MAPPING POWER PLANT INEQUALITIES

By

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Abstract: This study seeks to unveil how the siting of nuclear power plants differs from the siting of coal-fired power plants in the United States. More specifically, it addresses how the demographics of surrounding communities differ according to the type of facility, and explores the possible causes of these discrepancies. Utilizing the United States Environmental Protection Agency's Emissions & Generation Resource Integrated Database (eGRID), the locations of all coal and nuclear powered plants in the country were identified. Employing the 50 percent areal containment methods outlined by Mohai and Saha (2006), census tracts were categorized as non-host, coal host, nuclear host, or both host tracts. Multinomial logistic regression was used to compare 2010 demographic census data among the different tract types. Discussion draws from environmental inequality, green criminology, and risk perception literature to address the socio-structural implications of disparate demographics hosting coal and nuclear powered plants.

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CHAPTER I

INTRODUCTION

Employing one of the world's most advanced electricity generating and distributing systems, the United States consumed approximately 3,856 billion kilowatt-hours of electricity in 2011 (USEIA, 2012a). While there are clear benefits to our nation's widespread energy accessibility, this resource comes at a cost to public and environmental health. Over 60 percent of our national electricity is produced from coal and nuclear power which often employ environmentally hazardous methods of sourcing, extracting, and generating electricity (USIEA, 2012a). Coal-fired power plants require massive amounts of coal, most commonly extracted on U.S. soil through surface mining techniques including mountain top removal (USEIA, 2012b). This mining method requires blasting open mountains with explosive material to uncover coal beneath the earth's surface. The repercussions of mountaintop removal include the ecological devastation of entire habitats through the leveling of landscapes and the poisoning of ecosystems and human communities from chemical runoff (Epstein and Reinhart, 2010). When coal is burned for the production of electricity, greenhouse gases are released into the atmosphere where they contribute to changes in global climate patterns. Further, pollutants such as particulates and noxious gasses released during combustion from coal-fired energy production have grave implications for public health. For instance, exposure to particulates has been associated with heart attacks, strokes, and premature death (Keating, 2004). Additionally, gasses such as nitrous oxides and sulfur dioxide contribute to cardiovascular and respiratory diseases and mortality (Samoli et al., 2006; Sunyer et al., 2003).

Nuclear power production poses potentially greater risks than those of coal-fired energy. The process begins with the mining of uranium, which is harmful to human health and has been associated with adverse effects of the cardiovascular and nervous systems (Taylor and Taylor, 1997). Next, research has found that communities living in close proximity to a nuclear powered facility have higher rates of infant mortality and are at an increased risk of suffering from breast cancer and leukemia (Gould, 1996; Swings et al., 1989; Mangano, 2002). Further, as revealed by Three Mile Island, Chernobyl, and more recently, Fukushima, the production of nuclear power has the potential for devastating impacts in the form of nuclear melt-downs. Lastly, nuclear waste is a continually growing hazard for which there are currently no viable solutions for safe disposal.

As a result of the dangers posed by our nation's energy cycle, researchers (Brulle and Pellow, 2006; Bullard 1990; Bryant and Mohai, 1992; Grineski et al., 2010; Faber and Krieg, 2002), advocates (Energy Justice Network, 2012; Energy Action Coalition, 2012; Indigenous Environmental Network, 2012) and locally impacted citizens are seeking energy justice. Like other environmentally hazardous activities, the mining of coal and uranium and the disposal of nuclear waste and coal ash have attracted the attention of many environmental justice scholars. Many of these researchers have determined that poor, minority, and rural populations, including Native American communities, are disproportionately impacted by uranium mining and nuclear waste storage sites (Brugge and Goble, 2002; Malin and Petrzelka, 2010; Markstrom and Charley, 2003; Taliman, 1992; Gerrard, 1994). Similarly, findings suggest that poor and rural communities are more likely to live in U.S. coal fields and suffer negative impacts associated with mountaintop mining (Hendryx, 2011; Evans, 2010; McGinley, 2004). In contrast, to research on mining and disposal, environmental justice researchers have largely ignored inequalities concerning electricity generating power plants. Given the public health impacts associated with exposure to coal and nuclear powered stations, this gap in the literature is rather surprising.

While limited research has found that poor and minority communities are unequally impacted by coal-fired power plants, it is not clear whether these populations are disproportionately burdened by nuclear power plants (Faber and Krieg, 2002; Keating and Davis, 2002). One study seeking to identify populations most likely to host nuclear power plants found no environmental injustice at the national level (Alldred and Shrader-Frechette, 2009). This finding may suggest that variables beyond income and race help account for disproportionate exposure to environmental hazards. It may also indicate that nuclear power plants are not conceptualized as dangerous sites in a way that other hazardous facilities are.

Therefore, this research addresses how the demographics of surrounding communities differ according to the type of facility and explore the possible causes of discrepancies through the theoretical literature. By evaluating the percent of the population of people of color and income and poverty rates in host census tracts, I will identify relationships between race, class, and proximity to power plants. Additionally, as research has indicated that children are disproportionately impacted by environmental hazards, both in terms of proximity and health outcomes, I examine whether communities with higher percent of the population that is children, are more likely to be located near power plant sites (Grineski et al., 2010; Perlin et al., 2001; Hill and Keating, 2002).

Accordingly, this research seeks to answer the following questions:

1.) *Are minority populations more likely to live near a coal-fired or nuclear power plant?*
2.) *Are poverty and income indicators of living in close proximity to coal-fired or nuclear power plants?*
3.) *Are children more likely to live near a power plant?*

4.) *How does the aggregation of demographic data shift with changes in the scale of analysis?*

I begin this study by drawing from sociological theories to craft a framework useful for evaluating unequal exposure to risks arising from these coal-fired and nuclear power plants. Risk society theory is used to situate the formation and acceptance of risks from our nation's coal and nuclear power plants. Next, risk perception literature offers an understanding of how perceptions of risk influence populations' decisions to live near or move away from hazardous facilities. Then, I examine coal and nuclear power plant emissions as a form of environmental crime fueled by the treadmill of production. Lastly, I utilize environmental inequality theories to address unjust distributions of these risks and postulate mechanisms through which inequalities may arise.

With this framework established, I collected demographic data to determine whether disparities exist between power plant host and non-host communities. Using the United States Environmental Protection Agency's Emissions & Generation Resource Integrated Database (eGRID), I located all nuclear and coal-fired plant sites in the nation. After generating a map of U.S. census tracts containing plant site coordinates I employed the 50 percent areal containment methods outlined by Mohai and Saha (2006) to determine the qualifying census tracts. Using census data from 2010, multinomial logistic regression was employed to compare all coal host, nuclear host, both nuclear and coal host, and non-host tracts in the U.S. Because this study evaluates environmental inequalities based on distance from hazardous sites alone, it does not provide information regarding health impacts of plants on local communities. Plume-based methods are employed by researchers to evaluate dispersal patterns and estimate specific health outcomes however, the focus of this study is to identify demographics within close proximity to plant sites. Such distance-based findings are best equipped to measure various inequalities arising from hazardous sites including noise disturbances, declining property values, increased traffic, and stigmatization associated with living near an undesirable location (Mohai et al., 2009).

Additionally, as buffer sizes in this study were selected according to research identifying health impacts occurring within given radii of coal and nuclear power plants, it can be inferred that local communities identified in this study are at greater risk of specific diseases described in chapter two.

Results of this study suggest that while tracts hosting coal-fired power plants are more likely to have greater percentages of people of color and families living below the poverty line compared to non-host tracts, there is little evidence of environmental inequalities in tracts hosting nuclear power plants, particularly at smaller scales of analysis. However, as relationships between tract type and demographic variables shift with changes in buffer size, few findings are consistent over all distances. Although findings regarding demographics of nuclear host tracts are not surprising given the study by Alldred and Shrader-Frechette (2009), it remains unclear why nuclear host tracts do not exhibit the same demographic characteristics as other hazardous sites. The ambiguous nature of nuclear plant emissions, employment opportunities, and factors influencing risk perception are explored as possible explanations for the unique nature of these plants.

CHAPTER II

REVIEW OF LITERATURE

Introduction

This chapter pulls from sociological theories to explore the formation and distribution of risks arising from coal-fired and nuclear power plants in the United States. First, risk society and risk perception theories are examined to evaluate how acceptable levels of risk are determined and factors which influence this perception of risk. Next, I examine the role of coal and nuclear power plants in the treadmill of production and environmental crime. Lastly, I identify the public health concerns associated with living in close proximity to nuclear and coal-fired power plants and explore the environmental justice literature to evaluate mechanisms through which unequal distributions of risks arise. With this theoretical framework established, I craft the hypotheses of this study.

Risk Society and Risk Perception

Although the production of electricity from coal and nuclear power has serious impacts on human and ecosystem health, these costs are generally deemed acceptable in light of the energy intensive lifestyle of our nation. Risk society theory informs us that with increasing modernization there follows an increase in the number and severity of accompanying risks. From the widespread use of hazardous chemicals to the changes in global weather patterns, risks from our increasingly industrialized society are growing exponentially. Ulrich Beck (1992) coined the phrase “risk society” to refer to a society that is economically dependent upon intensive modernization, and consequently, vulnerable to the possible negative outcomes. Thus, given the consumption patterns of our nation, risks posed from energy production tend to be viewed as necessary consequences of our modern lifestyles. In order to maintain a particular standard of living, energy demands must be satisfied and the consequent risks are outweighed by the advantages of modernization. Therefore, it is within this context that we can understand the assent of harms associated with the production of U.S. energy.

Risk society theory is further useful in understanding the impacts of energy production as power plants pose risks that are not entirely understood and have the potential to be catastrophic. While in the past it was believed that the consequences of modernization could be controlled and compensation could be provided to those harmed by negative externalities, it has become evident that the hyper modernization of our present day has led to the formation of risks which cannot be so easily managed (Beck, 2006). These risks are distinct from those in earlier societies in that they are de-localized temporally, spatially, and socially, and are incalculable and non-compensable (Beck, 2006). Nuclear and coal-fired power plants provide striking examples of the sources of risk arising from modernity.

For instance, the impact of a nuclear meltdown would transcend geographic and political boundaries. Additionally, certain radionuclides would persist in affected areas over several generations. For example, some of the radionuclides released during a nuclear accident would decay over a period of several days or weeks while others such as plutonium-239 and plutonium-240 have half-lives of thousands of years (Nuclear Energy Agency, 2002). Further, this risk is de-localized socially as the ambiguity of impacts from a nuclear accident makes it difficult to identify and hold liable responsible parties. Secondly, the potential impact of an accident cannot be calculated and thus it cannot be known whether the potential consequences outweigh the benefits of nuclear power. For instance, scientists are unable to determine how many people would suffer specific adverse health outcomes as a result of a nuclear meltdown. Indeed, this feat is impossible even after an accident has occurred as there is no way to definitely determine that a specific individual's compromised health was a direct result of exposure to radiation. Lastly, a nuclear meltdown is non-compensable as harmed individuals cannot be compensated for loss of life or health.

The localized, incalculable, and non-compensable risks characteristic of risk society are also found in the production of coal powered electricity. To begin with, coal-fired stations pose spatially de-localized risks as they are major emitters of greenhouse gas emissions and thus contribute to global climate change. Changes in global climate patterns may be irreversible, thus impacts of coal plants are temporally de-localized. Further, coal plant companies are only one of many greenhouse gas contributors, and thus risks from coal plants are socially de-localized as companies will not be held socially or financially responsible for the consequences of emissions. Next, risks from coal plant releases are incalculable since shifting weather patterns are not fully understood and cannot be reliably quantified. Lastly, the impacts of these emissions may be non-compensable as changes in the global climate may create a planet no longer hospitable to human life.

Given the severity of the risks described within Beck's society, it would seem that humanity blindly accepts many forms of risk in the name of increasing modernity. However, there are factors aside from maintaining modern lifestyles which help explain decisions regarding risk. Risk perception literature offers explanations for how individuals, both expert and lay, perceive and weigh risks. For instance, risk perception informs us that when people receive benefits from a source of risk, they are more likely to selectively overlook information regarding the dangers of that risk (Margolis, 1996). Thus, those individuals responsible for determining acceptable levels of risk may be biased by potential benefits. Likewise, people may select to live in close proximity to a hazardous site such as a power plant to obtain benefits offered by the facility including employment, improved infrastructure, or lowered housing costs. Next, research has found that people tend to view risks as either significant, with a high probability of occurrence, or as insignificant and implausible (Margolis, 1996). In the case of nuclear power plants experts may determine that the occurrence of a nuclear meltdown is unlikely and thus rationalize that the plant poses no threat. These tendencies to minimize perceptions of risk may help to explain how individuals make choices which perpetuate risk society.

Green Criminology and the Treadmill of Production

As a result of the hyper-modernization characteristic of risk society there arose previously unforeseen consequences to the environment. These acts can be understood as green crimes which may be primary, such as direct environmental degradation and resource depletion, or secondary implying the breaking of laws or the formation of regulations which result in increased environmental harm (Carabine et al., 2004). Because there has not been widespread consensus among scholars concerning what constitutes a green crime the definition of green criminology is somewhat ambiguous. White (2007) explains that this ambiguity is due in part to the fact that environmental crimes have less to do with legal status and more to do with values and beliefs. Thus, it may be legal for a coal-fired power plant company to emit a specified amount of pollutants annually, but the consequent public health impacts can be defined as an environmental crime against surrounding communities. Although green crimes are not a recent occurrence, the extent and severity of these crimes has increased with the technological advances of our risk society. This modernization is also a critical component of the treadmill of production theory which has been used by environmental criminology scholars (Stretesky et al., 2013; Long et al., 2012) to situate the role of the political economy in crimes against nature.

The treadmill of production theory was crafted by Schnaiberg (1980) to describe how the political economy drives the destruction of the natural environment. This treadmill is propelled by five primary objectives (Schnaiberg et al., 2002). First, our capitalist society demands constant economic expansion, and thus, producers must maximize efficiency and increase their profits in order to survive in the system. With no ceiling for economic growth, the primary objective of a capitalist society is to increase profits. Second, much of this growth is expected to result from large firms who have the capital to invest in further growth and supply jobs to consumers, who then have the means to increase their personal consumption. Third, as economic growth occurs from the increased production of goods, the system requires an increase in consumption to perpetuate the cycle. Fourth, this cycle is kept in balance from alliances between capital, workers and the government. Fifth, the system seeks to resolve environmental and social dilemmas through further economic expansion. For example, speeding the treadmill can reduce unemployment by increasing the number of available jobs while environmental damages are expected to be repaired by the development of new technologies (Schnaiberg et al., 2002). These goals cannot be achieved without increasing the amount of energy produced, and thus power plants play a vital role in the sustenance and perpetuation of the treadmill and, consequently, in harms against nature.

Ecological welfare is not a primary goal of the treadmill of production, thus there occurred a shift in the relationship between humans and the environment with the implementation of this system. As economic objectives took precedent over environmental concerns, the system required the *withdrawal* of resources and the *additions* of waste into the ecosystem. Schnaiberg (1980) explains that modern factories demand increased raw materials for production and the withdrawal of these materials from the environment can lead to resource depletion. Additionally, modern factories use advanced and "efficient" technologies which generate the addition of harmful pollutants along with the finished product.

Coal and nuclear power plants are an important component of the treadmill of production not only because the product they generate literally fuels the system, but their operations are associated with extensive withdrawals and additions. The primary withdrawal associated with coal-fired power plants is the mining of coal. While the USEIA (2012c) projects that the United States possesses enough coal to meet the nation's energy needs for 200 years, the treadmill assumes increasing rates of production and therefore the finite amount of coal within the earth's surface will be unable to sustain the system for this period of time. Additionally, resource depletion is not the only consequence of coal extraction. For example, the mining of coal is often achieved through surface mining techniques including mountain top removal that results in the leveling of mountains, extensive deforestation, and the contamination of local streams (Epstein et al., 2011). Similarly, the mining of uranium required for the production of nuclear energy requires massive withdrawals from the environment. As uranium exists in small concentrations within the earth's surface, collecting a single ton of uranium requires the mining and processing of 98,000 tons of rock (Hughes, 2006). Additionally, uranium is a finite resource which is expected to be exhausted in 20 years should worldwide nuclear power production double as some have predicted (Hughes, 2006).

This research, however, is more concerned with the additions associated with coal and nuclear power plant operations because populations living near plant sites are more likely to be impacted by additions than by withdrawals. For instance, when coal is burned at a power plant, undesirable byproducts are produced along with the finished product, electricity. These additions include particulate matter, noxious gasses, and mercury which have been associated with adverse health outcomes including heart attacks, strokes, neurological disorders and premature death (Keating, 2004; Samoli et al., 2006; USEPA, 2012b). Similarly, the production of nuclear power requires the addition of hazardous substances, primarily in the form of radioactive waste. Most of this waste is stored in large steel and concrete pools at nuclear plant sites where it is expected to be safely stored for 120 years (Nuclear Energy Institute, 2012). However, leaks occur during routine plant operations including the storage of waste and these small amounts of radiation have been associated with increased incidences of cancer and infant mortality (Gould, 1996; Clapp et al., 1987; Mangano, 2008).

While the benefits of energy accessibility are shared by most citizens, the harmful additions associated with electricity production are not so equally distributed. Like many activities in the treadmill of production, the generation of electricity through coal-fired and nuclear power plants has greater impacts on select populations. In the case of power plant sites, communities living in close proximity suffer an unequal burden of adverse health outcomes from pollutant exposure.

Environmental Justice

Coal Fired Power Plants

In 2011 coal-fired power plants produced approximately 42 percent of the electricity consumed in the United States (USEIA, 2012a). Not only is coal the least expensive source of electricity production in the nation, it is also abundant in the United States. (USEIA, 2012a). However, generating electricity by burning coal has severe environmental and public health ramifications. Coal-fired plants produce approximately 27 percent of carbon dioxide (CO_2) emissions in the nation, making it a major contributor of greenhouse gas emissions (USEPA, 2012a). These plants are also responsible for emitting approximately 4,000,000 tons of nitrous oxides (NOx), 9,800,000 tons of sulfur dioxide (SO_2), 217,000 tons of particulate matter with a diameter of less than 10 microns (PM_{10}) and 110,000 tons of particulate matter with a diameter of less than 2.5 microns ($PM_{2.5}$) per year (Schneider, 2004).

While the synergistic effects of these pollutants combined is not yet fully understood, research has found adverse health outcomes associated with exposure to each of these pollutants individually. For example, exposure to particulate matter, especially finer particulates, has been shown to cause inflammation of the cardiovascular and respiratory systems and consequently, has been linked to heart attacks, strokes and premature death (Keating, 2004; USEPA, 2012b). Particulate matter exposure has also been associated with premature and low birth weight infants and sudden infant death syndrome, making pregnant women and children particularly vulnerable to adverse health outcomes (Keating, 2004). Coal-fired power plants further impact the health of women and children living in close proximity as they are responsible for producing more than 40 percent of our nation’s mercury emissions.

Exposure to mercury has been associated with disruptions in neurological development in fetuses, babies and children and irregular pulse and blood pressure and neurologic and kidney disorders in adults (Keating, 2004; USEPA, 2012b).

Hazardous gas emissions from coal powered plants also possess serious implications for public health. Research has found a strong association between exposure to NOx and cardiovascular and respiratory mortality (Samoli *et al*., 2006). Children exposed to the gas may experience adverse health effects such as colds, coughs, and sore throats (Pilotto *et al*., 1997). When released into the atmosphere nitrous dioxide (NO2) may react with hydrocarbons and sunlight to form a secondary pollutant, tropospheric ozone (Brunekreef and Holgate, 2002). Exposure to ozone has been associated with diminished lung function, respiratory illnesses, and cardiovascular and respiratory deaths (Galizia and Kinney, 1999; Gryparis *et al*., 2004). Similarly, exposure to another power plant gas, SO2, has been positively correlated with cardiovascular disease related hospital admissions in Europe (Sunyer *et al*., 2003; Ibald- Mulli *et al*., 2001). Additionally, the release of SO2 results in the formation of acidic particulates which have been linked to an increased incidence of bronchitis in children (Dockery *et al*., 1996).

Given the dangers associated with coal-fired power plant pollutants, it is not surprising that these facilities have been called the most harmful industrial air polluters in terms of impacts on human health and the natural environment (Keating and Davis, 2002; Schneider and Banks, 2010). Emissions from coal-fired power plants alone are estimated to have resulted in 9,700 hospital admissions, 12,300 emergency room visits for asthma, 20,400 non-fatal heart attacks and 13,200 mortalities in the year 2010. The monetary cost of these health outcomes is estimated at $100 billion per year (Schneider and Banks, 2010). The brunt of this health and economic burden is shouldered by communities living in close proximity to coal plants.

Nuclear Power Plants

While nuclear power plants serve a similar function to coal-fired plants, they have several important distinctions. Nuclear plants provide approximately 20 percent of U.S. electricity. However, this energy is generated at only 64 sites in the nation and thus, compared to the 560 coal-fired plants in the U.S., far fewer communities are exposed to nuclear facilities (USEIA, 2012b). Additionally, hazards posed by nuclear facilities are distinct from risks posed by coal-fired plants. Theoretically, nuclear power generation should not produce any emissions, although there are some releases of carbon dioxide that result from activities involving the maintenance of the facility. Rather, the public health dangers posed by nuclear power plants involve errors in some part of the production and storage of nuclear waste. These accidental releases are rarely catastrophic and generally involve small amounts of escaped radiation during routine procedures or leaks in storage containers (USEIA, 2012b). While these releases may be minute, this does not imply that they are harmless to human health. A report by the National Academy of Science (2005) determined that there is no safe threshold for exposure to radiation, and even very small amounts of exposure have the potential to result in cancer. This finding has grave implications for those living near nuclear power facilities as various studies have found increased rates of breast cancer, leukemia, childhood cancers and infant mortality in communities surrounding nuclear reactors (National Academy of Sciences, 2005; Gould, 1996; Swings et al., 1989; Clapp et al., 1987; Mangano, 2008).

Over the past three decades, the growing body of environmental justice research has increasingly found that poor and minority communities in the United States are disproportionately impacted by the risks posed from hazardous environmental sites. For instance, studies have revealed that these populations are unequally located near hazardous waste facilities, incinerators, manufacturing facilities and landfills (Faber and Krieg, 2002; Downey, 2005; Bullard, 1990; Mohai and Bryant, 1992; Pellow, 2000). However, studies have yet to evaluate disproportionate exposure to nuclear power plants despite the fact that hazards associated with living near a nuclear plant are well documented. One exception is the work of Alldred and Shrader-Frechette (2009) who examined whether zip codes containing nuclear plants had higher percentages of poor and minority populations than non-host zip codes with results indicating no environmental injustice at the national level. Otherwise, the majority of studies examining communities living in close proximity to nuclear plants focus on risk perceptions (Sjober, 2003; Hung and Wang, 2011; Stone, 2001; Eiser et al., 1995; Venables et al., 2009).

Conversely, previous research, although limited, indicates that coal-fired plants are unequally located in lower socioeconomic and minority communities (Faber and Krieg, 2002). Indeed, one study found that 68 percent of African Americans in the United States live within 30 miles of a coal-fired power plant compared to only 56 percent of whites (Keating and Davis, 2002). Further, research suggests that poor and minority populations are more likely to live near heavier polluting facilities compared to whiter and wealthier populations (Faber and Krieg, 2002). Additionally, certain minority groups are at a greater risk of exposure given lifestyle activities. For instance, African Americans and Hispanic Americans are more likely than whites to regularly engage in fishing for personal consumption and tend to eat fish in larger quantities and more frequently than whites (Keating and Davis, 2002; Tilden et al., 1997; Keating, 2004). As approximately half of our nation’s total mercury emissions are produced by coal-fired plants, and the primary pathway of exposure to this mercury is through consumption of fish, communities of color are particularly vulnerable to mercury poisoning (USEPA, 2012; Burger et al., 1999). Given these factors, the Clean Air Task Force determined that minority populations are more likely than whites to suffer health impacts associated with exposure to plant emissions including asthma related hospitalizations and mortality (Keating and Davis, 2002).

In addition to poor and minority populations, children are also particularly susceptible to coal plant emissions. For example, research has indicated that hazardous facilities tend to be located in communities with populations containing high percentages of children (Grineski et al., 2010; Perlin et al., 2001). Children are further vulnerable as their lungs are still developing and are larger in volume relative to body size than adults. Additionally, their immune systems are not fully developed and thus their bodies may react differently to pollutants compared to a healthy adult. Further, children have higher rates of respiration than adults and are more likely to spend time outside engaging in physical activity, both of which increase the inhalation of air pollutants (Hill and Keating 2002). For these reasons, children are of particular concern when addressing health impacts arising from plant emissions as they are not only more likely to be located near a hazardous facility, they are also more likely to suffer from associated adverse health outcomes.

Given the relationship between certain populations and exposure to environmental hazards, it follows that environmental justice scholars are concerned with whether the community or the facility was first situated in a location. The economic model of environmental inequality reasons that environmentally hazardous facilities tend to be located in areas where property values are low (Downey, 2005; Mohai and Bryant, 1992). Therefore, facilities are located within low income communities inhabiting these areas. Race is also an indicator of class, thus minorities are also more likely than whites to live near environmental hazards. Further, when polluting facilities are placed in a neighborhood, the prices of surrounding properties drop. Consequently, wealthier individuals with the resources to relocate, move away from these areas while poorer populations move in to take advantage of the lower cost of housing (Downey, 2005; Been, 1994; Hamilton, 1995). Other scholars argue that the increased likelihood of environmentally hazardous sites near communities of color is not related to housing markets but rather reflects deliberate, racist siting practices (Downey, 2005). Whether the figurative chicken or egg came first is an important question in determining the source of environmental inequalities, nevertheless this debate should not detract from the findings that poor and minority communities are disproportionately at risk as a result of discrimination, whether blatant or institutionalized.

While addressing whether the facility or the demographic composition of an area came first is beyond the scope of this study, models of environmental inequality may offer insight when making predictions concerning disparate exposure to undesirable facilities. For instance, given the hazards associated with coal-fired plants it is not surprising that property values are lower in areas surrounding these facilities (Blomquist, 1974). In contrast, research indicates that property prices are minimally if at all impacted by close proximity to nuclear plants (Gamble and Downing, 1982). This finding is both counterintuitive and rife with socioeconomic implications. Areas surrounding coal-fired plants tend to have lower property values, thus implying, in accordance with previous literature, that greater percentages of poor and minority communities live in these areas. However, the economic model of environmental inequality would suggest that given the unaffected property prices of areas in close proximity to nuclear plants, greater percentages of poor and minority populations would not be located in these areas. This suggestion is particularly intriguing in light of the racist intent model of environmental inequality which indicates that hazardous facilities will be placed in communities of people of color (Downey, 2005). If poor and minority populations are less likely to live near nuclear plants, the racist intent model would suggest that nuclear plants are generally not understood as hazardous facilities. Clearly, models of environmental inequality are crucial in forming hypotheses and interpreting outcomes in this study.

Hypotheses

Although there has been extensive debate as to whether race or class is the greater indicator of unequal exposure to environmental dangers, the large body of environmental justice literature determines that both play a role (Faber and Krieg, 2002; Keating and Davis, 2002). Consequently, I formed the following hypotheses:

Hypothesis 1: Tracts hosting coal-fired power plants contain greater percentages of minorities compared to non-host tracts.

Hypothesis 2: Tracts hosting coal-fired power plants contain lower median household incomes compared to non-host tracts.

Hypothesis 3: Tracts hosting coal-fired power plants contain greater percentages of families living below the poverty line compared to non-host tracts.

In contrast, although the environmental justice literature repeatedly indicates a connection between environmental hazards and poor and minority populations, I did not anticipate this relationship to be found in communities living near nuclear plants. I based this assumption on the study by Alldred and Shrader-Frechette (2009) which found no relationship between poor and minority communities and nuclear plant proximity at the national level. Further, previous research has indicated that property prices are minimally affected by close proximity to nuclear power plants (Gamble and Downing, 1982), and therefore, employing an economic model of environmental inequality (Downey, 2005) I predicted the following:

Hypothesis 4: Tracts hosting nuclear power plants do not contain greater percentages of minorities compared to non-host tracts.

Hypothesis 5: Tracts hosting nuclear power plants do not contain lower median household incomes compared to non-host tracts.

Hypothesis 6: Tracts hosting nuclear power plants do not contain greater percentages of families living below the poverty line compared to non-host tracts.

Finally, previous studies have indicated that children are disproportionately impacted by environmental hazards and are more vulnerable to the effects of pollutant exposure (Grineski et al., 2010; Perlin et al., 2001) and thus I predicted:

Hypothesis 7: Tracts hosting coal-fired plants contain higher percentages of children than non-host communities.

Hypothesis 8: Tracts hosting nuclear plants contain higher percentages of children than non-host communities.

By addressing these hypotheses with the methods described in the following chapter, this study will help to fill in the gap in the environmental justice literature regarding power plant inequalities. While coal-fired power plant inequalities have been examined at the state level (Faber and Krieg, 2002) there have been no studies evaluating coal plant inequalities at the national level. The one study which has evaluated nuclear plant inequalities employed a unit hazard coincidence method and found no incidence of national environmental injustice (Alldred and Shrader-Frechette, 2009). This research will offer greater insight into power plant inequalities in the United States by evaluating the issue at the national level and employing the 50 percent areal containment method, which as explained in the following chapter, is a more reliable measure of identifying impacted communities than the unit hazard coincidence method (Mohai and Saha, 2006).

CHAPTER III

METHODOLOGY

Introduction

This chapter covers the data, methods, and analyses employed in this study. I begin with an overview of methods commonly used in environmental justice distance-based studies and an explanation of why the 50 percent areal containment method was selected for this research. Next, I describe the data collected and identify dependent and independent variables. Then, I outline the process of conducting the 50 percent areal containment method and the tools required for data collection. Lastly, I explain the selection of statistical analyses employed in this study.

Spatial Studies

As environmental justice scholars seek to answer questions regarding the relative importance of race and class and proximity to hazardous sites, there are considerable divergences in their findings. Not only is there incongruence in the environmental justice literature regarding the connection between race, class, and environmental inequities, but the intensity of these relationships is also widely debated. Some of the discrepancies found within the literature can be explained by the variations in the methods utilized. Mohai and Saha (2006) determined that many of these disparities can be attributed to the unit hazard coincidence method which is commonly used in studies evaluating different populations' proximity to undesirable facilities. In this method researchers compare a unit of analysis containing a specified hazard with a control unit. Often, the unit of analysis is a geographic census unit such as a county, tract, or block group. The problem with this type of analysis is that these units may vary dramatically in size, shape, and population. Therefore, a hazardous facility located in the center of a large census tract may not affect the populations located along the edge of the tract, however as a resident of the tract their demographic data is included. Further, small census tracts may contain facilities that pose hazards beyond the boundary of the tract and therefore the unit hazard coincidence does not account for the entire affected population. Similarly, facilities may be located along the edge of a tract and have a greater impact on communities in neighboring tracts. Given these limitations it is not surprising that researchers employing unit hazard coincidence methods generate very different results.

Mohai and Saha (2006) offer three alternative methods for spatial analysis using census data that help to overcome some of the restrictions found within unit hazard coincidence. These methods include the 50 percent areal containment, the boundary intersection, and the areal apportionment method and all involve drawing buffer zones around an environmental hazard. The boundary intersection is the least reliable of the distance-based methods as all census units contained within or touching a buffer zone are included as impacted units and thus, this method faces many of the same limitations found within the unit hazard coincidence. The 50 percent areal containment method is a more robust alternative in which the demographic information for all units with 50 percent of their area contained within the buffer are considered impacted units. The areal containment method is similar however, instead of discounting units with less than half of their area within a buffer, researchers employing this method calculate the portion of the included population according to the portion of the unit contained within the buffer. As the 50 percent areal containment and areal apportionment methods yield similar results I employ the 50 percent areal containment method for its relative ease of computation (Mohai and Saha, 2006).

Although the type of method employed for determining qualifying census units helps to explain some of the discrepancies found within the environmental justice literature, the variation in researchers' geographic units of analysis may also play a role. Environmental justice researchers often employ units crafted by census data as they are easily accessible and readily available for analysis. The problem with these units is that their boundaries are not synonymous with the borders of a hazardous facility's impact. For example, researchers often assume that impacted communities fall within a given distance from a plant and thus the boundary of the impacted area forms a circle. However, aggregations of census units do not take this form. Thus, distance-based studies employing geographic units will likely exclude portions of the impacted community while including irrelevant data, and as a result, produce findings incongruent with other studies.

Additionally, findings may vary according to the scale of the unit being analyzed. Generally, smaller units are preferable in environmental justice studies as analyzing larger units increases the likelihood that heterogeneity of the population will result in misrepresentation of the effected communities (Sheppard et al., 1999, Maantay, 2002). Unfortunately, using blocks, the smallest census unit, is generally not feasible as demographic data is not consistently available at this level. Thus, block groups are generally considered an appropriate choice for analyzing environmental inequities (Sheppard et al, 1999).

Another possible explanatory factor for the divergences found in the environmental justice literature is the selection of the scale of impact. In studies employing analytic buffering, the choice of a buffer distance will inevitably impact the strength of relationships between facilities and the demographics of surrounding communities. Thus, it is essential that researchers carefully select buffer areas representative of impacted regions based on previous studies or theory. However, even an appropriately selected buffer size will influence the aggregation of data and consequently the results of the study in unknown ways (Mennis, 2002). For this reason researchers often employ multiple buffers around a hazardous site to determine how scale size influences the relationship between demographic characteristics and proximity to hazards (Shepard et al., 1999; Maantay, 2002).

Data

My dependent variable was *Tract Type* with categories *non-host tract, coal host tract, nuclear host tract*, and *both host tract*. Host tracts were operationalized as census tracts with 50 percent or more of their area falling within a selected buffer around plant sites. All other tracts were categorized as non-host tracts.

The data for the independent variables was derived from the 2010 census provided by American Fact Finder and included *percent of the population that is minority, median household income, percent of families living below the poverty line,* and *percent of the population that is children*. To evaluate the relationship between race and proximity to power plants, percent of the population that is minority was calculated for every census tract in the nation. For the purposes of this study, any race other than white was categorized as minority. Additionally, individuals identified as ethnically Hispanic in the census data were categorized as racially Hispanic and included as minorities. In order to evaluate relationships between class and proximity to coal and nuclear power plants, this study examined median household income and percentage of families living below the poverty line for each tract. Lastly, as previous studies have indicated that children are disproportionately impacted by environmental hazards, I calculated the percent of the population that is children aged 15 years and younger for each census tract (Grineski et al., 2010; Perlin et al., 2001).

This study also necessitated additional control variables. To begin with, urban areas are associated with both higher percentages of people of color and the presence of environmentally hazardous facilities. Thus, *population density,* reported as people per square mile, was included as a control variable. Additionally, certain socioeconomic variables have been indicated as significant predictors of proximity to environmentally hazardous facilities and were accounted for in this study. For instance, Anderton et al. (1994) found that employment in the manufacturing industry was more closely associated with living near hazardous waste treatment, storage, and disposal facilities than race and income. Thus, my research controlled for relationships between occupation and proximity to plant by including the variable *percent of the population employed in the utilities sector* to account for employees of coal and nuclear powered plants. This variable represents the percent of the employed civilian population 16 years and older that have occupations in the transportation, warehouse, and utility sectors. Additionally, level of education has been associated with unequal exposure to environmental harms with less educated communities at greater risk (Mohai and Saha, 2006). Bullard (1990) postulates that populations with greater resources including education are better able to successfully fight the placement of hazardous facilities in their communities. Therefore, to control for level of education I examined the *percent of the population with a bachelor's degree or above* for all census tracts. Lastly, as Alldred and Shrader-Frechette (2009) found disparities in demographics surrounding nuclear plants in the south, *region* was included as a variable in this study. Tracts were categorized as being in the West, Midwest, Northeast, or South according to the regions defined by the U.S. census.

Methods

To spatially analyze the data, I used a map of all census tracts in the United States containing demographic census data (United States Census Bureau 2010 Census TIGER/Line Shapefiles, 2012). Coordinate information for all coal-fired and nuclear power plants in the nation was accessed through the eGRID database and plotted on the base map. Using ArcMap 10 buffer tool, buffer zones were drawn around each of the plants (Figures 1 and 2). Three buffer zones were selected for this research based on studies evaluating the distances at which health impacts occur from plant emissions. One study calculated that people living within 30 miles of a coal-fired power plant are 3 to 4 times more likely to die a premature death compared to populations living further from the plant (Epstein, 2010). Additionally, a study evaluating particulate matter emissions from coal plants in Illinois determined that 40 percent of primary exposure occurred within approximately 30 miles of the facilities (Levy et al., 2002). Similarly, research on the health impacts of living near a nuclear plant reveal increased incidences of childhood cancer and infant mortality for populations living within 30 miles of a facility (Mangano, 2008; Chang et al., 2003). While communities living further than 30 miles from a nuclear plant are at risk of adverse health outcomes in the case of a nuclear meltdown, populations living closer to the plant will suffer the greatest burden of impact. Therefore, a buffer of 30 miles was selected to evaluate populations whose health may be impacted by coal-fired and nuclear plants. As multiscale analysis offers insight into the influence of buffer size on data outcomes, additional buffer zones of 20 and 10 miles were also utilized in this study (Mennis, 2002). Using the same buffer sizes at both coal and nuclear plant sites is not only appropriate according to literature examining health impacts, it also enables comparisons across plant type.

Figure 1. Coal-fired power plants in census tract map of U.S. with 30, 20, and 10 mile buffer zones.

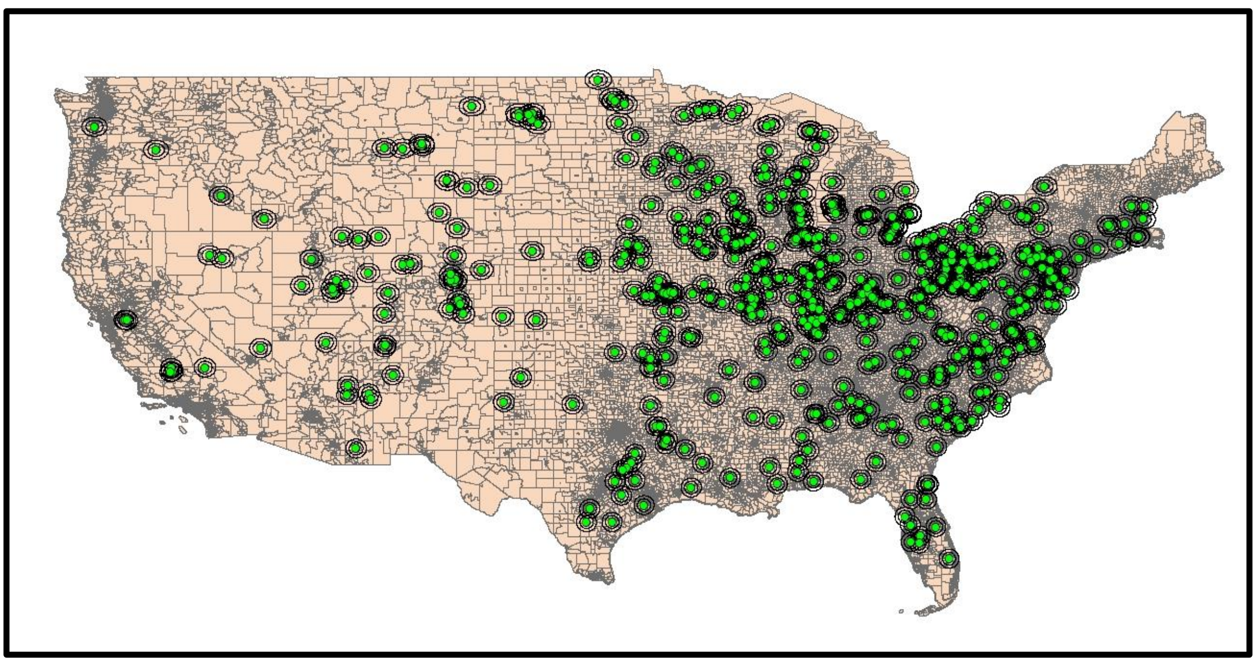
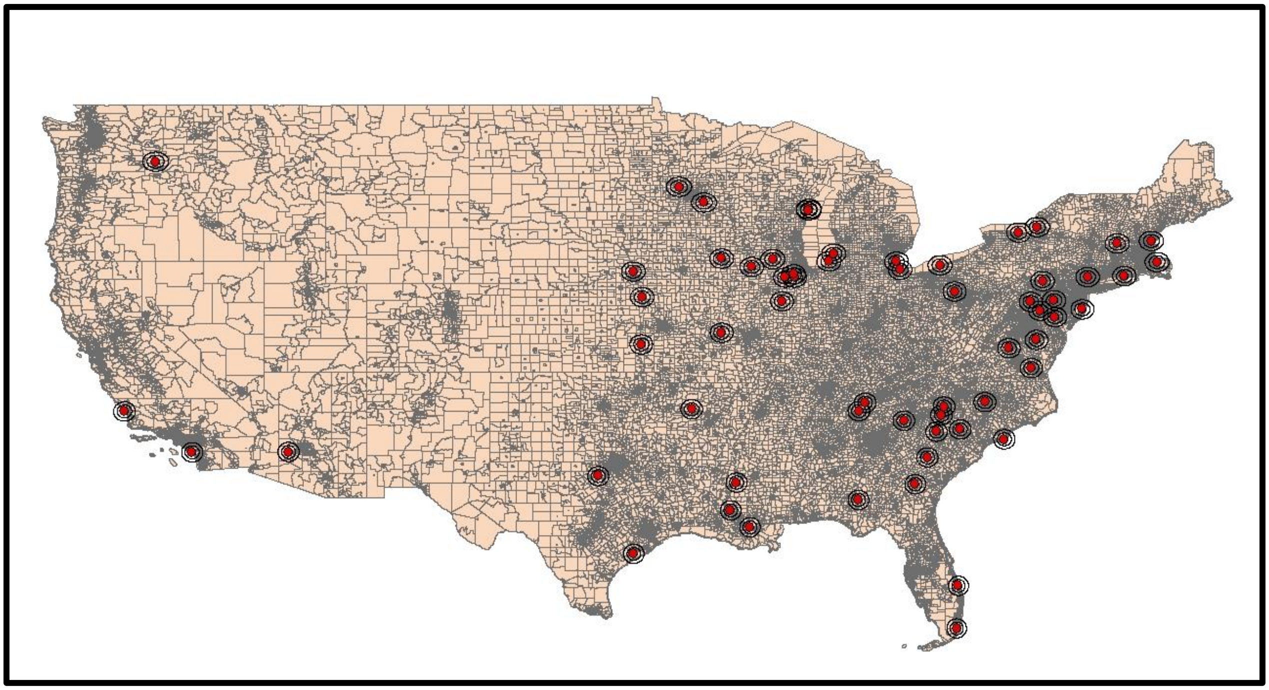


Figure 2. Nuclear powered plants in census tract map of U.S. with 30, 20, and 10 mile buffer zones.



After drawing buffers around plant sites, I used the ARCMap Clip function to extract the census data from all tracts with any of their area included in a buffer. Using SPSS, I determined qualifying tracts by comparing the size of the original tract to the size of the clipped tract fragment. Census tracts with half of their area falling within a buffer zone were labeled as coal host, nuclear host, or both host tracts if the buffer was surrounding a coal plant, nuclear plant, or both a coal and nuclear plant respectively. All other tracts were be labeled as non-host tracts. The data extracted from this map contained demographic information including race and age which were used to calculate percent population minority and children for every tract. Additional census tract information including median household income, percent families living below the poverty line, percent population with a bachelor's degree and percent population employed in the utilities sector were then merged with the demographic data according to the tract's unique geographic identifier. Thus, the raw data contained the geographic identifier of each tract in the United

States, my independent and control variables for every tract, and whether the tract was a non-host, coal host, nuclear host, or both host tract.

Although smaller geographic census areas tend to be preferable in spatially analyzing environmental inequalities, census tracts were utilized in this study. This was an appropriate unit of analysis as the selected buffer zones were large enough to entirely encompass multiple tracts at most of the power plant sites and thus using smaller units simply would have been inefficient (Sheppard et al., 1999). Further, various studies have found similar results by analyzing data at both the census tract and block group level, many of which employed smaller buffer zones or distances from sites (Cutter et al., 2005; McMaster et al., 1997; Mennis, 2002). Therefore, given the 10, 20 and 30 mile buffer zones, it is unlikely that analyzing the data at a smaller unit such as a block group would have a strong effect on my outcome.

Analyses

Descriptive, bivariate, and multivariate statistics were used in this study. Bivariate analyses utilized one-way ANOVA tests to examine the effect of each demographic variable, with the exception of region, on the tract type independently. Next, Scheffe's post hoc tests were employed to determine where differences exist among tract types. Scheffe's test was selected as all dependent variables, excluding region, are continuous variables and the dependent variable, tract type, is categorical and contains more than two categories. Chi- square was used for evaluating the effect of region as this variable is also categorical with four categories. Multinomial logistic regression was selected for multivariate analyses as the dependent variable in this study contained more than two categories, (Hoffman, 2004). 10, 20 and 30 mile buffer zones were evaluated independently. While multinomial logistic regression does not assume normality, linearity or homoscedasticity, it does require a categorical dependent variable and continuous or categorical independent variables (Anderson, 1982). All of the independent variables in this study were continuous, with the exception of the categorical variable *region*, and thus were appropriate for use in multinomial logistic regression. *South* was selected as the base category for the effect of region following the work of Alldred and Shrader-Frechette (2009) who found that poor communities in the South may be disproportionately burdened by nuclear power plants.

Initially, regressions for all buffer zones were generated with non-host as the base category. Next, coal host and nuclear host bases were employed to evaluate the relationships between all categories for each buffer distance. Thus, three models were generated for each buffer zone for a total of nine models. Measures of model fit utilized in this study include Likelihood Ratio (LR) Chi Square, Cragg-Uhler's R^2, Bayesian information criterion (BIC) and Akaike's information criterion (AIC). The results of these analyses are presented in the following chapter.

CHAPTER IV

FINDINGS

Introduction

This chapter contains results of all statistical analyses. I begin by providing descriptive statistics including, means, standard deviations, and minimum and maximum values for independent variables and frequencies and percentages for dependent variables. Next, I provide results of bivariate analyses including ANOVA tests, Scheffe's tests, and Pearson's Chi-square test by buffer size. Lastly, I present the results of multinomial logistic regressions, for each buffer size.

Descriptives

A total of 72,068 tracts contained the information for all independent variables used in this study. The average percent population minority for all tracts was 36.07 with a minimum and maximum of 0 and 100 percent respectively (Table 1). Average median household income was $55,506.30 for all tracts with a minimum of $5,000 and a maximum of $249,194. Mean percent families living below the poverty line was 11.38 for all tracts with a minimum and maximum of 0 and 100 percent respectively. Mean percent population with a bachelor's degree or above was 27.00 for all tracts with a minimum of 0 percent and a maximum of 100 percent. The average percent of the population that is children for all tracts was 20.72 with a minimum and maximum of 0 and 57.62 percent respectively. Mean population density for all tracts was 5,254.96 people per square mile with a minimum of 0.03 and a maximum of 508,698 people per square mile. Average percent population employed in the utilities sector for all tracts was 5.12 with a minimum and maximum of 0 and 63.20 percent respectively.

At the 10 mile buffer, nearly 80 percent of all tracts were non-host tracts while another 20 percent were coal-host tracts. Nuclear host tracts and both host tracts accounted for less than two percent of all tracts. When the buffer was widened to 20 miles, over half of the tracts remained non-host however coal-host tracts increased to 40 percent. Nuclear and both host tracts continued to account for only a few percent of all tracts. At the 30 mile buffer, the majority of the tracts were host tracts with coal host accounting for nearly 50 percent, both host accounting for 11 percent and nuclear host tracts accounting for 3 percent of all tracts. Only 40 percent of tracts at the 30 mile buffer were non-host tracts.

Table 1. Descriptive Statistics for Independent and Dependent Variables.

Independent Variables	Mean	SD	Min	Max	Description
Minorities	36.07	30.12	0	100	Percent Population Minorities
Median Income	55,506.30	26,885.80	5,000	249,194	Median Household Income
Poverty	11.38	11.15	0	100	Percent Families Living Below Poverty Line
Bachelors	27.00	18.22	0	100	Percent Population With Bachelor's Degree
Children	20.72	5.70	0	57.62	Percent Population Children
Population Density	5,254.96	11,747.80	0.03	508,698	People Per Square Mile
Utilities	5.12	3.45	0	63.20	Percent Population Employed in the Utilities Sector
Region					
West	0.22	0.42	0	1	West=1, Else=0
Midwest	0.23	0.42	0	1	Midwest=1, Else=0
South	0.36	0.48	0	1	South=1, Else=0
Northeast	0.19	0.39	0	1	Northeast=1, Else=0
Dependent Variables	**Frequency**	**Percent**			
Buffer 10					
Non-Host Tract	56,662	78.62			
Coal Host Tract	14,514	20.14			
Nuclear Host Tract	571	0.79			
Both Host Tract	321	0.45			
Total	72,068	100			
Buffer 20					
Non-Host Tract	38,760	53.78			
Coal Host Tract	29,037	40.29			
Nuclear Host Tract	1,663	2.31			
Both Host Tract	2,608	3.62			
Total	72,068	100			
Buffer 30					
Non-Host Tract	28,187	39.11			
Coal Host Tract	33,541	46.54			
Nuclear Host Tract	2,157	2.99			
Both Host Tract	8,183	11.35			
Total	72,068	100			

Note: N=72,068, Data comes from 2010 United States Census.

Bivariate Analyses

10 Mile Buffer ANOVA

One-way ANOVA was employed to test for differences among tract types for each demographic variable. As seen in Table 2, percent population minority was significantly different among tract types at the 10 mile buffer, F=125.23, $p<0.001$. Scheffe’s pairwise comparison post hoc tests reveal differences between non-host tracts (M=35.45, SD=29.65) and coal host tracts (M=39.30, SD=31.90), nuclear host tracts (M=24.26, SD=24.34), and both host tracts (M=19.70, SD=19.26) at the $p<0.001$ level (Table 3). Additionally, coal host tracts contained significantly different percent population minority than nuclear and both host tracts, $p<0.001$. There was no difference between nuclear and both host tracts, $p=0.192$.

Table 2. Means and One-way ANOVA Results Examining Differences in Demographics Among Tract Types for the 10 Mile Buffer.

	Non-Host	Coal	Nuclear	Both	ANOVA/Chi2
Minorities	35.45	39.30	24.26	19.70	125.23***
	(29.65)	(31.90)	(24.34)	(19.26)	268.4207***
Median Income	56.42	51.53	61.07	63.33	145.72***
	(27.17)	(25.56)	(23.72)	(22.55)	117.4954***
Poverty	10.91	13.45	8.05	6.79	237.86***
	(10.56)	(13.12)	(8.31)	(7.34)	1,300***
Bachelors	26.85	27.54	27.38	28.55	6.46***
	(17.83)	(19.78)	(15.49)	(15.00)	308.2995***
Children	20.82	20.31	20.55	21.19	32.02***
	(5.65)	(5.91)	(5.33)	(4.65)	73.0268***
Population Density	4.33	9.09	1.74	1.81	679.57***
	(9.09)	(18.53)	(2.29)	(2.01)	17,0000***
Utilities	5.03	5.41	6.08	6.17	70.76***
	(3.35)	(3.77)	(3.72)	(3.51)	358.1630***

Standard deviations reported in parentheses. Chi2 reported below ANOVA.
**p*<0.05, ***p*<0.01, ****p*<0.001.

Table 3. 10 Mile Buffer Summary of Scheffe's Post Hoc Statistically Significant Results at the $p<0.05$ level.

	Non-Host vs. Coal	Non-Host vs. Nuclear	Non-Host vs. Both Host	Coal vs. Nuclear	Coal vs. Both Host	Nuclear vs. Both Host
Minority	Coal	Non-Host	Non-Host	Coal	Coal	*
Median Income	Non-Host	Nuclear	Both Host	Nuclear	Both Host	*
Poverty	Coal	Non-Host	Non-Host	Coal	Coal	*
Bachelors	Coal	*	*	*	*	*
Children	Non-Host	*	*	*	*	*
Population Density	Coal	Non-Host	Non-Host	Coal	Coal	*
Utilities	Coal	Nuclear	Both Host	Nuclear	Both Host	*

Tract type reported contained the higher mean. Asterisks indicate no significant difference between tract types.

Median household income at the 10 mile buffer varied significantly among tract type, F= 145.72, $p<0.001$. Similar to percent population minority, Scheffe's test reveal that median income was significantly different between non-host tracts (M=56.42, SD=27.17) and coal host tracts (M=51.53, SD=25.56), nuclear host tracts (M=61.08, SD=23.72), and both host tracts (M=63.34, SD=22.55) at the $p<0.001$ level. Further coal host tracts had significantly different median incomes than nuclear and both host tracts, $p<0.001$. There was no difference between nuclear and both host tracts, $p=0.691$.

Percent families living in poverty also varied significantly by tract type F= 237.86, $p<0.001$. Scheffes' test reveal that poverty follows the same trend as median income with significant differences between non-host tracts (M=10.91, SD=10.56) and coal host tracts (M=13.45, SD=13.12), nuclear host tracts (M=8.05, SD=8.31), and both host tracts (M=6.79, SD=7.34) at the $p<0.001$ level. Additionally, coal host tracts contained significantly different percent families living in poverty than nuclear and both host tracts, $p<0.001$. There was no difference between poverty levels between nuclear and both host tracts, $p=0.444$.

At the 10 mile buffer, percent population with a bachelor's degree varies significantly by tract type F= 6.46, $p<0.001$. Pairwise post hoc test reveals that the only significant difference among tract types exists between non-host (M=26.85, SD=17.83) and coal host tracts (M=27.54, SD=19.78), $p<0.001$.

Percent population children was significantly different among tract types, F= 32.02, $p<0.001$. Scheffe's tests determine that this difference exists between non-host (M=20.82, SD=5.65) and coal host (M=20.31, SD=5.91) tracts, $p<0.001$. No significant differences existed between percent children in nuclear host tracts (M=20.55, SD=5.33) and other tract types.

Further, there was no difference between both host (M=21.19, SD=4.65) and coal host tracts, p=0.060.

At the 10 mile buffer, population density varied significantly by tract type F= 679.57, p<0.001. These differences existed between non-host tracts (M=4.33, SD=9.09) and coal host tracts (M=9.09, SD=18.53), nuclear host tracts (M=1.74, SD=2.29), and both host tracts (M=1.81, SD=2.01) at the p<0.001 level. Additionally, coal host tracts contained significantly different population densities than nuclear host tracts and both host tracts, p<0.001. There was no difference between population density between nuclear and both host tracts, p=1.000.

Percent population employed in the utilities sector also varied significantly by tract type F= 70.76, p<0.001. These differences existed between non-host tracts (M=5.03, SD=3.35) and coal host tracts (M=5.41, SD=3.77), nuclear host tracts (M=6.08, SD=3.72), and both host tracts (M=6.17, SD=3.52) at the p<0.001 level. Further, coal host tracts contained significantly different population densities than nuclear host tracts, p<0.001, and both host tracts, p=0.002. There was no difference between population density between nuclear and both host tracts, p=0.989.

10 Mile Buffer Chi-Square

Pearson's chi-square test reveals differences in location among tract types at the 10 mile buffer, X^2=6,700, p<0.001. Non-host tracts were most likely to be located in the South, followed by the West, Midwest and lastly, Northeast (Table 4). Coal host tracts tended to be sited in the Midwest, followed by the Northeast, South, and West. Nuclear plants were most likely to be located in the South and Northeast and were found less frequently in the Midwest and West. Both host tracts tended to be located in the Northeast, followed by the South, Midwest and lastly West.

Table 4. 10 Mile Buffer Tract Type Frequency by Region.

	Non-Host	Coal Host	Nuclear Host	Both Host
West	14,908	985	22	0
	(26.31)	(6.79)	(03.85)	(0)
Midwest	10,541	6,205	88	85
	(18.60)	(42.75)	(15.41)	(26.48)
South	21,966	3,436	254	100
	(38.77)	(23.67)	(44.48)	(31.15)
Northeast	9,247	3,888	207	136
	(16.32)	(26.79)	(36.25)	(42.37)
Total	56,662	14,514	571	321
	(100)	(100)	(100)	(100)

Percentages reported in parentheses.

20 Mile Buffer ANOVA

As shown in Table 5, percent population minority at the 20 mile buffer varied significantly among tract type, F=131.21, $p<0.001$. Scheffe's tests reveal significant differences between all tract types at the $p<0.001$ level with coal host tracts containing the greatest percent population minority (M=37.37, SD=31.54), followed by non-host (M=35.98, SD=29.35), then nuclear host (M=31.48, SD=27.17), and lastly both host (M=25.87, SD=24.34) tracts (Table 6).

Table 5. Means and One-way ANOVA Results Examining Differences in Demographics Among Tract Types for the 20 Mile Buffer.

	Non-Host	Coal	Nuclear	Both	ANOVA/Chi2
Minorities	35.98	37.37	31.47	25.87	131.21***
	(29.35)	(31.54)	(27.17)	(24.34)	416.4107***
Median Income	55.06	55.38	60.44	60.41	51.52***
	(26.30)	(27.51)	(29.95)	(25.60)	121.8792***
Poverty	11.24	11.85	10.02	8.99	67.60***
	(10.39)	(12.10)	(10.79)	(10.86)	785.3135***
Bachelors	25.62	28.50	28.61	29.69	163.87***
	(17.22)	(19.39)	(17.26)	(18.01)	482.7273***
Children	20.94	20.45	19.94	20.90	52.30***
	(5.81)	(5.57)	(6.00)	(5.20)	107.2308***
Population Density	3.45	8.02	3.05	2.67	937.24***
	(5.74)	(16.85)	(3.76)	(3.36)	42,000***
Utilities	4.95	5.32	5.29	5.31	70.06***
	(3.29)	(3.64)	(3.49)	(3.31)	359.3931***

Standard deviations reported in parentheses. Chi2 reported below ANOVA.
*p<0.05, **p<0.01, ***p<0.001.

Table 6. 20 Mile Buffer Summary of Scheffe's Post Hoc Statistically Significant Results at the p<0.05 level.

	Non-Host vs. Coal	Non-Host vs. Nuclear	Non-Host vs. Both Host	Coal vs. Nuclear	Coal vs. Both Host	Nuclear vs. Both Host
Minority	Coal	Non-Host	Non-Host	Coal	Coal	Nuclear
Median Income	*	Nuclear	Both Host	Nuclear	Both Host	*
Poverty	Coal	Non-Host	Non-Host	Coal	Coal	*
Bachelors	Coal	Nuclear	Both Host	*	Both Host	*
Children	Non-Host	Non-Host	*	Coal	Both Host	Both Host
Population Density	Coal	*	Non-Host	Coal	Coal	*
Utilities	Coal	Nuclear	Both Host	*	*	*

Tract type reported contained the higher mean. Asterisks indicate no significant difference between tract types.

Median income at the 20 mile buffer followed the same trend as the 10 mile buffer with significant differences in median income found among tract types F= 51.52, $p<0.001$. Pairwise comparison post hoc tests reveal significant differences between non-host tracts (M=55.06, SD=26.30) and nuclear host tracts (M=60.44, SD=29.95), and both host tracts (M=60.41, SD=25.60) at the $p<0.001$ level. Further, median income varied significantly from coal host tracts (M=55.38, SD=27.51) and nuclear and both host tracts, $p<0.001$. There was no difference between median income in nuclear and both host tracts, $p=1.000$, or between non-host and coal host tracts, $p=0.479$.

Percent families living in poverty varied significantly across tract types F= 67.60, $p<0.001$. Post hoc tests reveal significant differences in percent poverty between all tract types with coal host tracts containing the greatest poverty (M=11.86, SD=12.10) followed closely by non-host tracts (M=11.25, SD=10.39), then nuclear host tracts (M=10.02, SD=10.79), and finally both host tracts (M=8.99, SD=10.87). These differences were significant at the $p<0.001$ level between all tract types with the exception of nuclear and both host tracts, $p=0.034$.

At the 20 mile buffer, percent population possessing a bachelor's degree or above was significantly different among tract types F= 163.87, $p<0.001$. Scheffe's test reveal that non-host tracts (M=25.62, SD=17.22), vary significantly from coal host (M=28.50, SD=19.39), nuclear host (M=28.61, SD=17.26), and both host (M=29.69, SD=18.01) tracts at the $p<0.001$ level. Further, coal host and both host tracts contained significantly different percent population with a bachelor's degree, $p=0.016$. However, there was no difference between coal host and nuclear host tracts, $p=0.996$ and both host and nuclear host tracts, $p=0.312$.

Percent population children also varied significantly by tract type F= 52.30, $p<0.001$. Significant differences were found between non-host tracts (M=20.94, SD=5.81) and coal host tracts (M=20.45, SD=5.57) and nuclear host tracts (M=19.94, SD=6.00) as well as both host tracts (M=20.90, SD=5.20) and nuclear host tracts at the $p<0.001$ level. Further, coal host tracts contained significantly different population densities than nuclear host tracts, $p=0.005$ and both host tracts, $p=0.002$. There was no significant difference in percent population children between non-host and both host tracts, $p=0.986$.

At the 20 mile buffer, population density was significantly different among tract types F= 937.24, $p<0.001$. Scheffe's test reveal that non-host tracts (M=3.45, SD=5.74), vary significantly from coal host (M=8.02, SD=16.85), $p<0.001$ and both host (M=2.67, SD=3.36), $p=0.110$ tracts. Further, coal host tracts contained significantly different population densities than nuclear host (M=3.06, SD=3.76), and both host tracts at the $p<0.001$ level. There was no difference in population densities between non-host and nuclear host tracts, $p=0.595$ and both host and nuclear host tracts, $p=0.770$.

Percent population employed in the utilities sector also varied significantly among tract types F= 70.06, $p<0.001$. Post hoc tests reveal differences between non-host tracts (M=4.95, SD=3.29) and coal host tracts (M=5.33, SD=3.64), nuclear host tracts (M=5.29, SD=3.49), and both host tracts (M=5.31, SD=3.31) at the $p<0.001$ level. There were no significant differences between coal host tracts and nuclear host tracts, $p=0.983$ and both host tracts, $p=0.998$. Further, there was no difference in population employed in the utilities sector between nuclear host and both host tracts, $p=0.998$.

20 Mile Buffer Chi-Square

Differences were found in location among tract types at the 20 mile buffer, X^2=14,000, $p<0.001$. Similar to the 10 mile buffer, non-host tracts continued to be located primarily in the South, followed by closely by the West, Midwest and lastly, Northeast (Table 7). Coal host tracts tended to be sited in the Midwest, followed by the South, Northeast and West. Nuclear plants were most likely to be located in the South and Northeast and were found less frequently in the

Midwest and West. Both host tracts tended to be located in the Northeast, followed by the South, Midwest and lastly West.

Table 7. 20 Mile Buffer Tract Type Frequency by Region.

	Non-Host	Coal Host	Nuclear Host	Both Host
West	13,845	1,854	216	0
	(35.72)	(06.38)	(12.99)	(00.00)
Midwest	5,634	10,446	215	624
	(14.54)	(35.97)	(12.93)	(23.93)
South	15,281	8,821	761	893
	(39.42)	(30.38)	(45.76)	(34.24)
Northeast	4,000	7,916	471	1,091
	(10.32)	(27.26)	(28.32)	(41.83)
Total	38,760	29,037	1,663	2,608
	(100)	(100)	(100)	(100)

Percentages reported in parentheses.

30 Mile Buffer ANOVA

At the 30 mile buffer, percent population minority was significantly different among tract types (Table 8), F= 174.83, $p<0.001$. Scheffe's test reveal significant differences between all tract types at the $p<0.001$ level with nuclear host tracts containing the greatest percent population minority (M=41.97, SD=31.28), followed by non-host (M=38.53, SD=29.83), then coal host (M=34.72, SD=30.36), and lastly both host (M=31.56, SD=28.84) tracts (Table 9).

Table 8. Means and One-way ANOVA Results Examining Differences in Demographics Among Tract Types for the 30 Mile Buffer.

	Non-Host	Coal	Nuclear	Both	ANOVA/Chi2
Minorities	38.52	34.72	41.97	31.56	174.83***
	(29.83)	(30.36)	(31.28)	(28.83)	44.4366***
Median Income	53.86	55.91	56.04	59.40	95.62***
	(25.34)	(27.62)	(27.34)	(28.38)	290.3275***
Poverty	11.71	11.35	11.46	10.34	32.40***
	(10.46)	(11.45)	(11.38)	(12.07)	376.8444***
Bachelors	25.11	28.03	27.36	29.18	176.81***
	(17.01)	(19.06)	(17.63)	(18.25)	396.5617***
Children	20.98	20.56	19.81	20.72	47.02***
	(6.02)	(5.50)	(5.65)	(5.34)	326.6746***
Population Density	3.83	6.39	4.27	5.76	255.12***
	(6.29)	(14.43)	(5.72)	(14.29)	21,000***
Utilities	4.95	5.24	5.48	5.11	43.76***
	(3.34)	(3.55)	(3.97)	(3.17)	312.0416***

Standard deviations reported in parentheses. Chi2 reported below ANOVA.
*p<0.05, **p<0.01, ***p<0.001.

Table 9. Buffer 30 Summary of Scheffe's Post Hoc Statistically Significant Results at the p<0.05 level.

	Non-Host vs. Coal	Non-Host vs. Nuclear	Non-Host vs. Both Host	Coal vs. Nuclear	Coal vs. Both Host	Nuclear vs. Both Host
Minority	Non-Host	Nuclear	Non-Host	Nuclear	Coal	Nuclear
Median Income	Coal	Nuclear	Both Host	*	Both Host	Both Host
Poverty	Non-Host	*	Non-Host	*	Coal	Nuclear
Bachelors	Coal	Nuclear	Both Host	*	Both Host	Both Host
Children	Non-Host	Non-Host	Non-Host	Coal	*	Both Host
Population Density	Coal	*	Both Host	Coal	Coal	Both Host
Utilities	Coal	Nuclear	Both Host	Nuclear	Coal	Nuclear

Tract type reported contained the higher mean. Asterisks indicate no significant difference between tract types.

Median household income also varied significantly among tract types F=95.62, p<0.001. Post hoc tests determine that median income in both host tracts (M=59.40, SD=28.38) is significantly different from non-host (M=53.86, SD=25.34), coal host (M=55.91, SD=27.62), and nuclear host (M=56.05, SD=27.34) tracts at the p<0.001 level. Further non-host tracts were significantly different than coal host tracts, p<0.001 and nuclear host tracts, p=0.004. There was no significant difference in median income between nuclear host and coal host tracts at the 30 mile buffer, p=0.997.

There were significant differences in percent families living below the poverty line among tract types F= 32.40, p<0.001. Scheffe's test reveal that poverty in both host tracts (M=10.34, SD=12.08) is significantly different from non-host (M=11.71, SD=10.46), coal host (M=11.35, SD=11.45), and nuclear host (M=11.46, SD=11.38) tracts at the p<0.001 level. Additionally, coal host tracts were significantly different than non-host tracts, p=0.001. There was no difference in poverty between nuclear host tracts and non-host, p=0.787 and coal host tracts, p=0.982.

Percent population holding a bachelor's degree or above also varied significantly among tract types F= 176.81, p<0.001. Post hoc tests determine that percent population with a bachelor's degree in both host tracts (M=29.18, SD=18.25) is significantly different from non-host (M=25.11, SD=17.01), coal host (M=28.03, SD=19.06), and nuclear host (M=27.36, SD=17.63) tracts at the p<0.001 level. Further non-host tracts were significantly different than coal host tracts and nuclear host tracts at the p<0.001 level. Percent population with a bachelor's degree did not vary significantly from coal host to nuclear host tracts, p=0.437.

At the 30 mile buffer, percent population children was significantly different among tract types F= 47.02, p<0.001. Scheffe's test reveal that percent population children in nuclear host tracts (M=19.81, SD=5.65) is significantly different from non-host (M=20.98, SD=6.02), coal host (M=20.56, SD=5.50), and both host (M=20.72, SD=5.34) tracts at the p<0.001 level.

Additionally, non-host tracts differed from coal host tracts, $p<0.001$ and both host tracts, $p=0.005$. There was no significant difference in percent population children between both host and coal host tracts, $p=0.132$.

Population density also varied significantly among tract types at the 30 mile buffer $F= 255.12$, $p<0.001$. Post hoc tests determine population density in both host tracts (M=5.76, SD=14.29) is significantly different from non-host (M=3.83, SD=6.29), coal host (M=6.39, SD=14.43), and nuclear host (M=4.27, SD=5.72) tracts at the $p<0.001$ level. Additionally, coal host tracts differ from non-host and nuclear tracts at the $p<0.001$ level. There was no significant difference between nuclear and non-host tracts, $p=418$.

Percent population employed in the utilities sector also varied significantly among tract types at the 30 mile buffer $F= 43.76$, $p<0.001$. Scheffe's tests reveal significant differences between all tract types at the 0.05 level with nuclear host tracts containing the greatest percent population employed in the utilities sector (M=5.48, SD=3.97), followed by coal host (M=5.24, SD=3.55), then both host (M=5.11, SD=3.18), and lastly non-host (M=4.95, SD=3.34) tracts.

30 Mile Buffer Chi-Square

Pearson's chi-square test reveals differences in location among tract types at the 30 mile buffer, X^2=23,000, $p<0.001$. In contrast to the smaller buffer sizes, non-host tracts at the 30 mile buffer were most likely to be located in the West, followed by the South, Midwest and lastly, Northeast (Table 10). Coal host tracts tended to be sited in the South, followed closely by the Midwest, Northeast and West. Nuclear host tracts continued to be located primarily in the South, followed by the West, Midwest and Northeast. Both host tracts tended to be located in the Northeast, followed by the Midwest, South, and lastly West.

Table 10. Buffer 30 Tract Type Frequency by Region.

	Non-Host	Coal Host	Nuclear Host	Both Host
West	13,014	2,387	514	0
	(46.17)	(07.12)	(23.83)	(00.00)
Midwest	3,078	11,401	252	2,188
	(10.92)	(33.99)	(11.68)	(26.74)
South	10,335	12,121	1,160	2,140
	(36.67)	(36.14)	(53.78)	(26.15)
Northeast	1,760	7,632	231	3,855
	(06.24)	(22.75)	(10.71)	(47.11)
Total	28,187	33,541	2,157	8,183
	(100)	(100)	(100)	(100)

Percentages reported in parentheses.

Summary of Bivariate Results

Coal Host Tracts vs. Non-Host Tracts

Coal tracts contained greater percent of the population that is minority and percent of families living in poverty than non-host tracts at the 10 and 20 mile buffers although, at the 30 mile buffer this relationship was inverted. Median income was higher in non-host tracts compared to coal host tracts at the 10 mile buffer however this relationship disappeared at the 20 mile buffer and was inverted at the 30 mile buffer. Coal host tracts contained greater population density, percent of the population that is employed in the utilities sector and percent of the population with a bachelor's degree and fewer percent of the population that is children at all buffer sizes.

Nuclear Host Tracts vs. Non-Host Tracts

Median income and percent of the population that is employed in the utilities sector was higher in nuclear host tracts compared to non-host tracts at all buffer sizes. Nuclear host tracts contained less percent of the population that is minority and percent of families living in poverty at the 10 and 20 mile buffers. At the 30 mile buffer, there was no difference between poverty rates and nuclear tracts contained more percent of the population that is minority. Nuclear host tracts contained less population density at the 10 mile buffer however this relationship disappeared at the larger buffer sizes. While there was no difference between percent of the population with a bachelor's degree and children at the 10 mile buffer, nuclear host tracts contained more percent of the population with a bachelor's degree and fewer percent of the population that is children compared to non-host tracts at the 20 and 30 miles buffers.

Coal Host Tracts vs. Nuclear Host Tracts

At the 10 and 20 mile buffers, coal host tracts contained greater percent of the population that is minority, and families living in poverty, and less median income than nuclear host tracts. At the 30 mile buffer these relationships disappeared with the exception of percent of the population minority which was greater in nuclear host tracts. In all buffer sizes, population density was greater in coal host tracts and there was no difference in the percent of the population with a bachelor's degree. There was no difference in the percent of the population that is children at the 10 mile buffer however at the 20 and 30 mile buffers, coal host tracts contained more children. Lastly, at the 10 and 30 mile buffers, nuclear host tracts contained greater percent of the population that is minority compared to coal host tracts, although this relationship was not found at the 20 mile buffer.

Multivariate Analyses

10 Mile Buffer Multinomial Logistic Regression

Tables 11 through 16 provide the outcomes, including coefficients, relative risk ratios, and significant findings of all multinomial logistic regression models. As shown in Table 11, the LR chi-square was significant at the p<0.001 level in models examining the 10 mile buffer

(9979.07), indicating a relationship between the dependent variable and the combination of independent variables in each model. AIC and BIC for these models were 72,860.04 and 73,163.16 respectively. Cragg and Uhler's R^2 was 0.19 for the 10 Mile buffer.

Model 1 estimates the effects of demographic variables on the probability of tracts being located within a 10 mile radius of a plant compared to being located outside the buffer. As predicted, this model indicates that communities which contain higher percent population minority are more likely to be located in a coal host tract versus a non-host tract (Relative Risk Ratio=1.008; p<0.001). Additionally, populations living within a coal host tract are more likely to have lower median household incomes (RRR=0.992; p<0.001) and higher percent population families living below the poverty line (RRR=1.011; p<0.001) than non-host tracts. Tracts with greater percent population with a bachelor's degree or above are expected to be coal host versus non-host tracts (RRR=1.018; p<0.001). Coal host tracts are also more likely to have greater population densities (RRR=1.015; p<0.001) and higher percent population employed in the utilities industry (RRR=1.038; p<0.001) compared to non-host tracts. Attributes for region reveal that living in the West versus living in the South decreases the likelihood of living in a coal host tract compared to a non-host tract (RRR=0.399; p<0.001). Conversely, the likelihood of being located in a coal host tract compared to a non-host tract increases if living in the Midwest (RRR=4.453; p<0.001) or the Northeast (RRR=2.394; p<0.001), compared to living in the South.

At the 10 mile buffer, percent population minority, median household income, percent population children, and population density are not significant determinants of being located in a nuclear versus non-host tract. However, tracts with lower percent population poverty are expected to be nuclear host tracts compared to non-host tracts (RRR=0.980; p<0.001). Additionally, population density is expected to be lower in nuclear host tracts compared to non-host tracts (RRR=0.878; p<0.001). Further, tracts with greater percent population employed in the utilities sector are expected to be nuclear host tracts compared to non-host tracts (RRR=1.092; p<0.001).

Dummy variables for region indicate that tracts are less likely to be nuclear host than non-host if located in the West (RRR=0.159; $p<0.001$) or Midwest (RRR=0.702; $p<0.01$) compared to the South. Conversely, tracts are more likely to be nuclear host than non-host if they are located in the Northeast compared to the South (RRR=2.361; $p<0.001$).

Model 1 reveals that both host tracts are less likely than non-host tracts to contain higher percent population minority (RRR=0.991; $p<0.05$) and percent families living below the poverty line (RRR=0.956; $p<0.001$). Conversely, both host tracts are more likely than non-host tracts to contain higher percent population children (RRR=1.080; $p<0.001$) and percent population employed in the utilities sector (RRR=1.119; $p<0.001$). At the 10 mile buffer, tracts with greater population density are more likely to be non-host tracts than both host tracts (RRR=0.912; $p<0.001$). Region variables show that tracts located in the Midwest (RRR=1.483; $p<0.05$) and Northeast (RRR=3.795l; $p<0.001$) compared to the South, are more likely to be both host tracts than non-host tracts. Median household income, percent population with a bachelor's degree or above and living in the West compared to the South are not significant determinants of being a both host tract versus a non-host tract.

Table 11. Multinomial Logistic Regression Analysis Examining the Effect of Demographic Variables on the Probability of Living in a Tract Located Within 10 Miles of a Coal Plant, Nuclear Plant, or Both.

	Model 1[a]					
	Coal Host		Nuclear Host		Both Host	
	B	*SE*	*B*	*SE*	*B*	*SE*
Minority	0.00762***	0.00044	-0.00108	0.0024	-0.00870*	0.0035
	(1.008)		(0.999)		(0.991)	
Median Income[b]	-0.00802***	0.00073	0.00121	0.0029	-0.00668	0.0041
	(0.992)		(1.001)		(0.993)	
Poverty	0.0105***	0.0013	-0.0205**	0.0075	-0.045***	0.011
	(1.011)		(0.980)		(0.956)	
Bachelors	0.0181***	0.00092	0.00140	0.0043	0.00919	0.0059
	(1.018)		(1.001)		(1.009)	
Children	-0.0123***	0.0022	0.0122	0.011	0.0765***	0.015
	(0.988)		(1.012)		(1.080)	
Population Density	0.0148***	0.00090	-0.130***	0.020	-0.0916***	0.024
	(1.015)		(0.878)		(0.912)	
Utilities	0.0377***	0.0030	0.0879***	0.010	0.113***	0.014
	(1.038)		(1.092)		(1.119)	
West[c]	-0.920***	0.039	-1.839***	0.22	-16.161	417.86
	(0.399)		(0.159)		(9.58e-8)	
Midwest[c]	1.494***	0.026	-0.354***	0.13	0.394*	0.16
	(4.453)		(0.702)		(1.483)	
Northeast[c]	0.873***	0.030	0.859***	0.11	1.334***	0.15
	(2.394)		(2.361)		(3.795)	
Constant	-2.368***	0.057	-4.824***	0.24	-6.650***	0.34
LR $Chi^2(30)$	9979.07***					
Cragg-Uhler R^2	0.189					
AIC	72860.042					
BIC	73163.159					

[a]Coefficients vs. the base category of non-host. Relative risk ratios are in parentheses. [b]Median Income and Population Density are reported in thousands. [c] Effect of region with South as base category. *p<0.05, **p<0.01, ***p<0.001.

When compared to coal host tracts, nuclear host tracts (see Table 12) are more likely to contain populations with lesser percent minorities (RRR=0.991; $p<0.001$) and families living below the poverty line (RRR=0.969; $p<0.001$). Similarly, tracts with higher median incomes are expected to be located in nuclear host tracts compared to coal host tracts (RRR=1.009; $p<0.01$). Interestingly, tracts with higher percent population holding a bachelor's degree are expected to be coal host tracts compared to nuclear host tracts. Compared to coal host tracts, nuclear tracts are expected to be tracts with higher percent population children (RRR=1.025; $p<0.05$) and percent population employed in the utilities sector (RRR=1.051; $p<0.001$). Additionally, tracts with higher population densities are expected to be coal host tracts versus nuclear host tracts (RRR=0.865; $p<0.001$). Variables for region reveal that tracts are more likely to be coal host tracts than nuclear host tracts if located in the West (RRR=0.399; $p<0.001$) and Midwest (RRR=0.158; $p<0.001$) versus the South. Being located in the Northeast versus the South is a not a significant determinant of being a coal host versus nuclear host tract.

Model 2 shows the relationship between coal host tracts and nuclear and both host tracts. Similarly to nuclear host tracts, both host tracts are less likely than coal host tracts to contain higher percent population minorities (RRR=0.984; $p<0.001$), percent families living below the poverty line (RRR=0.946; $p<0.001$), and population density (RRR=0.899; $p<0.001$). Conversely, both host tracts are more likely than coal host tracts to contain higher percent population children (RRR=1.093; $p<0.001$) and percent population employed in the utilities sector (RRR=1.078; $p<0.001$). Regional variables indicate that tracts located in the Midwest compared to the South are more likely to be coal host tracts versus both host tracts (RRR=0.333; $p<0.001$). In contrast, tracts in the Northeast compared to the South are more likely to be both host tracts than coal host tracts (RRR=1.585; $p<0.01$). Living in the West versus the South, median household income, and percent population with a bachelor's degree or above are not significant determinants of being a both host tract versus a coal host tract.

Table 12. Multinomial Logistic Regression Analysis Examining the Effect of Demographic Variables on the Probability of Living in a Tract Located Within 10 Miles of a Nuclear Plant or Both a Coal and Nuclear Plant.

	Model 2[a]				Model 3[b]	
	Nuclear Host		Both Host		Both Host	
	B	*SE*	*β*	*SE*	*β*	*SE*
Minority	-0.00870***	0.0024	-0.0163***	0.0036	-0.00761	0.0043
	(0.991)		(0.984)		(0.992)	
Median Income[c]	0.00922**	0.0030	0.00134	0.0041	-0.00789	0.0050
	(1.009)		(1.001)		(0.992)	
Poverty	-0.0310***	0.0075	-0.0558***	0.012	-0.0248	0.014
	(0.969)		(0.946)		(0.976)	
Bachelors	-0.0167***	0.0044	-0.00889	0.0059	0.00780	0.0072
	(0.983)		(0.991)		(1.008)	
Children	0.0245*	0.011	0.0889***	0.015	0.0643***	0.018
	(1.025)		(1.093)		(1.066)	
Population Density	-0.145***	0.020	-0.106***	0.024	0.0388	0.031
	(0.865)		(0.899)		(1.040)	
Utilities	0.0502***	0.011	0.0751***	0.015	0.0249	0.017
	(1.051)		(1.078)		(1.025)	
West[d]	-0.919***	0.23	-15.241	417.86	-14.322	417.86
	(0.399)		(2.40e-7)		(6.03e-7)	
Midwest[d]	-1.847***	0.13	-1.100***	0.16	0.748***	0.21
	(0.158)		(0.333)		(2.112)	
Northeast[d]	-0.0140	0.11	0.461**	0.15	0.475**	0.18
	(0.986)		(1.585)		(1.607)	
Constant	-2.455***	0.25	-4.282***	0.35	-1.826***	0.42

[a]Coefficients vs. the base category of coal host. [b]Coefficients vs. the base category of nuclear host. Relative risk ratios are in parentheses. [c]Median Income and Population Density are reported in thousands. [d]Effect of region with South as base category. *p<0.05, **p<0.01, ***p<0.001.

Interestingly, when comparing nuclear tracts to both host tracts, percent population minority, percent population with a bachelor's degree, percent population living in poverty, median household income, population density and living in the West compared to the South are not significant determinants of tract type. However, tracts with higher percent population children are expected to be both host tracts compared to nuclear host tracts (RRR=1.066; $p<0.001$). Additionally, tracts in the Midwest (RRR=2.112; $p<0.001$) and Northeast (RRR=1.607; $p<0.01$) compared to the South are also more likely to be both host tracts than nuclear host tracts.

20 Mile Buffer Multinomial Logistic Regression

Models 4 through 6 provide the outcomes of multinomial logistic regression models employing the 20 mile buffer. The LR chi-square was significant at the $p<0.001$ level in models examining the 20 mile buffer (20805.95), indicating a relationship between the dependent variable and the combination of independent variables in each model (Table 13). AIC and BIC for these models were 109,978.84 and 110,281.96 respectively. Cragg and Uhler's R^2 was 0.300 for models employing the 20 Mile buffer.

Model 4 examines the effect of demographic variables on the probability of tracts being located within 20 miles of a coal plant, nuclear plant, or both, compared to being non-host tracts. This model reveals that coal host tracts are more likely than non-host tracts to contain higher percent population minorities (RRR=1.007; $p<0.001$), percent population with a bachelor's degree (RRR=1.016; $p<0.001$), population density (RRR=1.058; $p<0.001$), and percent population employed in the utilities sector (RRR=1.048; $p<0.001$). Conversely, tracts with higher percent population children are more likely to be non-host tracts than coal host tracts (RRR=0.996; $p<0.05$). Additionally, variables for region indicate that tracts in the West compared the South, are more likely to be non-host tracts than coal host tracts (RRR=0.157; $p<0.001$). In contrast, coal host tracts are more likely than non-host tracts to be located in the

Midwest (RRR=3.684; $p<0.001$) and Northeast (RRR=2.481; $p<0.001$) compared to the South. Median household income and percent families living below the poverty line are the only demographic variables not significant determinants of being a coal host versus non-host tract.

Similarly to coal host tracts, nuclear host tracts are more likely than non-host tracts to contain greater percent population minorities (RRR=1.004; $p<0.01$). Further, nuclear host tracts are more likely than non-host tracts to contain higher median household incomes (RRR=1.010; $p<0.001$), percent families living below the poverty line (RRR=1.008; $p<0.05$), and percent population employed in the utilities industry (RRR=1.049; $p<0.001$). In contrast, tracts with higher percent population children are more likely to be non-host tracts compared to nuclear host tracts (RRR=0.965; $p<0.001$). Additionally, nuclear host tracts are more likely than non-host tracts to be located in the Northeast compared to the South (RRR=2.217; $p<0.001$). Conversely, tracts located in the West (RRR=0.287; $p<0.001$) and the Midwest (RRR=0.845; $p<0.05$) compared to the South are more likely to be non-host tracts than nuclear host tracts. The only independent variable that is not a significant determinant of living in a nuclear host versus non-host tract is the percent population holding a bachelor's degree or above.

In contrast to nuclear host tracts, both host tracts are less likely than non-host tracts to contain higher median incomes (RRR=0.993; $p<0.001$) and percent families living in poverty (RRR=0.989; $p<0.001$). Tracts with higher percent population children (RRR=1.048; $p<0.001$), percent population with a bachelor's degree (RRR=1.025; $p<0.001$), and percent population employed in the utilities sector (RRR=1.070; $p<0.001$) are more likely to be both host tracts than non-host tracts. Additionally, both host tracts are more likely than non-host tracts to be located in the Midwest (RRR=1.945; $p<0.001$) and Northeast (RRR=4.991; $p<0.001$) compared to the South. Interestingly, at this 20 mile buffer, percent population minority and population density are not significant determinants of living in a both host tract versus a non-host tract.

Table 13. Multinomial Logistic Regression Analysis Examining the Effect of Demographic Variables on the Probability of Living in a Tract Located Within 20 Miles of a Coal Plant, Nuclear Plant, or Both.

	Model 4[a]					
	Coal Host		Nuclear Host		Both Host	
	B	*SE*	*β*	*SE*	*B*	*SE*
Minority	0.00726***	0.00043	0.00352**	0.0013	0.0000960	0.0011
	(1.007)		(1.004)		(1.000)	
Median Income[b]	0.000923	0.00062	0.0103***	0.0015	-0.00675***	0.0015
	(1.001)		(1.010)		(0.993)	
Poverty	0.00155	0.0012	0.00840*	0.0034	-0.011**	0.0032
	(1.002)		(1.008)		(0.989)	
Bachelors	0.0161***	0.00085	0.00259	0.0024	0.0248***	0.0020
	(1.016)		(1.003)		(1.025)	
Children	-0.00429*	0.0020	-0.0354***	0.0055	0.0466***	0.0051
	(0.996)		(0.965)		(1.048)	
Population Density	0.0560***	0.0018	-0.0110	0.0065	-0.0224***	0.00591
	(1.058)		(0.989)		(0.978)	
Utilities	0.0468***	0.0028	0.0479***	0.0074	0.0673***	0.0065
	(1.048)		(1.049)		(1.070)	
West[c]	-1.851***	0.031	-1.248***	0.081	-19.417	574.78
	(0.157)		(0.287)		(3.69e-9)	
Midwest[c]	1.304***	0.023	-0.168*	0.082	0.665***	0.058
	(3.684)		(0.845)		(1.945)	
Northeast[c]	0.909***	0.027	0.796***	0.067	1.608***	0.054
	(2.481)		(2.217)		(4.991)	
Constant	-1.621***	0.049	-3.341***	0.13	-4.304***	0.12
LR $Chi^2(30)$	20805.95***					
Cragg-Uhler R^2	0.300					
AIC	109978.84					
BIC	110281.96					

[a]Coefficients vs. the base category of non-host. Relative risk ratios are in parentheses. [b]Median Income and Population Density are reported in thousands. [c] Effect of region with South as base category. *p<0.05, **p<0.01, ***p<0.001.

Model 5 examines the effect of independent variables on the probability of tracts being nuclear hosts and both hosts compared to being coal host tracts at the 20 mile buffer (Table 14). This model reveals that tracts with higher percent population minorities are more likely to be coal host tracts versus nuclear host tracts (RRR=0.996; $p<0.01$). However, tracts with higher median income (RRR=1.009; $p<0.001$) and percent families living in poverty (RRR=1.007; $p<0.05$) are more likely to be nuclear host tracts. Nuclear host tracts are also less likely than coal host tracts to contain higher percent population children (RRR=0.969; $p<0.001$), percent population with a bachelor's degree or above (RRR=0.987; $p<0.001$) and population density (RRR=0.935; $p<0.001$). Regional variables determine that while nuclear host tracts compared to coal host tracts are more likely to be located in the West compared to the South (RRR=1.828; $p<0.001$), coal host tracts are more likely to be located in the Midwest compared to the South (RRR=0.229; $p<0.001$). Percent population employed in the utilities sector and living in the West compared to the South are not significant determinants of being a nuclear host tract compared to a coal host tract.

However, all demographic variables (excluding West) are significant determinants of being a both host tract versus a coal host tract at the 20 mile buffer. To begin with, tracts with greater percent population minority (RRR=0.993; $p<0.001$), percent families living in poverty (RRR=0.988; $p<0.001$), median household income (RRR=0.992; $p<0.001$), and population density (RRR=0.925; $p<0.001$) are more likely to be coal host tracts compared to both host tracts. However, both host tracts are more likely than coal host tracts to contain higher percent population children (RRR=1.052; $p<0.001$), percent population with a bachelor's degree or above (RRR=1.009; $p<0.001$), and percent population employed in the utilities sector (RRR=1.021; $p<0.001$). Lastly, tracts located in the Midwest compared to the South are more likely to be coal host tracts than both host tracts (RRR=0.528; $p<0.001$) while tracts located in the Northeast are more likely to be both host tracts than coal host tracts (RRR=2.012; $p<0.001$).

Table 14. Multinomial Logistic Regression Analysis Examining the Effect of Demographic Variables on the Probability of Living in a Tract Located Within 20 Miles of a Nuclear Plant or Both a Coal and Nuclear Plant.

	Model 5[a]				Model 6[b]	
	Nuclear Host		Both Host		Both Host	
	B	*SE*	*β*	*SE*	*β*	*SE*
Minority	-0.00374**	0.0013	-0.00717***	0.0011	-0.00342*	0.0016
	(0.996)		(0.993)		(0.997)	
Median Income[c]	0.00940***	0.0015	-0.00767***	0.0015	-0.0171***	0.0020
	(1.009)		(0.992)		(0.983)	
Poverty	0.00685*	0.0034	-0.0123***	0.0032	-0.0192***	0.0045
	(1.007)		(0.988)		(0.981)	
Bachelors	-0.0136***	0.0024	0.00866***	0.0020	0.0222***	0.0030
	(0.987)		(1.009)		(1.022)	
Children	-0.0311***	0.0056	0.0509***	0.0051	0.0820***	0.0073
	(0.969)		(1.052)		(1.085)	
Population Density	-0.0670***	0.0064	-0.0784***	0.0058	-0.0114	0.0085
	(0.935)		(0.925)		(0.989)	
Utilities	0.00115	0.0074	0.0205***	0.0064	0.0194*	0.0094
	(1.001)		(1.021)		(1.020)	
West[d]	0.603***	0.085	-17.566	574.78	-18.169	574.78
	(1.828)		(2.35e-8)		(1.29e-8)	
Midwest[d]	-1.472***	0.082	-0.639***	0.058	0.834***	0.097
	(0.229)		(0.528)		(2.301)	
Northeast[d]	-0.113	0.067	0.699***	0.054	0.812***	0.082
	(0.893)		(2.012)		(2.252)	
Constant	-1.720***	0.14	-2.684***	0.12	-0.964***	0.17

[a]Coefficients vs. the base category of coal host. [b]Coefficients vs. the base category of nuclear host. Relative risk ratios are in parentheses. [c]Median Income and Population Density are reported in thousands. [d]Effect of region with South as base category. *p<0.05, **p<0.01, ***p<0.001

The effect of demographic variables on the probability of tracts hosting a nuclear plant versus tracts hosting both a nuclear and coal plant at the 20 mile buffer is examined in model 6. This model reveals that tracts hosting a nuclear plant are more likely than both host tracts to contain higher percent population minorities (RRR=0.997; $p<0.05$), percent families living below the poverty line (RRR=0.981; $p<0.001$), and median household income (RRR=0.983; $p<0.001$). In contrast, tracts with higher percent population with a bachelor's degree (RRR=1.022; $p<0.001$), percent population children (RRR=1.085; $p<0.008$), and percent population employed in the utilities sector (RRR=1.020; $p<0.05$) are more likely to be both host tracts than nuclear host tracts. Regional variables indicate that tracts in the Midwest (RRR=2.301; $p<0.001$) and Northeast (RRR=2.252; $p<0.001$) compared to the South are more likely to be both host tracts than nuclear host tracts. Population density is not a significant determinant of living in a both host tract compared to nuclear host tract at the 20 mile buffer.

30 Mile Buffer Multinomial Logistic Regression

Models 7 through 9 provide the outcomes of multinomial logistic regression models employing the 30 mile buffer. The LR chi-square was significant at the $p<0.001$ level in models examining the 30 mile buffer (27109.53), indicating a relationship between the dependent variable and the combination of independent variables in each model (Table 15). AIC and BIC for these models were 127,927.05 and 128,230.17 respectively. Cragg and Uhler's R^2 was 0.355 for the 30 Mile buffer.

Model 7 examines the effect of demographic variables on the probability of tracts being located within 30 miles of a nuclear plant, coal plant, or both, compared to being non-host tracts. This model shows that coal host tracts are more likely than non-host tracts to have greater percent population minorities (RRR=1.004; $p<0.001$), median household income (RRR=1.007; $p<0.001$), percent population holding a bachelor's degree (RRR=1.013; $p<0.001$), percent population children (RRR=1.004; $p<0.05$), percent population employed in the utilities sector (RRR=1.038; $p<0.001$), and population density (RRR=1.039; $p<0.001$). Additionally, variables for region determine that tracts in the Midwest (RRR=3.375; $p<0.001$) and Northeast (RRR=2.733; $p<0.001$) compared to the South are more likely to be coal host tracts than non-host tracts. In contrast, tracts in the West compared to the South are more likely to be non-host tracts versus coal host tracts (RRR=0.111; $p<0.001$). Percent families living below the poverty line is not a significant determinant of being a coal host versus non-host tract in this model.

Similar to coal host tracts, nuclear host tracts are more likely than non-host tracts to contain greater percent population minorities (RRR=1.012; $p<0.001$), median household income (RRR=1.011; $p<0.001$), population density (RRR=1.010; $p<0.05$), and percent population employed in the utilities sector (RRR=1.049; $p<0.001$). Conversely, tracts with greater percent population children are more likely to be non-host tracts than nuclear host tracts (RRR=0.951; $p<0.001$). Additionally, tracts located in the West compared to the South are more likely to be non-host tracts than coal host tracts (RRR=0.270; $p<0.001$). Percent families living in poverty, percent population possessing a bachelor's degree, and living in the Midwest and Northeast compared to the South are not significant predictors of being a nuclear host tract versus a non-host tract.

Both host tracts closely resemble coal and nuclear host tracts compared to non-host tracts at the 30 mile buffer. For instance, both host tracts are more likely than non-host tracts to contain greater percent population minorities (RRR=1.004; $p<0.001$), median household income (RRR=1.006; $p<0.001$), percent population with a bachelor's degree or above (RRR=1.045; $p<0.001$), percent population children (RRR=1.030; $p<0.001$), population density (RRR=1.024; $p<0.001$), and percent population employed in the utilities sector (RRR=1.030; $p<0.001$). In this model, both host tracts are also more likely than non-host tracts to be located in the Midwest (RRR=3.708; $p<0.001$) and Northeast (RRR=9.266; $p<0.001$) compared to the South. Percent families living in poverty is the only variable which is not a significant determinant of being a both host tract versus a non-host tract at the 30 mile buffer.

Table 15. Multinomial Logistic Regression Analysis Examining the Effect of Demographic Variables on the Probability of Living in a Tract Located Within 30 Miles of a Coal Plant, Nuclear Plant, or Both.

	Model 7[a]					
	Coal Host		Nuclear Host		Both Host	
	B	*SE*	*β*	*SE*	*β*	*SE*
Minority	0.00414***	0.00045	0.0123***	0.0010	0.00446***	0.00067
	(1.004)		(1.012)		(1.004)	
Median Income[b]	0.00701***	0.00068	0.0110***	0.0014	0.00647***	0.0010
	(1.007)		(1.011)		(1.006)	
Poverty	0.00189	0.0013	0.000922	0.0029	-0.00233	0.0019
	(1.002)		(1.001)		(0.998)	
Bachelors	0.0124***	0.00091	0.00363	0.0020	0.0145***	0.0014
	(1.013)		(1.004)		(1.015)	
Children	0.00424*	0.0021	-0.0507***	0.0046	0.0299***	0.0033
	(1.004)		(0.951)		(1.030)	
Population Density	0.0387***	0.0019	0.00972*	0.0040	0.0241***	0.0021
	(1.039)		(1.010)		(1.024)	
Utilities	0.0375***	0.0030	0.0481***	0.0062	0.0292***	0.0045
	(1.038)		(1.049)		(1.030)	
West[c]	-2.201***	0.029	-1.311***	0.059	-20.339	431.75
	(0.111)		(0.270)		(1.47e-9)	
Midwest[c]	1.216***	0.026	-0.104	0.074	1.311***	0.038
	(3.375)		(0.901)		(3.708)	
Northeast[c]	1.005***	0.032	0.0696	0.081	2.226***	0.040
	(2.733)		(1.072)		(9.266)	
Constant	-1.059***	0.052	-2.572***	0.12	-3.246***	0.080
LR Chi^2(30)	27109.532***					
Cragg-Uhler R^2	0.355					
AIC	127927.05					
BIC	128230.167					

[a]Coefficients vs. the base category of non-host. Relative risk ratios are in parentheses. [b]Median Income and Population Density are reported in thousands. [c] Effect of region with South as base category. *p<0.05, **p<0.01, ***p<0.001.

Model 8 provides the effect of the demographic variables on the probability of tracts being nuclear host and both host tracts compared to being coal host tracts (Table 16). This model reveals that nuclear host tracts are more likely than coal host tracts to contain greater percent population minorities (RRR=1.008; $p<0.001$) and median household income (RRR=1.004; $p<0.01$). Nuclear host tracts are also more likely than coal host tracts to be located in the West compared to the South (RRR2.436; $p<0.001$). In contrast, coal host tracts are more likely than nuclear host tracts to contain greater percent population with a bachelor's degree (RRR=0.991; $p<0.001$), percent population children (RRR=0.947; $p<0.001$), and population density (RRR=0.971; $p<0.001$). Additionally, tracts located in the Midwest (RRR=0.267; $p<0.001$) and Northeast (RRR=0.392; $p<0.001$) compared to the South are more likely to be coal host tracts than nuclear host tracts. Percent families living in poverty and percent population employed in the utilities sector are not significant predictors of being a nuclear host tract versus a coal host tract in this model.

In contrast to nuclear host tracts, both host tracts compared to coal host tracts are more likely to contain greater percent population children (RRR=1.026; $p<0.001$). However, coal host tracts are more likely than both host tracts to contain greater percent families living below the poverty line (RRR=0.996; $p<0.05$), population density (RRR=0.986; $p<0.001$), and percent population employed in the utilities sector (RRR=0.992; $p<0.05$). Regional variables determine that both host tracts are more likely than coal host tracts to be located in the Midwest (RRR=1.099; $p<0.01$) and Northeast (RRR=3.391; $p<0.001$) compared to the South. Interestingly, percent population minorities, median household income, and percent population with a bachelor's degree are not significant determinants of being a both host tract compared to a coal host tract at the 30 mile buffer.

Table 16. Multinomial Logistic Regression Analysis Examining the Effect of Demographic Variables on the Probability of Living in a Tract Located Within 30 Miles of a Nuclear Plant or Both a Coal and Nuclear Plant.

	Model 8[a]				Model 9[b]	
	Nuclear Host		Both Host		Both Host	
	β	SE	β		β	SE
Minority	0.00815***	0.00099	0.000317	0.00058	-0.00783***	0.0011
	(1.008)		(1.000)		(0.992)	
Median Income[c]	0.00402**	0.0014	-0.000531	0.00086	-0.00455**	0.0016
	(1.004)		(0.999)		(0.995)	
Poverty	-0.000965	0.0029	-0.00421*	0.0017	-0.00325	0.0032
	(0.999)		(0.996)		(0.997)	
Bachelors	-0.00882***	0.0020	0.00201	0.0012	0.0108***	0.0022
	(0.991)		(1.002)		(1.011)	
Children	-0.0549***	0.0046	0.0257***	0.0030	0.0806***	0.0053
	(0.947)		(1.026)		(1.084)	
Population Density	-0.0290***	0.0039	-0.0145***	0.0012	0.0144***	0.0040
	(0.971)		(0.986)		(1.015)	
Utilities	0.0106	0.0061	-0.00825*	0.0040	-0.0189**	0.0070
	(1.011)		(0.992)		(0.981)	
West[d]	0.890***	0.062	-18.138	431.75	-19.0286	431.75
	(2.436)		(1.33e-8)		(5.44e-9)	
Midwest[d]	-1.321***	0.073	0.0941**	0.034	1.415***	0.078
	(0.267)		(1.099)		(4.117)	
Northeast[d]	-0.936***	0.078	1.221***	0.033	2.157***	0.082
	(0.392)		(3.391)		(8.643)	
Constant	-1.513***	0.12	-2.187***	0.072	-0.675***	0.13

[a]Coefficients vs. the base category of coal host. [b] Coefficients vs. the base category of nuclear host. Relative risk ratios are in parentheses. [c]Median Income and Population Density are reported in thousands. [d] Effect of region with South as base category. *p<0.05, **p<0.01, ***p<0.001.

Model 9 presents the effect of demographic variables on the probability of tracts being located within a 30 mile radius of both a coal and nuclear plant versus tracts being nuclear host alone. This model shows that both host tracts are more likely than nuclear host tracts to contain greater percent population with a bachelor's degree or above (RRR=1.011; p<0.001), percent population children (RRR=1.084; p<0.001), and population density (RRR=1.014; p<0.001). Conversely, tracts with greater percent population minorities (RRR=0.992; p<0.001), median household income (RRR=0.995; p<0.01), and percent population employed in the utilities sector (RRR=0.981; p<0.01) are more likely to be nuclear host tracts than both host tracts. Regional variables determine that tracts located in the Midwest (RRR=4.117; p<0.001) and Northeast (RRR=8.643; p<0.001) compared to the South are more likely to be both host tracts than nuclear host tracts. In this model percent families living below the poverty line is the only variable which is not a significant predictor of being a both host tract compared to nuclear host tract at the 30 mile buffer.

Summary of Multivariate Findings

Coal Host Tracts vs. Non-Host Tracts

At the 10 mile buffer, multinomial logistic regression equations reveal that compared to non-host tracts, coal host tracts contained significantly greater percent of the population that is minority, percent families living in poverty, percent of the population with a bachelor's degree or above, population density and percent of the population that is employed in the utilities sector. In contrast, coal host tracts had lower median household income and percent of the population that is children compared to non-host tracts. Coal host tracts were more likely than non-host tracts to be located in the Midwest and Northeast versus the South.

At the 20 mile buffer, coal host tracts continued to have greater percent of the population that is minority, percent of the population with a bachelor's degree, percent of the population employed in the utilities sector and population density than non-host tracts. However, coal tracts no longer contained more poverty and lower incomes than non-host tracts. Coal host tracts continued to be more likely than non-host tracts to be located in Midwest and Northeast compared to the South. Additionally, coal host tracts were less likely than non-host tracts to be located in the West versus the South.

At the 30 mile buffer, coal host tracts continued to have greater percent of the population that is minority, percent of the population with a bachelor's degree, population density, and percent of the population that is employed in the utilities sector compared to non-host tracts. Additionally, at this buffer size median household income and percent of the population that is children was also greater in coal host tracts compared to non-host tracts. Coal host tracts were more likely than non-host tracts to be located in the Midwest and Northeast and less likely to be located in the West versus the South.

Nuclear Host Tracts vs. Non-Host Tracts

Multivariate analyses reveal that nuclear host tracts at the 10 Mile buffer possessed lower rates of poverty and population density and higher percent of the population employed in the utilities sector than non-host tracts. Nuclear tracts were less likely than non-host tracts to be located in the Northeast and West. Additionally, nuclear tracts more likely than non-host tracts to be located in the Midwest compared to the South.

At the 20 mile buffer, nuclear host tracts contained greater percent of the population that is minority, median household income, percent of families living in poverty, and percent of the population employed in the utilities sector than non-host tracts. Additionally, nuclear tracts contained fewer children than non-host tracts. Compared to non-host tracts, nuclear host tracts were less likely to be located in the West and Midwest and more likely to be located in the Northeast versus the South.

Nuclear host tracts at the 30 mile buffer had greater percent of the population that is minority, median household income, and percent of the population that is employed in the utility sector compared to non-host tracts. Additionally, nuclear host tracts had lower percent of the population that is children. Compared to non-host tracts, nuclear tracts were less likely to be located in the West versus the South.

Coal Host Tracts vs. Nuclear Host Tracts

At the 10 mile buffer, multinomial logistic regression equations reveal that compared to nuclear host tracts, coal host tracts contained significantly greater percent of the population that is minority, percent families living in poverty, percent of the population with a bachelor's degree or above, and population density and lower percent of the population that is children. Coal host tracts also had lower median household income and percent of the population that is employed in the utilities sector than nuclear host tracts. Compared to nuclear host tracts, coal host tracts were more likely to be located in the West, Midwest, and Northeast versus the South.

At the 20 mile buffer, coal host tracts continued to have greater percent of the population that is minority and population density than nuclear tracts. Median income and percent population with a bachelor's degree also remained greater in nuclear tracts compared to coal tracts, however, at this buffer nuclear tracts also contained more poverty and less percent population children. Compared to nuclear host tracts, coal host tracts were more likely to be located in the Midwest and less likely to be located in the West versus the South.

At the 30 mile buffer coal host tracts contained lower percent of the population that is minority and median household income than nuclear host tracts. Coal host tracts also had greater percent of the population with a bachelor's degree, percent of the population that is children, and population density. Compared to nuclear host tracts, coal host tracts at the 30 mile buffer were more likely to be located in the Midwest and Northeast and less likely to be located in the West versus the South.

CHAPTER V

CONCLUSION

Discussion of Findings

This study sought to determine whether race, class, and percent of the population that is children are indicators of power plant injustices. Hypothesis 1 was supported with coal host tracts containing greater percent of the population that is minority than non-host tracts at all buffer sizes (Table 17). Further, as predicted in Hypotheses 2 and 3 median incomes were lower and poverty rates were higher in coal host tracts compared to non-host tracts at the 10 mile buffer, although this finding did not persist at the 20 and 30 mile buffers. These findings are congruent with other studies examining inequalities concerning the location of coal-fired power plants in particular (Keating and Davis, 2002; Faber and Krieg, 2002) and the environmental justice literature more broadly (Downey, 2005; Bullard, 1990; Mohai and Bryant, 1992; Pellow, 2000).

Nuclear host tract demographics tell a very different story. As predicted in Hypothesis 4, and corresponding to the results of Alldred and Shrader-Frechette (2009), there were no differences in the percent of the population that is minority between nuclear and non-host tracts at the 10 mile buffer. Interestingly, at the 20 and 30 mile buffers this hypothesis was rejected as nuclear host tracts contained significantly greater percent of the population that is minority compared to non-host tracts.

Table 17. Supported hypotheses by buffer size.

	10 Mile	20 Mile	30 Mile
Hypothesis 1 *Coal tracts contain more minorities* [a.]	*	*	*
Hypothesis 2 *Coal tracts contain lower incomes*	*		
Hypothesis 3 *Coal tracts contain more poverty*	*		
Hypothesis 4 *Nuclear tracts do not contain more minorities*	*		
Hypothesis 5 *Nuclear tracts do not contain lower incomes*	*	*	*
Hypothesis 6 *Nuclear tracts do not contain more poverty*	*		*
Hypothesis 7 *Coal tracts contain more children*			*
Hypothesis 8 *Nuclear tracts contain more children*			

[a.] Compared to non-host tracts.

As anticipated given the economic model of environmental inequality (i.e. Hypothesis 5), median household incomes were not lower in nuclear host tracts compared to coal host tracts at all buffer sizes. In fact, median incomes were higher in nuclear tracts at the 20 and 30 mile buffers. Further, as predicted in Hypothesis 6, poverty rates were not greater in nuclear host tracts compared to non-host tracts at the 10 mile and 30 mile buffers. These finding were expected as nuclear plants, unlike coal plants, do not appear to have a strong impact on property values in surrounding areas (Farber, 1998). It should be noted however, that while the 30 mile buffer showed no difference in poverty rates between nuclear host tracts and non-host tracts, at the 10 mile buffer nuclear host tracts contained significantly lower rates of poverty. Thus, these tracts are not simply unaffected by their host tract status, they appear to be benefitting from decreased rates of poverty. This may suggest that nuclear plants provide economic benefits distinct from other types of hazardous facilities. In contrast, Hypothesis 6 was not accepted at the 20 mile buffer and therefore these benefits dissolve at larger buffer sizes.

Although the aforementioned hypotheses were largely supported by the data, predictions concerning the percent of the population children were unexpected. Hypothesis 7 was only supported at the 30 mile buffer where coal host tracts contained greater percent of the population that is children compared to non-host tracts. In contrast, at the 10 and 20 mile buffers there were lower percent of the population that is children compared to non-host tracts. Hypothesis 8 was rejected at all buffer types with no differences found between percent of the population that is children at the 10 mile buffer and less children found in nuclear tracts at the 20 and 30 mile buffers. These findings are in contrast to previous studies which have indicated children as a group disproportionately exposed to environmental hazards (Grineski et. al., 2010; Perlin et al., 2001).

Findings from both host tracts may offer further insight into the influence of being a coal and nuclear host tract on population demographics. To begin with, both host tracts have fewer minorities and less poverty than non-host tracts at the 10 mile buffer, and thus it can be assumed that the advantaged populations in both host tracts have the agency to move to a non-host tract if desired. Additionally, nuclear host tract demographics closely resemble both host demographics at the 10 mile buffer, possibly indicating that it is the presence of the nuclear plant and not the coal plant that is influencing the demographics of the surrounding community. If this is the case, then it may be assumed that the benefits of living near a nuclear reactor are so great that residents are willing to tolerate the presence of a coal-fired facility in exchange for nuclear plant advantages. However, the benefits of living in a both host tract may not originate from either type of power plant as some findings suggest both host tracts possess distinct characteristics. For instance, both host tracts contain more children than all other tract types at all buffer sizes. The fact that children are not disproportionately exposed to nuclear or coal-fired plants alone suggests that both host tracts contain unique features not controlled for in this study.

While it was hypothesized that nuclear host tracts would be more affluent than coal host tracts, given the dangers of radiation exposure associated with living nearby a site, it remains unclear why people with the resources to relocate would select to live near a nuclear powered plant. One possible explanation is that local residents simply do not view nuclear plants as hazardous facilities. The types of additions which result from coal and nuclear plants may help to explain why the former may be viewed as noxious while the latter are not. Emissions from coal-fired power plants can be seen rising from smoke stacks and decreasing visibility, smelt in the air, and felt in the throats and lungs of nearby residents. Community members can make connections in their daily lives between the density of haze in the air and immediate impacts on their local environment and health. For instance, nearby residents may notice increases in coughing, asthma attacks, and exacerbation of respiratory illnesses on days with decreased visibility from coal emissions. Thus, the costs associated with living near a coal plant are undeniable, they can be perceived with human senses and health impacts are both long term and acute.

In contrast, the additions resulting from nuclear powered plants are far more imperceptible and are associated with delayed adverse health effects. The only visible releases from nuclear facilities are clouds of steam. Although escaped radiation has the potential to result in cancer in nearby residents, this exposure cannot be perceived by the affected individual and does not interfere with their daily lives. Additionally, connections between radiation exposure occurring over many years and negative health outcomes such as cancer are not as apparent as suffering from asthma attacks on a day with high levels of smog. Thus, nearby residents of nuclear plants do not experience the same day to day consequences associated with coal plants, although the long term health impacts may be comparable.

While residents of nuclear host tracts may not be as acutely aware of the emissions resulting from nuclear plants as they might be from coal fired plants, the risks associated with living near a nuclear facility remain well documented. Therefore, it is still not entirely clear why residents with the agency to relocate would select to remain in these hazardous areas. Risk perception theory may offer insight into this perplexity. Perhaps most importantly, risk perception literature informs us that when people receive benefits from a source of risk, they are more likely to selectively overlook information regarding the dangers of that risk (Margolis, 1996). If this explains why wealthier communities live in close proximity to nuclear power sites, then we would expect that nuclear plants provide amenities to the community that are not provided by coal-fired plants. One clear advantage of any power facility is the availability of jobs. However, the work environments and number of jobs available to the local community will likely vary by facility type. For instance, a study examining mental health in nuclear and coal plant workers found that coal plant employees perceived more problems with workplace exposure than nuclear plant employees (Parkinson and Bromet, 1983). Additionally, jobs provided from construction and operation of coal-fired plants tend to be overestimated and communities receive little economic benefit from hosting a facility (Ochs Center for Metropolitan Studies, 2009). While coal-fired plants provide increasingly limited numbers of jobs to local residents and most employment benefits go outside of the host county, this is not clear in the case of nuclear plant employment. Multivariate analyses from this study support this notion as nuclear and both host tracts possessed greater percent population employed in the utilities industry than coal host tracts at the 10 mile buffer. Additionally, while both host tracts continued to contain more utility sector employees at the 20 mile buffer, this finding was inverted at the 30 mile buffer, further supporting the finding that coal plants employ workers outside the immediate community. While there are other financial advantages of living near a nuclear facility, such as opportunities for trade and improved infrastructure including better road maintenance, the availability of jobs is likely the most influential benefit in terms of risk perception within nuclear plant host communities (Eiser et al., 1995).

However, benefits alone do not necessarily explain why communities would expose themselves to the severe risks posed by nuclear plants. Studies of risk perception offer other possible explanations for why people would willingly accept or engage in a risky activity such as living near a nuclear facility. To begin with, researchers have found that people tend to be influenced by the knowledge of experts in situations in which they feel they know little about the subject matter (Siegrist and Cvetovich, 2000). In the case of nuclear power, it seems unlikely that the majority of the population is familiar with the process of nuclear energy production and the corresponding probability of a plant melt down. Thus, if the federal government and professionals in the field assure local communities that the operations at a nuclear plant pose little to no threats to public health, residents may rest assured in the expertise of specialists. Another explanatory finding is that people tend to view voluntary activities as being less risky than activities which are involuntary (Finucane, 2000). As populations living within 10 miles of a nuclear plant have lower rates of poverty than non-host tract populations, it can be assumed that these individuals have the ability to relocate and thus voluntarily live in areas surrounding the plant. Additionally, familiar risks are perceived as less of a concern than newly introduced risks (Finucane, 2000). As the average age of U.S. nuclear reactors is 32 years, it is possible that people have become accustomed to the presence of the plants and therefore experience a diminished perception of nuclear plant risk (USEIA, 2012a). Further, people tend to view risks as either significant with a high probability of occurrence, or as insignificant and implausible (Margolis, 1996). Thus, residents may determine that the hazards posed by the plant are unlikely and thus rationalize that the plant poses no threat.

Lastly, perception of risk may be influenced by a community's sense of place. Venables et al., (2012) found that with closer proximity to a nuclear facility, there is an increase in resident's sense of place and consequently a decrease in the perceived level of risk posed by the plant. This may explain why no incidences of environmental injustice and nuclear power plants were found at the 10 mile buffer yet existed at the 20 and 30 mile buffers. Community members living closest to the facility may not perceive the plant as an environmentally hazardous facility and thus electively remain in the area while communities 20 and 30 miles from the site do not experience a diminished sense of risk and thus contain demographics similar to communities surrounding other undesirable sites.

In addition to the aforementioned influences of risk perception, there is another important factor influencing how individuals understand risk. Previous literature informs us that risk perception is not only a measure of how people rationalize acceptable levels of risk; it is also a matter of *who* is doing the rationalizing. Risk perception studies have found that race, gender, age, and education are all influential factors in determining how risks are understood. For instance, females, minorities, younger individuals, and individuals with less education are more likely to perceive risks as serious (Savage, 1993; Flynn et al. 1994; Davidson and Freudenberg, 1996; Finucane et al., 2000). Consequently, research has found that white males view environmental risks as less significant than their female and non-white counterparts. Interestingly, studies have found that this "white male effect" results from only a third of the white male population and these individuals tend to possess a higher socioeconomic standing and identify as more politically conservative (Flynn et al., 1994). Therefore, it is suggested that this lesser concern of risk is the result of the sociocultural status of white males in our society and their diminished perception of risk can be attributed to their less vulnerable position in society and the fact that they are more likely to receive benefits from environmental risks than non-whites and females (Marshall, 2004; Slovic, 1997). Given the whiter, wealthier communities in nuclear host tracts compared to coal host tracts, these findings may contribute to an understanding of why a community with agency would be more likely to accept the risks of living near a nuclear power facility.

Limitations and Future Research

There are several limitations to this study that warrant comment. To begin with, the 50 percent areal containment method does not guarantee that all communities contained within a buffer area are categorized as impacted populations. This is particularly true for communities living in large tracts or tracts located along the boundary of a buffer zone as these factors increase the likelihood that less than 50 percent of the units' area will be contained in the buffer. For this reason, a census tract may contain a coal or nuclear plant and yet not be categorized as a host unit as the majority of its area falls outside the selected buffer zone. Similarly, communities living outside the buffer zone may be included as host communities if more than half of their corresponding tract is contained within the buffer.

Another concern with this approach is that all facilities are treated as equal. In reality, emissions from coal-fired power plants vary greatly according to plant. Further, local weather patterns and geography may influence pollutant dispersion meaning that emission data alone does not account for ambient air quality in a given community (Levy et al., 2009). Similarly, for nuclear facilities, the number of reactors, the plant's operating capacity and the age and design of the plant may influence the exposure and risk for surrounding communities. Therefore, the implications of living near a plant vary by facility and location. As research has indicated that heavier polluting coal power plants are more likely to be located in poor and minority communities than plants with lower emissions (Faber and Krieg, 2002), more research is needed to determine whether this trend is found nationally, and whether demographics differ in nuclear host communities according to the size and age of nuclear reactors.

It is also worth mentioning, that this study would have benefitted from the incorporation of additional, smaller buffer sizes. Some researchers recommend employing a finer spatial resolution such as analyzing data at the block group level to avoid homogenization of the contained population (Sheppard et al., 1999). While the 30 mile buffer was selected because it represents an area encompassing the possible dispersal of pollutant health impacts, residents living along the edges of this buffer likely do not experience many of the nuisances associated with facilities including increased traffic, noise disturbances, visual blight, and stigmatization of living in close proximity to an undesirable facility. Particularly for coal plants, which tend to be located in urban areas and are thus obstructed from view by surrounding structures, residents living along the boundary of the 30 mile buffer may not even be aware of the presence of the facility. Therefore, while all buffer sizes indicate potentially impacted populations, smaller buffer zones likely provide more accurate information regarding populations most impacted by the presence of plants.

Further, it should be noted that this study does not address whether tract demographics were influenced by the presence of power plants, or whether power plants were sited in tracts as a result of their demographic composition. Therefore, this research is unable to answer, for instance, whether certain minorities are disproportionately exposed to coal power plant risks as a result of racist siting decisions or white flight and lower housing costs associated with undesirable facilities. To determine causality, future research should incorporate historic census data and plant construction dates. These methods would offer insight into the types of mechanisms through which power plant inequalities occur. Nevertheless, whether the racism is blatant or institutionalized, the outcome remains the same; minority populations are unequally burdened by the presence of coal power plants in the United States.

Lastly, caution must be used when extrapolating conclusions from this type of distance-based method of measuring environmental inequalities. Determining the population within a given distance from a polluting facility does not necessarily correspond to the population most impacted by the hazards. Plume- based methods are more appropriate for measuring affected populations as they evaluate dispersion of pollutants. Further, even if pollutants did disperse from point sources in perfect concentric circles such as buffer zones, it is difficult to determine public health impacts from exposure. While associations have been made between various environmental hazards and adverse health outcomes, it is nearly impossible to determine that an individual's poor health is the direct result of a particular source of pollution. Thus, distance-based methods are unable to offer a concrete understanding of the health impacts of hazardous facilities.

While it is essential to understand the limitations of these methods, this is not to imply that distance-based methods are obsolete. Rather, Mohai et al. (2009) asserts that risk-based modeling methods will not replace distance-based methods as both strategies have unique advantages. While plume models are superior at estimating health impacts on local communities, distance-based methods are better equipped to evaluate communities impacted by "noises, odors, traffic congestion, risks to children, visual blight, falling property values, and social stigmatization associated with polluting industrial facilities and hazardous waste sites" (413). Further, there is certainly a correlation between exposure and proximity to hazardous facilities and even the most rudimentary distance-based methods can offer substantial insights regarding specific environmental inequalities.

Conclusion

While environmental justice scholars have examined various parts of the energy production lifecycle including the mining of uranium and disposal of nuclear waste (Brugge and Goble, 2002; Malin and Petrzelka, 2010; Markstrom and Charley, 2003; Taliman, 1992; Gerrard, 1994), and the extraction of coal through mountaintop removal (Hendryx, 2011; Evans, 2010; McGinley, 2004), little attention has been paid to power plant inequalities. The few exceptions indicate that while populations surrounding coal-fired plants tend to be poorer and contain more people of color than non-host communities (Faber and Krieg, 2002; Keating and Davis, 2002), there is no evidence of environmental inequalities concerning nuclear plants at the national level (Alldred and Shrader-Frechette, 2009). This study sought to help fill the gap in the environmental justice literature by examining whether relationships exist between race, class, and proximity to coal-fired and nuclear power plants in the United States.

Results of this research indicate that at smaller scales (i.e. 10 miles) coal-fired power plants appear to be disproportionately located in communities with more people of color and fewer economic resources. In contrast, nuclear power plants appear to be located in areas with less poverty with no suggestion of racial inequalities. This discrepancy may be explained by perceptions of risk and the undetectable quality of nuclear plant emissions. Interestingly, both host tracts are distinct in their demographics and tend to contain less poverty and people of color and more children. This finding may suggest that these tracts have unique characteristics not accounted for in this study. It is important to note that few of these relationships were static over increasing buffer sizes and thus determining what size buffer is most appropriate for evaluating specific hazards is essential in making claims about environmental inequalities.

While the relationships between race, class, and exposure to power plants shift with changes in the scale of analysis, one thing remains clear: power plant risks are not the issue of isolated communities. More than 60 percent of all tracts in the United States fall within a 30 mile buffer from a coal-fired or nuclear power plant, the distance at which most health risks have been reported. While certain populations may be particularly vulnerable at close distances, the hazards from these plants are clearly an issue of national extent. Unfortunately, in our society public health is not prioritized over the objectives of the treadmill of production, which requires a massive supply of economically produced electricity.

This treadmill demands exponentially increasing expansion and requires producers to increase profits in order to survive in the system. Coal and nuclear energy are popular methods of electricity production because they are relatively cheap to produce and thus maximize profits. Coal is particularly appealing in the United States as it is an abundant, and thus inexpensive, domestic resource. Nuclear powered electricity costs even less to produce than electricity generated from burning fossil fuels and is expected to be even cheaper in the future (World Nuclear Association, 2012). Producers are further enticed by economic incentives resulting from alliances formed between capital, workers, and the government. Policies advocating energy security and "clean energy" (i.e. energy produced with little to no greenhouse gas emissions) have made nuclear power particularly attractive in the United States. While the negative externalities arising from these forms of electricity production are immense, the treadmill promises to resolve issues of environmental concern including greenhouse emissions, and the safe disposal of nuclear waste through the development of new technologies. Meanwhile, nearby communities exposed to the risks of power plant operations pay a heavy portion of the price of generating low-cost electricity.

Risk society theory informs us that risks from power plants are the expected consequences of our modern lifestyle. However, this does not suggest that these risks are necessary nor that intensive modernization is desirable. Given the large portion of the United States which is potentially impacted by the daily operations of energy production, a reevaluation of the costs and benefits of current energy consumption is needed. Such an analysis must take into consideration the ambiguity in identifying the extent of risks arising from our modern world. It must also consider the players most vulnerable to these risks. While producers may be able to measure the costs of power plant risks in dollar amounts, local communities are vulnerable to the delocalized, non-compensable, and incalculable risks arising from plant operations including long-term contamination of local environments, the loss of life from exposure to emissions, and the unknown health outcomes of a plant accident. Thus, policy makers and government officials responsible for determining acceptable levels of emissions and safety controls should consider not only the cost of the materials necessary for electricity production, but also the cost of medical bills and lost work days arising from power plant emissions. If producers, rather than local communities, were responsible for these costs, then perhaps our society would place a higher priority on public health.

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