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Monetising the impacts of waste incinerators sited on brownfield land using the hedonic pricing method

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ABSTRACT

In England and Wales planning regulations require local governments to treat waste near its source. This policy principle alongside regional self-sufficiency and the logistical advantages of minimising distances for waste treatment mean that waste incinerators have been built close to, or even within urban conurbations. There is a clear policy need to balance the benefits of EfW against the negative externalities experienced by local residents in a European context. This study uses the Hedonic Pricing Method to estimate the monetary value of impacts associated with three incinerators. Once operational, the impact of the incinerators on local house prices ranged from approximately 0.4% to 1.3% of the mean house price for the respective areas. Each of the incinerators studied had been sited on previously industrialised land to minimise overall impact. To an extent this was achieved and results support the effectiveness of spatial planning strategies to reduce the impact on residents. However, negative impacts occurred in areas further afield from the incinerator, suggesting that more can be done to minimise the impacts of incinerators.

Keywords: hedonic pricing method; incinerator; willingness to pay; negative externalities

1. Introduction

The waste hierarchy is the rationale that underpins most European waste legislation, such as the European Waste Framework Directive 2008/98/EC (EU, 2008). The hierarchy is based on the principle that prevention of waste is the most desirable form of waste management and disposal of waste in landfill without energy recovery is the least. There are a range of other management options between these polar opposites, such as incineration with energy recovery, also known as Energy from Waste (EfW). When waste avoidance and recycling opportunities are unfeasible EfW is the next best alternative.

In England and Wales compliance with European legislation has driven significant investment in waste management facilities that offer alternatives to landfill (Defra, 2014). In addition to the 30 incinerators currently operating in England and Wales (Defra, 2013), over 100 new incinerators are in the proposal or planning stage (UKWIN, 2015). Two major guiding principles of waste management strategy in England and Wales are that facilities should be located such that: waste is managed or treated as close as possible to its source; and that the environmental or social impacts of a waste management facility should be minimised (DCLG, 2015). These two principles have the potential to conflict, given that those who create waste are those that must be protected from the impacts of waste management.

This conflict has given rise to notable public protests where incinerators have been proposed near residential areas (BBC, 2015; BBC, 2013; BBC, 2012). This opposition arises partly because of the nuisances and risks associated with waste incineration (COWI, 2000; Eshet *et al*., 2005; Rabl *et al*., 2008; Defra, 2013). Incinerators share many of the same negative externalities as landfills including noise, unpleasant odour, windblown litter, dust, vermin, presence of seagulls, flies, traffic, visual intrusion and enhanced perception of health risks among local residents (Havranek *et al*., 2009). Thus, while the decision to site an incinerator requires a technical and spatial assessment it also remains a highly sensitive issue for local residents.

Considering where to site EfW incinerators requires an analysis of all costs and benefits associated with waste incineration. While the benefits of incineration are largely tangible, such as the monetary value of electricity generated and number of jobs created, many of the disamenities are not. To date, the literature has typically used the Hedonic Pricing Method (HPM) to monetise the negative externalities of waste management. The HPM uses housing market data to estimate the price individuals are willing to pay for a non-marketed quality (Lancaster *et al*., 1996), such as distance from a waste management site.

Most studies that investigate the impact of incinerators on house prices have focused on US sites. These results are unsuitable for use in a European policy context (Havranek *et al*. 2009) because of differences in environmental policy and property markets. This leaves an important research gap. There is a clear policy need to balance the benefits of EfW against the negative externalities experienced by local residents in a European context. Such analysis helps policy makers identify instances where EfW offers clear gains in net present value and others where EfW is unsuitable and alternative waste management options should be considered.

To meet this research need, this paper uses the HPM to quantify the impact of three EfW incinerators in England. In particular, the study focuses on the effect that these waste management sites have on property prices at three development stages: planning, construction and operational. The analysis processes over 55,000 transactions over a 20 year period. To the authors' knowledge this is the first European study on incinerator negative externalities that adopts a HPM approach using such a large volume of data. Although this study focuses on sites in England, the results have relevance to other countries with duties to comply with EU Waste Regulations. This study also has international relevance, offering another comparison measurement of the cost of the negative externalities of incinerators, as well as an analysis of whether spatial planning provides a useful option for waste management.

2. The impacts of EfW incinerators on house prices

Compared with research estimating the negative externalities landfill sites, the negative externalities of waste incineration have received less attention. The results of many existing studies that monetise the negative externalities of incineration, such as Kiel and McClain (1995a and 1995b) are based on outdated incinerator technology and hence resulting emissions have outdated incinerator technology and hence resulting emissions have improved significantly over the intervening period (HPA, 2009). Several other studies (Kohlhase, 1991; Deaton and Hoehnb, 2004; Kiel and Williams, 2007) focus on hazardous waste sites, which, owing to the intrinsic toxic characteristics of the waste are expected to generate stronger negative impacts on local properties relative to municipal and/or industrial waste processing sites. This study focuses entirely on municipal waste sites, which are more common, and as such the impact of the disposal of toxic waste is outside the scope of this paper.

All European empirical studies that investigate the cost of externalities associated with proximity to incinerators focus on UK sites. Pragnell (2003) used the HPM to assess the monetary impact of proximity to 10 UK EfW incinerators. Their results show that incinerators had a negative effect on house prices up to 1.6km from the incinerator. Between 0.4km and 1.6km the impact on house prices declined with increasing distance from the incinerator, eventually reaching zero at 1.7km. The results from Pragnell (2003) must be treated with caution. Firstly, the study only considers housing transactions in the fourth quarter of 2002. This is opposed to Kiel and McClain (1995a and 1995b), who use a continuous time series. Furthermore, the study assumes neighbourhood characteristics are homogeneous across different sites. Thus, the research excludes other factors, such as quality of schools or crime rates, which could affect house prices. Finally, the study uses data from the UK Land Registry transaction dataset. This dataset excludes some critical housing characteristics, such as, number of bedrooms and bathrooms, property and garden size, access to parking and garage, which can explain approximately 60% of price variance (Cambridge Econometrics, 2003).

Havranek *et al*. (2009) focused on an EfW incinerator in Dudley, England. The study used a choice experiment to estimate the impacts of noise, odour, visual intrusion and traffic. The study found that participants had a low Willingness to Pay (WTP) to reduce the impact of the incinerator's disamenities. However, the authors argue that the very small size of the incinerator, the highly industrialised area in which it is sited and the fact that the facility has existed for over 70 years are all factors that might have significantly affected the results of the research. For all these reasons Havranek *et al*. (2009) concludes that the study offers limited inferences for other UK incinerators.

Phillips *et al*. (2014) provides the most recent research on the impact of UK EfW incinerators on property prices. They investigated three existing facilities that began operations between 2000 and 2004, organising data into five 1km radius bands from the centre of each site. The analysis adopted an approach similar to the repeat sales method (OECD, 2013), only considering houses that sold twice during the period: once before the facility was operational and once after. The results show that houses around two of three incinerators (Kirklees and Chineham plants) experienced an increase in price after the facility became operative. Property values within 1.2 km from Marchwood incinerator, the largest and most visually intrusive of the facilities examined by the study, were found to be lower after the facility became operative. However, none of these results were statistically significant (α=0.05). Thus, all three incinerators were found to have no effect on local house prices.

Again, these results must be treated with caution. The repeat sales approach has some limitations. Houses that sell twice during a given period could have some intrinsic characteristics that differentiate them from houses that were only sold once (for instance, for refurbishment), leading to a sample selection bias. Secondly, this technique significantly decreases the number of available observations, thus reducing the robustness of the analysis. The study researched house prices differentials associated with the proximity to an incinerator in the operative phases of the facility, and should not be interpreted as the overall impact of the facility on the local household prices. As demonstrated by Kiel and McClain (1995a), the construction stage, which usually last several years, has a significant impact on property values. Finally, each of the three EfW plants chosen for the study was on the sites of previous incinerators. Although each of these decommissioned facilities had been offline before the planning and construction of the new plant took place, a significant habituation effect (Havranek *et al*., 2009) might have affected the transaction prices and could explain why the study was unable to detect any impacts. Fourthly, as already noted, this study did not control for changes in neighbourhood characteristics and used the Land Registry dataset, which does not include several housing characteristics.

3. Methods

3.1. Site selection

Site selection involved the identification of a range of incinerator plants that were representative of overall waste treatment activity in the UK and had suitable characteristics for the implementation of the HPM. Incinerator plants managing municipal solid waste were identified from an initial set of 134 facilities in England and Wales. Facilities located further than 0.8km from urban areas were excluded from the analysis as negative externalities are expected only to be observed in close proximity to the source (Kiel and McClain, 1995a; Cambridge Econometrics, 2003). Incinerators that burn waste from their own in-house processes were also excluded. The remaining facilities were screened to exclude all sites with insufficient number of housing transactions over the observed period (Havranek *et al*., 2009; Defra, 2013). Following this filtering process, three incinerator facilities (Table 1 and Figure 1) were selected for analysis.

3.2. Data

House price data were obtained from mortgage records between 1983 and 2014 held by Lloyds Banking Group. The database holds records describing the transaction price and property characteristics for over 6 million transactions. These were matched to annual ACORN (A Classification Of Residential Neighbourhoods) geo-demographic segmentation records of the UK population (CACI, 2006). To ensure the negative externalities of the incinerator were quantified accurately, only houses within an 8km radius from the plant were included in line with Kiel and Mclain (1995a) and Cambridge Econometrics (2003). House selection was plotted within a Geographical Information System (GIS) environment (ArcGIS version 9.3; ESRI Inc.).

Selected transactions were divided into incinerator planning, construction and operational phases (Table 1) to assess the negative externalities within each of these phases.

3.3. Analytical framework

HPM models generally focus on five main house descriptors as defined by Malpezzi (2003): (i) geographical location; (ii) neighbourhood characteristics; (iii) property structural characteristics; (iv) contract arrangements and additional conditions affecting price; and (v) the date of the transaction.

The basic statistical approach to HPM is a simple linear regression model (Eq. 1).

$$P = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon \qquad \text{Eq. 1}$$

where ***P*** is the dependent variable price (i.e. house price), $\boldsymbol{X_i}$ are a set of independent variables describing the price (e.g. house and incinerator characteristic), ***n*** is the total number of model parameters, ***β*** are the regression coefficients and ε is the error term.

More complex but common functional forms for hedonic regression are nonlinear models such as semi-log and log-log. Here, we used a log-linear based HP model as described by Eq. 2.

$$Log(P) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon \qquad \text{Eq. 2}$$

The functional form was selected after comparing the objective functions of linear, log-linear, Box-Cox and quadratic models. For each site, models were independently fitted for the overall data set as well as for each of the construction phases beforehand mentioned. Within each phase, four regression models were fitted to test the negative externalities between 0-2km, 2-4km, 4-6km and 6-8km from the incinerator. All models were fitted using Ordinary Least Squares. To ease comparison between sites and ensure analytical consistency, all models were fitted with the same initial list of independent variables (Table 2). The validity of the model assumptions (i.e. multicolinearity, residual normality and homocedasticity) as well as presence of specification errors was checked via residual analysis.

The monetary impact (***I***) of incinerators on house prices per 100m distance from incinerator was quantified as follows:

$$I = \bar{P}_{2013} * \beta_d * 100 \qquad \text{Eq. 3}$$

where $\bar{P}_{2013}$ is the mean house price (2013 constant prices) calculated using the UK historic Consumer Price Index (CPI) data (ONS, 2014) and β_{d} is the regression coefficient for variable "distance to EfW" (D_EfW in Table 2).

3.4. Results

3.4.1 Newhaven

Newhaven is the model with the smallest sample of transactions (2,958), which might impact the overall reliability of the results of this particular model. The results indicate that during the planning and construction phase all the statistically significant coefficients were positively signed, suggesting that the incinerator had a positive impact on house prices (Table 3). Once the EfW incinerator became operational the model suggests there were negative impacts on the price of houses at 2-4km from the site, but positive impacts on houses at 6-8km. Houses in the 2-4km zone appear to be the only houses affected by negative impacts where the incinerator reduced house prices by an average of £2,277 per house.

3.4.2 Allington

The model results for Allington (Table 4) suggests that proximity to the incinerator had a negative impact on local house prices. During the planning phase there were negative impacts at 2-4km and 4-6km during construction there were negative impacts at 4-6km and 6-8km. Once operational there was a negative impact only at 6-8km. According to the literature, the strongest effect should be expected in close proximity to the incinerator. However, the nearest residential area is at least 380m from the incinerator. Hence the number of observations in the 0-2km model is significantly lower than the other zones. In monetary terms the negative impacts during the planning phase at 2-4km and 4-6km were on average £14,866 (the largest negative effect detected in this study) and £589 per house respectively, while the impacts at construction at 4-6km and 6-8km were £562 and £1,405 per house respectively. Once operational the impact at 6-8km was £836 per house.

3.4.3 Marchwood

In all significant results (p-value<0.05) in the planning stages (Table 5), proximity to Marchwood EfW enhanced property prices, albeit by a relatively small margin. Furthermore, in the construction phase there was a slight increase in house price at a distance of 2-4km. However, model coefficients show that once operational the EfW site had a negative impact house prices at 0-2km of £2,422 per house.

3.4.4 Collected results and aggregate impacts

Table 6 shows that the incinerator at Allington had the largest and most consistent negative effect through the three stages of incinerator development and operation. The Newhaven and Marchwood models have a broadly similar negative effect per house. Table 6 aggregates the impact on price per house over the number of observed transactions to gauge the total impact of the incinerator. The negative impact (externalities) of the Allington incinerator aggregates to £22,651,116. This is followed by the Marchwood incinerator at £995,442 then the Newhaven incinerator with a negative impact of £195,822.

4 Discussion

With the exception of Allington the results show a number of significant positive coefficients, which suggests the planning, construction and/or operation of the incinerator increased the value of houses within a specified distance of incinerators. There is nothing in our models that can explain why house prices would increase as a result of the construction of an incinerator. We can hypothesise that the increase in house prices could be associated with there being less impact than local people expected. Thus the housing market response is positive after construction or operation begins. However, it may also be possible that there are some explanatory variables missing from the models, such as impact on employment.

Phillips *et al*. (2014) also found that three UK incinerators had no significant impact on local house prices. The results from this current study in-part are supportive of Phillips *et al*. (2014), although some statistically significant negative impacts were also detected. This may indicate that the impacts of local incinerators on house prices are not necessarily negative under certain conditions, counter to much previous literature. However, it is unclear what conditions support positive, neutral or negative impacts. This is a current gap in the literature and provides a fruitful area of future research. Given that there is nothing in our models to account for positive impacts, henceforward we will only deal with the significant negative impacts.

The models of Allington, Newhaven and Marchwood show evidence of negative impacts from the incinerators. However, there is little commonality across the results, which may be because of the geographic differences between each incinerator and its surrounding area. All three incinerators have been built on brownfield sites, but with different previous uses:

- The Newhaven site is built in an industrial area on the banks of the tidal estuary of the River Ouse, over land formerly used as railway maintenance yard.
- The Marchwood incinerator is sited in an industrial area on the banks of Southampton Water, a tidal estuary characterised by areas of both residential and industrial development. In the proximity of the facility an incinerator was closed nine years before the current plant went online, but used as a waste transfer station for further ten years (Hampshire County Council, 2006) and demolished in 2012, further six years later (New Forest District Council, 2012).
- The Allington site was previously a stone quarry, with the incinerator being built within the quarry site and as such is mostly invisible from any residential structure. There is also a small industrial area, a reservoir and agricultural land in the proximity of the facility

The highest per house impact is found in Allington and aggregated over all transactions provides the largest negative impact from the three incinerators (Table 6). It is worth noting that the closest house to the incinerator at Allington is 380m distant, which may have mitigated some of the largest impacts. Allington is the only site selected which was not the site of a previous waste management facility.

The Marchwood incinerator had the second largest impact on local house prices. Marchwood has been the site of a previous waste management facility and some habituation effect is to be expected. Marchwood also has a series of other potential sources of current nuisance. It is host to a large military port (built in 1943), a sewage treatment work (established in the 1960s), and a natural gas power station (established in 2009 and replacing a former power station from the 1960s) (New Forest District Council, 2004; Marchwood Power Limited, 2014). The sewage treatment works, whose odour emissions are a major complaint of local residents (Marchwood Parish Council, 2012) might have an important role in hiding any negative externalities caused by the incinerator. Given this range of potential nuisance sources it is notable that the incinerator still had an additional negative effect.

The Newhaven incinerator had the third largest impact per house, although it was very similar to the per house impact at Marchwood. Newhaven also had the third highest aggregate impact, although there was a relatively small sample of transactions. The negative value is in line with the opposition shown by local residents to the incinerator. Newhaven has 12,000 residents, yet there were more than 16,000 objections to the development of the incinerator (van der Zee and Jones, 2012).

It is useful to compare the results with the literature. In terms of studies that have estimated the negative impacts of incinerators, Pragnell (2003) found that in postcode sectors containing EfW incinerators average house prices are 18 percent lower than house prices at 2.8km from EfW sites. The results in this study show that the impacts are much lower than suggested by Pragnell (2003), although our model suggests that prices decreased in Allington by 10% in the planning phase at 2-4km), but greater than those estimated by Havranek *et al*. (2009), who found that households were willing to pay £3.69 for a 50% reduction in incinerator chimney size, £2.12 for a 50% reduction in odour, £5.86 for a 50% reduction in traffic. Phillips *et al*. (2014) reported that the Marchwood EfW plant had no statistically significant impact on house prices within 5km of the incinerator, whereas this current study found that the Marchwood incinerator had reduced the average house price within 2km of the incinerator by 1.3%.

The figures from Table 6 are generally (with the exception of Allington) within the estimated costs of negative externalities of landfill sites. Cambridge Econometrics (2003) found that on average, across the UK, operational landfills reduce the price of houses within 0.25 miles by approximately £5,500 and about £1,600 for those between 0.25 and 0.5 miles. It is notable that the impact of incinerators is detected at a greater range than that suggested by Cambridge Econometrics (2003) and in line with other literature looking at the disamenties of incinerators.

The study by Cambridge Econometrics (2003) treated the impacts of landfill on the surrounding area as 'stock disamenities', meaning that these impacts occur from the very existence of the landfill and are independent of the size or type of waste facility. The results of this current study suggests that the impacts of incinerator vary by site, so the use of stock disamenity as an indicator of impact may be less useful for the analysis of the impacts of incinerators than it is for landfill.

UK planning regulations require incinerators to be sited near the source of waste, but also in a location that minimises the impacts of negative externalities. The incinerators studied were on brownfield sites, which are perceived to have lower impacts than incinerators on virgin sites.

The results show that despite this careful siting, there is a still a detectable impact in the operational phase of the incinerator. In Marchwood there is an impact in the immediate vicinity of the incinerator, despite the fact that there is likely to be a habituation effect from an older incinerator. The impacts at Newhaven were experienced at 2-4km from the incinerator and even further out at Allington (6-8km). For Allington there are very few houses to impact upon within 2-4km. The largest negative effect is experienced at 6-8km; again we can speculate that this may because negative impacts were unanticipated at this distance. In Newhaven the impact was again beyond the 0-2km range, suggesting that similarly to Allington, the impact of the incinerator has been largely mitigated at close proximity, but there have been unanticipated impacts further away.

Therefore, the findings broadly support the hypothesis that careful siting of incinerators minimises the social impacts (as indicated by house price changes), based on the evidence that (apart from Marchwood) there were no impacts in the immediate vicinity of the incinerator. However, it appears that there is a need for extra measures in terms of minimising nuisance beyond the immediate proximity (0-2km) of the incinerator. It should be noted that the largest effect was experienced in the planning phase of the Allington incinerator. Section 1 highlighted that there are usually large protests when a new incinerator is planned. As Allington had no previous history of waste management it can be speculated that residents had serious concerns about the potential impacts of the incinerator in the planning phase.

It should be noted that this study did not analyse the benefits of waste incineration, nor did it assess the negative impacts of alternative sites that could have been used for the four incinerators considered. In this way we have valued negative externalities, rather than determine the net social costs of these incinerators.

The results of this study should be treated with caution. For instance, there is no consideration of prevailing wind in these models, nor surface features. Many of the impacts associated with incinerators depend on wind direction and also whether any natural barriers, such as woodlands or mountains separate source and receptor. This may have played a part in our results. It is possible for an incinerator to be in close proximity to dwellings, but have low impact because of prevailing wind and intervening geographic features (such as hills). Indeed, to our knowledge, the impact of geographical features and meteorological conditions has not been considered. This is grounds for further research.

Conclusions

This paper uses the Hedonic Pricing Method, utilising 55,000 transactions over a 20 year period to quantify the impact of four EfW incinerators in England, which have been sited on previously industrialised land. Broadly the results show inconsistent impacts across the stage of development (planning, construction or operation) and distance from incinerator. In this way the impacts of incineration appear to be different from those of landfill, which is often treated as a stock disamenity (Cambridge Econometrics, 2003), so that individual analysis of incinerators should be undertaken individually rather than aggregated.

The results show a number of significant positive coefficients, which suggests some incinerators have increased the value of houses within a specified distance. There is nothing in our models that can explain why house prices would increase as a result of the construction of an incinerator and so this study focuses on the significant negative impact. The cause of the positive coefficients was hypothesised to be where impacts were less severe than expected, causing prices to increase. This represents grounds for further research.

Each of the incinerators studied was sited in previously industrialised land to minimise the impact on local residents. To an extent this was achieved. In two out of the three incinerators there were no significant negative impacts detected within 2km of the incinerator. This suggests that careful siting of incinerators reduced the impact on residents. However, negative impacts occurred in areas further afield, suggesting more can be done to minimise the impacts of incinerators. At the Marchwood incinerator there was a significant negative impact within 2km of the incinerator, despite this area previously hosting a now defunct incinerator. The largest negative impact was in the planning phase of the Allington incinerator, where the land was previously used for quarrying, unconnected to municipal waste management. It appears that the perceived impacts of an incinerator negatively impacted local property prices.

Once operational, the impact of the incinerators studied ranged from approximately 0.4% of the mean house price to 1.3%. These estimates fall in between the highest and lowest estimates from the literature. The highest impact (of an operational incinerator) per house is at

Marchwood (1.3% of the mean 2013 house price for the area). However, this differs from the results of Phillips *et al*. (2014), who using the repeated sales method found the incinerator had no significant negative impact on nearby households. Although the impact is a small proportion of total house sale value, the total negative impact of incinerators on their local communities to date have been estimated as £22,651,116 for Allington followed by the Marchwood incinerator at £995,442 then the Newhaven incinerator with a negative impact of £195,822.

The study of the economic impacts of waste management disamentities could be better understood by including environmental factors, such as local topography and prevailing wind direction. We also hypothesise that expected impacts relative to actual impacts could have a large influence on the results of a hedonic pricing study of incinerators.

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Tables

Table 1. Summary description of the four incinerator facilities selected to assess the impact of negative externalities on house prices. Permitted capacity (tn) and tonnage incinerated correspond to values obtained for 2012. AT, MW and NH stand for Allington, Marchwood and Newhaven, respectively.

Incinerator	Permitted capacity	Tonnage incinerated	Phase			Previous land use	Location
			Planning	Construction	Operational		
AT	500,000	419,402	1996-2002	2003-2008	2008-2014	Quarry	Maidstone
MW	210,000	206,700	1995-2001	2002-2004	2004-2014	Incinerator and industrial	Southampton
NV	240,000	224,730	2001-2007	2008-2011	2011-2014	Rail maintenance yard and brownfield	East Sussex

Table 2. Independent variables considered for inclusion in the Hedonic Pricing Model. Variables have been grouped into five categories based on Malpezzi (2003).

Category	Variable	Description
Dependent Variable	Transaction price	Transaction price in £
Transaction time	Transaction date	Date when the transaction took place
	Pre 1919	Household sold before 1919 (dummy variable yes/no)
	1919-1945	Household sold between 1919 and 1945 (dummy variable yes/no)
	1945-1960	Household sold between 1945 and 196- (dummy variable yes/no)
	1960+	House sold after 1960 (dummy variable yes/no)
	Year#	Dummy variables for each year there are existing records of houses being sold
Contract arrangement	Tenure	Freehold or leasehold
Property structural characteristics	NW	New household (dummy variable yes/no)
	FT	Flat (dummy variable yes/no)
	BLW	Bungalow (dummy variable yes/no)
	DTC	Detached property (dummy variable yes/no)
	SDTC	Semi-detached property (dummy variable yes/no)
	TRC	Terraced property (dummy variable yes/no)
	LIV	Number of livingrooms
	BED	Number of bedrooms
	BTH	Number of bathrooms
	TLT	Number of toilets
	FCH	Full central heating (dummy variable (yes/no)
	PCH	Partial central heating (dummy variable yes/no)
	NCH	No central heating installed (dummy variable yes/no)

	NG	Number of garages
	NGS	The number of garage spaces
	GR	Garden (dummy yes/no).
	RCH	Road charge liable (dummy variable yes/no)
Neighbourhood characteristics	A	Property is in Acorn zone A- wealthy investors (dummy variable yes/no).
	B	Property is in Acorn zone B -prospering families (dummy variable yes/no).
	C	Property is in Acorn zone C - traditional money (dummy variable yes/no).
	D	Property is in Acorn zone - young urbanites (dummy variable yes/no).
	E, F, G	Property is in Acorn zone E/F/G - middle-aged families (comfortable), contented pensioners and families and individuals looking to settle down. Middle aged comfort €, contented pensioners (F) and settling down (G) (dummy variable yes/no).
	H	Property is in Acorn zone H - moderate living (dummy variable yes/no)
	I, K	Property is in Acorn zone I/K - meagre means and impoverished pensioners (dummy variable yes/no).
	J	Property is in Acorn zone J - inner city existence (low income singles and couples, multi ethnic young singles renting flats, high rise poverty dependent on welfare and poor young financially inactive (dummy variable yes/no).
Location within the market	House location	Postcode

Spatial	D_EfW	Linear distance to the incinerator

Table 3. Results obtained for the Hedonic Pricing Method (Lancaster *et al.*, 1996) for the case study area of Newhaven. I is the monetary impact of the incinerator on house prices estimated as in Eq. 3. (*) indicates statistically significant coefficients (p-value <0.05). $\overline{P}_{2013}$ is the mean house price in 2013 calculated using historic Consumer Price Index data (ONS, 2014). β_d is the regression coefficient as described in Eq. 3 and N is the number of records included in the regression model. The F-test for the overall model was statistically significant (p-value<0.05).

Phase	Distance (km)	N	β_d	$\overline{P}_{2013}$	*I*
Planning	0-2km	380	0.000062*	210247	1304
	2-4km	532	0.000021		
	4-6km	922	0.000035*	258307	904
	6-8km	352	0.00018*	392859	7071
Construction	0-2km	84	0.000098		
	2-4km	139	-0.000467		
	4-6km	191	0.000023		
	6-8km	54	0.000463*	336291	15570
Operational	0-2km	78	0.000045		
	2-4km	86	-0.000099*	230050	-2277
	4-6km	115	0.00004		
	6-8km	25	0.000221*	288800	6382

Table 4. Results obtained for the Hedonic Pricing Method (Lancaster *et al*., 1996) for the case study area of Allington. I is the monetary impact of the incinerator on house prices estimated as in Eq. 3. (*) indicates statistically significant coefficients (p-value <0.05). $\overline{P}_{2013}$ is the mean house price in 2013 calculated using historic Consumer Price Index data (ONS, 2014). β_d is the regression coefficient as described in Eq. 3 and N is the number of records included in the regression model. The F-test for the overall model was statistically significant (p-value<0.05).

Phase	Distance (km)	N	β_d	$\overline{P}_{2013}$	*I*
Planning	0-2km	324	0.00001		
	2-4km	1162	-0.00101*	147190	-14866
	4-6km	1437	-0.00004*	147190	-589
	6-8km	1528	-0.00001		
Construction	0-2km	453	0		
	2-4km	2018	0.00001		
	4-6km	1915	-0.00002*	281088	-562
	6-8km	2089	-0.00005*	281088	-1405
Operational	0-2km	109	0.00003		
	2-4km	576	0.00001		
	4-6km	556	-0.00001		
	6-8km	621	-0.00004*	208876	-836

Table 5. Results obtained for the Hedonic Pricing Method (Lancaster *et al*., 1996) for the case study area of Marchwood. I is the monetary impact of the incinerator on house prices estimated as in Eq. 3. (*) indicates statistically significant coefficients (p-value <0.05). $\overline{P}_{2013}$ is the mean house price in 2013 calculated using historic Cobsumer Price Index data (ONS, 2014). β_d is the regression coefficient as described in Eq. 3 and N is the number of records included in the regression model. The F-test for the overall model was statistically significant (p-value<0.05)

Phase	Distance (km)	N	β_d	$\overline{P}_{2013}$	*I*
Planning	0-2km	327	0.000129*	98450	1270
	2-4km	1238	0		
	4-6km	2359	-0.00001		
	6-8km	135	0.00003*	106966	321
Construction	0-2km	148	-0.00004		
	2-4km	657	0.000052*	200254	1041
	4-6km	1040	-0.00001		
	6-8km	613	0.00001		
Operational	0-2km	411	-0.000133*	182141	-2422
	2-4km	1927	0.00001		
	4-6km	2992	0		
	6-8km	1843	0.000016		

Table 6. Total monetary impact per incinerator. N stands for the number of transactions included in the overall Hedonic Pricing Model.

Phase	Distance (km)	Average economic impact per house (£)			N	Total impact on house prices(£)	Percentage of mean house price
		Newhaven	Allington	Marchwood			

							(%)
Planning	2-4km	N/A	-14866	N/A	1162	-17,274,513	10
	4-6km	N/A	-589	N/A	1437	-846,393	0.4
Construction	4-6km	N/A	-562	N/A	1915	-1,076,239	0.2
	6-8km	N/A	-1405	N/A	2089	-2,935,045	0.5
Operational	0-2km	N/A	N/A	-2422	411	-995,442	1.3
	2-4km	-2277	N/A	N/A	86	-195,822	1
	6-8km	N/A	-836	N/A	621	-519,156	0.4

Figures

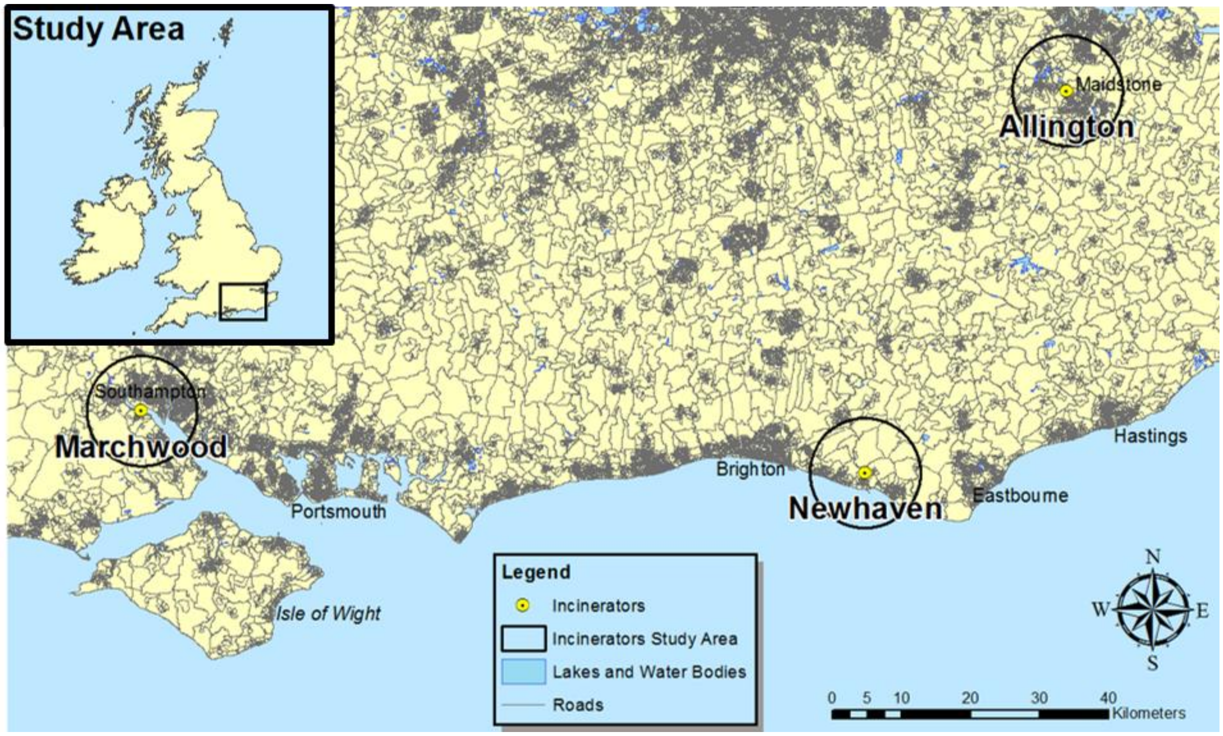

Figure 1: study areas selected for analysis.

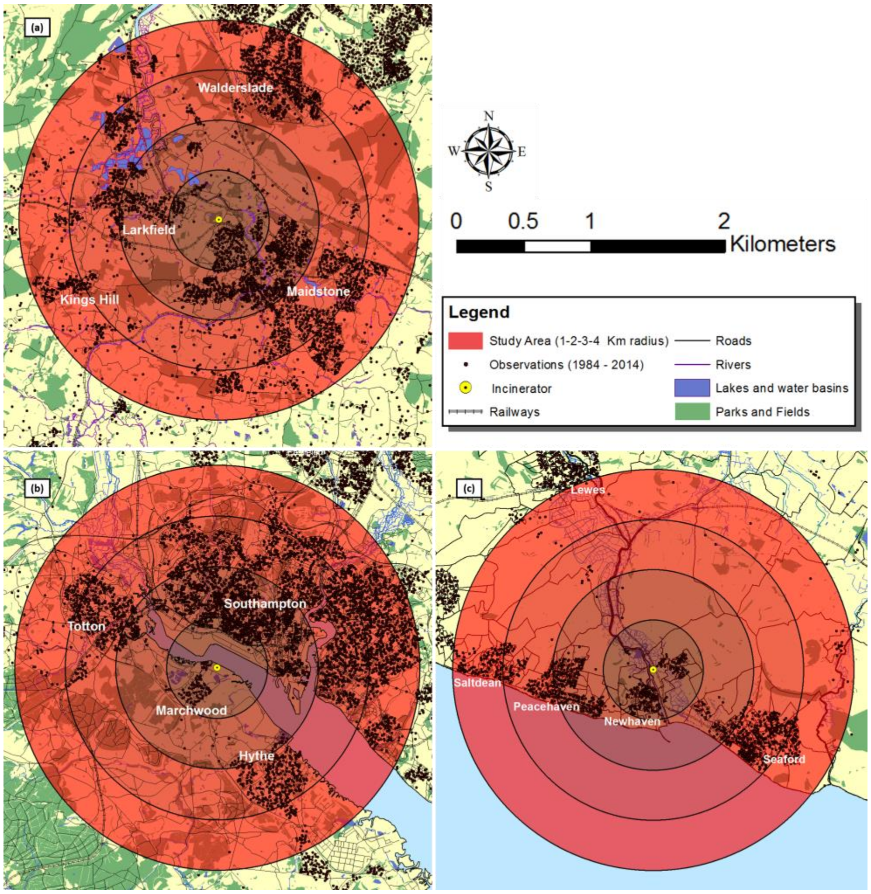

Figure 2: Detailed map showing the houses selected for analysis falling within a 2km, 4km, 6km and 8km radius for the sites at (a) Allington, (c) Marchwood and (d) Newhaven.

Monetising the impacts of waste incinerators sited on brownfield land using the hedonic pricing method

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