appropriate point, the moderator read participants the following statement:

> *"What sometimes looks like smoke coming from the top of the chimney is mostly water vapour. This turns into condensation when the air around the*

top of the chimney is cold, in the same way as your breath does on wintry days."

The participants were generally surprised by this and this was sufficient to ease participants concerns about respiratory effects.

Noise from steam release valve

Many participants raised noise from the steam release valve as a cause of concern without prompt from the moderator. Participants described the noise as highly intrusive and said that there was no way of avoiding it's effects, particularly in the middle of the night. Participants described the sound as similar to a very loud whistle from a traditional kettle. Participants reported hearing the noise up to 12 times per year, which contrasts heavily with the 4 occurrences reported by the site operators. This is likely to be related to recall bias, where individuals have a tendency to think that memorable event happens more frequently than it actually does. In contrast, a minority of participants are not familiar with the noise at all.

Odour from Green Waste

Virtually all participants are familiar with this problem, describing it as similar to old food or rotting compost. There was a lack of consensus regarding the frequency of odour events, though most agreed that odours are common. All participants who had noticed this smell attributed them to activities at the Lister Road site. As expected, they described the odour as worse during periods of warmer weather.

Visual Intrusion

Few respondents raised visual intrusion as an issue, though once it was suggested by the moderator, some participants indicated that the site of the chimney plume was more worrying than the chimney itself. Other participants agreed with this point once it was raised by others.

The main cause of concern with respect to the plume is that it is 'smoke' and is a potential cause of respiratory problems and soot in the local area. This is a cause of concern for this research as this would suggest that visual intrusion is correlated with perceived health effect, and therefore health effects could reflect welfare estimates.

Soot/Windblown Ashes

As noted above, a small number of participants suggested that 'soot' from the chimney causes additional dust in their homes and their cars to become dirtier. Additional questions revealed that participant considered the 'Soot' to be windblown ashes released during the incineration process. This is surprising as the site operators assert that fly ashes are captured by bag filters installed on the chimney. Furthermore, this would constitute a serious breach of the licence conditions imposed by regulators, and there is no further evidence to suggest that this is the case[9]. It is possible that passing waste vehicles cause 'soot'. Alternatively, residents could falsely perceive the presence of this problem.

The moderator read respondents the following statement:

> *There is no soot because it is collected using filters to prevent it being released into the air.*

In general, respondents accepted this to be true, but, perhaps unsurprisingly, maintained that they suffered from excess levels of dust.

Views on the Survey Instrument

The participants were taken through the scenario description and presented with an example choice card. The scenario description and choice cards used were virtually identical to the one used in the pilot surveys and are therefore not reproduced here. Participants were generally supportive of the approach presented. However, the following changes were made in response to suggestions by the participants:

With respect to the chimney height, some participants were worried that lowering the chimney would make air quality worse in areas close to the site. The moderator discussed ways in which this fear could be reduced, and as a result, the following text was inserted into the scenario:

To maintain air quality is kept the same, new equipment would also be installed to burn waste at a higher temperature.

Air quality in nearby areas would be completely unaffected by this change.
With respect to the payment vehicle, participants were keen to establish whether the money would be go towards making the changes. Again, the moderator discussed this further with the groups and the following text was inserted into the scenario:
The council have an agreement with the site operators to pay for any major changes, such as the ones described here.

- The money would go directly to the site operators and is guaranteed to be used for this purpose and not for anything else.
- The maximum payment that we should used in the choice cards was discussed with participants. The participants agreed on a value of around £20.

[9] Discuss the Biker Incinerator…

Appendix 3: Results of pilot studies

The results of the initial pilot study showed that most of the respondents were unaffected by the issues raised in the survey. As a result, the design of the choice cards was not adequately tested and there is little information on distance decay effects of annoyance and exposure. Thus, an additional pilot study was needed before the main sample could begin.

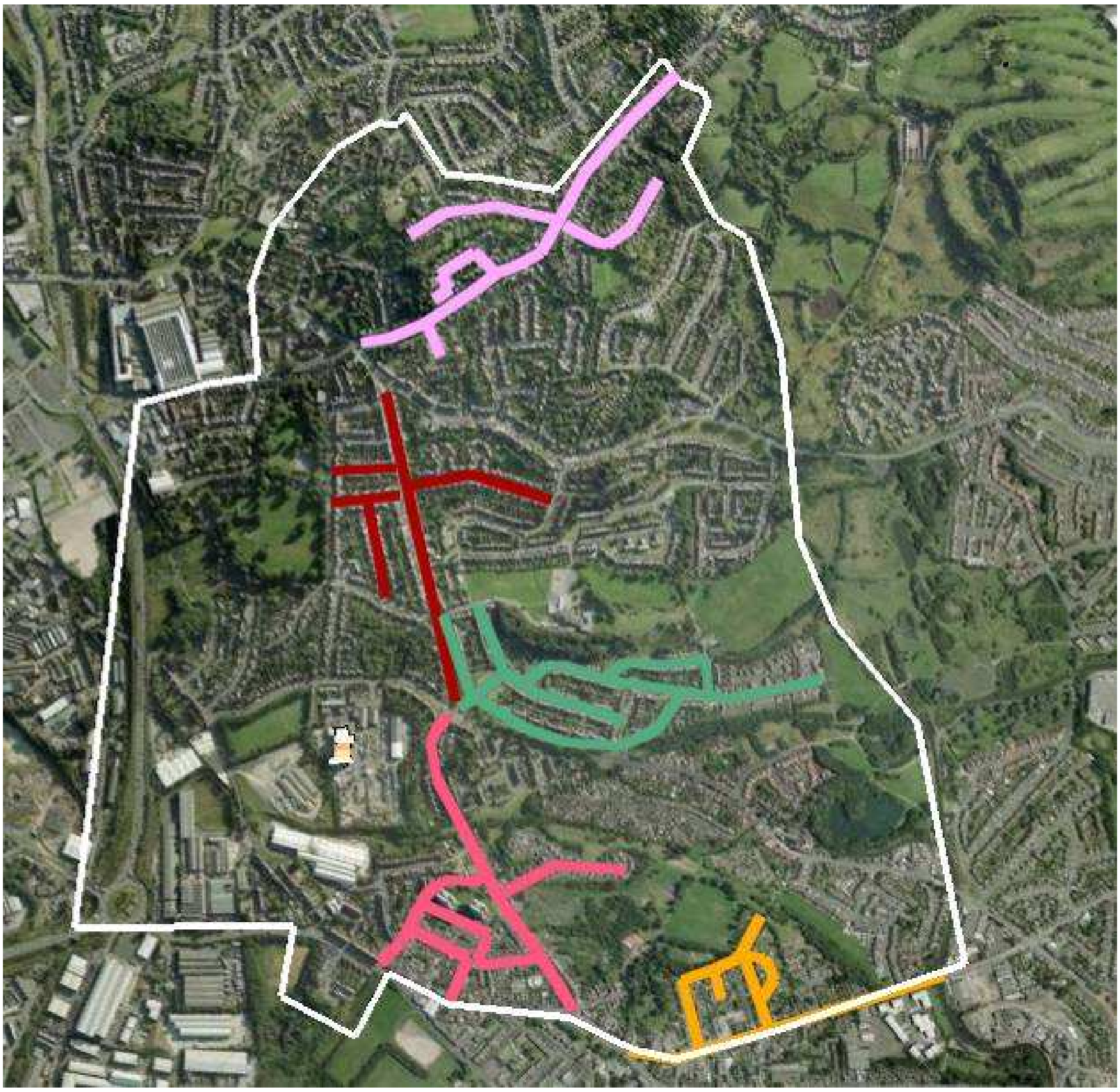


Figure 31: Sample Plan for Second Pilot Study

The sample area selected for the second pilot study is much smaller. The shape and size of this area of this area, as shown in Figure 31, is influenced by the topography of the surrounding area and is therefore not a concentric shape. The maximum distance from the site is 1500 metres. Five zones of four streets were selected from within this area, as shown by the different coloured lines in Figure 31. Interviewers conducted 12 interviews in each zone with no more than three interviews per street. Interviewers tried to spread the interviews out as much as possible. Interviewers were instructed to keep records of which residents they interviewed and which residents declined to be interviewed. This allowed interviewers to revisit these streets for the purposes of the main sample with the knowledge that these residents would not be asked to provide an interview again.

Socio-demographic Characteristics

Table 61: Age

	18-24	25-34	35-44	45-54	55-64	65+
Count	2	7	17	8	9	17
Percent	3%	12%	28%	13%	15%	28%

Summary: *Reasonably representative, though low proportion of first two groups*

Table 62: Gender

	Count	Percent
Male	29	48%
Female	31	52%

Summary: *Representative*

Table 63: Household Size

	Mean	Min	Max
Number of Persons	2.78	1	6

Summary: *Larger than UK Average (2.39 persons)*

Table 64: Marital Status

	Single	Married/Living with someone	Divorced/ Separated	Widowed
Count	7	42	4	7
Percent	12%	70%	7%	12%

Summary: *Low number of single people*

Table 65: Employment Status

	Count	Percent
Self employed	1	2%
Full time employment	17	28%
Part-time employment	5	8%
Student	0	0%

Unemployed	3	5%
Looks after home	13	22%
Retired	19	32%
Sick/disabled	2	3%

Summary: *Very high proportion of economically inactive*

Table 66: Educational Attainment

	Count	**Percent**
None	27	45%
Basic GCSEs	17	28%
More GCSEs	7	12%
A-levels	3	5%
Degree	5	8%

Summary: *Low overall attainment. Number of degree levels respondents is very low.*

Table 67: Household Income

	Count	**Percent**
£0 - £5,000	1	2%
£5,001 - £10,000	2	3%
£10,001 - £15,000	5	8%
£15,001 - £20,000	8	13%
£20,001 - £30,000	4	7%
£30,001 - £40,000	3	5%
£40,001 - £60,000	0	0%
£60,001 - £100,000	0	0%
>£100,000	0	0%
Refused	26	43%
Unsure	11	18%

Summary: *Only 39% provided answer. Median group is £15k -£20k, inline with national average. True median is probably lower given amount of non-responses.*

Table 68: Council Tax Relief

	Count	Percent
Full	14	23%
Partial	6	10%
None	40	67%
Refused	0	0%
Unsure	0	0%

Summary: *Excellent response rate. High levels of claimants.*

In general, the socio-demographic characteristics of the sample are representative of the deprived nature of the area.

Annoyance and Exposure

Table 69 summarises exposure and annoyance caused by amenity loss. Someone is classified as annoyed if they report that they are at least slightly annoyed (point 2 on a 5-point scale).

Table 69: Exposure and Annoyance caused by Lister Road Site

	Responses	Number Exposed in Last Year		At Least Slightly Annoyed		
		Count	% of Total	Count	% of Total exposed	% of Total
Noise	60	13	22%	14	108%	23%
Odour	60	11	18%	13	118%	22%
Visual Intrusion	60	23[1]	38%	12	52%	20%
Traffic	60	10[2]	17%	7	70%	12%

[1] Total respondents who can see chimney from their property

[2] Total respondents who think they are affected

The table indicates that:

- Overall exposure to the causes of amenity loss in the sample is relatively low.

- High proportions of those exposed to noise and odour are subsequently annoyed. These values exceed 100% because some of those who are annoyed last noticed the problem more than 12 months ago.

- Lower proportions of those exposed to visual intrusion and traffic are annoyed.

Figures Figure 32Figure 35 show the distribution of annoyance and exposure across different distances. Percentages of respondents at least moderately annoyed (point 3 on a 5-point scale) are also shown in these figures.

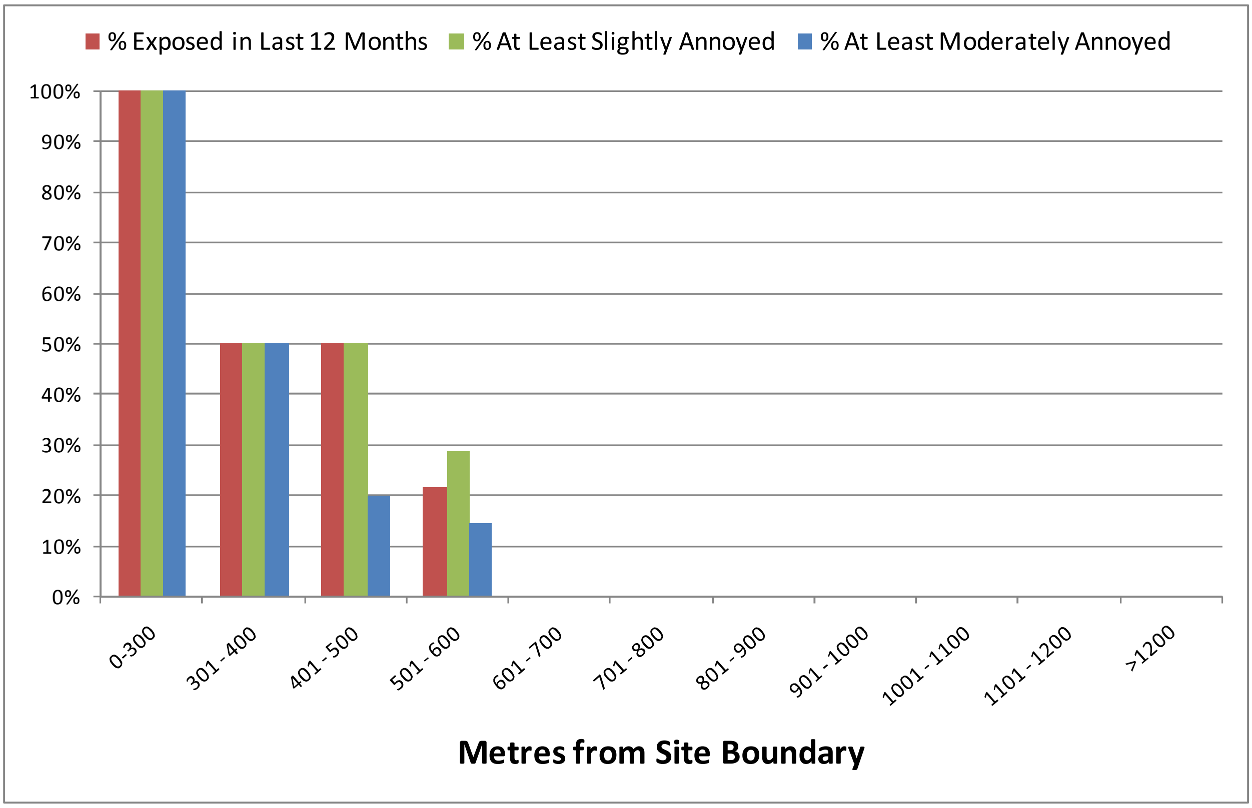


Figure 32: Effects of Distance on Noise

- 13 people reported that they have been exposed to noise in the last year.
- There is no reported annoyance or exposure beyond 600 metres from the chimney.
- Both annoyance and exposure are a decreasing function of distance.
- Most people who are exposed are annoyed. Some values exceed 100% because some of those who are annoyed last noticed the problem more than 12 months ago.

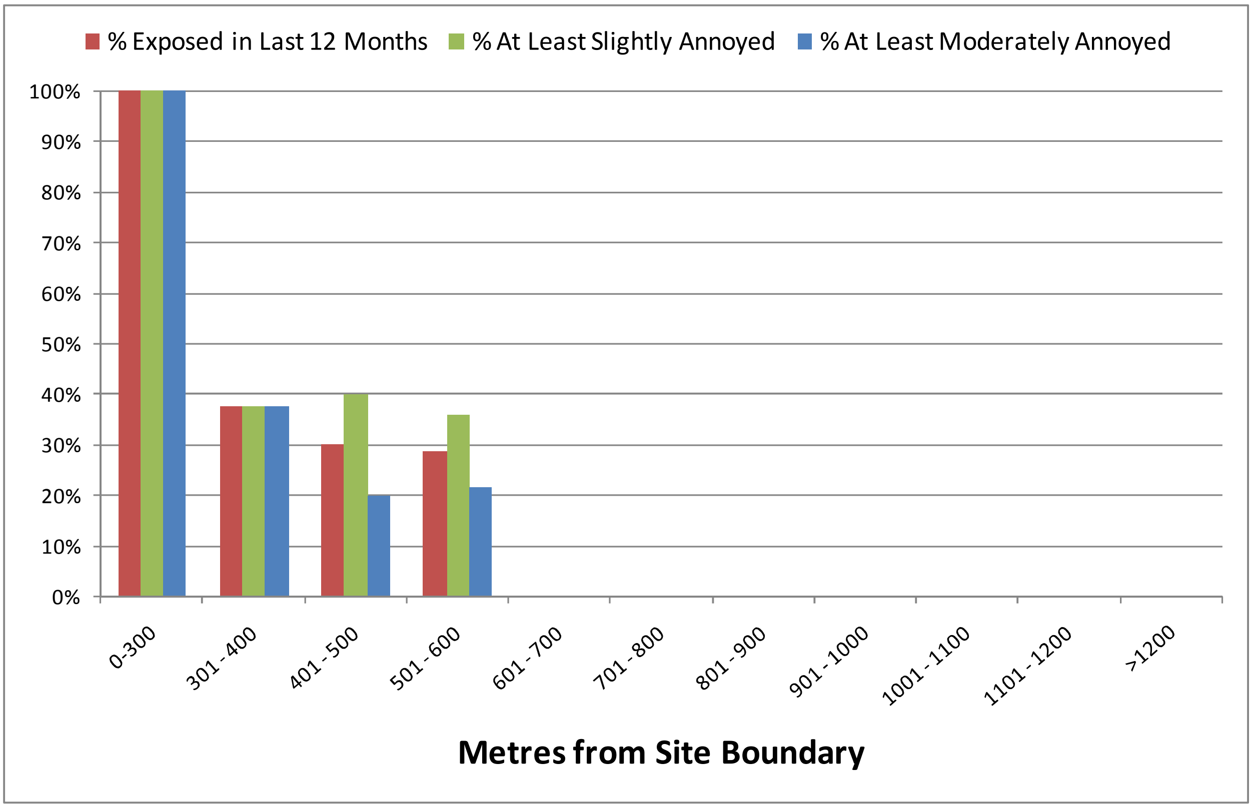


Figure 33: Effects of Distance on Odour

- The results are similar to those for noise.
- 11 people have been exposed to odour in the last year.
- There is no reported annoyance or exposure beyond 600 metres from the chimney.
- Both annoyance and exposure are a decreasing function of distance.
- Most people who are exposed are annoyed. Some values exceed 100% because some of those who are annoyed last noticed the problem more than 12 months ago.

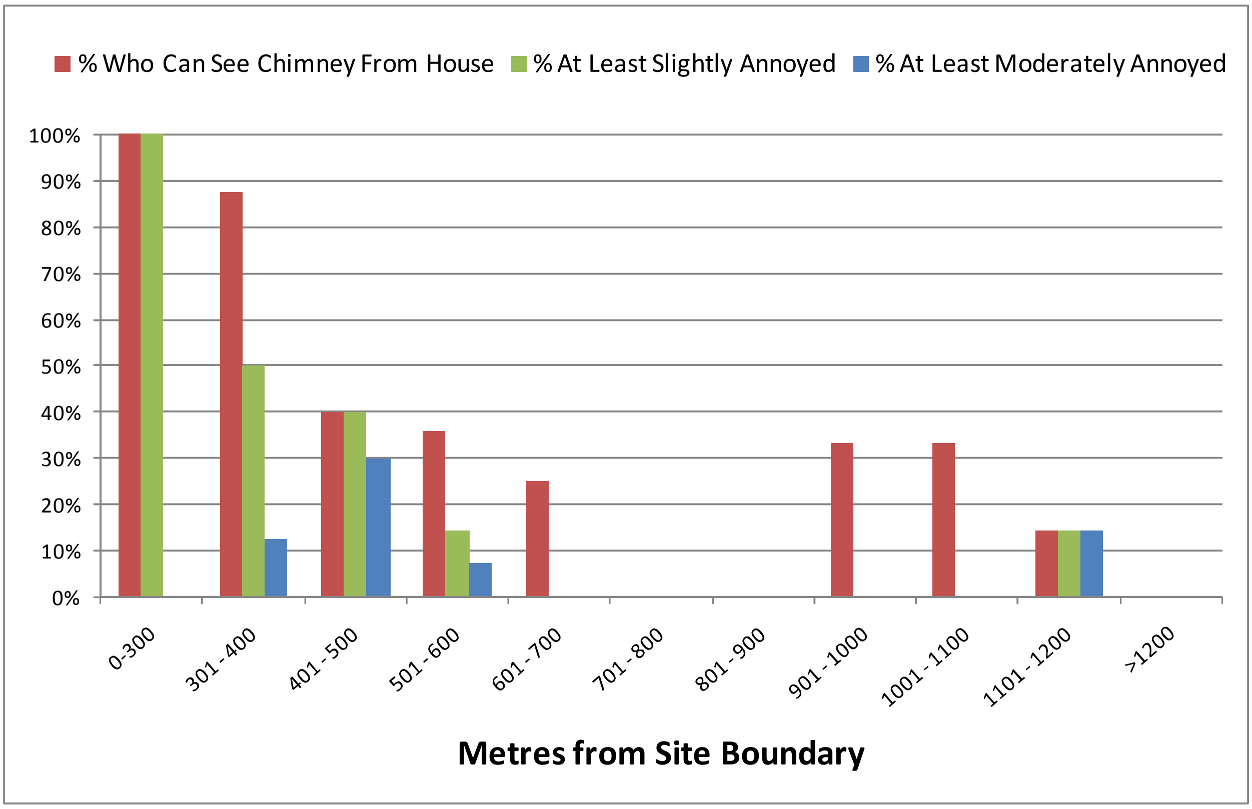


Figure 34: Effects of Distance on Visual Intrusion

- 23 respondents can see the chimney from their house. More respondents are likely to see the chimney on a day to day basis.
- The chimney can be seen properies across the sample area. No respondents between 700 and 900 metres report that they can see the chimney from their house, though this is probably due to the small sample size.
- Relatively high amonts of those exposed are slightly annoyed up to 600m away from the chimney. Less are more than slightly annoyed.
- Low levels of moderate annoyance imply that residents are quite used to the view of the chimney and are largely unaffected in terms of welfare.

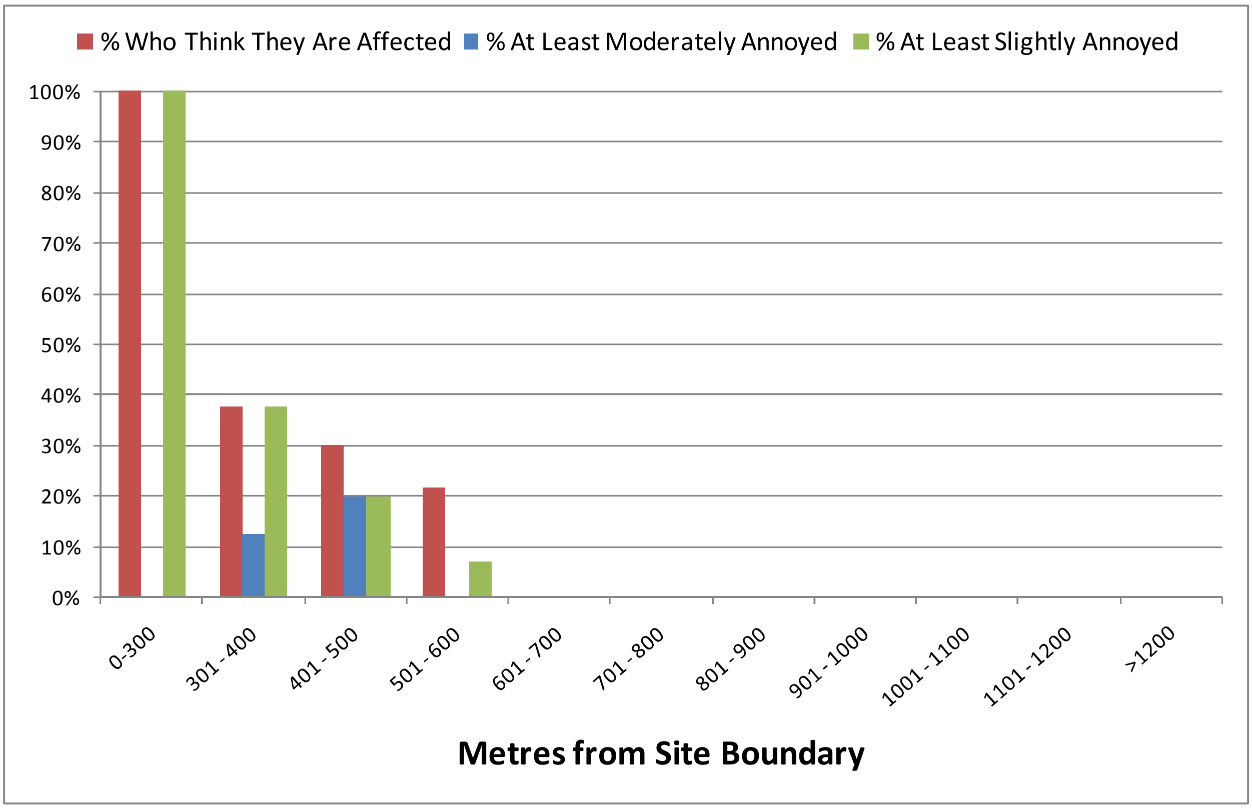


Figure 35: Effects of Distance on Traffic

- 10 respondents considered that they are exposed to vehicle traffic from the site.
- There is no reported annoyance or exposure beyond 600 metres from the chimney.
- Reported annoyance levels are quite low.
- It should be remembered that the reported traffic exposure are relatively unreliable compared to other attributes.

Table 70: Annoyance Correlation Coefficients

	Noise	Odour	Visual Intrusion	Traffic
Noise	1.00	-	-	-
Odour	0.83	1.00	-	-
Visual Intrusion	0.86	0.74	1.00	-
Traffic	0.80	0.65	0.87	1.00

Table 70 shows that the correlation between being annoyed about one thing and being annoyed about another is quite high. This is supported by the fact that only 15 of the 60 respondents report being annoyed about anyone problem.

Perceived Health Effects

Do you think that the Lister road site affects the health of those living nearby? (Question B18)		
Yes	7	12%
No	53	88%

As shown above, only 7 of the 60 respondents considered that the incinerator is a cause of health effects. After this question, all respondents were read a statement saying that the health risks are very low. The results are shown below:

Given this information, do you still think that the Lister Road Site affects the health of those living nearby? (Question B20)			
		Answered no to B18	Answered yes to B18
	Yes	1	4
	No	49	3

The results imply that the statement is a useful tool for mitigating existing health concerns.

Choice Experiment Responses

Table 71 shows that two thirds, or forty respondents, always chose option c (the *status quo*) and only 20 volunteered a payment. This is a relatively high amount for valuation studies.

The results also show that:

- The proportions remain the same when we just consider exposed individuals only
- The proportion of non-payers increases slightly when we considered annoyed individuals only. The proportion of respondents who always chose C and are annoyed is 27.5%, while the proportion who is annoyed and volunteered payment is 20%.

Table 71: Summary of Choice Experiment Responses

	Annoyance			**Exposure**		
	Annoyed	Not Annoyed	Total	Exposed	Not Exposed	Total
Always chose C	11	29	40	18	22	40
Did not always choose C	4	16	20	9	11	20

Total	15	45	60	27	33	60

Table 72 and

However, most of the protest voters are not annoyed by the site. The proportion of council tax benefit claimants who protest matches the proportion in the sample as a whole.

Table 73 investigate reasons for non-payment. The tables show that most of the reasons for non-payment can be classified as protest votes. Most of the protest voters do so because they resent the payment vehicle proposed, confirming earlier fears about this issue. In contrast, very few of the protest votes can be explained by any other part of the scenario description. Only one of the non-payers is not a protest voter. 65% of the overall sample are protest voters.

Table 72: Reasons for Not-Paying

Reasons given	Mentions	
Pay too much council tax*	33	32%
Not my responsibility*	25	24%
Can not afford payments	13	13%
Money spent better elsewhere	12	12%
Changes are not worth it	6	6%
Changes will not work*	6	6%
Money would not be used for this purpose*	5	5%
Not affected by issues	3	3%
Total	103	100%
Of which protest votes	69	67%

*Denoted as a protest vote

However, most of the protest voters are not annoyed by the site. The proportion of council tax benefit claimants who protest matches the proportion in the sample as a whole.

Table 73: Protest Voters

Number	39	65% of overall sample
of which annoyed	11	28% of protest voters
of which not annoyed	28	72% “
of which full c. tax claimants	9	23% “

of which partial c. tax claimants	0	0% "

Table **74** summarises the importance of each attribute and health in the choice experiment. This is calculated based on the reported importance provided by each respondent.

Table 74: Importance of Attributes in Responses

	Not at all	Slightly	Moderately	Very	Extremel y	At Least Moderately Important
Noise*	60%	20%	20%	5%	0%	25%
Odour*	45%	20%	25%	10%	5%	40%
Traffic*	45%	35%	15%	10%	0%	25%
V. Intrusion*	95%	5%	5%	0%	0%	5%
Price*	25%	30%	30%	20%	0%	50%
Health**	60%	35%	10%	0%	0%	10%

*Excluding Protest Voters

** Including Protest Voters

The key result of this table is that health was not a major concern in the choice experiment responses. This implies that welfare estimates would largely exclude health effects, thus meeting one of the key objectives of this research.

Summary

1. The sample is representative of the level of deprivation in the area.
2. Exposure to amenity loss is contained within 600 metres for noise, odour and traffic and 1200 metres for visual intrusion. Reported annoyance follows the same pattern. Distance decay functions tend to be always decreasing in shape.
3. Reported annoyance tends to originate from a core of concerned respondents. Only 25% of the whole sample reported annoyance of any kind.
4. The design of the survey is effective at reducing the role of health effects in the choice experiment answers.

5. There is a very high incidence of non-payment, virtually all of which is classified as protest behaviour. This is mainly due to the payment vehicle, though the effects are possibly compounded by the level of deprivation in the area. The useable sample is forecasted to be 87.5 respondents and 700 observations, or 108.5 respondents and 868 observations if the pilot survey sample can be retained.

Recommendations for main sample

1. The council tax payment vehicle is realistically the only one available and should be retained.
2. It may be possible to reduce non-payment by decreasing the payment profile, though only a low proportion of protest voters were motivated by cost. An advantage of maintaining the existing payment profile is that the results can be maintained for the full sample.
3. The sample area used in this pilot should be maintained for the main sample, though should be extended slightly in two directions to ensure that all households within 1250 metres are in the sample area, subject to topographical restrictions.

Appendix 4 : Variables coding

Variables used	Code	Coded
WHISTLE	WHISTLE	CONTINUOUS
SMELL	SMELL	CONTINUOUS
WASTE	WASTE	CONTINUOUS
HEIGHT	HEIGHT	CONTINUOUS
WTP	COST/WTP	CONTINUOUS
DISTANCE FROM CHIMNEY	DIST	CONTINUOUS
DISTANCE FROM CHIMNEY	DISBI	DUMMY 0 – if live further than 600 meters 1- if less than 600 meters from Lister Rd.
No. of FLOORS	FLOORS	
GENDER	gender	Dummy variable 0- Male 1- Female
Age	Age	Categories 1) 18-24 2) 25-34 3) 35-44 4) 45-54 5) 55-64 6) 65+
Tenure (A1)	A1	Continuous
HOUSEHOLD SIZE	HHSIZE	Continuous Sum of all individuals
CHILDREN	Child	Dummy 0 – no, don't have children 1- yes, do have children
Married	Married	Categorical -Single -Married/living -Divorced/separated

		-widowed
Marital status	BINE4	Dummy 0 – Single/ Divorced/separated/widowed 1- Married/living
OCCUPATION	Occu	Categorical 1) Self employed 2) full time 3) part-time 4) student 5) unemployed 6) looks after home 7) retired 8) sick/disabled
UNEMPL	Unemployed	Dummy 0 – all else 1 – unemployed, unable to work, other
EDUCATION		Categorical 1) None 2) basic gcse's 3) more gcses 4) a-levels 5) degree
Level of education	furtheredu	Dummy 0 – none, up to 4 GCSEs, 5 GCSEs 1 – A-Levels, Degree
No education	Noqual	Dummy 0 – all else 1 – no formal qualifications
INCOME	INCOME	Continuous 1) 0-5000 2) 5000-10000 3) 10000-15000 4) 15000-20000

		5) 20000-30000 6) 30000-40000 7) 40000-60000 8) 60000-100000
COUNCIL TAX 1) full 2) partial 3) none	Countax	Categorical 1) full 2) partial 3) none
COUNTAX BINARY	COUNTAXBI	DUMMY 0 – FULL/PARTIAL 1 – NONE
DOUBGLAZING 1) yes 2) no 3) partial	DOUBGLAZ	CATEGORICAL 1) yes 2) no 3) partial
DOUBLEGLAZING BINARY	BINGLAZING	DUMMY 0 – NO 1 - YES
WHISTLE BOTHERED	WHISBOTH	CATEGORICAL 1 – NOT 2 – SLIGHT 3 – MODERATELY 4 – VERY 5 – EXTREMELY
Annoyed by whistle	B1bi	Dummy 0 – not and slight 1 – moderately, very, extremely
WHISTLE FREQUENCY	WF	CATEGORICAL 1 – MORE THAN 20 TIMES 2 – 16-20 TIMES 3 – 12-15 TIMES 4 – 8-11 TIMES 5 – 4-7 TIMES 6 – 1-3 TIMES 7 – NEVER

Exposed to whistle	B3bi	Dummy 0 – never, NA 1 – 1-more than 20 times
SMELL BOTHERED	SMELBOTH	CATEGORICAL 1 – NOT 2 – SLIGHT 3 – MODERATELY 4 – VERY 5 – EXTREMELY
Annoyed by smell	B5bi	Dummy 0 – not and slight 1 – moderately, very, extremely
SMELL FREQUENCY		CATEGORICAL 1 – 6-7 DAYS WEEK 2 – 4-5 DAYS WEEK 3 – 1-3 DAYS WEEK 4 – 3 TIMES MONTH 5 – LESS THAN ONCE MONTH 6 – NEVER
Exposed to smell	b7bi	Dummy 0 – never, NA 1 – less than once a month– 6-7 days a week
CHIMNEY BOTHERED	CHIMBOTH	CATEGORICAL 1 – NOT 2 – SLIGHT 3 – MODERATELY 4 – VERY 5 – EXTREMELY
Annoyed by chimney	B10BI	Dummy 0 – not and slight 1 – moderately, very, extremely
Is it possible to see the chimney from your home B12	B12	Dummy 0 – no 1- yes

TRAFFIC BOTHERED	TRAFBOTH	CATEGORICAL 1 – NOT 2 – SLIGHT 3 – MODERATELY 4 – VERY 5 – EXTREMELY
TRAFFIC PASSES	TRAFPASS	CATEGORICAL 1 – NONE 2 3 – A BIT 4 5 – A LOT
Annoyed by traffic	B14BI	Dummy 0 – not and slight 1 – moderately, very, extremely
This area is industrial	A7ABI	Dummy 0 – strongly disagree, disagree, neither disagree nor agree 1- agree, strongly agree

Appendix 5: Survey instrument

DJS Research Ltd, The Old Chapel, Rainow, Macclesfield, SK10 5XF
Tel: 01625-573573

I declare that this interview was carried out according to instructions, within the MRS Code of Conduct and that the respondent was not previously known to me.

Name:………………………………… Signature…………………………………..

Date:………………………………… Actual Interview Duration:……..minutes

University of Bath Quality Of Life Research: Pilot Questionnaire

CLASSIFICATION QUESTIONS

Name (Mr/Mrs/Miss/Ms): ....

Address: ....

Postcode: ....

Telephone Number (inc STD Code)..

Number of floors in property:..

Flats only

Floor number ....

Number of floors in block:..

GENDER	*(RECRUIT A MIX)*	*TYPE OF STREET/ROAD*		*DOUBLE*	*GLAZING*
Male	☐ 1	Cul-de-sac	☐ 1	Yes	☐ 1
Female	☐ 2	Main Road	☐ 2	No	☐ 2
		Other	☐ 3	Partial	☐ 3

AGE	**(RECRUIT A MIX)**	**TYPE OF PROPERTY**	
18-24	☐ 1	Flat	☐ 1
25-34	☐ 2	Detached	☐ 2
35-44	☐ 3	Semi-detached	☐ 3
45-54	☐ 4	Terraced	☐ 4
55-64	☐ 5	Other	☐ 5
65+	☐ 6		

INTERVIEWER: SHOW ID CARD

Good morning/afternoon My name is ....from DJS Research Ltd, an independent research company and I am doing a survey on behalf of the University of Bath on your opinions about how to improve the environment in your neighbourhood. Can you spare 15-20 minutes to help me?

"May I assure you that everything you say will remain completely confidential and this interview shall be conducted in accordance to the MRS (Market Research Society) Code of Conduct. The questionnaires will be passed back to the University of Bath for processing and analysis"

SECTION A

Thank you. This survey will focus on your opinions of your neighbourhood. By neighbourhood, I mean the street you live on and the surrounding roads and parks.

A1 How long have you lived in this property?

Years: ____________

Months:___________

A2 Have you lived anywhere else in this area before?

Yes ☐1 **GOTO A3**

No ☐2 **GOTO A4**

A3 Which street(s) and town(s) have you lived in previously, and how many years did you live at each one?

(A) ____________________________________ Number of years:__________

(B) ____________________________________ Number of years:__________

A4 How often do you leave your neighbourhood, for example to go to work or for recreational purposes? By neighbourhood, I mean the street you live on and the surrounding roads and parks. Please choose from the following list.

SHOWCARD A

6-7 days a week ☐1

4-5 days a week	☐ 2
1-3 days a week	☐ 3
Up to 3 times a month	☐ 4
Less than once a month	☐ 5
Never	☐ 6
NA	☐ 7

A5 I would like to ask about some other potential features of your neighbourhood. I will read to you a list of possible issues. On a scale of 1 to 5, please tell me how much these are a problem to you, where 1 is not a problem and 5 is a major problem.

	Scale (1-5)	
(A) Odours or smells		NA
(B) Noise at night		NA
(C) Noise in the daytime		NA
(D) Traffic from heavy vehicles		NA
(E) Traffic from cars and smaller vehicles		NA
(F) Anti Social Behaviour		NA
(G) Litter		NA
(H) Vermin/pests, e.g. pigeons		NA
(I) Dog Mess on the pavement		NA
(J) Potholes in the roads		NA
(K) Other:__________________		NA

A6 I will now ask a couple of questions about traffic in your neighbourhood. By neighbourhood, I mean the street you live on and the surrounding roads and parks. I will read out some types of vehicle. On a scale of 1 to 5, please indicate how much traffic you think there is from each one, where 1 is 'very little traffic' and 5 is 'a lot of traffic'.

Cars	1	2	3	4	5	NA
Heavy Vehicles	1	2	3	4	5	NA
Vans	1	2	3	4	5	NA

A7 We would like to record your opinions on some other things about Dudley. Please indicate how much you agree with the following statements: Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree.

SHOW CARD B

ROTATE STARTING POINT: __________________

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	
(a) This area is industrial	1	2	3	4	5	NA
(b) The area is well-maintained	1	2	3	4	5	NA

(c)	This area is polluted	1	2	3	4	5	NA
(d)	The views in this area are attractive	1	2	3	4	5	NA
(e)	There is a lot of greenery in this area	1	2	3	4	5	NA
(f)	This area is run-down	1	2	3	4	5	NA
(g)	This area is a nice place to live	1	2	3	4	5	NA

SECTION B

I am now going to ask about some specific problems that have been reported in this area.

Some people have reported hearing a whistling noise in this area caused by local industrial activity. It reportedly sounds like a screeching sound or like a loud kettle going off, and can be extremely loud in some cases. This can happen at any time of day or night.

B1 Thinking about the last 12 months or so, when you are here at home, how much does a whistling noise like the one described bother, disturb or annoy you: Not at all, Slightly, Moderately, Very, Extremely?

SHOWCARD C

NOT	SLIGHT	MOD	VERY	EXT	NA

B2 We will now ask the same question, this though this time we would like you to responds on a scale from zero to ten. If you are not at all annoyed choose zero, if you are extremely annoyed choose ten, if you are somewhere in between, choose a number between one and ten.

SHOWCARD D

What number from zero to ten best shows how much you are bothered, disturbed or annoyed by a noise like this?

0	1	2	3	4	5	6	7	8	9	10	NA

B3 Thinking back over the past 12 months, how many times have you heard a whistling noise like the one described whilst here in your home? Please choose from the following list:

SHOW CARD E

More than 20 times	☐ 1	**GO TO B4**
16-20 times	☐ 2	
12-15 times	☐ 3	
8-11 times	☐ 4	
4-7 times	☐ 5	
1-3 times	☐ 6	
Never	☐ 7	**GO TO B5**
NA	☐ 8	**GO TO B5**

B4 Can you tell me where you think this noise comes from?

RESPONSE:____

Some people have reported noticing a strong odour in this area that smells similar to something rotting, perhaps food or compost, especially when the weather is warm.

B5 Thinking about the last 12 months or so, when you are here at home, how much does a smell like the one described bother, disturb or annoy you: Not at all, Slightly, Moderately, Very, Extremely?

SHOWCARD C

NOT	SLIGHT	MOD	VERY	EXT	NA

B6 Next is a zero-to-ten opinion scale for how much a smell like the one described bothers, disturbs or annoys you when you are here at home. If you are not at all annoyed choose zero, if you are extremely annoyed choose ten, if you are somewhere in between, choose a number between one and ten.

SHOWCARD D

What number from zero to ten best shows how much you are bothered, disturbed or annoyed by a smell like this?

0	1	2	3	4	5	6	7	8	9	10	NA

B7 Thinking about the last 12 months, how frequently have you noticed an odour like this whilst here in your home? Please choose from the following list:

SHOWCARD F

6-7 days a week	☐ 1	**GO TO B8** (1–4)
4-5 days a week	☐ 2	
1-3 days a week	☐ 3	
Up to 3 times a month	☐ 4	
Less than once a month	☐ 5	
Never	☐ 6	**GO TO B9**
NA	☐ 7	**GO TO B9**

B8 Can you tell me where you think this odour comes from?

RESPONSE:____

SHOW CARD G

B9 Here are some pictures of an industrial facility located in this area. They are all pictures of the same building, just taken from different angles and distances. Have you seen the building and chimney in these pictures before?

Yes	☐1
No	☐2
NA	☐3

B10 We would like to ask you about effects of the incinerator on the landscape and views in this area. Thinking about the last 12 months or so, how much has the presence of this chimney, out of your windows or on the horizon, bothered, disturbed or annoyed you: Not at all, Slightly, Moderately, Very, Extremely?

SHOWCARD C

NOT	SLIGHT	MOD	VERY	EXT	NA

B11 Next is a zero-to-ten opinion scale for how much the view of the chimney bothers disturbs or annoys you. If you are not at all annoyed choose zero, if you are extremely annoyed choose ten, if you are somewhere in between, choose a number between one and ten.

SHOWCARD D

What number from zero to ten best shows how much you are bothered, disturbed or annoyed by the view of this chimney?

0	1	2	3	4	5	6	7	8	9	10	NA

B12 Is it possible to see the chimney from your home? At home means inside your home or outdoors at home, for example in the garden or on a balcony.

Yes	☐1
No	☐2

B13 Do you now what this building is used for?

RESPONSE:____
____
____
____

The chimney is part of the waste incinerator at the Lister Road depot in Dudley. All household and business waste collected in Dudley is taken there to be burnt. Numerous other activities carried out by the council are also based at this site. Approximately 120 lorries and trucks carrying waste material go in and out of the site each day.

B14 Thinking about the last 12 months or so, and not including times when your rubbish is collected from outside your home, how much does traffic caused by the Lister Road site bother, disturb or annoy you: Not at all, Slightly, Moderately, Very, Extremely?

SHOWCARD C

NOT	SLIGHT	MOD	VERY	EXT	NA

B15 Next is a zero-to-ten opinion scale for how much traffic from the Lister Road site bothers, disturbs or annoys you. If you are not at all annoyed choose zero, if you are extremely annoyed choose ten, if you are somewhere in between, choose a number between one and ten.

What number from zero to ten best shows how much you are bothered, disturbed or annoyed you are by traffic from the Lister Road site?

SHOWCARD D

0	1	2	3	4	5	6	7	8	9	10	NA

B16 How much of this traffic do you think passes close to your home: Please answer on a scale of 0 to 5, where 0 is none and 5 is a lot.

0	1	2	3	4	5	NA

B17 As I have described, all the rubbish created by homes and businesses in the Dudley area is collected and brought to the Lister Road Site.

Are you concerned that the Lister Road site affects the health of those living nearby?

Yes	☐ 1	**GO TO B18**
No	☐ 2	**GO TO B19**
NA	☐ 3	**GO TO B19**

B18 In what way do you think it affects health?

RESPONSE:____

B19 **ALL RESPONDENTS ARE TO BE READ THE FOLLOWING TEXT**

The incinerator located on Lister Road is a modern facility and meets strict conditions imposed by the regulator. For example:

- *The waste is burned at a very high temperature to make sure the air released is as clean as possible. In fact, events such as firework displays and bonfires cause much more pollution in a single year than the incinerator.*
- *What sometimes looks like smoke coming from the top of the chimney is mostly water vapour. This turns into condensation when the air around the top of the chimney is cold, in the same way as your breath does on wintry days. There is no soot because it is collected using filters to prevent it being released into the air.*
- *Detailed reviews of scientific studies show no link between incinerators and the health of people living nearby.*

B20 Given this information, do you think that the Lister Road site affects the health of those living nearby?

Yes	☐	1
No	☐	2
NA	☐	3

SECTION C

The operators of the Lister Road Depot are considering making changes to Lister Road Depot. We would like to find out which changes you think would improve the local area most.

SHOW PROPOSAL V1

ASK RESPONDENT IF THEY UNDERSTAND AND GO THROUGH ANYTHING THAT IS UNCLEAR

I would now like to assess your preferences for different potential changes to the Lister Road Depot. I will show you eight cards of this type and ask you to select one of the options.

ROTATE STARTING POINT: ____________________

SET USED: ____________

PRESENT STARTING CHOICE CARD

Please tell me which option you would choose.

CIRCLE ANSWER IN TABLE AND REPEAT FOR REMAINING CARDS

C1

CARD 1	**A**	**B**	**C**
CARD 2	**A**	**B**	**C**
CARD 3	**A**	**B**	**C**
CARD 4	**A**	**B**	**C**
CARD 5	**A**	**B**	**C**
CARD 6	**A**	**B**	**C**
CARD 7	**A**	**B**	**C**
CARD 8	**A**	**B**	**C**

SECTION D – DEBRIEFING QUESTIONS

IF RESPONDENT SELECTED OPTION C IN EVERY CHOICE CARD (QUESTION C1) ASK QUESTION D1. OTHERWISE GO TO D2

D1 I notice that you always selected option C, 'no change', on the choice cards. Why was this? **OPEN QUESTION/MULTICODE ANSWERS**

Not my responsibility to pay for these changes.	1
Could not afford any of the payments.	2
Pay too much in council tax.	3
Not affected by any of these issues.	4
Changes are not worth it.	5
Money could be better spent elsewhere.	6
Money may/would not be used for this purpose	7
Changes will not work	8
Other (please specify):	9

D2 Thinking back over this task, how difficult did you find it: Not at all, Slightly, Moderately, Very, Extremely?

SHOW CARD C

NOT	SLIGHT	MOD	VERY	EXT	NA

D3 Thinking back over your responses to the choice cards, how important was each attribute in your decision: Not at all, Slightly, Moderately, Very, Extremely?

SHOW CARD C

ROTATE STARTING POINT: ___________________

		Not at All	Slightly	Moderately	Very	Extremely	NA
(A)	Whistling Noise	NOT	SLIGHT	MOD	VERY	EXT	NA
(B)	Smell from Green Waste	NOT	SLIGHT	MOD	VERY	EXT	NA
(C)	Waste Vehicle Journeys	NOT	SLIGHT	MOD	VERY	EXT	NA
(D)	Chimney Height	NOT	SLIGHT	MOD	VERY	EXT	NA
(E)	Cost of the option	NOT	SLIGHT	MOD	VERY	EXT	NA

D5 How important was health in your decisions, Not at all, Slightly, Moderately, Very, Extremely?

SHOW CARD C

NOT	SLIGHT	MOD	VERY	EXT	NA

D6 Within the last 12 months, have you ever made or considered making a formal complaint about any of the issues I have raised today?

Complained	☐ 1	**GOTO D7**
Considered	☐ 2	**GOTO D8**
No	☐ 3	**GO TO D9**

D7 What have you complained about, who have you complained to, and how many times have you complained?

Issue: ____________________

Recipient: ____________________

Number of times: ____________________

D8 What issue have you considered complaining about?

Issue:____

D9 Do you or does any member of your household currently work at the Lister Road Depot?

Yes ☐1

No ☐2

D10 Please indicate how much you agree with the following statements: Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree.

SHOW CARD B

ROTATE STARTING POINT: ___________________

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
(a) Incineration is needed to reduce landfill	1	2	3	4	5
(b) Incineration should be stopped as it reduces things like recycling	1	2	3	4	5
(c) I am concerned that the Lister Road depot is too close to my house	1	2	3	4	5
(d) I am concerned that the Lister Road depot is too close to residential areas.	1	2	3	4	5
(e) The health of someone in my household is affected by the incinerator	1	2	3	4	5
(f) The incinerator could cause the health of someone in my household to deteriorate in the future.	1	2	3	4	5
(g) I have considered moving because of the incinerator	1	2	3	4	5
(h) I am actively considering moving because of the incinerator	1	2	3	4	5
(i) The incinerator is a local landmark.	1	2	3	4	5

D11 How often do you talk to your neighbours?

SHOWCARD H

Most days	☐ 1
Weekly	☐ 2
Monthly	☐ 3
Few times a year	☐ 4
Never	☐ 5

`

SECTION E – BACKGROUND QUESTIONS

These last few questions are about your current circumstances

E1 How many children live in this property aged 12 and under? Number: ______

E2 How many people who live in this property are aged 13 to 18? Number:_____

E3 How many people over the age of 18 live in this property? Number:_____

E4 How would you describe your marital status? Please choose from the following list:

SHOWCARD I

Single	1
Married/civil partnership/living with someone	2
Divorced/separated	3
Widowed	4

E5 How would you describe your occupational status?

SHOWCARD J

Self-employed	1
Employed full-time	2
Employed part-time	3
Student	4
Unemployed	5
Looking after the home full-time	6
Retired	7
Unable to work due to sickness or disability	8
Other (please specify)	9

E6 What is the occupation of the chief income earner in your household?

Response: ____

E7 Does anybody else in your household work?

Yes ☐1

No ☐2

E8 What is the highest level of formal education you have reached? Please look at the following list and circle the option that applies to you.

SHOWCARD K

No formal qualification	1
Up to 4 GCSE's, CSE's, or O-Levels, NVQ level 1 Foundation level GNVQ	2
5 + GCSE's, CSE's, or O-Levels 1 A-Level/AS-Level NVQ level 2 Intermediate GNVQ	3
2+ A-Levels 4+ AS-Levels NVQ level 3 Advanced GNVQ	4
Degree Level (undergraduate/postgraduate) NVQ 4 or 5 HNC/HND Teacher, Doctor, Nurse, Midwife or other professional qualification	5

E9 Of all the values shown below, which best describes your post-tax **household** yearly income, including benefits, interest, pensions and all other sources? Please give you best guess, I will treat this answer confidentially, and please recall that all answers are anonymous.

SHOWCARD L

£0 - £5,000	1
£5,001 - £10,000	2
£10,000 - £15000	3
£15,000 – £20,000	4
£21,000 – £30,000	5
£31,000 – £40,000	6
£41,000 – £60,000	7
£61,000 – £100,000	8
Over £100,000	9
Refused	10
Unsure	11

E10 Does your household receive council tax benefit? If yes, is it full or partial?

Full ☐ 1

Partial ☐ 2

No ☐ 3

Refused ☐ 4

Don't know ☐ 5

Thank you very much for your time, your responses are very valuable to us.

THANK AND CLOSE

SAY TO ALL

Thank you for your help. Can I just remind you that this interview is part of a market research survey being carried out by DJS Research Ltd who adhere to the Market Research Society Code of Conduct. If you want to verify that we are a bona fide agency, I can give you the Freephone number of the Market Research Society to ring.

GIVE NUMBER IF REQUIRED (+44 (0) 500 396 999).

Please complete page overleaf

To be completed by the Interviewer

Do you think the respondent understood the choice exercise?

Yes ☐ 1

No ☐ 2

On a 1 to 5 scale, was the respondent annoyed by the interview? Where 5 is very annoyed and 1 is not at all annoyed.

Answer (Scale 1-5):________

In the event the respondent stopped the survey, does the interviewer think the respondent:

Did not understand the survey ☐ 1

Did not believe in the survey ☐ 2

Was annoyed by the survey ☐ 3

Was annoyed at the length of the survey ☐ 4

Did not like the contents of the choice cards ☐ 5

Other ☐ 6

____

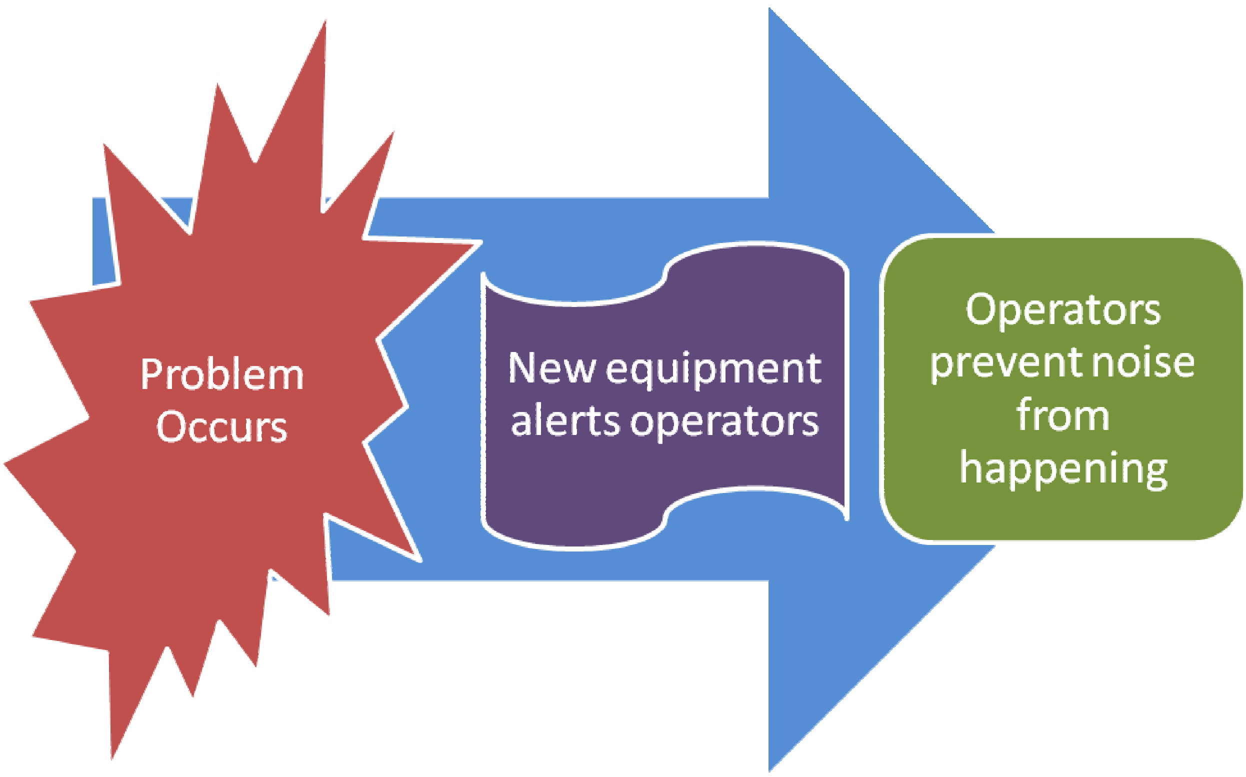
General comments from the interview:

____
____
____
____
____
____
____
____

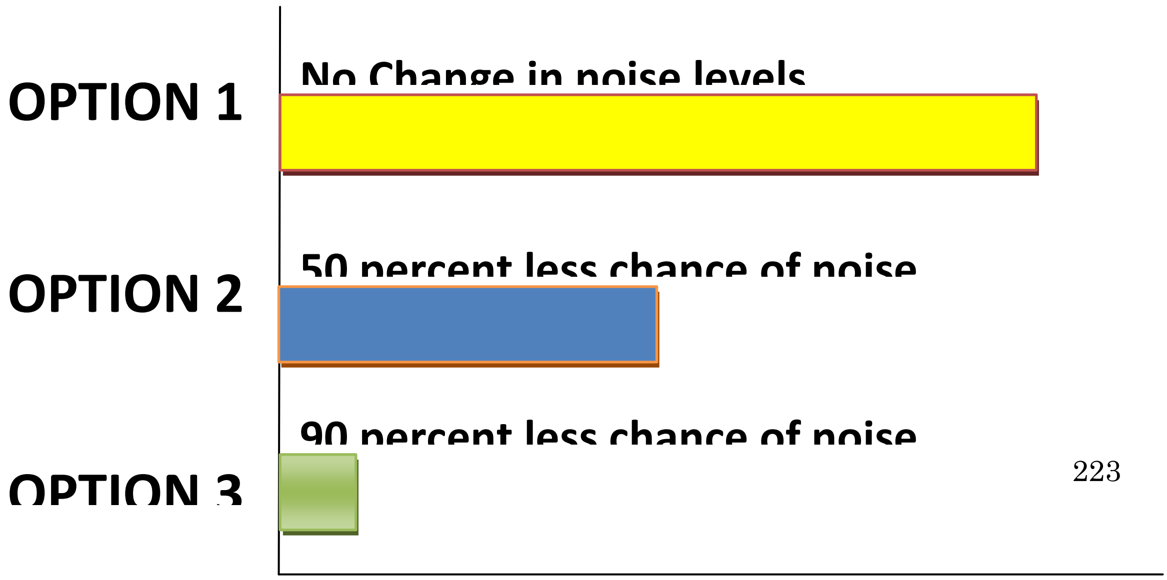
WHISTLING NOISE

- This happens when the incinerator stops working and the boilers inside the facility have to let off steam very quickly, creating a loud noise
- Some people describe this noise as similar to a kettle boiling very loudly.

SOLUTION: INSTALL NEW EQUIPMENT



- Different combinations of equipment are available
- Each would reduce the chances of the whistling noise occurring by a different amount.
- For example, one option could reduce the chances of hearing the noise by 50%. So, if you used to hear the noise 8 times a year, you would now expect hear it 4 times a year.
- These are the three options under consideration:



ROTTING SMELL

- Green Waste, which includes food waste and garden cuttings, is stored in an open area of the depot before it is picked up and taken elsewhere.
- Some people have reported a smell coming from this waste.
- Three options are available to reduce the number of days when the smell is noticeable.

SMELL: OPTION ONE

Do Nothing

You would experience the smell as normal

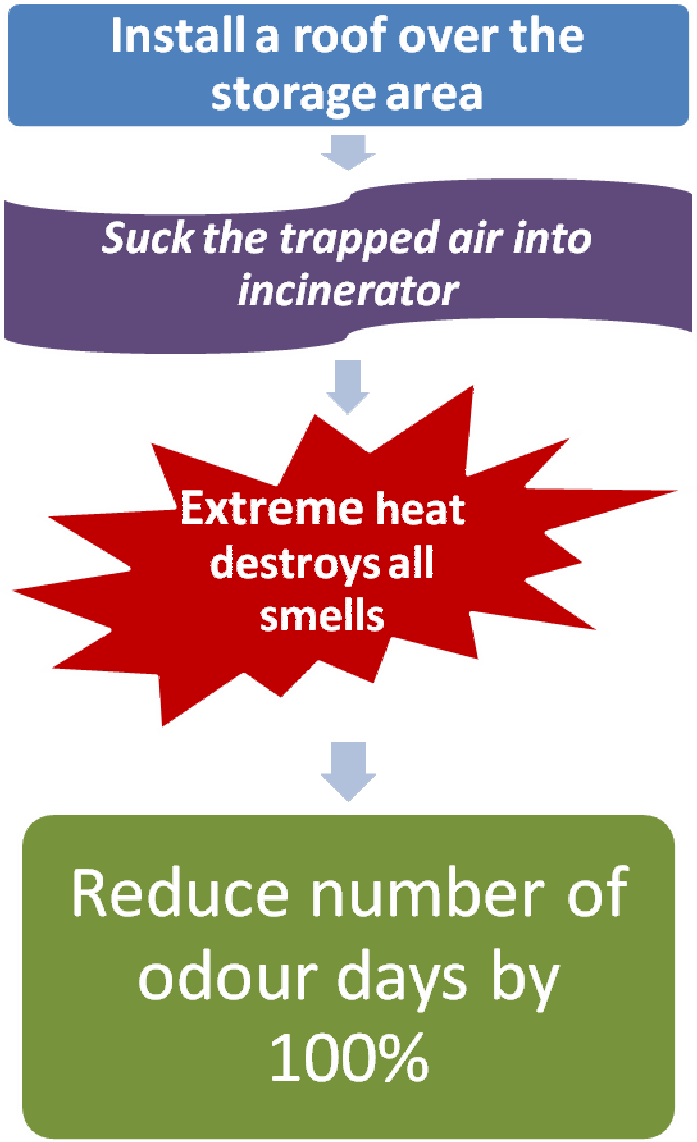
Reduce number of odour days by 50%

SMELL: OPTION TWO

Install a roof over the storage area

For example, if you normally smell it 30 days per year, you would now only smell it 15 days per year.

SMELL: OPTION THREE


Install a roof over the storage area
Suck the trapped air into incinerator
Extreme heat destroys all smells
Reduce number of odour days by 100%

HEIGHT OF THE CHIMNEY

The height of the chimney could be reduced

- To maintain air quality is kept the same, new equipment would also be installed to burn waste at a higher temperature.
- Air quality in nearby areas would be completely unaffected by this change.

Three possible chimney heights are available

EXISTING CHIMNEY HEIGHT

CHIMNEY HEIGHT REDUCED BY HALF

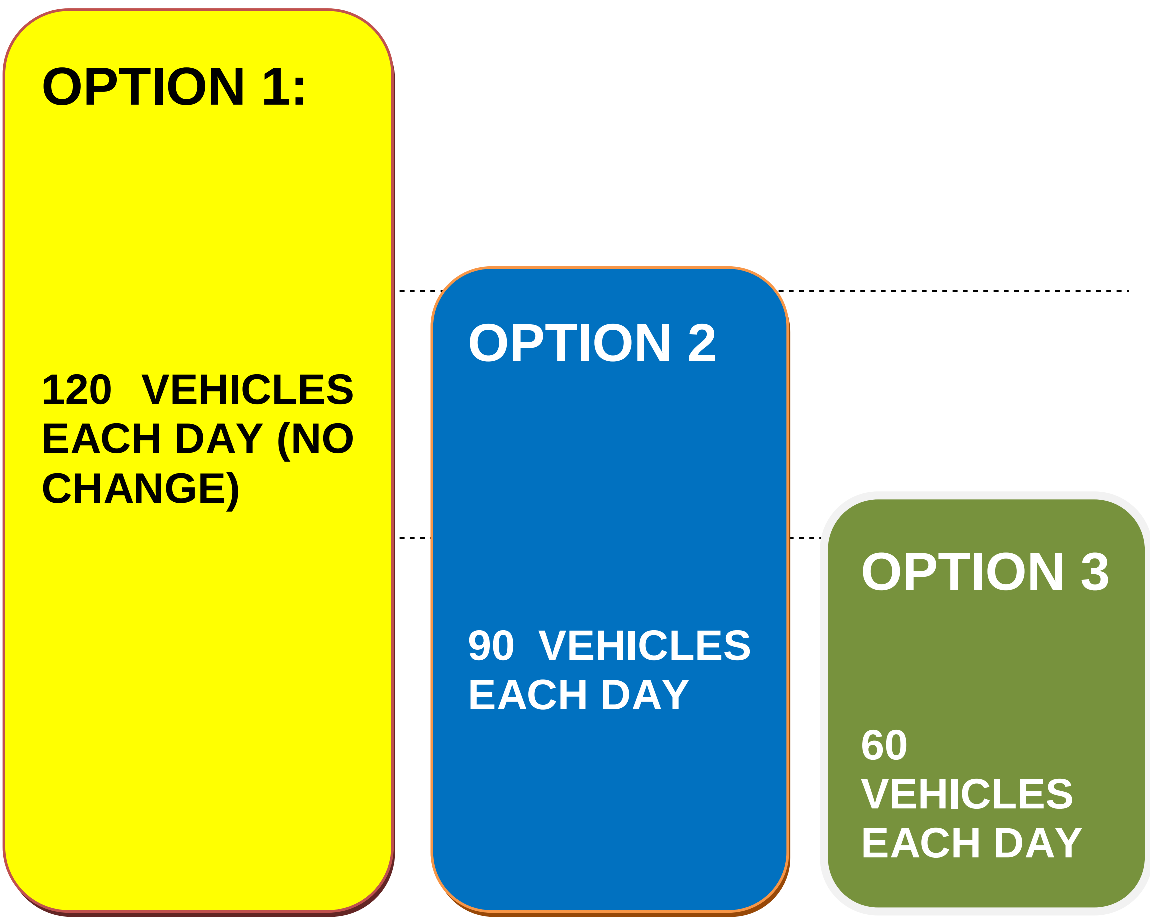
CHIMNEY HEIGHT REDUCED BY 90 PERCENT


NEW
ROAD
LAYOUT
AHEAD

HEAVY VEHICLE TRAFFIC

- Currently, up to 120 heavy vehicles go in and out of the Lister Road Depot each day.
- The number could be reduced by making sure more vehicles are full.

These vehicles approach the site from all directions, entering the site via Lister Road.



- These changes are expensive and come at a cost
- Some are more effective than others.
- We would like to find out which ones would have the most benefit to those currently affected.

These changes would be funded by **a compulsory one off payment**

- This would be made by all households in the Dudley area, not just those affected by these issues.
- It would be added to your normal council tax bill. This would be for one year only.
- The council have an agreement with the site operators to pay for any major changes, such as the ones described here.

- The money would go directly to the site operators and is guaranteed to be used for this purpose and not for anything else.

To help us understand which things are most important to you, I would like you to choose between different combinations of changes to the depot. This example shows you how I would like you to do this.

	CHOICE A	CHOICE B	CHOICE C
Whistling noise	90% less occurrences	50% less occurrences	No Change
Smell from Green Waste	50% less times	No Change	No Change
Waste vehicle journeys	90 Each Day	60 Each Day	No Change (120 Each Day)
Chimney height	90% Shorter	50% Shorter	No Change
Amount to be paid <u>once</u> by each household in Dudley	£12	£18	£0

Please select an option:		✓	

Appendix 7: Choice cards

	CHOICE A	CHOICE B	CHOICE C
Whistling noise	50% less occurrences	No Change	No Change
Smell from Green Waste	No Change	50% less Times	No Change
Waste vehicle journeys	60 each day	No Change (120 each day)	No Change (120 Each Day)
Chimney height	90% shorter	50% shorter	No Change
Amount to be paid once by each household in Dudley	£6	£18	£0
Please select an option:			

	CHOICE A	CHOICE B	CHOICE C
Whistling noise	No Change	90% less occurrences	No Change
Smell from Green Waste	100% less Times	No Change	No Change
Waste vehicle journeys	60 each day	No Change (120 Each Day)	No Change (120 Each Day)
Chimney height	No Change	90% shorter	No Change
Amount to be paid once by each household in Dudley	£18	£12	£0
Please select an option:			

	CHOICE A	CHOICE B	CHOICE C
Whistling noise	50% less occurrences	No Change	No Change
Smell from Green Waste	No Change	50% less Times	No Change
Waste vehicle journeys	No Change (120 each day)	90 each day	No Change (120 Each Day)
Chimney height	50% shorter	No Change	No Change
Amount to be paid once by each household in Dudley	£12	£6	£0
Please select an option:			

	CHOICE A	CHOICE B	CHOICE C
Whistling noise	50% less occurrences	No Change	No Change
Smell from Green Waste	No Change	50% less Times	No Change
Waste vehicle journeys	No Change (120 Each Day)	90 each day	No Change (120 Each Day)
Chimney height	No Change	90% shorter	No Change
Amount to be paid <u>once</u> by each household in Dudley	£18	£12	£0
Please select an option:			

	CHOICE A	CHOICE B	CHOICE C
Whistling noise	No Change	90% less occurrences	No Change
Smell from Green Waste	50% less Times	100% less	No Change
Waste vehicle journeys	60 each day	No Change (120 each day)	No Change (120 Each Day)
Chimney height	No Change	90% shorter	No Change
Amount to be paid once by each household in Dudley	£18	£12	£0
Please select an option:			

	CHOICE A	CHOICE B	CHOICE C
Whistling noise	No Change	90% less occurrences	No Change
Smell from Green Waste	100% less Times	No Change	No Change
Waste vehicle journeys	No Change (120 Each Day)	90 each day	No Change (120 Each Day)
Chimney height	50% shorter	No Change	No Change
Amount to be paid once by each household in Dudley	£6	£18	£0
Please select an option:			

	CHOICE A	CHOICE B	CHOICE C
Whistling noise	No Change	90% less occurrences	No Change
Smell from Green Waste	100% less Times	No Change	No Change
Waste vehicle journeys	60 each day	No Change (120 each day)	No Change (120 Each Day)
Chimney height	No Change	90% shorter	No Change
Amount to be paid <u>once</u> by each household in Dudley	£12	£6	£0
Please select an option:			

	CHOICE A	CHOICE B	CHOICE C
Whistling noise	No Change	90% less occurrences	No Change
Smell from Green Waste	No Change	50% less Times	No Change
Waste vehicle journeys	90 each day	60 each day	No Change (120 Each Day)
Chimney height	90% shorter	50% shorter	No Change
Amount to be paid once by each household in Dudley	£12	£6	£0
Please select an option:			

	CHOICE A	CHOICE B	CHOICE C
Whistling noise	90% less occurrences	50% less occurrences	No Change
Smell from Green Waste	No Change	50% less Times	No Change
Waste vehicle journeys	No Change (120 each day)	90 each day	No Change (120 Each Day)
Chimney height	No Change	90% shorter	No Change
Amount to be paid once by each household in Dudley	£12	£6	£0
Please select an option:			

	CHOICE A	CHOICE B	CHOICE C
Whistling noise	90% less occurrences	50% less occurrences	No Change
Smell from Green Waste	100% less Times	No Change	No Change
Waste vehicle journeys	No Change (120 each day)	90 each day	No Change (120 Each Day)
Chimney height	90% shorter	50% shorter	No Change
Amount to be paid <u>once</u> by each household in Dudley	£18	£12	£0
Please select an option:			

	CHOICE A	CHOICE B	CHOICE C
Whistling noise	50% less occurrences	No Change	No Change
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Chimney height	No Change	90% shorter	No Change
Amount to be paid once by each household in Dudley	£6	£18	£0
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Smell from Green Waste	50% less Times	100% less Times	No Change
Waste vehicle journeys	No Change (120 each day)	90 each day	No Change (120 Each Day)
Chimney height	90% shorter	50% shorter	No Change
Amount to be paid once by each household in Dudley	£12	£6	£0
Please select an option:			

Annex II: Contributors to the report

This report is the result of discussions between all partners in the EXIOPOL consortium. It has been edited by Miroslav Havranek (CUEC). The different chapters were written by the following persons:

Chapter 1-4:	Assaad Zoughaib (ARMINE), Ari Rabl (ARMINE)
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Chapter 6:	Xingshu Zhao (CASS), Timothy Taylor (UBATH)
Chapter 7 :	Steve Liston (UBATH), Timothy Taylor (UBATH), Harry Walton (UBATH)