ORGANISATION DE COOPÉRATION ET DE DÉVELOPPEMENT ÉCONOMIQUES

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Environmental Equity and the Siting of Hazardous Waste Facilities in OECD Countries: Evidence and Policies

by

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Paper presented at:

Workshop on

The Distribution of Benefits and Costs of Environmental Policies: Analysis, Evidence and Policy Issues

organised by the

National Policies Division, OECD Environment Directorate

March 4th-5th, 2003

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Introduction

Measuring environmental equity entails as many challenges as defining it. Pearce (2002) reveals how economics can be used to explain and evaluate the distribution of environmental quality across socioeconomic groups. This paper looks at a particular type of environmental hazard, the siting of hazardous waste facilities, from the perspective of environmental equity. Section 1 reviews the nature of the data available, the methodologies of analysis used, and the comparability of studies within and across OECD countries. Section 2 reviews and discusses the studies of hazardous waste facilities and focuses in particular on the distribution of potential risks by demographic group, including different income groups. Section 3 discusses the determinants of disparities in exposure. Section 4 reviews the policy actions taken to address the disparities in the distribution of exposure to environmental impacts from hazardous waste facilities. Though the majority of the studies analyzed in each section focus on the United States, the available research published in English from other OECD countries is included in each part of the analysis.

Conclusions about the distribution of risks from hazardous waste facilities depend in part on how these hazards are defined. Studies of facility siting, operation, and cleanup indicate that the greatest hazards appear to be distributed in some countries as if the environment were a normal good. Risks are greater for those with lower incomes. During the 1980s and early 1990s, many of the policies dealing with hazardous waste focused on how to site new facilities and how to cleanup older plants. The explicit incorporation of environmental equity concerns came in later policies. This means that while efforts to focus attention on the distribution of risks by income class have recently succeeded in generating new policies in some countries, it is too early to determine the actual efficacy of these policies.

1.0 Data and Methods in Hazardous Waste Studies

Assessing how risks arising from hazardous waste facilities vary by demographic groups involves defining risks, wastes, facilities, and demographic groups. The definition of a “facility” offers numerous options: plants that generate hazardous waste, facilities that treat, store, or dispose (TSDs) of hazardous waste, or even sites now abandoned that once generated or managed these materials. The operation of the facility can be judged in the siting stage (e.g., who will be exposed to new risks?), during its operation (e.g., which facilities violate environmental regulations), and during remediation (e.g., how has environmental contamination been handled?). Risks can be characterized in a number of ways. Some studies use a simple indicator variable approach, where a facility either does or does not handle specific wastes, is or is not in violation of rules, or contains or does not contain a particular type of environmental contamination. Risks are also proxied by function of facility, so that plants are categorized by whether they generate and manage their own hazardous waste or whether they receive shipments from other facilities and process the waste for a fee. In countries with detailed data on waste management, plants are often grouped by the amount of hazardous waste stored or treated. More sophisticated assessments describe risks by tracking amounts of waste released to the environment, such as air emissions or underground injections. Databases that track reported and/or detected chemical spills at a facility are another source of risk information.

The advent of geographic information systems (GIS) technology has allowed risk assessments to be conducted at the facility level for some types of hazardous waste sites. This involves a number of judgments, starting with the radius of externalities generated by a plant. Modeling how far out risks extend requires assumptions about dispersion of air emissions or the likelihood of groundwater contamination and migration. Calculation of risks posed by groundwater contamination entail assumptions about ingestion, chemical toxicity, and the population around a facility. Some analyses focus on determining the lifetime excess cancer risks arising from exposure to a particular chemical for an individual. Though these

estimates are generally made with a standard set of assumptions, more sophisticated analyses do use Monte Carlo analysis to generate a range of risks arising from exposure to a given chemical. Multiplying individual risk levels by likely populations exposed offers a way to characterize risks by estimating the likely number of cancer cases arising from the presence of a site. Noncancer health effects are harder to quantify since an analyst often lacks slope factors that allow one to translate a given level of exposure into an estimated probability of experiencing a noncancer effect. These noncancer risks are more often expressed in terms of the degree exposure exceeds the level of exposure generally associated with no adverse health effects.

Defining the radius of risks around a plant is most often an exercise in modeling. Exposure routes are estimated and health effects are calculated by modeling. An alternative methodology used in some studies of hazardous waste sites draws on epidemiology. The health of residents living around a site is monitored and calculations are made to determine whether higher than expected levels of disease are noted. The multiple sources of risks make it difficult to isolate the separate effect of a plant's operation on residents, however. If residents close to a plant have lower incomes, for example, higher rates of illness may come from poor diet, inadequate health care, and exposure to toxics from a facility. The turnover in residents may also make it difficult to detect effects through epidemiology, since there may be a long lag time between the exposure and the onset of cancer. Another drawback of using a single radius to assess risks is that this will often ignore the transportation risks that arise in a community if wastes are transported to a facility by truck or rail. Defining risks by plant location also misses another set of stakeholders, those individuals who have an existence or bequest motive to value the environment surrounding a plant. Individuals may care about natural resource damages in an area even if they never visit it. People distant from a plant may also have a willingness to pay value that they attach to living in a just society. These existence values may become important in siting conflicts where residents may be willing to tradeoff risks for jobs but others outside the community may wish to block the siting because of perceived injustice.

Studies of environmental equity also entail decisions about what reference points to use in analyzing exposure and what demographic categories to use in comparing risks. Researchers may focus on a single site or small group of facilities and analyze how demographics change as distance from the hazard increases. This type of approach uses the residents within a given radius as the population to study. Other studies take the city as the geographic unit to analyze and explore how neighborhoods within a city that contain hazardous waste sites differ from those without. Some analyses view the country as a whole as the potential site of hazardous plants and compare how geographic units such as counties, cities, census tracts, or even zip code areas compare for those with and without facilities. The demographic categories that researchers use to examine variations in exposure include race, income, education, and age. Population density is also factored into to comparisons of areas with and without hazardous waste facilities.

A snapshot of facility locations across a country can reveal what factors are correlated with risks, but more information is required to tell a causation story about how exposures arise. For example, if one observes a hazardous waste facility located in a neighborhood with low-income residents, several scenarios could explain the association of income and pollution. A plant might locate in a given neighborhood because of factor price considerations. The plant's negative externalities could lower housing prices, and low-income residents might move in because of their willingness (due to constrained budgets) to tradeoff environmental quality for housing costs. Or a facility might target its location in a low-income neighborhood because anticipated political opposition might be lower. To see the relation between pollutants and people, some studies analyze census data for a number of years to see the change over time in neighborhood demographics and facility location. Other works use plans about the expansion of hazardous waste facilities to determine what types of areas are targeted by plants. Researchers also analyze how the current composition of an area affects the enforcement of environmental regulations at facilities and the cleanup of hazardous waste sites. These approaches, which go beyond a simple snapshot of

exposure, allow researchers to explore the degree that disparities in environmental quality are driven by differences in race, income, political power, or education.

A final way to analyze the disposition of hazardous waste is to examine the flow of hazardous materials across borders. This analysis takes the country as the unit of observation and explores how trade in waste varies with differences in income levels and environmental policies across states. The literature reviewed in this paper focuses on the analysis of environmental equity within a given country. Most of the detailed studies on hazardous waste facility siting and operation are conducted using data from the United States. For each section of the paper, however, I compare results from the United States with those studies published in English that examine the operation of plants in other North American countries, Europe, and Asia.

Studies of environmental equity in the U.S. have evolved rapidly with the decline in computing prices, increase in data availability, and growth in the sophistication of spatial analysis software. Research in the U.S. in the early 1990s on hazardous waste facilities focused on the state or county as the unit of geographic analysis. Investigators next explored how risks varied by zip code area or census data tract. The ease of GIS analysis in the mid-1990s made explicit modeling of risks possible at plants and hazardous waste sites. In the next section I will review the environmental equity literature on hazardous waste facilities using the following strategy. I will not attempt to summarize every article on disparities in exposure to hazardous waste, since detailed research summaries are available in Bryant and Mohai 1992, Bullard 1996, Mohai 1996, Foreman 1998, and Bowen 2002. Instead I will discuss in detail representative results from a subset of the most sophisticated analyses. I will divide the results based on the geographic unit of analysis adopted in the report, the degree that the research focuses on exposure versus causation, and whether the analysis uses data from the United States versus other OECD countries. Overall this review of the literature indicates that in general low income residents face the higher risks from hazardous waste facilities.

2.0 Literature Review on the Distribution of Hazardous Waste Facilities

2.1 Exposures within the United States

The U.S. Environmental Protection Agency (EPA) generally defines hazardous waste as waste that is ignitable, corrosive, reactive, or toxic. Facilities that generate hazardous waste or manage hazardous waste through treatment, storage, or disposal (TSDs) register with the EPA under the Resource Conservation and Recovery Act (RCRA) and often supply regulators with quantity data through shipping forms or regular surveys. Early research on environmental equity used information from the EPA's hazardous waste program to examine how potential risks are distributed across demographic groups. In 1987 the Commission on Racial Justice issued a report that found that when communities with commercial hazardous waste facilities were compared with their surrounding county, the community with the facility had a higher minority percentage, lower household income, more sites contaminated by previous exposure to hazardous waste, lower house values, and higher levels of waste generated per person. The study sparked a debate still continuing in the United States over equity and the environment, a debate which involves concepts such as environmental racism, environmental equity, and environmental justice. In this subsection I review four types of studies generated by this debate: national studies of commercial TSDs, reports that focus primarily on hazardous waste sites in a given city, research that uses company self-reported pollution figures from the U.S. Toxics Release Inventory, and information on environmental cleanups in the U.S. Superfund program. Table 1 contains a summary of studies dealing with the distribution of exposure to hazardous waste facilities.

Anderton et al. (1994a, 1994b) use the census tract, a county subdivision they indicate averages about 4,000 individuals, as the unit of observation in their national study of hazardous waste distribution. The

authors first compare the 408 census tracts in 1980 with commercial hazardous waste facilities (i.e., privately owned plants that receive waste from other firms) to the 31,595 other census tracts. They find no statistically significant differences in the mean percentage of black residents in the tracts with TSDs (14.54 black percentage) versus the other tracts (15.20%). They did find statistically significant differences between the TSD tracts and others for the mean percentage of Hispanic residents (9.41% vs 7.74%), the mean percentage of families below the poverty line (14.50% vs 13.94%), mean value of housing stock ($47,120 vs $58,352), and mean percentage employed in precision occupations (38.60% vs 30.61%). When they restrict the analysis to tracts in the largest 25 metropolitan areas in the US, they find when comparing the 150 census tracts with commercial TSDs with the other 17,406 tracts that those with TSDs had statically significant differences in means for percentage black (12.23% in tracts with TSDs vs 16.43% without), percentage Hispanic (13.88% vs 10.05%), percentage employed in precision occupations (37.08% vs 28.95%), and mean value of housing stock ($55,980 vs $65,764). There was no statistically significant difference in the mean percentage of families below the poverty line (12.46% vs 13.53%). The authors also compared the 408 tracts with commercials TSDs to the immediately surrounding tracts, defined as 4,239 tracts where at least 50% of the area is within a 2.5 mile radius of the TSD tract. They find statistically significant differences in the mean percentage black (14.54% for TSDs vs 25.70% other), percentage of families below the poverty line (14.50% vs 19.48%), and percentage employed in precision occupations (38.60% vs 35.41%). There were no statistically significant differences in mean percentage Hispanic (9.41% vs 10.79%) or mean value of housing stock ($47,120 vs $45,754).

Anderton et al. go on to combine the tracts with commercial TSDs with the nearby tracts to form a new set of TSD and nearby tracts (N= 4,647) to compare to the other tracts (27,356) in the nation. Here they find that the TSD and nearby tracts had statistically different means in terms of percentage black residents (24.72% vs 13.57%), Hispanic residents (10.67% vs 7.27%), percentage of families below the poverty line (19.04% vs 13.08%), percentage employed in precision occupations (35.69% vs 29.87%), and mean value of housing stock ($45,876 vs $60,291). One's assessment of environmental equity thus depends in part on how far one believes the negative externalities generated by plants extend. If the harms extend to nearby tracts, then those minority and low income residents appear to bear higher risks than residents living in other areas. If the harms extend primarily to the census tract with the TSD, then poor families and Hispanic residents appear to be more exposed. Relative to nearby tracts those that contain the actual TSD have lower percentages of black residents or poor families. A consistent pattern is the association of employment in industrial facilities (denoted by percentage employed in precision occupations) with the presence of commercial TSDs.

Atlas (2001a) makes several contributions to the analysis of national TSD locations. He reviews the evidence on the actual risks posed by current hazardous waste TSDs and concludes (p. 952) that:

> There is no evidence that TSDFs pose, much less have produced, meaningful harm to surrounding populations. The strict regulations under which they operate, the types and quantities of substances that they manage, the minimal potential exposure paths from them to people, and their compliance records all make the risks that they pose pale in comparison to other environmentally regulated facilities, such as those with air emissions.

He puts the waste handled by TSDs in perspective by noting that of 1.1 trillion pounds of hazardous waste generated in the U.S. in 1995, less than 2% (21 billion pounds) were transported off-site for management. The focus on commercial hazardous waste facilities thus can miss the 98% of waste that is managed onsite by generators. The EPA estimated that in 1997 there were between 700,000 and 950,000 generators of hazardous waste and 2,025 TSDs. Atlas focuses his analysis on those TSDs that received waste from other facilities and accounted for at least .2% of the managed hazardous wastes tracked in surveys by the EPA. This results in a set of 97 TSDs in 1991, 104 in 1993, 101 in 1995, and 108 in 1997.

Using GIS technology and 1990 census data, Atlas determined there were 65,736 individuals living within a radius of .5 miles of the TSDs he examined in 1991 and 1,690,505 within a 2 mile radius. For 1997, there were 71,079 individuals living with .5 miles of the TSDs in the sample and 1,494,231 within 2 miles. Looking at the mean of the percentage of minorities living within a given ring, Atlas found mean minority percentages of 27.0 for the .5 ring and 28.4 for the 2 mile ring in 1991 and 23.8 for the .5 ring and 26.1 for the 2 mile ring in 1997. These means are generally higher than the 24.2 minority percentage in the national population in the 1990 census. For low-income populations (defined as those with incomes less than 150% of the poverty level), in 1991 the mean low income population percentage for the .5 ring was 23.8% and 26.1% for the 2 mile ring; for 1997 it was 29.6% for the .5 ring and 30.4% for the 2 mile ring. These mean percentages are higher than the 21.7% figure for the national low-income population. By looking at the mean percentages, one sees some evidence that TSDs operate in neighborhoods with higher minority and low-income residents. If you weight the means by population, a stronger association between race, income, and exposure appears. Of the total populations within a given ring, for 1991 at the .5 mile radius 29.0% were minorities and 44.1% minorities at the 2 mile ring. In 1997, the figures were 23.4% minority population at the .5 ring and 41.4% at the 2 mile ring. In terms of income, 25.3% of the population living within .5 miles of TSDs in 1991 were low income and 27.9% within the 2 mile ring. In 1997, 25.9% of the population within .5 miles were low income residents and 30.4% for the 2 mile ring. Atlas notes that although on an aggregate basis minority and low-income residents have a greater likelihood of living near a TSD, this is because of the presence of a small subset of TSD in heavily populated areas that have a high percentage of minority or low-income residents. He finds that half of the total minority population living within a given radius of a TSD are concentrated at between 2% and 7% of all TSDs. Analyzing the data in another way, he generally finds a negative correlation between the minority population percentage in a ring and the amount of hazardous waste managed at the TSD. This negative correlation also held for the percentage of low income population and the amount of waste generated.

The expansion plans of hazardous waste facilities provide another way to look at potential exposure by demographic group. Hamilton (1995) uses a 1987 EPA national survey of TSD capacity plans and matches facility decisions with census data on the zip code neighborhood surrounding a plant. Of 207 zip codes with commercial hazardous waste facilities, net positive expansions in capacity were planned in 84 areas versus no net expansion in 123 zip codes. The difference of means tests comparing the areas targeted for expansion to the other zip codes were statistically significant for a number of demographic variables. The mean percentage of families in poverty was higher in zips targeted for expansion (14% vs 11%), the average of the median household incomes was lower ($15,750 vs $17,060), mean nonwhite population percentage was higher (25% vs 18%), average zip code population lower (18,700 vs 24, 000), and mean voter turnout in the county (a proxy for collective action potential) was lower (51.8 vs 54.8). Commercial hazardous waste facilities were thus planning expansions in areas with lower populations, more minorities, poorer populations, and less politically active individuals.

Many authors analyzing environmental equity have examined the populations surrounding hazardous waste sites slated for cleanup in the EPA's Superfund program (see Zimmerman 1993, Hird 1993, 1994, Anderton et al. 1997). Hamilton and Viscusi (1999) use 1990 census data to determine that overall 50.9 million people live within four miles of the 1,173 sites they examine on the Superfund's National Priorities List. Overall, minorities account for 28.9% of residents living within 4 miles of the sites, 35.1% of onsite populations, and 24.2% of the U.S. population. The percentage of most nonwhite populations and minority groups as whole declines as one moves farther from the sites, indicating that these groups bear more of the potential exposures from Superfund sites. Viewed in terms of probability of living within one mile of a site, minorities had a .05 probability compared to .03 for whites. At the four-mile range, a minority resident had a .24 probability of living in this area compared to a .20 probability for white residents. The probability of living within four miles was particularly high for Asians (.31) and Hispanics (.29), while the probability for blacks (.21) is close to that for U.S. residents as a whole (.20).

Hamilton and Viscusi show the dangers of focusing on a single measure of environmental equity in assessing the distribution of exposure. For example, they find that the average white population percentage at Superfund sites is 85.6%, which is larger than the national white percentage of 80.3%. This comparison, however, is not weighted by population and misses the fact that sites with higher minority percentages tend to be more populous. Less than one third of the sites (347 out of 1,173) account for 89% of the minority residents living within one mile of the NPL sites. Sites with 0 to 10% minority populations in the one-mile ring around a site have a mean population of 3,966, while sites with 40 to 50% minorities in the one mile ring had a mean population of 22, 396. Thus on a site basis Superfund problems are concentrated in neighborhoods with lower minority population percentages than the national minority population percentages. The location of some sites in highly populous minority neighborhoods, however, means that the overall set of residents surrounding Superfund sites are more likely to be minorities than one would predict based on their national population percentages.

Looking at site level (i.e., unweighted by population) means, Hamilton and Viscusi find that site-level mean household incomes are lower at the one mile ring around Superfund sites ($36,930) and the four-mile ring ($37,690) than the mean household income for the nation as a whole ($38,450). Note that mean household income steadily increases as one moves from one-mile to four-mile to ten-mile rings. At 61% of the sites, the mean household income is lower in the 0-1 mile ring than in the 1-4 mile ring. The increase in income levels with distance from the site is consistent with the prediction that the environment is a normal economic good. The site-level mean house values for residents living within one mile ($98,590) or within four miles ($103,900) were lower house values than the U.S. mean ($112,660). Such differences would be consistent with the location of NPL sites in industrial working class neighborhoods. The ring trend is generally consistent with the theory that the negative externalities associated with the sites will drive down housing values. At 62% of the sites, the mean housing value is lower for the 0-1 mile ring than for the 1-4 mile ring. For populations living within 1 mile, the percentage of residents with less than a high school education (25.5%) is higher than the national figure (24.8%) and the percentage of residents with higher education levels (16.5%) is lower than the national figure (20.3%). If one weights the results by population or household, the ring trends generally remain evident. As distance from a site increases, the mean household income for the populations potentially exposed increases, the mean housing values increase, and the percentage of highly educated residents increases. However, on a population weighted basis, residents within four or ten miles of Superfund sites have higher mean household incomes and greater housing values than those for the United States as a whole. Such income differences may arise because of the high concentration of sites in urban areas, where both incomes and housing values are higher.

For a subset of 150 Superfund sites, Hamilton and Viscusi conducted risk assessments to determine the potential cancer and noncancer risk arising over a thirty year period. They estimate that there would be 731 expected cancer cases arising from contamination at these sites. The breakdown by demographic group of the percentage of the 731 estimated cancer cases was minorities 43%, whites 68%, other race 9%, Hispanic 22%, black 4%, Asian 18%, and American Indian 1%. If the site (i.e., the Westinghouse site in Sunnyvale California) with the largest number (652) of cancers is dropped from the analysis, however, the results are reversed. Minorities would account for 16% of the remaining cancer cases, while whites (including Hispanic whites) would account for 87% of the expected cases. The conclusion that minorities bear a disproportionate share of the expected cancers must be tempered by the fact that this result is driven primarily by one extremely hazardous site. The EPA's risk assessments at NPL sites focus on individual lifetime excess cancer risks arising from contamination rather than the expected number of cancer cases. In terms of population weighted mean maximum individual cancer risks at sites, minorities face higher risks than white populations surrounding the 150 NPL sites in the sample. Minority populations within four miles of the sites face a mean risk of .142 versus .125 for the white population. The magnitude and distribution of the risk exposure again depends to a great extent on the Westinghouse site. If this extremely hazardous site from California is dropped from the analysis, the gap between mean risks faced by minorities (.108) and whites (.102) nearly disappears. These calculated risk levels are high in part because

of the EPA's requirement that analyses use conservative parameter values for variables such as ingestion rate or exposure duration in the calculation of individual risks.

In the EPA's site level risk assessment, the agency distinguishes between current risks and future risks, which are hypothetical risks that could arise if land use changed or if the likelihood of contamination changed through a mechanism such as the migration of a groundwater plume. Data on both potential exposures and estimated individual cancer levels indicate that minorities may be more likely to be exposed to current risks from Superfund sites. At sites where minorities account for more than 20% of the population within one mile, the mean of the maximum current cumulative risks is .013, while the mean for sites where minority population percentages are 20% or lower is .0022 (t=1.7). Minorities make up a higher proportion of the population at sites where EPA survey data indicate current residential use. At the 165 sites where the EPA data indicate current residential land use, minorities constitute 45% of the population living within a quarter mile. At the sites (N=343) where there is no current use (e.g., residential, industrial, commercial), minorities constitute 22% of the populations living within a quarter mile.

The approach by Hamilton and Viscusi shows how multiple indicators can be used to assess national environmental equity outcomes when significant amounts of data are available (note that the EPA budgets overs $1 million to study contamination and remediation options at each Superfund site). In terms of the estimated risks at Superfund sites, minority groups are disproportionately exposed. There is some evidence that minority groups account for a larger fraction of the estimated cancers than their national population percentage, evidence that the population weighted mean maximum cancer risks for minorities is higher than that of whites, and strong evidence that minorities bear larger current risks arising from present land uses at sites.

Though this review focuses on the siting of hazardous waste facilities, the fact that much hazardous waste is managed onsite by industrial facilities and the overlap between hazardous and toxic chemicals make research conducted on toxic emissions from plants relevant. Brooks and Sethi (1997) use information from the U.S. EPA's Toxics Release Inventory, which contains annual self-reported figures by plants on their toxic releases and transfers. They construct an air pollution index at the zip code level that takes into account TRI emissions in and around the zip code and the toxicity of the chemicals released. Using 1990 census data for U.S. zip codes, Brooks and Sethi find that minorities, renters, individuals with fewer years of schooling, and people with incomes below the poverty line are more highly exposed to toxic air emissions from TRI facilities. Sadd et al. (1999) use GIS technology to study TRI air releases in southern California. They find that census tracts in the metropolitan Los Angeles area that contain a facility releasing air emissions tracked in the TRI had many statistically significant differences from other Los Angeles census tracts. The TRI tracts had higher minority percentages, higher percentages of Latino residents, lower per capita incomes, lower household incomes, a higher percentage of industrial land, a higher percentage of the population employed in manufacturing, and lower housing values. Chakraborty (2001) uses data on the amount and toxicity of hazardous chemicals stored at plants in a given area (Hillsborough County, Florida) to model the dangers arising from acute events such as the accidental releases of toxic chemicals. The study found a positive and statistically significant association between the degree of potential exposure to chemical accidents and the proportion of non-white residents and residents below the poverty line. These studies are typical of the growing environmental equity literature that uses TRI data (Cutter, Holm, and Clark 1996, Ringquist 1997, Hockman and Morris 1998, Arora and Cason 1999, and Daniels and Friedman 1999) and/or tries to devise more direct indicators of risk exposure from air toxics (Graham et al. 1999, Morello-Frosch, Pastor, Sadd 2001).

While recent studies often use GIS technology to link exposures with populations in 1 mile rings around facilities or sites, Millimet and Slottje (2000) demonstrate the usefulness of broad assessments of equity. They develop environmental Gini coefficients to measure inequality across U.S. states in per capita releases of different types of pollution. They find that states with relatively high proportions of women,

minorities, and children are (p. 25) "over-represented in the upper tail of the per capita pollution distribution" and point out that environmental policies that do not take this into account may end up increasing measures of environmental inequity.

2.2 Exposures in other OECD Countries

Detailed analysis of exposure to hazardous waste risks within a country requires data on waste facility location, quantities of waste handled, and the demographics of surrounding. The building blocks of this analysis are available in some OECD countries. A 1998 report by the OECD, for example, presents estimates of hazardous waste generation, export, and import in the early 1990s. McDougall and Fonteyne (1999) examine waste management data from 11 European cities and find that quantitative comparisons were difficult because of variations in the definitions of waste. Prokop, Schamann, and Edelgaard (2000) survey the management of contaminated sites in 18 Western European countries, determine that 13 had started a systematic process to identify potentially contaminated industrial or waste disposal sites, and (while noting the wide variation in data quality) present estimates of potentially contaminated sites for most of these countries. Page (1997) describes the cleanup programs for contaminated sites in the Netherlands, United Kingdom, and Central and Eastern Europe. Christiansen and Munck-Kampmann (2000) also note the difficulties of comparing hazardous waste generation data across OECD countries in Europe. A report by the Commission for Environmental Cooperation (1999) notes the problems associated with tracking the transborder shipments of hazardous waste between Canada, the United States, and Mexico. Connor (1992) notes the problems associated with tracking the disposal of hazardous waste by Mexican facilities on the United States border. The Canadian Institute for Environmental Law and Policy (2000) uses information from Ontario's Hazardous Waste Manifest tracking system to provide a detailed description of the generation and shipment waste in the province. Overall these studies indicate that data on hazardous waste generation or contamination at sites may be available in some OECD countries, but differences in definition of hazardous waste and lack of consistent reporting would make it difficult to compare environmental equity across countries in terms of hazardous waste exposure. As the use of Pollution Release and Transfer Registers (PRTRs) that record which facilities release particular types of pollution spreads across countries, more detailed environmental justice analyses will become available in the future. Harjula (2003) notes that countries with operating PRTRs include Australia, Canada, Ireland, Korea, Japan, Netherlands, Norway, Mexico, Slovak Republic, United Kingdom, and the United States. For more on PRTRs, see Johnson (2001).

There are analyses that focus on the calculation of risks at particular types of sites within a given country. Openshaw (1982) presents estimates of populations exposed and expected thyroid cancers around a set of nuclear plants in the U.K. Walker and Pratts (2000) offer estimates of the number of residents exposed to major industrial accident hazards for a set of industrial facilities in Britain. Ragaini (1997) describes how site-level assessments can be conducted at contaminated waste sites in Central and Eastern Europe. Dolk et al. (1998) examine data from registries of congenital anomalies in five countries (Belgium, Denmark, France, Italy, and the UK) to analyze at 21 hazardous waste landfills the impact of proximity to potential contamination and birth defects. The authors conclude that living within 3 km of a landfill was associated with an increased chance of congenital anomalies (after controlling for socioeconomic status), that the risk decreases for residents more distant from a site, and that more research is needed to determine whether the association is caused by contamination at the sites.

The most complete studies on environmental equity from OECD countries other than the United States are from the United Kingdom and Canada (but see also the work by Kruize and Bouwman (2003) that analyzes environmental justice outcomes in the Rijnmond region of the Netherlands using GIS technology). A 1999 report for Friends of the Earth used information on postcode location of industrial plants registered between 1992 and 1996 under the Integrated Pollution Control program and household income distribution by postcode. The authors conclude (p. 1):

All across England and Wales the poorest families (reporting average household income below 5,000 Pds) are twice as likely to have a polluting factory close by than those with average household incomes over 60,000 Pds. ... Over ninety percent of London's most polluting factories are located in communities of below average income. London is just the most extreme example. A similar pattern is found throughout England and Wales. Overall, almost two-thirds of the most polluting industrial facilities are to be found in areas of below average income.

A 2001 report by Friends of the Earth examines the distribution of the 156 plants in England emitting more than 1,000 kilogrammes of carcinogens in 1999. Using the government's Index of Multiple Deprivation that ranks wards by indicators such as health, income, education, employment, housing, and access to services, the authors found that the polluting facilities were primarily located in the most deprived wards. They note (p.1) that of the 11,400 tonnes of carcinogenic chemicals emitted in 1999 by the factories in the study, " 66% of carcinogen emissions are in the most deprived 10% of wards; 82% of carcinogen emissions are in the most deprived 20% of wards; only 8% of carcinogen emissions are in the least deprived 50% of wards."

Three studies focus on the exposure to particular air pollutants by demographic group. Brainard et al. (2002) use modeled emissions from vehicles and measured emissions from monitoring sites to estimate exposures to carbon monoxide (CO) and nitrogen dioxide (NO_2) in Birmingham, England. Using GIS technology and 1991 census data at the enumeration district level, the authors conclude that (p. 707) "both ethnicity and poverty are associated with pollutant emissions in Birmingham, with the highest emissions being recorded for populations with the highest proportions of minority ethnic groups and impoverished residents." Note that census forms did not provide an explicit question about income, so the authors use questions about occupation of the household head (e.g., works in a professional and managerial position versus a partly or unskilled position). McLeod et al. (2000) used monitoring data on sulphur dioxide, nitrogen dioxide, and fine particulates to estimate exposures at the local authority district level in England and Wales in 1994. They find in regression analysis that pollution decreases as their social class index increases. Once they control for population density, however, they find that (p. 82) "the concentrations of all three air pollutants are higher in higher social class areas." Pye et al. (2001) use data on air pollution, GIS technology, and demographic data at the ward level to study four areas: Greater Belfast in Northern Ireland, Cardiff City Council in Wales, and Greater London and Birmingham City District in England. They conclude that (p. iii):

Greater London, Birmingham City District and Greater Belfast appear to show a positive correlation between air pollution and social deprivation, with higher pollutant concentrations of NO_2 and PM_{10} found in areas exhibiting higher levels of deprivation. Cardiff City Council does not appear to show any significant relationship between air pollution and social deprivation.

Canada's National Pollutant Release Inventory, which contains self-reported facility emissions similar to that collected in the U.S. Toxics Release Inventory program, has generated research on environmental equity. Jerrett, Eyles, Cole, and Reader (1997) aggregate 1993 facility air, water, and land emissions to the county level in Ontario and model the county emissions total as a function of four county characteristics: median income per household, average dwelling value, total population, and manufacturing employment. They found that the coefficients on median income per household is positive and statistically significant (as are the population and manufacturing variables) and that the housing variable is negative and statistically significant. They note that the positive relation between income and pollution may arise if high wages are part of compensation for pollution exposure, and note (p. 1793) that their use of interaction terms suggests that housing value is a "more important explanator of the location of pollution emissions than income." Harrison and Antweiler (2002) examine at the facility level on-site releases (i.e., air, water, land, and underground injection) and off-site transfers. Modeling the level and changes across time in releases and transfers as a function of plant and community characteristics, they (p. 22) "generally do not find

significant impacts of community income on either the current releases or changes in releases over time." They measure average community income based on census figures for the enumeration districts within a 50 km^2 area around each plant.

3.0 Literature Review of the Determinants of Exposure to Hazardous Waste Facilities

3.1 Influences on Siting and Exposure in the United States

Studies that link pollution data with demographic information provide snapshots of who is exposed to potential risks from hazardous waste facilities at a given point in time. Research that focuses on the current location of plants and people, however, cannot determine causation. Because the externalities generated by facilities change the landscape and perceptions of an area, the actual operation of hazardous waste plants may change the desirability of living in an area, affect housing values, and lead to shifts in population characteristics. The key to isolating what determines exposures to risk is to gather information on the demographics of a community when the decisions of interest are made. In this section I review a number of different approaches used in environmental research in the U.S. to examine what causes exposures to risk to vary across demographic groups. These approaches include analyzing what communities are targeted by firms when they plan to expand hazardous waste capacity, how regulators respond to communities as they cleanup hazardous waste sites, the impact of neighborhood characteristics on the reduction of carcinogenic air emissions by facilities, the change in area demographics over time as plants locate, the response of housing prices to changes at waste sites, and the reported reactions of individuals when they are queried about siting hazardous facilities. Table 2 contains a summary of studies dealing with the determinants of exposure.

Hamilton (1993, 1995) examines the expansion plans for 1987-1992 submitted by commercial hazardous waste facilities to the U.S. EPA. The study of planned changes has the advantage of being prospective, so that the effects of the proposed expansion of the facilities are unlikely to be reflected in changes in neighborhood demographics. The work tests three theories of why race may be associated with the location of hazardous waste facilities. In the pure discrimination model, owners of waste facilities may trade-off profits for prejudice and gain utility from the exposing minority communities to potential risks. According to standard interpretations of the Coase Theorem (1960), a polluting plant such as a hazardous waste facility may locate where it does the least damage, ceteris paribus, because this is where compensation is the least. The firm takes into account the physical and demographic characteristics of the surrounding neighborhood that influence the "cost" of its externalities: the number of people affected; incomes; property values; and residents' willingness to pay for environmental amenities. To the extent that low incomes and education are related to low willingness to pay for the environment and low expected damages in liability cases, and these variables are associated with race, profit-maximizing firms may choose to locate in minority areas because compensation demands and expected liabilities from operation are lower there. In the actual process of siting facilities, compensation demands are typically voiced through the political process. Firms will care about the expressed opposition to siting, which depends on a combination of political activity and willingness to pay. If collective action is required to lead a firm to internalize its externalities, then differences in political participation may help explain why minority neighborhoods would be less costly locations for polluting firms.

Of the 205 zip codes with commercial hazardous waste facilities operating in 1986, Hamilton finds 83 had net planned expansions in processing capacity. He uses a logit model to predict where firms will decide to expand which includes community demographic variables and market variables relating to processing capacity surplus in the county and state importation and generation of hazardous waste. The results demonstrate that firms care about compensation and political involvement. Consistent with the collective action theory, voter turnout in the county associated with the zip code is negative and statistically significant. The higher the county voter turnout, the less likely that a zip code neighborhood

will be targeted for additional capacity. The Coasean compensation variables generally have the expected sign. The number of people in the zip code and percentage renters are both statistically significant. The more people in the zip code (a factor in compensation demands and liability calculations), the less likely a firm is to expand in the area. The higher the percentage renters, the more likely firms are to expand capacity, in part because compensation may be lower where residents have fewer sunk costs associated with living in a particular area. The higher the average house price or percentage of adults with a high school education, the less likely the area would be chosen as a site for expansion (though these effects are not statistically significant). The higher the income in the zip code, the greater the probability of expansion. This result, which is statistically significant in one of two expansion specifications, may be due to the fact that areas with expanding waste capacity are areas with expanding industry and higher incomes. The nonwhite population figure is not statistically significant. Though zip codes with planned expansions do have a higher nonwhite population percentage, once one controls for other community characteristics race is not a predictor of where firms target expansions.

Decisions by firms to reduce their toxic emissions offer another avenue to examine how differences in risks arise across demographic groups. Hamilton (1999) examines at the facility level the change in air releases between 1988 and 1991 of 16 carcinogens. For a set of 2,788 plants tracked in the Toxics Release Inventory, he uses GIS technology to calculate the expected cancer risks arising around a plant and the nature of the community bearing these risks. He finds that controlling for the level of air pollution emitted in 1988, a facility with a higher expected number of deaths due to the release of the carcinogen had greater reductions in emissions between 1988 and 1991. In other words, the most hazardous plants in terms of human carcinogenic risks reduced their emissions more. As voter turnout in the area surrounding a facility increased, emissions declined. This indicates that for a given level of pollution, facilities may be more likely to engage in reductions if they believe that the affected parties are likely to engage in collective action to force firms to internalize the cost of their pollution. The impact of collective action is evident even after one controls for other socioeconomic measures, such as median household income, percentage of college graduates, or percentage vote for the Republican presidential candidate in 1988. None of the community variables other than voting was consistently statistically significant. Median household income and percentage of the zip code population that was black were not statistically significant. While plants do take into account the nature of who bears the risks of their contaminants, it is the likelihood that residents will engage in collective action and thereby force plants to consider the costs of their pollutants that affects plant decisionmaking.

A growing literature (see Zimmerman 1993, Hird 1994, Gupta, Van Houtven, and Cropper 1996, Hamilton and Viscusi 1999, and Atlas 2001) examines how the U.S. EPA responds to hazardous waste sites depending on the nature of the surrounding community. Viscusi and Hamilton (1999) provide a detailed analysis using risk assessments conducted at a sample of 150 Superfund sites. They analyze in regression analyses the target risk levels regulators choose to remain after cleanups and the cost per cancer case avoided implied by the remediation decisions. Looking first at the risk pathway targets chosen, they divide up the risks into two sets – those where the original risk posed by a given pathway of exposure to a chemical was greater than or equal to 10^{-4} (i.e., high risk pathways) and those where the unremediated risk was less than 10^{-4} (i.e., low risk pathways). The higher the voter turnout in an area, ceteris paribus, the more stringent the target risk chosen to remain after remediation when the original risks are low. When risks are high, political activity has no effect on cleanup standards. It is only when risks are low that political activity matters. The higher the average income level in the 1-mile ring around a site, the less stringent risk target will be chosen. This result may be because regulators believe wealthier residents are less likely to be exposed as assumed in risk assessments (e.g., groundwater exposures assume well-water consumption, while wealthier residents may be connected to public systems). A higher minority percentage in the area leads to the selection of a more stringent risk target. This could be evidence that regulators were concerned with environmental equity or might believe that calculated risks were more likely to arise in minority communities (e.g., if minorities were more likely to consume contaminated groundwater). In

terms of the cost per cancer case avoided at Superfund sites, Viscusi and Hamilton find that variables such as the minority population percentage within a 1-mile ring of a site or the mean income of residents within 1 mile had no impact on the cleanup expenditures chosen by the EPA. The higher the voter turnout in the county, however, the greater the cost per cancer averted implied by the EPA's cleanup decision. Cleanups at hazardous waste sites appear in part to follow a "fire-alarm" process (McCubbins and Schwarz 1984), where regulators respond to the likelihood that residents will complain about the nature of site remediation.

Another explanation for demographic variations in exposure to hazardous waste facilities is that facilities may generate negative externalities that lower surrounding housing prices. Lower housing prices in turn may attract lower income residents, whose budget constraints limit their ability to pay for a clean and safe environment. Economists have used a variety of hedonic methods to see how housing prices react to the presence of "locally undesirable land uses" (see Nelson, Genereux, and Genereux 1992, Kiel and McClain 1995, and Hite 2000). Farber (1998) summarizes the results of 25 studies on the impact of undesirable facilities on housing prices. He finds for ten studies of the impact of hazardous waste or Superfund sites that there housing prices do increase with distance from these sites. For three studies that estimated the housing price impacts after a site had been placed on the Superfund's NPL list, Farber finds a consistent effect that housing prices increased approximately $3,500 (1993$) per mile from the site. Gayer, Hamilton, Viscusi (2000) find that residents' willingness to pay to avoid risks actually declines after the release of remedial investigation studies at Superfund sites, suggesting that the information in the EPA studies lowers the perceived risks at sites. Gayer (2000) uses estimates of cancer risks at a set of Superfund sites and analyzes what housing prices imply about the marginal valuation of risk reduction in different neighborhoods. He finds that the price-risk tradeoff is greater for households in areas with residents with higher education and residents with higher incomes. The price-risk tradeoff implied in housing sale data is lower in neighborhoods with a higher proportion of non-white residents.

Research about the current patterns of exposure to hazardous waste facilities have generated significant debate and controversy (see Been 1995, Mohai 1995, Yandle and Burton 1996, Boer et al. 1997, Liu 1997, Boyce et al. 1999). One of the most direct ways to analyze exposure causation is to examine the nature of communities at the time of facility siting. Been (1994) examined four hazardous waste landfills studied in a 1983 General Accounting Office environmental report and concluded "at the time the facilities were sited ... the host communities were home to a considerably larger percentage of African-Americans and were somewhat poorer than other communities within the host states. The analysis therefore suggests that the siting process had a disproportionate effect on the poor and people of color." In examining ten landfills and incinerators first studied by Robert Bullard (1983, 1990), Been found that when they were originally sited five of the ten facilities were in areas with higher percentages of minority residents than the surrounding county and that three of ten were in areas with higher poverty rates. By 1990 the neighborhoods had changed so that nine out of ten had greater than average proportions of minorities and seven of ten had relatively higher poverty rates. Been and Gupta (1997) conducted a national study of 544 communities that in 1994 contained active commercial hazardous waste TSDs. Using census data at the tract level for 1970, 1980, and 1990, they examined the nature of neighborhoods at the time sitings occurred and the changes in demographics for these areas across time. They found (p. 9):

> ... no substantial evidence that the facilities that began operating between 1970 and 1990 were sited in areas that were disproportionately African American. Nor did we find any evidence that these facilities were sited in areas with high concentrations of the poor; indeed, the evidence indicates that poverty is negatively correlated with sitings. We did find evidence that the facilities were sited in areas that were disproportionately Hispanic at the time of siting. The analysis produced little evidence that the siting of a facility was followed by substantial changes in a neighborhood's socioeconomic status or racial and ethnic composition.

Environmental equity studies focused on causation have also begun to look at historical relationships between facilities and neighborhoods within a given city. Baden and Coursey (2002) examine the distribution of hazardous facilities and waste sites across time in Chicago. By matching facility siting dates with community demographic data (often at the census tract level), they determine that (p. 87):

> ...past waste-generating activities tended to be in less populous, lower income areas with good access to highways and waterways. Present waste sites tend to be located in less populous, wealthier neighborhoods, with convenient access to transportation infrastructure. There is no good evidence that African Americans of any income class are more likely to live in areas with more concentrated waste sites in the city of Chicago, or that they have been targeted to be disproportionately exposed to more hazardous waste. Several of the 1990 regressions found that the percentage Hispanic in a community was significant in describing the presence of a site in, or near, a community.

Lambert and Boerner (1997) examine changes over time in the city of St. Louis for census tracts with hazardous facilities or waste sites. They find that between 1970 and 1990 the percentage of residents below the poverty line and percentage of minority residents increased disproportionately in neighborhoods with TSDs, hazardous waste sites, and nonhazardous landfills and incinerators. They determine that mean real family incomes fell in these tracts (while the mean for St. Louis as a whole was rising) and that median real housing values increased at a less rapid pace around the hazardous sites. Pastor, Sadd, and Hipp (2001) examine the historical siting patterns of high-capacity TSDs in Los Angeles by matching siting dates with census tract data from 1970 through 1990. They find more evidence to support disproportionate exposure of minorities at the time of siting than a later move-in of minorities once a TSD is located in an area.

A final way to analyze why hazardous waste facilities are distributed in current patterns is to examine the results of surveys done about siting, risk perception, and compensation (see Bord and O'Connor 1992, Groothius and Miller 1994, Rogers 1997, Halstead, Whitcomb, and Hamilton 1999). A significant literature exists on how individuals in surveys differ in their expressed support for the siting of hypothetical or actual NIMBY (Not in my Backyard) facilities. Summarizing the role of potential compensation in facility siting, Oberholzer-Gee and Kunreuther (1999) note that compensation appears to increase support for siting of facilities such as prisons or airports but has little impact on prospective acceptance of projects perceived as highly risks such as incinerators or nuclear waste repositories; they note that for projects perceived as very risky compensation can in some cases reduce support for siting if it is perceived as a bribe. Smith and Kunreuther (1999) estimated in a study of compensation and mitigation for four hypothetical facilities that there is a core of respondents who view a siting as unacceptable even under a wide range of compensation/mitigation. They estimated this core of opponents to be 11.7% for a prison siting, 13.4% for a municipal landfill, 26.9% for a hazardous waste incinerator, and 40.2% for a disposal repository for high-level radioactive waste. Mitchell and Carson (1986) report that to reach a cumulative percentage of 50% of respondents accepting a facility a large factory or coal plant would have to be five miles from residents but a hazardous waste facility would not reach this level of acceptance until it was nearly 50 miles from residents. Mansfield, Van Houtven, and Huber (2001) find that those who are more likely to oppose nuisance facilities are also more likely to vote or participate in other forms of collective action, which suggests that political siting processes may engender more participation from opponents. Focusing on the role of trust in siting, Groothuis and Miller (1997) find that younger respondents and those with lower incomes express more distrust of waste disposal firms and the government, that people who distrust the media, government, and business express a higher estimate of the risks of hazardous waste disposal facilities, and that distrust affects the willingness to accept a facility siting. Swallow et al. (1994) show the importance of using contingent-valuation surveys to estimate different willingness to pay measures in siting disputes for different demographic groups (e.g., based on age or income). Much of the research on siting attitudes comes from surveys relating to the siting of a high-level nuclear waste repository in Nevada (see Kunreuther and Easterling 1990 and 1996, Easterling 1992, Dunlap, Kraft, and Rosa 1993). This research shows residents more willing to support a facility the

lower the perceived risks to future generations, the better the mitigation efforts taken to limit risks from a facility, and the more residents view the siting as the best policy outcome.

3.2 Influences on siting and exposure in other OECD countries

Most of the literature that explains siting patterns for hazardous waste facilities in OECD countries other than the U.S. focuses on individual-level survey data or case studies of particular siting mechanisms. A series of papers focus on survey interviews done in Switzerland in 1993 a week before a referendum on nuclear waste repositories (see Frey and Oberholzer-Gee 1996, 1997, Frey, Oberholzer-Gee, Eichenberger 1996). The researchers find expected results that willingness to have a nuclear waste repository located in a resident's community declined as perceived risks or negative economic impacts were larger. The authors determine, however, that compensation offers reduce the willingness to accept a nuclear waste site. They report (1997, p. 749,), "While 50.8% of the respondents agreed to accept the nuclear waste repository without compensation, the level of acceptance dropped to 24.6% when compensation was offered." They determine that compensation reduces acceptance not because it signals more risk but because it crowds out a feeling of civic duty. Once monetary rewards are introduced, respondents are less likely to view siting acceptance as related to civic duty and less likely to accept the facility. Respondents viewed compensation as bribes to be rejected (though note that rejecting compensation in votes or surveys is relatively costless, compared to rejected compensation in actual market settings). If a proposed siting process was seen as fair by respondents, they were more likely to accept the facility. Research by Renn, Webler, and Kastenholz (1996) on siting of a Swiss landfill showed via focus groups that notions of fair siting involved considerations of the amount of waste generated in an area, whether an area was already exposed to hazardous facility, and the need to prevent unacceptable levels of risk.

A different assessment emerges in research on the role of compensation in siting in Japan. Lesbirel (1998) examines the siting of energy plants in Japan and finds that compensation packages facilitated the siting of these facilities. Lesbirel notes that the Ministry of International Trade and Industry (MITI) has set up structures to facilitate bargaining between utilities and community interests, that adjacent areas to locations are involved in negotiations, that risk mitigation strategies are pursued, and that powerful fishing cooperatives are able to strike bargains with prospective plants. Broadbent (1998) examines the general impact of protest on environmental politics in Japan and finds that national party politics, bureaucratic constraints, the influence of big business interests, and (at times) local protest influenced the location of polluting plants and landfills. Kleinhesselink and Rosa (1994) use survey evidence from college students in the United States and Japan to demonstrate the similarities in risk perception across the two countries. In both countries perceptions of the risks from particular sources are governed by characteristics such as the degree the risk is seen as involuntary or infrequent. They note that the Japanese respondents (p. 116) "rated the technological risks associated with nuclear power as older and risks of which they had individual or scientific knowledge, whereas U.S. students rated these as newer and risks for which they had significantly less individual or scientific knowledge."

Studies of waste siting in Canada stress the role of participation. Fischer (1995) discusses the successful siting of a hazardous waste treatment plant in Alberta and ascribes the final approval to the high level of public participation designed into the process, including an early local plebiscite on accepting the siting, the regional government's provision of funds for the local community to hire experts to help analyze and discuss the plant's impacts, the government's provision of funds once the plant was sited to compensate for infrastructure costs and retain more experts, and the formation of a local committee to advise the facility on community concerns about its operation and review monitoring data. Huitema (1998) reviews studies of hazardous waste disposal facilities in Canada and the U.S. and concludes that voluntary approaches mixed with compensation may be the most effective, though he notes that few new facilities have actually been sited overall, that capacity is underutilized at the sites, that communities outside the host community may left out of the process, and that it is difficult to generate high levels of sustained

public participation. Baxter, Eyles, and Elliott (1999) analyze landfill siting in Canada and note that environmental suitability and community control played much larger roles in the siting procedures than equity considerations, that considerations of fair procedure were often crowded out, and that the importance attached to public participation meant that some (p. 520) "residents were successful in their opposition to the siting process in part because they had the financial and educational means to mount sophisticated opposition ... ."

Explanations for siting difficulties are also the topic of research in many European countries. Linnerooth-Bayer and Fitzgerald (1996) found in a survey of 111 residents of Lower Austria that there are wide variations in what concepts fairness in siting, with support for hierarchical, market, and lottery approaches among some segments of the population. They note (p. 6):

> When the respondents were asked if they would disregard all features of the host communities (whether they are already burdened by other industrial hazards, whether they are poor and vulnerable, whether they have benefitted from industrial production, etc.) if experts reported that the proposed site was technically superior or posed the lowest overall risk to the public, 53% of the respondents answered positively (and 70% of the industrial experts). This shows remarkable deference to expert authority and an acceptance of Austrian hierarchical political procedures ... .

Schneider and Renn (1999) describe how a structured discussion process involving ten groups of citizens was used to elicit rankings of sites for waste facilities in the Northern Black Forest Region of Germany, though the political process ultimately did not draw upon the reports written. Gaussier (2001) analyzes the actual location of garbage dumps in the Provence-Alpes-Cote d'Azur region of France and demonstrates the influence of transportation costs and NIMBY forces on the spatial distribution of dumps. Sjoberg, Viklund, and Truedsson (1999) describe how debates in Sweden at the municipal level over the desirabilty of initiating a feasibility study in a given municipality for siting a national high-level nuclear waste repository often focus on the benefits and costs of the repository rather than of the study. In terms of jobs brought by a future repository, they note (p. 5):

> ... unemployment, while certainly unpleasant, is not economically disastrous in Sweden. The social welfare benefits are generous. ... The jobs promised at a repository are in a rather distant future and may not be, in themselves, very attractive to the young people of today who would be the ones to get them.

Vari (1996) conducted 24 interviews with individuals involved in a disputed siting in Hungary of a low-level radioactive waste facility and found that perceptions of fairness depended in part on questions about whether those who generate waste bear its risks and a desire to avoid targeting of those who are economically or socially disadvantaged. Snary (2002) finds that the public participation process involved in the potential siting of a waste-to-energy incinerator in Portsmouth, Hampshire, UK was flawed in part because participants were directed to focus on technical questions rather than broader waste management issues. Coenen (1998) describes how the process of participation in "green planning" at the national and province level in the Netherlands can lead to improved decisionmaking about pollution because of communication and learning sparked by the planning process.

4.0 Siting Policies and Environmental Equity

4.1 General Siting Policies for Hazardous Waste Facilities in the United States

The difficulties associated with siting commercial hazardous waste TSDs in the U.S. has in part generated large literatures on theories of siting noxious facilities (Sullivan 1990, 1992, Gregory et al. 1991, Swallow, Opaluch, and Weaver 1992, O'Sullivan 1993, Ingberman 1995, Fredriksson 1998, Quah and Tan

1998, Lejano and Davos 2002, Minehart and Neeman 2002, Waehrer 2002) and on lessons learned from attempts to locate NIMBY projects (O'Hare and Sanderson 1992, Gerrard 1994, 1997, Wheeler 1994, Miranda, Miller, Jacobs 2000, Richman 2001, . Understanding the potential role for equity concerns to play in siting policies entails an understanding of how siting practices and the siting literature evolved in the U.S. and the limitations evident in siting procedures.

Facilities that process hazardous waste attracted growing attention during the 1980s from environmentalists, state legislators, and academics. Incidents of chemical contamination such as the highly publicized unraveling of a dump site in Love Canal, New York and the abandonment of an entire town because of dioxin exposure in Times Beach, Missouri raised public awareness of dangers posed by hazardous waste and increased scrutiny of facilities dealing with such waste. Legislation such as the Resource Conservation and Recovery Act of 1976, which established cradle to grave monitoring of hazardous wastes, and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, which established the Superfund ex post liability system for cleaning up waste sites, marked the beginning of an era of more stringent regulation. Attempts to site new facilities to treat, store, or dispose of hazardous wastes (TSDs), however, were often halted by public opposition. Public hearings during the permitting process for these facilities became a forum for debate over potential adverse impacts: groundwater contamination from accidental releases; airborne contamination from spills and incineration of wastes; noise and odors from plant operation and traffic; and threats to neighborhood property values. A survey of state hazardous waste officials in 1987 noted that nearly half of the commercial facilities that were rejected were stopped by public opposition (Mason 1989). The gridlock in siting led to continual revision of state laws governing location of such "locally undesirable land uses" (LULUS). By 1988, 41 states had enacted specific laws dealing with the siting of hazardous waste facilities (National Governors' Association, 1989). During the same period, legal scholars, economists, and political scientists produced models aimed at breaking the siting impasse and easing the location of facilities that entailed concentrated costs and dispersed benefits (see Morell and Magorian 1982, O'Hare, Bacow, and Sanderson 1983).

The "Coase theorem" offers a framework for understanding both the details of state siting laws and the design of academic siting models. Coase focused on the relationship between property rights and externalities in his seminal 1960 article "The Problem of Social Cost" (often referred to as Coase II, to distinguish it from an earlier influential 1937 piece, "The Nature of the Firm" (hereafter referred to as Coase I)). He noted that in a world of zero transaction costs, property rights would be fully defined, contracts could be costlessly negotiated and enforced, and trades would be easily consummated so that resources would flow to their highest valued use. In this model, the definition of property rights leads to a market for pollution. If individuals in a community enjoyed the right to be free from pollution, then a firm such as a hazardous waste facility that generated externalities would consider the impact of its location on communities. The firm would end up locating, ceteris paribus, where its environmental damage would be the least because that is where the compensation for pollution it would have to pay affected communities would be the lowest. The market for pollution rights, where either individuals enjoy the right to be free from pollution and must be compensated by firms or firms possess the right to pollute and must be paid by affected neighbors to restrict their pollution, creates a market for the location of polluting facilities.

State laws adopted during the 1980s that dealt with siting hazardous waste facilities were often viewed as establishing markets for locating these facilities. Though the statutes varied in format, the basic provisions involved defining the specific property rights of facility operators, affected communities, and state and local governments. The statutes were interpreted as facilitating negotiations in a world where transaction costs did matter. Explicit compensation mechanisms were established, so that a locality targeted for a facility would be able to extract some compensation for hosting a facility. Technical assistance grants were provided to communities so that they could conduct their own studies to determine risks posed by a facility. Public hearings were designed to educate potential neighbors, who would then

negotiate based on information about particular operations at the proposed facility. Some states even considered the spillover effects on communities close to the community with the facility, so that some compensation would be paid to areas which did not enjoy the larger compensation package which came with hosting a facility but did bear some additional risk because of the transportation of waste through their area.

Academic models of the siting process generally recommended making the market elements of siting mechanisms even more explicit. Many proposals for breaking the NIMBY gridlock in siting unwanted facilities involved auctions in which communities submitted bids to receive compensation for hosting a hazardous waste facilities. Though the formats of the proposed auctions differed, economists and political scientists who made these recommendations generally focused on the siting problem as an exercise in demand revelation, i.e., in determining the demand for environmental amenities across communities. The community was generally the unit of observation, though sometimes individual preferences were also aggregated within each community through procedures such as referenda on siting compensation. The models stressed that if a community's rights to compensation were well-defined and firms had to pay compensation through a system such as a auction for the right to locate in an particular community, then a firm could end up choosing to locate where citizens place a lower value on the environmental risks posed by the facility's operation. In the models, clearer property rights and an auction system would lead to the Coasian solution.

Despite the attention devoted by legislators and scholars to resolving locational conflicts, few commercial hazardous waste facilities were sited under the newly revised laws. Models and statutes that view the location of a hazardous waste facility as an exercise in auctioning a facility among communities focus on one strand of the law and economics literature (Coase II) while ignoring other insights from this literature. Specifically, lessons from at least four separate literatures are useful in understanding the current regime of U.S. siting laws: Coase's early work on the firm versus the market (Coase I); the theories of collective action; evidence on the psychology and political economy of risk perception; and the positive political theory of institutions. These disparate literatures in law, economics, and political science offer explanations of why previous understandings of siting statutes and previous versions of siting models are inadequate and, in part, unlikely to succeed as long as they are based primarily on establishing a "market" for locally noxious facilities.

One key to understanding the design of the current siting literature is to see how the evolution of siting statutes parallels the discussion of institutional design in Coase I.. In "The Nature of the Firm," Coase determined that whether a decision would be made within a firm or through the marketplace depended on the relative transaction costs of using the particular mode of operation. If the centralized decisionmaking power that constitutes a firm can reach a decision more easily because of transaction costs of market exchange, then the production step will take place within the firm. The evolution of decisionmaking power about siting hazardous waste facilities shows a shift from market to firm, a shift associated with a rise in transaction costs. In the era of less intense scrutiny of hazardous wastes, firms that treated hazardous substances enjoyed the right to locate freely within the constraints imposed by local zoning ordinances. As local opposition to such facilities increased with heightened perceptions of hazards, however, the operation of the "market" for location broke down as protests, zoning battles, and litigation slowed the siting of hazardous waste facilities. These siting battles led state legislatures in the U.S. to clarify and redefine property rights involving facility location. Some of the states adopted provisions which did attempt to establish a market in siting through better definition of the rights of the parties involved, a solution in the spirit of Coase II. But some legislatures opted instead to create a decisionmaking process similar to that of a firm to site LULUs such as hazardous waste facilities. Ultimate authority to site a facility was given to the state, or the state was given the right to override local attempts to block a facility. At times this use of centralized decisionmaking was supplemented by a process that would elicit preferences within communities about proposed siting, much like firms may

attempt to use market-like mechanisms internally to establish the appropriate transfer prices in production decisions. Whether the state actually possesses sufficient centralized decisionmaking power to overrule a locality and place a facility where it is not wanted is an empirical question. The important point in understanding the legislation that emerged to deal with the siting gridlock, however, is that it was not necessarily trying to establish a market in well-defined pollution rights across communities (Coase II). State laws are better understood as designed to make a decision (where to locate a facility) given a set of transaction costs that may vary by state, with some states choosing a system that resembles a market and some states choosing a mechanism that resembles a firm in its reliance on centralized authority to select a site.

Theories of collective action provide offer another set of qualifications to current siting statutes and models, which generally treat "the community" as the relevant unit of observation in siting disputes. In legislation, compensation schemes are often based on negotiations between the elected officials of a locality and developers. In academic models, auctions are conducted where a "community" names its compensation fee for accepting a facility, though the details of arriving at such a figure are often ignored or are seen as a preference revelation problem. Yet Mancur Olson (1965) pointed out long ago the dangers of equating group interests with group action. Current models assume that compensation demands expressed by communities vary only because of the individuals' differences in valuing environmental risks and willingness to pay for the environment. Often, however, individuals will vary in the degree that they are able to overcome freerider problems and engage in collective action. If communities vary in the degree that they engage in the collective action necessary to force a locating firm to pay compensation, then facilities which generate externalities will choose to locate where the expressed compensation demands are the least (ceteris paribus). Further complications arise when one considers the principal-agent relationships in models where elected representatives announce the compensation figures. Depending on the strength of monitoring by the electorate and the state of local political competition, the compensation figures announced by elected representatives may or may not relate to the preferences of affected constituents. Compensation may flow directly to representatives, to representatives' favored constituents, or to those put at risk by the facility. The "community" affected by a facility is often viewed as those residents whose activities are physically affected by the potential operation of the facility, for it is their "use value" of the environment that is threatened. Individuals also have existence values and bequest motives over the environment, however, which means that affected parties who may be active in siting disputes also include those people who place a value on knowing that the environment is undisturbed by the risks of such a facility and those who wish to transfer an environment to future generations that does not entail the risks posed by such facilities. Thus the theories of collective action indicate the importance of starting the modeling process and statutory design with individuals rather than "the community" as the basic unit of observation.

The literature on risk perception provides a third set of qualifications to the market models of locating hazardous waste facilities, which generally are based on an expected utility framework where individuals' preferences over facility siting are driven by expected values for outcomes calculated from the available information about a facility's risk. Many of the siting statutes provide for public education programs to inform citizens about the risks associated with particular technologies. State officials often view part of the NIMBY gridlock as arising from a tendency of environmentalists' and citizens' perceived risks to outrun the actual risks posed by facility operations. This ignores, however, the fact that most citizens will remain rationally ignorant of hazardous waste policy and that risk regulation policies are more likely to be driven by perceived risks than actual risks. Noll and Krier (1990) have assembled the evidence from cognitive psychology about behavior that indicates risk perceptions may diverge from the expected utility model: individuals reason by relating situations to previous experiences (representativeness heuristic); valuations are determined by how a choice is presented (framing effect); estimates of probabilities are influenced by whether a similar event readily comes to mind (availability heuristic); people act as if they believe small-probability events are more likely than their own beliefs would suggest; and people have preferences over

how probabilities arise. The implications for siting a hazardous waste facility are that public reactions to a facility will not simply be based on the risk analyses presented for an individual facility's technology. Acceptance of the facility will in part be path dependent, in that previous experiences with similar technologies will drive assessments of newly proposed facilities. Assessments of the dangers posed may depend on general world views of participants (e.g., their interpretations of past experiences with the ability of market incentives and regulatory scrutiny to affect corporate health and safety decisions). Participants in siting battles will also react to how probabilities are generated, e.g., what process ultimately results in the expected outcomes at particular facilities.

The positive political theory of institutions also provides insights for understanding the operation of siting statutes and the design of siting models. Discussion of the decisionmaking procedures used to select a site often portray the design of the procedure itself as a question of how to incorporate scientific criteria into the process so that the "best" site is chosen. Positive political theory, however, implies that just as legislators have preferences over the outcomes of siting battles they will have explicit preferences over the types of institutional designs likely to lead to particular outcomes. Legislators who wish for a facility to be sited may attempt to delegate the decision to a separate board and raise the transaction costs of overturning the board's decision, an exercise in blame-shifting (to the delegated decisionmakers) and in commitment strategy (the costs of overturning a decision may make future legislative intervention less likely). Though it is often assumed that legislators make decisions about siting procedures behind a veil of ignorance that hides whose districts may be likely candidates, some legislators will have general preferences over whether any facility is sited and thus preferences over particular features of the siting procedures. Those concerned with discouraging siting may include substantial public participation requirements that provide activists with the ability to use litigation to halt siting activity, while those concerned with facilitating location may provide the state siting authority with the ability to override local objections to a facility. Separate from the outcomes likely with a particular decisionmaking process, individuals may also have preferences over such elements as whether a process is fair, open, and incorporates public participation. Preferences over procedure allow opponents of facilities to combine multiple issues into opposition to a facility, so that the debates are framed both in terms of risks posed by technology and the fairness of procedures used to narrow down possible sites. Though discussions of siting laws often proceed as if goal were to site a facility, the positive theory of institutions offers warnings on how preferences over outcomes can map backwards into preferences over the design of institutions and how people may value the details of institutions because they relate to broader notions of democracy, participation, and equity.

In 1977 three states in the US had statutes that dealt with the siting of hazardous waste facilities; by 1988, forty-one states had passed such laws. The evolution of these laws demonstrate how more resources are devoted to structuring property rights as the returns to well-specified rights in a given area increase. While plants such as commercial hazardous waste facilities have always generated nuisances such as odors and truck traffic, vehement opposition to such facilities did not coalesce around most proposed sitings until the later part of the 1970s and the early 1980s. Few new facilities that treated hazardous waste generated at another site (e.g. commercial facilities) were sited in the 1980s, according to the permit data for the facilities in an EPA survey of hazardous waste TSDs (Hamilton 1993). Demand for offsite waste treatment increased as more wastes were declared hazardous under federal legislation and companies that treated waste onsite were subject to strict regulatory scrutiny. Yet public opposition to commercial facilities led to siting gridlocks. Environmentalists used local zoning power to halt attempted sitings across the country, buttressed by additional litigation over whether proposed facilities violated environmental statutes. Against this background of public protest, state legislatures passed laws specifically detailing the procedures governing the siting of hazardous waste facilities. These laws spelled out with clarity the property rights of developers, localities, and state government in terms of the power to initiate sitings, compensate affected localities, and finalize the location of a particular facility. This marked a shift in the previous siting method that was often referred to as the "Decide-Announce-Defend" model in which

developers simply attempted to place the facility in a given locality without an extended public selection process.

Academic articles and models written during this period concentrated on breaking siting impasses through compensation mechanisms aimed at reducing local opposition. These models typically used the community as the unit of observation and proposed siting mechanisms that involved communities submitting compensation bids in an auction for siting a facility. The community with the lowest compensation figure announced or submitted would be the host to the facility. The details of the auctions varied, including sealed-bid auctions in which communities submitted a compensation figure, a reverse Dutch auction in which the first community to accept a declared compensation package would "win" the facility, and public referenda in which citizens would vote on particular compensation packages. A common thread throughout these models is the focus on siting battles as a demand revelation problem, e.g., how can the facility operator or state government determine which community places the lowest value on the potential environmental risks and would demand the least compensation for hosting a hazardous waste facility.

These siting models differed in whether they emphasized strategic factors in securing approval for a facility, equity considerations in the distributional impact, or efficiency in matching a plant with an area which demanded the lowest compensation for its externalities. Works by O'Hare and others (1977, 1983) emphasized how compensation mechanisms could contribute to the probability of successfully siting a facility with concentrated costs and diffuse benefits. These models focused not on questions of efficiency but on how to overcome local opposition. Methods for securing local support for a noxious facility included a community referendum on a single proposed compensation offer from a developer, a vote on different bids, or the use of the existing political structure such as the town government to negotiate on behalf of the affected community. These models also stress the equity considerations of compensating residents whose health and safety are threatened by the operation of a facility or who experience economic losses such as property value declines because of externalities generated by the locating firm. Compensation thus becomes a method of sharing the benefits generated by the facility with those experiencing the costs. Sullivan (1990) has explored the interaction between equity and efficiency considerations in the design of compensation mechanisms. He notes that if victims are in part compensated for their exposure to pollution then they may be less likely to take averting actions and explores the conditions under which these schemes may make residents less likely to locate away from polluting facilities.

A third type of compensation model emphasizes the use of an auction process as an instrument to reveal where the facility's externalities will result in lower disamenities. Models by Kunreuther and coauthors (1986, 1987) approach the NIMBY process as a demand revelation process in which the challenge is to structure an auction that will cause communities to reveal truthfully the compensation they would demand for receiving a facility. These models are in the tradition of public finance mechanism that attempt to elicit true preferences for public goods. An auction process is designed is which a community submits the payment it would demand to be a host site, the community with the lowest bid wins, and other communities pay it compensation based on their submitted bids. The community is the unit of observation, although the authors point out that if one views individuals' preferences in each community as quasilinear in site value and income than one can view the community's bids as aggregations of residents' willingness to accept compensation figures. Though the auction process is typically described as a sealed-bidding process, Inhaber (1992) proposes a "reverse Dutch" auction in which the government would announce a figure that would increase over time that would be paid to compensate a host community. The first community to accept the proffered compensation package would end up with the facility.

Discussion of these siting statutes and models often centers on the creation of a "market" for the location of hazardous waste facilities. The notion is that if property rights are well-defined then the

operation of the market will lead a firm to locate where its risks involve the lowest compensation to affected neighbors. Some siting articles explicitly cite Coase II as evidence that if property rights can be specified better than the siting gridlock can be eased. Mitchell and Carson (1986) state that the often ambiguous nature of property rights in siting disputes results in protracted disputes; they recommend that a community be given the explicit right to refuse a proposed siting through a referendum process in which residents would vote on a proposed compensation package. They point out that if each individual in the community had the right to block sitings then the transaction costs of negotiating with the developer of a facility could be prohibitive. Bacow and Milkey (1982) point to the compensation negotiations provided for in the Massachusetts siting statute as evidence that Coasian transactions can be facilitated through the explicit arrangement of property rights. They say that the Massachusetts process where developers negotiation compensation with potentially affected communities is "more efficient because developers must consider the full social cost when choosing where to site a facility."

The evolution and details of the state siting laws, however, are also consistent with Coase's earlier article, "The Nature of the Firm." In that work Coase points out that whether a particular production decision is made within the firm or across a market will depend on the transaction costs of using one method of organization versus another. When costs of negotiation and contract enforcement in a market are high relative to the costs of internal production, then a good will be produced within a firm. Numerous factors associated with negotiating compensation contracts between a community and a developer make such agreements costly to arrive at: the problem of how elected officials can bind their successors to honor particular agreements; the possibility that disgruntled residents within the community or environmental groups outside the community may attempt to use legal means to delay construction even after community officials have reached an agreement; the difficulty of specifying exact payments dependent on environmental outcomes, especially since a firm may be bankrupted by adverse outcomes; and the danger that explicit compensation contracts will be interpreted as bribes by residents. The key advantage of using a firm-like structure to make the production decision is that the use of centralized decisionmaking authority reduces the problems of breach and holdup that are associated with incomplete contracts in a market.

The changes in siting regimes for hazardous waste facilities are consistent with Coase's insight about the relative transaction costs of different institutional arrangements. In an era when the perceived risks of waste handling were low, firms that operated hazardous waste facilities were free to site their facilities within the normal constraints on the market for industrial location imposed by zoning. As public opposition mounted, however, negotiations over siting became increasingly protracted and expensive. The transaction costs of siting battles became a weapon used by environmentalists to raise the costs of location to firms. State legislatures responded to a perceived need to increase available treatment capacity by drafting laws that explicitly dealt with siting of hazardous waste TSDs. Though the laws across states were similar in that they attempted to specify the particular property rights of developers, localities, and state government, they varied in the degree that they left the location decision to institutions that resembled a market versus a firm (National Governors' Association, 1989). States that adopted a market model typically left the initiation of siting to a private developer, specified a process of explicit negotiation between the developer of the facility and the targeted community, and provided for compensation mechanisms that transferred payments to affected localities. In a 1988 National Governors' Association survey of state siting regimes, at least 13 of the states had laws that mandated the provision of compensation to host communities. Compensation took various forms, including a tax on gross receipts at the facility whose proceeds went to the locality, per ton tipping fees that went to the community, license fees, or general compensation packages that included money and inkind contributions of goods and services. Twenty-two states had programs that entailed direct negotiations between developers and communities affected by proposed facilities. Sixteen states provided technical assistance grants to allow communities selected as potential sites to develop the expertise and information necessary to participate in negotiations over siting.

Other states relied on a siting process that resembled a firm's decisionmaking process in reliance on centralized decisionmaking power to ultimately determine the location of the facility. In 11 states, the state itself had authority to initiate the siting process for a new hazardous waste facility. Fourteen states gave their state governments preemption power, where the state essentially preempts the delegated zoning power of localities in this case and simply makes the siting decision. In this process, the state assumes zoning power and excludes the targeted community from the decisionmaking process. The NGA study found that twenty-two states provided state government with override power, so that state agency or board could override a local decision that attempted to block a siting. The state would not initiate the siting, but the threat of using state power remained in background so that it could be used to resolve siting disputes. Note that even where the firm model was adopted, often provisions for negotiation with community and compensation were included in the siting statute. Local representatives from affected communities, may be provided with membership on state siting boards. Such procedures are similar to mechanisms within a firm that help establish "transfer prices" for internal transaction. Though the location decision has been moved within a central decisionmaking authority (in this case a state agency or board with ultimate decisionmaking power), there is still a need to elicit information on how communities vary in the value they place on environmental amenities.

Statutes that provide a state agency or board with preemption or override power are attempts to solve the NIMBY gridlock by creating a firm-like structure in which centralized decisionmaking power makes the resource allocation decision, i.e., where should the facility be located. It remains an empirical question, however, whether such decisionmaking power can be effectively exercised. For even if the state nominally has the right to locate a facility in an area where opposition runs deep, local governments may possess sufficient power to frustrate the developer and the state so that the attempt is ultimately unsuccessful. Local governments determined to block a siting have used police powers to slow traffic to sites to a standstill, disrupted roads leading into facilities for long-term construction, and established zoning requirements that generate further litigation. Environmentalists have also been successful in appealing to state legislatures to remove sites selected by agencies from consideration once they are targeted. In at least one state, the backlash against a siting process directed by a state commission caused the legislature to halt all funding for the commission. The leverage of local governments and possibility for appeal back to state legislatures thus weaken the actual exercise of "centralized" decisionmaking power in states with preemption and override provisions. Morell and Magorian captured the essence of this operation of siting mechanisms in their book title *Siting Hazardous Waste Facilities: Local Opposition and the Myth of Preemption*. Bacow and Milkey have also pointed out that a state's use of preemption power may simply lead facility opponents to turn to litigation to slow construction of a facility.

No one configuration of property rights has become dominant across states or proved successful in facilitating the siting of commercial hazardous waste facilities. Most of the models of the siting process emphasize the use of market mechanisms such as auctions to solve the problem of determining where facilities will elicit the lowest demand for compensation. Discussions of the siting laws that have clarified property rights in this area often assume that the definition of property rights is the same thing as the establishment of a market for location of facilities, a market where firms internalize their externalities in the manner described in Coase II, "The Problem of Social Cost." Yet a review of the siting statutes reveals that the procedures employed resemble both the arm's length transactions of a market and the centralized decisionmaking power of the firm. Coase still provides insight into the structure of these laws, but it is the insight from Coase I that relative transaction costs determine the institutional framework used for making a decision that explains the evolution of siting laws.

To see how siting progressed after the debate in the academic literature and state legislatures over effective procedures, Ibitayo and Pijawka (1999) conducted a national survey of state environmental agencies to analyze the siting of hazardous waste facilities over the previous decade. For the 42 states responding, they found five states had successfully sited hazardous waste facilities, 12 states had mounted

efforts that did not work, 13 had ongoing siting processes, and 12 had not attempted to site such facilities. Contrasting the procedures in the five states with successful sitings with the efforts of other states, they conclude (p. 387):

The success of any strategy depends on the extent to which the strategy deals with issues such as public trust, early and continuous public involvement in the siting process, public education on hazardous waste, empowerment of host communities, and the incorporation of citizens' concerns into risk mitigation plans.

4.2 General Siting Policies for Hazardous Waste Facilities in Other OECD Countries

The concentrated costs and generally diffuse benefits of facilities that treat and dispose of hazardous waste have made their sitings controversial and relatively rare recently in most OECD countries. The literature on siting policies generally focuses on case studies within a given country and assessments by the authors of what factors led to siting success or failure in a particular case. The successful sitings of hazardous waste facilities in the Canadian provinces of Alberta and Manitoba have generated much research (Rabe 1994, Castle and Munton, 1996, Richards 1996). The voluntary siting process used there involved the stages of an expression of local interest by a community, hosting of open houses to discuss the facility with residents, creation of local citizen advisory committees funded by the proponent to investigate the process and plant, a referendum on the proposal, and a negotiation stage where facility operation issues and local input are discussed. This gives a community multiple points to veto a project. In terms of the socioeconomic characteristics of the two towns (Swan Hills and Montcalm) that accepted facilities, Castle and Munton note (p. 78):

> The evidence to support the argument that the Alberta or Manitoba volunteer siting process singled out poor or otherwise disadvantaged communities to host hazardous waste treatment facilities seems ... lacking. ... The town of Swan Hills had an average household income of $44,023 in 1986, significantly higher than the Alberta norm ($36,796). Unemployment in Swan Hills in 1986 was 7%, one of the lowest in the province. Montcalm is much poorer than Swan Hills, but the community is not economically disadvantaged compared to other rural areas in Manitoba.

The jobs associated with the plants were a considerable factor in public acceptance. In the case of Swan Hills, a town of approximately 2,000 residents, a "1991 report concluded that the facility provides more than ninety full-time jobs in Swan Hills that contribute $2.7 million a year to the local economy in salaries and makes an overall impact of $6 million on the economy each year" (Rabe, p. 76.). Additionally, proponents in Alberta stressed that the waste would come primarily from within the province so that the siting was seen as solving a local problem rather than creating a outlet for waste from across the country. Additional research on siting waste facilities (Lawrence 1996) and toxic disposal facilities (Ristoratore 1987, Richards 1996) in Canada analyzes the use of voluntary process, the role of compensation or jobs in generating support, and the importance of ensuring a minimum level of safety in the operation of facilities.

Research on hazardous waste facility siting in European countries reveals wide variety in public participation and reaction. Linnerooth-Bayer (1997) notes that survey evidence from Austria indicates multiple views on fairness in siting, with some stressing support for hierarchical processes based on expert opinion, others favoring market mechanisms, a segment objecting on distributive justice grounds to siting in economically or socially disadvantaged communities, and others believing in spreading the burdens of waste management broadly across communities. Lidskog (1993) emphasizes the role that economic benefits played in leading a local government to host a disposal facility in Sweden. Seeliger (1996) examines four case studies of siting waste facilities in Germany and stresses the large role of state governments in initiating the siting process and the experimentation with public consultation in more

recent policies. Describing the lack of opposition in one neighborhood hosting an incinerator, he notes (p. 241):

> The GSB facility is located not in the town of Ebenhausen itself but a subsection called Ebenhausen-Werk ... Ebenhausen-Werk is about a kilometer from the town proper, and home to a working-class population of 400-500, of low social status. The proportion of foreign and migrant workers living in Ebenhausen-Werk is also said to be high ... . It is possible that this social setting is not conducive to the emergence of a local environmental initiative.

Analyzing lessons from siting disputes in Europe overall, Kunreuther, Linnerooth-Bayer, and Fitzgerald (1996) describe variations in siting policies by two main characteristics, the degree that the process is open versus closed to public participation and the degree decisionmaking authority rests with the local community versus the national/state government or developer. They note examples of efforts taken to increase public support for proposed facilities, such as the case in Austria where local citizens were involved with the selection of experts chosen to assess risks from a facility and use of substantial compensation (i.e., a promise of 2.5 million Swiss francs for 25 years for a town of 500 households) in the siting of an underground nuclear waste repository in Switzerland.

Dente, Fareri, and Ligteringen (1998) review successful sitings of waste facilities in France, Hungary, Italy, the Netherlands, Slovenia, Spain, and Switzerland. Their findings emphasize that many factors related to equity are involved in the siting of facilities in these European countries. In areas with higher unemployment rates, residents appear more likely to accept facilities because of the employment opportunities provided. In successful sitings those trying to locate the plants are more likely to succeed if they can transform the debate from a zero sum game in which one area gains and another loses to a situation where compensation in some form comes along with the risks of a facility. The distance the waste travels appears to matter to residents, for if the waste is seen as local then disposal is interpreted as more equitable. Fewer communities appear willing to accept waste generated far away. Siting attempts overall worked more easily in industrial areas for at least three reasons: the waste is seen as local; residents are more likely to work in plants generating the waste; and residents are used to the risks posed by industrial pollution. A final equity consideration emerges in the design of the siting process, with procedures involving more public participation being seen as more equitable.

Huitema (2002) develops in depth three case studies of hazardous waste siting attempts in each of three different countries: Canada, the Netherlands, and the United Kingdom. In terms of procedure, he finds all three countries provide an increasing role for citizen participation, though this does not overwhelm the prominent roles played by experts and elected officials. Environmental impact assessments are now common elements of siting in each country. Overall the market plays a greater role in sitings in the UK and Canada and a lesser role in the Netherlands. Huitema notes that there are distinct procedural differences across the three countries, differences which may help explain outcomes in sitings. In the Netherlands siting disputes are much more likely to spill over into the courts. In the UK the inquiry system (a quasi-judicial investigation procedure) generates substantial dialogue about siting issues, though Huitema finds overall that regulations in the UK are likely to limit the ability of government to block the actions of private developers. Looking across the three countries he concludes that debates about siting are more likely to involve notions of managerialism (e.g., importance of experts) and conservative pluralism (e.g., right of private parties to pursue development) than ideas of distributive equity.

Research on Japan notes the role of rewards used in the siting process. Shaw (1996) describes how laws in Japan smoothed the siting of power plants by providing communities with compensation without having to prove damages. Electricity is taxed, and the revenues are redistributed to local communities in the form of expenditures on public facilities such as roads, schools, or sewage systems. Ohkawara (1999) discusses compensation in the case of siting of nuclear power plants. Munton (1996) reviews the siting of

hazardous waste facilities in Japan and notes problems similar to that found in the US: NIMBY opposition to construction, declining capacity, and illegal dumping. Attempts to overcome opposition to siting included a policy of offering side payments to communities, which would receive public works projects from the national government in return for hosting a treatment facility.

Probst and Beierle (1999) stress how facility operation is embedded in a larger regulatory structure affecting hazardous waste generation and management. They examine hazardous waste management systems in Germany, Denmark, United States, Canada, Malaysia, Hong Kong, Thailand, and Indonesia. Their results stress the time needed to establish a comprehensive system to regulate waste, the need to create a culture of compliance, and the expense of constructing hazardous waste treatment facilities. To encourage the development of treatment capacity, the countries studied had tried a range of ownership for the facilities (e.g., public, private, mixed). Initial subsidies from some governments encouraged generators to use the facilities, a step in creating compliance with hazardous waste management.

A substantial legal and policy literature exists on international trade and hazardous waste (see Enger et al. 1991, Walsh 1992, Murphy 1994, Pinzon 1994, Kummer 1995, Marbug 1995, Bradford 1997, Sundram 1997, OECD 1998, Park 1998, Belenky 1999, Verchick 1999, O'Neill 2000, and Waugh 2000). Part of this literature focuses on notions of fairness in the export of waste and risks across borders. Lofstedt (1996) analyzes the literal spillover of risks across borders in the case of a nuclear power plant in Sweden sited close to the border with Denmark. Explicit consideration of the impact of siting on risk exposure by income or ethnicity is less prevalent in much of the European literature, though Johnson (2001) notes that analysis of such disparities is growing as more detailed information on pollution incidence becomes available in OECD countries. A European Commission March 1997 Council Directive on environmental impact assessment does specifically encourage the analysis of how waste disposal installations dealing with hazardous waste will affect the environment. The European Commission (2001) has also encouraged greater use of public participation mechanisms in environmental decisionmaking.

4.3 Incorporating Environmental Equity Considerations into Siting– US Perspective

In 1994 President Clinton issued Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," which required federal agencies to create environmental justice strategies and examine whether their policies have disproportionate impacts on minority or low-income populations. In response to this order, the EPA began to develop guidance documents to incorporate environmental equity considerations into government decisonmaking. The EPA's Administrator, Christine Todd Whitman, noted in 2001 that the agency's program includes:

a) Conducting our programs, policies, and activities that substantially affect human health and the environment in a manner that ensures the fair treatment of all people, including minority populations and/or low income populations;

b) Ensuring equal enforcement of protective environmental laws for all people, including minority populations and/or low-income populations;

c) Ensuring greater public participation in the Agency's development and implementation of environmental regulations and policies; and

d) Improving research and data collection for Agency programs relating to the health of, and the environment of all people, including minority populations and/or low-income populations.

The agency's efforts to define and implement environmental equity have attracted significant legal research (see Georges 1999, Johnson 1999, Mank 1999, Foster 2002, Yang 2002). Yet the number of permitting or enforcement actions specifically taken on environmental justice concerns is so small that to

date no statistical investigations have analyzed the agency's implementation. In the most famous case to date, the transaction costs generated by the EPA's environmental justice investigation of the Shintech plant in part led the company to shift the plant's proposed location from a predominantly African-American community to a white community (see Lambert 2000). The EPA's consideration of environmental justice concerns in permitting facilities (see EPA 2000) has generated controversy among industry participants concerned about the freedom to locate facilities, officials in economically depressed areas who want to attract plants to stimulate the economy, and activists concerned that the EPA's consideration of disparate impacts will not alter the location and operation of polluting facilities. The greatest lessons to date for considering equity in the siting of hazardous waste facilities may lie in examining two sets of environmental equity guidance instructions adopted by the EPA.

Under the National Environmental Policy Act (NEPA), EPA must often create an environmental impact statement (EIS) or environmental assessment (EA) of agency actions. In 1998 the EPA issued its guidance documents for incorporating environmental justice considerations into developing an EIS or EA. The guidance encourages analysts to look at affected populations using detailed census data; take into account how differences in diet might results in different exposure; look for cumulative effects (e.g., what other sources of pollution are already in the area); examine local health outcomes data; be cognizant of local literacy rates, especially when communicating complex risk information; consider occupational exposures; and determine whether community representatives are involved in local decisionmaking. The guidance encourages analysts to use GIS technology to analyze potential exposures. Mitigation measures are also to be incorporated into the analysis, including monitoring of emissions, encouraging participation of affected communities, reducing pollutants to reduce cumulative exposures, and requiring mitigation of pollution as part of a permitting process.

The operations of many environmental regulatory programs are delegated to the states by the EPA, so that state environmental agencies will end up writing permits needed for the construction and operation of polluting facilities. The most controversial EPA environmental equity rules concern the guidance documents issued that define when a permit may be challenged under Title VI of the 1964 Civil Rights Act, which relates to discrimination involving disparate impacts by entities that receive federal funding (such as funding for state environmental programs). These rules have attracted great attention among legal scholars (see Lazarus and Tai 1999, Lyle 2000, Guana 2001, Mank 2000, 2001, Cody 2002, Santiago 2002). The guidance documents set forth what types of evidence the EPA would expect when parties file a civil rights complaint with the EPA about a state or local permitting decision. The guidance states that for evidence of disparate impacts the agency expects detailed information on the exposed population, which may include census data on racial composition in an area, GIS analysis of exposure to pollutants, information on reported chemical releases, monitoring data, and health outcomes information. The guidance notes that the EPA's Office of Civil Rights (OCR) is unlikely to find an adverse health impact when cumulative risks of cancer calculated in the analysis are less than 10^{-6} and much more likely in cases where the cancer risk is 10^{-4} or higher; the higher the noncancer hazard index for a chemical is above one the more likely the OCR is to find an adverse health impact. The rules indicate that in determining whether a plant generates a disparate impact that the comparison population can be the general surrounding population (e.g., city or state) or the non-affected segment of the local population. The guidance documents suggest that a denial of a permit solely on environment justice grounds is unlikely. Rather, if the EPA finds a violation the agency will focus on mitigating the impact of a facility, such as reducing permissible pollution levels or requiring stricter monitoring.

4.4 Conclusions

Statistical studies in the United States suggest that low income and minority populations are often exposed to greater risks arising from the siting and operation of hazardous waste facilities. Less detailed information exists on the exposure of residents by income to hazardous waste risks in other OECD

countries, though the evidence suggests that in some countries disparate exposures may exist by income (in part because of the draw of jobs and compensation programs in siting procedures). Concerns about environmental equity may involve dissatisfaction with disparate exposure or dismay at how these differences arise across demographic groups. Thinking about policies to address environmental equity (see Table 3) requires definitions of equity, an assortment of policy tools that take into account how disparate impacts arise, and a recognition of the prospect that market dynamics may make equity policies hard to implement in the long run.

Consider first how to define a fair siting process. Vicki Been (1993, p. 1008) notes at least seven ways that fair siting is defined: even distribution of NIMBY sites across neighborhoods; compensation to those affected by residents in neighborhoods that do not host facilities; progressive siting, where areas with more income bear more sitings or pay more in damages; equal vetoes by communities to bid in excluding facilities; siting where those who benefit pay the cost; no intentional discrimination against minorities; and a process that shows "equal concern and respect" for all communities. Hampton (1999) adds the complication that concepts of fairness reside in procedures and outcomes, so fair policies may involve meeting standards of participation, information provision, trust in the decisionmaking process, and expression of public values.

The tool box of policy options to promote equity in siting is large. Site permitting could involve an analysis of whether a plant involves a disparate impact on low-income or minority communities, with impact defined by the radius of externalities and risks modeled using GIS technology and information on emissions or adverse health outcomes. If differences in collective action give rise to disparities, authorities may take steps to increase involvement such as technical assistance grants to communities involved in siting, information provision, or attentive enforcement of rules in areas less likely to call upon regulators for help. The process of negotiation in siting and permitting may give rise to mitigation efforts, which may include reductions in emissions or increases in monitoring for ambient exposures. Compensation for siting may come in numerous forms, such as the jobs provided by plants, tax payments that reduce tax burdens in a community, or expenditures on public goods such as roads or schools. If disparate impact arises from racism in housing markets or job market outcomes that limit incomes, then attempts to address discrimination in these markets will provide minority residents with greater freedom to avoid environmental hazards. Greater research on how cumulative risks arise and vary across demographic groups would aid the design of these programs.

At least three problems may arise with equity policies. In the short run some compensation may off-set damages for current residents when a facility is sited. Yet in the long run a facility may generate externalities that end up lowering property values and attracting more low-income residents to an area. These low-income individuals may be willing because of their constrained budgets to accept a larger risk for a lower housing price, though this offends the values of individuals who do not believe environmental quality should be traded like a normal good. A related point is that in some areas poor residents may be willing to accept a facility because of the jobs provided, which again may generate dissatisfaction among those who have preferences about the distribution of risk across demographic groups. If plants are channeled outside of current industrial areas because of equity concerns, this raises the likelihood that new environments will be diminished. In devising environmental equity policies, there are few easy and obvious choices. Selection of programs to pursue environmental equity involve potential tradeoffs between equity and efficiency, across demographic groups, and among values relating to procedures, outcomes, and self-determination.

Box 1: Evidence on the Distribution of Hazardous Waste Facilities

Sample of US Studies

Anderton et al. (1994a, b)
408 census tracts (c. 4,000 residents each) with commercial TSDs had slightly higher percentage poverty than other tracts in nation in 1980. Within top 25 cities, tracts with commercial TSDs do not have statistically significant difference in poverty percentage compared to other tracts in the areas. If one compares 408 tracts with 4,239 tracts within 2.5 miles of facility, tracts closer to plant have higher percentage workers in precision occupations and lower percentage of families in poverty. If one compares the location and nearby tracts (4,647) with other national tracts, the tracts affected by TSDs have higher percentage of families below poverty (19% vs 13%) and lower housing prices ($45,876 vs $60,291). Conclusion: Radius? Reference group?

Atlas (2001)
In 1997 108 commercial TSDs (in sample if accounted for at least .2% managed wastes). For .5 mile ring around facility, mean low income population percentage (150% of poverty level) was 29.6% and 30.4% for 2 mile ring; nationwide 21.7%. On a population weighted basis: 25.9% of residents within .5 mile and 30.4% for 2 mile ring were low income populations.

Hamilton (1995)
Of 207 zip codes with commercial hazardous waste facilities in 1987, 84 areas had plans for expansion in capacity. Mean percentage of families in poverty higher in zips targeted for expansion (14% vs 11%) and average of median household income was lower ($15,750 vs $17,060). Expansion planned in areas with lower populations, more minorities, poorer populations, and less politically active individuals.

Hamilton and Viscusi (1999)
For 1,173 hazardous waste sites being cleaned up under the Superfund program, site-level mean household incomes lower at the one mile ring ($36,930) and four mile ring ($37,690) than national average ($38,450 1990 census). At 61% of sites, mean household income lower in 0-1 ring than 1-4 mile ring. Site-level mean house values for residents within one mile ($98,590) or within four miles ($103,900) were lower than the US mean ($112,660). Also calculated individual cancer risks, expected cancer cases, current land use at 150 sites. Found some evidence that minority groups account for a larger fraction of the estimated cancers than their national population, evidence that population weighted mean maximum individual cancer risk higher for minorities, and strong evidence that minorities bear larger current risks arising from present land uses at sites.

Studies in Other OECD Countries

Friends of the Earth (1999)
Examine postcode location of industrial plants registered under Integrated Pollution Control program and household income distribution by postcode. Find:
"All across England and Wales the poorest families (reporting average household income below 5,000 Pds) are twice as likely to have a polluting factory close by than those with average household incomes over 60,000 Pds. ... Overall, almost two-thirds of the most polluting industrial facilities are to be found in areas of below average income."

Friends of the Earth (2001)
Analyzes distribution of 156 plants in England emitting more than 1,000 kilogrammes of carcinogens in 1999. Found "66% of carcinogen emissions are in the most deprived 10% of wards; 82% of carcinogen

emissions are in the most deprived 20% of wards; only 8% of carcinogen emissions are in the least deprived 50% of wards.
Jerrett, Eyles, Cole, Reader (1997) Examine Canada's National Pollutant Release Inventory. Model county aggregate pollution as function 4 variables: median income per household, average dwelling value, total population, manufacturing employment. All statistically significant, with income, population, and manufacturing positive and housing negative. Harrison and Antweiler (2002) Using Canadian NPRI at facility level, "generally do not find significant impacts of community income on either the current releases or changes in releases over time."

Box 2: Determinants of Exposure to Hazardous Waste Facilities

Sample of US Studies

Hamilton (1993, 1995)
In expansion plans of commercial hazardous waste facilities, zip code areas targeted for expansion had lower voting rates, fewer people, and higher percentage of renters.

Hamilton (1999)
Uses Toxics Release Inventory data to analyze reduction in air carcinogen emissions between 1988 and 1991. Plants reduced emissions more the greater the expected cancers generated by the facility and the higher the voting rate around the plant, a proxy for collective action. Median household income and minority percentage in the zip code were not statistically significant.

Viscusi and Hamilton (1999)
At cleanup of hazardous waste sites, when cancer risks are low more stringent cleanups are chosen if surrounding residents are more politically active. The higher the average income in the 1 mile ring around a site, less stringent cleanup chosen (though this may be because wealthier residents can take more preventive measures on their own). Higher voter turnout at a site, greater cost per cancer case averted implied in EPA cleanup. Income level of residents had no impact on cleanup expenditure levels.

Been and Gupta (1997)
Examined census tract data for 1970, 1980, 1990. Found that when TSDs originally sited they were not located in areas with high concentrations of the poor or African Americans. Locations did have a disproportionate share of Hispanics.

Lambert and Boerner (1997), Pastor, Sadd, Hipp (2001)
Mixed evidence on whether TSDs sited in poor areas originally or whether poor residents moved to areas after plants were located.

Sample studies in other OECD Countries: Surveys and case studies

Frey and Oberholzer-Gee 1996, 1997, Frey, Oberholzer-Gee, Eichenberger 1996
Survey interviews in Switzerland in 1993 before referendum on nuclear waste repositories. Willingness to have repository located in a resident's community declined as perceived risks or negative economic impacts were larger. Compensation offers in the survey reduced willingness to accept the nuclear waste site. Compensation offers can crowd out a feeling of civic duty.

Lesbirel (1998)
Compensation facilitates siting of energy plants in Japan.

Fisher (1995)
Examines successful siting of hazardous waste treatment plant in Alberta, Canada. Ascribes approval to early local plebiscite on accepting siting, regional government's provision of funds for local community to hire experts to analyze plant impacts, government's provision of compensation for infrastructure costs and more experts, and formation of local committee to monitor plant operation.

Numerous case studies in Europe
Emphasize role of compensation, unemployment, public participation in explaining success/failure of siting.

Box 3: Conclusions

How can environmental equity be incorporated in siting policies? Analysis of impact; technical assistance grants to communities to analyze facilities; mitigation efforts, including reductions in pollution or increases in monitoring; compensation mechanisms (e.g., payments for community infrastructure).

Example: In the US, Executive Order requires agencies to incorporate environmental justice considerations (e.g., exposure by race and income) into their policies.

EPA guidance documents on when permit may be challenged on civil rights grounds:

* For evidence on disparate exposure, expect detailed information. Examples would include GIS analysis of census population, potential routes of exposure, monitoring data on cumulative impacts, and health outcomes information.

*Agency unlikely to find adverse health impact if cumulative risks of cancer calculated are less than 10^{-6}, more likely if 10^{-4}.

*Comparison population: general population, or non-affected local population.

*Guidance suggests unlikely EPA would deny permit solely on environmental justice grounds. Rather, agency would focus on reducing pollution levels or requiring stricter monitoring.

Challenges to incorporating equity in siting:
* Residents may accept risks in return for jobs provided by facilities. Policies that steer facilities away from poor/minority areas may discourage development/employment.

* Even if local residents who are poor are willing to accept facility, those outside the area may have existence/bequest motives of justice that hold this tradeoff is unfair. Whose preferences matter more? How incorporate existence values (contingent valuation)? Related point– procedures have intrinsic and instrumental fairness values.

* If compensation is involved in siting, where does it flow? How can you avoid principal-agent problems between representatives and residents in compensation negotiations?

* Will environmental equity policies force more sitings into green fields? Where is marginal damage of plant greater, already polluted area or new environment?

* What are the long-term impacts on the poor of cleaning up an area? Rise in housing prices that causes them to relocate?

These are the types of concerns that make debates over environmental equity difficult to resolve.

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