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Sustainability Planning, Environmental Justice and Climate Change: Applications of the Long Island MARKAL Model

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I. INTRODUCTION

A. SUSTAINABILITY PLANNING & ENVIRONMENTAL JUSTICE

The United Nations Brundtland Commission (1987), defined “sustainability” as “meeting the needs of the present without compromising the ability of future generations to meet their own needs.” Within the business sector, the concept of sustainability has been examined by many (Gladwin, et al, 1995; Jennings and Zandbergen, 1995; Sharma and Ruud, 2003; Schaefer, 2004), and is generally defined by the imperative that a company should take into account social, environmental, and financial performance (Spreckley, 1981). John Elkington (1998) used this concept to coin the phrase “triple bottom line,” which is the foundation of the stakeholder theory¹ and for shaping concepts such as the Global Reporting Initiative² (GRI) and Dow Jones Sustainability Indexes. Similarly, the 2005 World Summit on Social Development (United Nations General Assembly, 2005) explained that the framework of all United Nations activities must include sustainable environmental components, and social equity, while meeting economic demands. In connecting the demands of economic growth with our environmental concerns, Daly (1990) characterizes *environmental sustainability* as consumption levels that are within “sustainable limits.” These limits require that our consumption of renewable resources should not exceed replacement rates; our use of non-renewable resources should not outpace the rate at which we can develop renewable substitutes; our discharge of pollutants should not exceed the rate at which the environment can safely absorb and decompose them.

In the twenty-five years since the Brundtland Report, society has witnessed a number of sustainability initiatives, spanning institutions such as corporations, universities, and political entities at all levels, from nations and groups of nations to local municipalities. One active area of research has explored the numerous sustainability initiatives undertaken by U.S. cities (Portney, 2003; 2005). An example of a local urban sustainability plan is PlaNYC 2030, a New York City initiative aimed at creating a sustainable New York City. This initiative embraces twenty nine sustainability indicators to frame nine progressive themes that the city seeks to accomplish in the near future. It is an ongoing initiative and

¹ The stakeholder theory explains that businesses should have a responsibility to all those that are influenced by the firms actions, and not shareholders. Elkington discusses the need for business entities to, among other things, long term reflection, transparency, responsibility, and diversity.

² The GRI is the dominant corporate sustainability reporting (CSR) framework for reporting financial and nonfinancial information to stakeholders. The GRI has established and regularly updated criteria that must be included and discussed in sustainability reports (Ballou, 2006).

has achieved the cooperation of a number of local stakeholders, among them the major universities within New York City.

Similar to PlaNYC is The Baltimore Sustainability Plan which incorporates seven themes (such as conservation, education and awareness, and pollution prevention) and 29 major goals. Some of these goals are clearly defined, such as a doubling of Baltimore's tree canopy by 2037 and a reduction of Baltimore's energy use by 15% by 2015. Common to these sustainability initiatives are the goals of economic growth, ecological protection, and social equity. Unfortunately, many of these plans set forth seemingly arbitrary goals, without first establishing clear criteria for determining the “best” choices from among available options. To a certain extent, economic growth in all the plans is the initiative that remains at the top of the entire framework. The primary reason is that the other initiatives are designed in a manner that does not need impede economic growth.

Although urban areas have taken the lead in establishing sustainability goals, suburbs have pushed this concept as well. This is a crucial development; as of the 2000 census, U.S. suburban populations have exceeded urban and rural populations, and this trend is expected to continue. Suburban areas have increasingly felt the pressures of increased traffic, strained infrastructure, and loss of open space (Dunham-Jones, 2005), and have begun to establish sustainability plans in response to these pressures.

Prior to the initiation of large scale sustainability plans on Long Island, programs were established to simply improve household efficiency, in some cases via door-to-door or large group informational sessions. One such effort was undertaken in Levittown, New York, America's first suburb. In cooperation with Nassau County and private stakeholders, the Citizens Campaign for the Environment and Green Levittown were established. This initiative strived to improve the environment by improving efficiency and creating a more sustainable future. This initiative was hampered by the failure to establish measurable goals, and the lack of communication among stakeholder groups. As a result, the plan ceased operations within a year. Green Levittown may thus be seen as a failure.

Sustainability programs at a regional scale have targeted residential energy use with the goals of mitigating energy expenditures and, as a result, air emissions. The objectives of the Long Island Green Homes Consortium, a cooperative effort started in 2008, were to raise homeowners' awareness of energy use and costs. Toward that end, homeowners were encouraged to complete comprehensive home energy audits. The partnership between local municipalities, nonprofit organizations, energy providers and governmental agencies offers funding for free or reduced-cost home energy audits conducted by Building Performance Institute accredited contractors through NYSERDA's Home Performance with ENERGY STAR Program. Long Island Green Homes

targets older, less efficient homes for retrofit. Energy efficiency upgrades, including lighting, furnaces, boilers, weather-stripping, duct/air sealing and insulation, are eligible for financing plans, as well as grants and rebates of up to \$5,000 or 50% of the costs.

Specific programs and costs vary by municipality. In the Town of Babylon, the town pays the cost of energy audits to contractors, and offers participants a 3% financing option on costs up to \$12,000. Participants in Babylon experienced a reduction of \$1,024 in energy costs annually. (Home Performance Resource Center, 2010) As of 2011, the Town signed up 600 homes, 1% of all single family homes, leading to a projected reduction of 2,777 metric tons of CO₂ emissions annually. The program aimed to enroll 1,000 homes by 2012. Unfortunately, the program has not conducted a detailed self-study, and thus estimates of the reduction of emissions for Long Island Green Homes are not available. Nationally, existing technologies in energy efficient retrofitting can potentially lead to a reduction in 160 million metric tons of greenhouse gas emissions annually by 2020. (LeBaron and Rinaldi, 2010) Given Long Island's large proportion of residential energy usage, programs like Long Island Green Homes have the potential to substantially limit the region's energy demand and enable sustainability improvements.

In 2009, New York State announced plans to reduce 2050 greenhouse gas emissions in the State to 80% below the levels emitted in 1990 and a benchmark reduction of 40% below 1990 levels in 2030. Executive Order 24, promulgated by Governor Patterson, created the Climate Action Council. That body was assigned responsibilities to assess how all economic sectors can reduce greenhouse gas emissions, adapt to climate change, and be responsible for meeting the goals set in the Executive Order. Industry portfolios in buildings and industry, transportation and land use, power supply and delivery, and agriculture, forestry and waste, were developed to target sector-specific policies. In power supply and delivery, the plan proposed to introduce zero to low carbon sources of power, while maintaining power grid reliability. Policies include introducing renewable energy standards, expanding the Regional Greenhouse Gas Initiative, GHG emission standards for new power plants, and encouraging the repowering of existing fossil fuel power plants, with a focus on vulnerable coastal zones (New York State Climate Action Plan Interim Report, 2009).

A report from Brookhaven National Laboratory (Stokes and Looney, 2010) highlighted the need for New York's climate plans to be an integrated approach with municipalities and take a bottom up approach. The NY Department of Conservation has started a Climate Smart Communities Pledge program. This program established ten elements including "setting goals, inventory emissions and move to action" and "plan for adaptation to unavoidable climate change." One hundred and twenty two communities have taken the State's pledge,

including Suffolk County and 10 of its towns and villages, and 5 towns and villages in Nassau County. Suffolk County's Climate Smart Community Program includes reducing electricity usage 15% by projected levels in 2015 and identifying critical impact areas such as water supply and sewer infrastructure. The Climate Smart Communities program is handicapped by the failure to include either direct incentives for participating or penalties for failing to meet the program's guidelines. More detailed goals and policies to attain those goals from both state and local governments would enable further progress to be made on adapting to climate change.

By May of 2013, the Cleaner Greener Long Island Regional Sustainability Plan (CGLI) was established by the Cleaner Greener Consortium of Long Island and its partners which included over 800 Long Island leaders. The plan aims to reduce green house gas emissions (described in the plan as a "paramount goal"), improve economic development and housing, as well as deal with energy, transportation, land use, waste management, and water management issues. By using a greenhouse gas inventory established by NYIT (2010) the plan calls for expanded use of food waste biogas, introduction of "solar ready" construction codes, and measures to encourage the use of geothermal heat pumps. The "Energy" section of the plan does call for municipalities to carry out feasibility studies of renewables and promotion of efficiency. The plan however does not explain why each of these goals has been chosen nor do they determine whether these are optimal solutions for the problem of increasing green house gas emission.

Another component of sustainability, beyond dealing with climate change, which must be taken into consideration, is environmental justice. The environmental justice movement is generally agreed to have been developed in the United States during the 1970s primarily as a result of racially divided siting of environmental risks, waste management being the major issue (Harvey, 1996; Dobson, 1998; Agyeman, 2002). The United Church of Christ's Commission for Racial Justice report in 1987 pushed environmental justice into the spotlight, with many other papers following it. Bowen (2002) reviewed 42 such environmental justice papers and noted many flaws in statistical analysis and overall methodology. Been (1994) posed an interesting question; what came first, the hazard or the population? But regardless of when these Locally Unwanted Land Uses (LULUs) were established, it is important that no one group feels a disproportionate burden. As Oran Young stated we must "ensure that the rich and powerful do not insulate themselves from environmental harm largely by displacing problems on to the poor and weak."

Environmental justice is not solely about distribution of environmental ills; it is also about participation in the environmental policy making process. This participation can promote policies and actions that link sustainability with

environmental justice. Faber and McCarthy (2001) call for “sustainability and environmental protection,” as a means to ensure a more “socially and ecologically just society.” Further, environmental justice is ultimately about sustainability, as environmental justice leaders have fought hard against the label of NIMBYs (Not In My Backyard) and in turn proclaiming themselves NIABYs (Not In Anyone's Backyard) (Dowie, 1995). Of course, this approach can be carried to an extreme, precluding economic development itself: NIMTOO (Not In My Term Of Office); BANANA (Build Absolutely Nothing Anywhere Near Anyone); NOPE (Not On Planet Earth; and CAVEs (Citizens Against Virtually Everything) (Schively, 2007).

It is clear that the definition(s) of sustainability, its goals, and the means to reach them are contested (Holling, 2000). Green-washing has been the word coined for describing this disingenuous process of call everything under the sun sustainable. In the words of Parris (2003), sustainability has “broad appeal and little specificity.” Baumgartner and Ebner (2010) noted, “...sustainability issues are pursued more coincidentally than with a clear strategy.” And there lies the main problem of the sustainability movement, green-washing has become endemic problem and in many situation has led to very little environmental progress. Although few policy makers would balk at the notion of sustainability, we face ever-growing economic constraints and difficult choices (Hess and Winner, 2007). There is thus a clear need to establish clear, quantifiable sustainability goals and to identify policies and technologies that will enable us to reach these ends.

B. GLOBAL CLIMATE CHANGE AND GREENHOUSE GAS MITIGATION POLICIES

Human demand for energy is clearly and unequivocally intertwined with many of our most pressing environmental threats. Among these threats, the risk of climate change is perhaps the one that looms largest in the eyes of many scientists and policy makers. Other environmental issues associated with our energy systems, including acid deposition and the dispersion of metals from mining and burning fossil fuels, have an impact at local or regional scales (Johansson and Lundqvist, 1999). Although, there are a number of sources of criteria air pollutants (lead, ozone, particulate matter, carbon monoxide, nitrogen oxides and sulfur dioxide) and greenhouse gases (carbon dioxide, methane, nitrous oxide and fluorinated gases), electric power plants are regarded as the largest single point source (Jeong, et al., 2008). Approximately two-thirds of U.S. fossil fuels (coal, petroleum and natural gas) are used by the U.S. electricity sector, and this share is growing over time (Nagurney, et al., 2006). Although the magnitude of the anthropogenic contribution to global warming is subject to

debate, the basic relationship between the combustion of fossil fuels, the atmospheric concentration of carbon dioxide, and mean global temperature is clear.

Although there are numerous greenhouse gases (GHGs), carbon dioxide is generally targeted because it is a major byproduct of fossil fuel combustion, from which the majority of our electricity generation is derived. In addition, the bulk of the other GHGs are related to the combustion of fossil fuels (Gielen and Kram, 2000). Further, it has been noted that CO₂ emissions reductions simultaneously reduces other criteria pollutants such as, SO₂, NO_x, PM₁₀ (Chen et. al., 2001). Since the non-CO₂ emissions are falling below the IPCCs scenarios, the current focus of climate change policy is on carbon dioxide emissions (Hansen, et. al., 2008). Unfortunately, as other GHG rates fall, CO₂ emissions are rising at a rate that many models predict can lead to a temperature increase equal in magnitude to the cooling experienced during the last Ice Age. This increase may be responsible for, among other things, coral bleaching, shut down of the ocean's thermohaline circulation, and rise of sea level (Hoffert, 2002).

The United States Earth Summit (UN Framework Convention on Climate Change, 1992), called for a worldwide stabilization of greenhouse gases as to avoid, "dangerous anthropogenic interference with the climate system." The 2007 report of the Intergovernmental Panel on Climate Change (IPCC) (Fourth Assessment Report: Climate Change, 2007) concluded: 1, warming of the climate is unequivocal; 2, warming observed since the mid-20th century is likely associated to anthropogenic activity; 3, the probability of this warming being a natural event alone is less than 5%; and 4, the past, current, and future anthropogenic CO₂ emissions will continue to contribute to warming for more than a millennium. Some predict a rapid climate change impacting Earth systems within a century or less (Hansen, et. al., 2007) and there is growing realization that an Earth energy balance no longer exists and further warming lies ahead (Hansen, et al, 2005). The most recent (2013) IPCC Report concluded:

1. *It is virtually certain that globally the troposphere has warmed since the mid-20th century.*
2. *It is virtually certain that global mean sea level rise will continue beyond 2100, with sea level rise due to thermal expansion to continue for many centuries.*
3. *It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century* (Alexander, et al, 2013).

In response to these potential issues, many politicians, scientists and industrial leaders, such as Exxon Mobil CEO Rex Tillerson³, have called for action. Regardless of what is decided, it is likely that the new legislation will be more stringent than predecessors such as the 1990 Clean Air Act, or international accords, such as Kyoto. A wide range of proposals to impose mandatory caps on U.S. greenhouse gas emissions have been introduced in the U.S. Congress (Paltsev et al., 2007). Although the prospects for action at the national level are uncertain, other programs have been introduced by state governments, acting individually and in concert with their neighbors⁴. Recently, the United Nations Climate Change Conference 2009 (COP15) has concluded with mixed outcomes. A Copenhagen Accord has been established which seeks to enact a Copenhagen Green Climate Fund. Among other policies the Accord seeks to cap temperature rise to 2°C and reduce CO₂ emissions.

II. ABOUT THE MARKAL MODEL

MARKAL is an integrated energy systems analysis methodology used to design optimal strategies for long-term energy security, climate change mitigation and environmental sustainability at local, regional and national scales by nearly 100 institutions in more than 55 countries. The methodology comprehensively evaluates costs and benefits of alternative technology and resource use options to aid effective decision making. It identifies interdependencies of various energy sub-systems (including energy supply, production, distribution and consumption technologies and alternatives and comprehensively analyzes the behavior of the entire energy system for long-term planning. MARKAL is a bottom up linear programming model that captures interactions and potential substitutions between energy forms and technologies, from conventional energy resources such as oil and natural gas to renewable energy sources such as wind and solar. Policy instruments, ranging from pollution taxes, emissions caps, and renewable energy portfolio standards, are incorporated within MARKAL as constraints; the model chooses the optimal (cost-minimizing) set of technologies subject to a specified set of constraints (Loulou, et al, 2004). MARKAL has found a range of technology and policy applications, including the determination of least-cost energy systems subject to energy and environmental policies such as: 1, restrictions on emissions; 2, required use of renewable energy resources; and 3, the introduction of energy regulations, taxes, and subsidies.

³ Rex Tillerson called on Congress to enact a “lucient” and efficient carbon tax. (Gold and Talley, 2009)

⁴ Examples of these regional actions include the Regional Greenhouse Gas Initiative (RGGI) and Western Regional Climate Action Initiative (WRCIA).

The economic and environmental impact of proposed energy technologies and policy instruments will be estimated with respect to a baseline, “business-as-usual” scenario. This baseline represents the modeler's best projection of energy use and emissions over the planning horizon (generally short term, 5 years to long term, 50 years). The structure of this model is captured by the MARKAL Reference Energy System (Figure 1). The Reference Energy System (RES) requires input data from primary energy supply (e.g., natural gas), intermediate conversion and process (e.g., electricity generation), to end-use technologies (e.g., refrigerator) that satisfy energy service demands (e.g., home appliances). Every component in the RES is characterized by three groups of data: technical (e.g., efficiency), economic (e.g., capital cost), and environmental (e.g., carbon emission coefficient) (Friedman and Klein, 2010).

Figure 1: Long Island Reference Energy System

III. APPLICATIONS OF THE MARKAL MODEL: SUSTAINABILITY PLANNING, ENVIRONMENTAL JUSTICE, AND ADAPTATION TO CLIMATE CHANGE

Once the base case has been established, scenarios called for in sustainability plans, investigations of environmental justice, and responses to climate change, can be run and analyzed. This section discusses applications of the MARKAL model to address these important policy issues.

Carbon Tax or Cap and Trade policies:

Both carbon dioxide emissions taxes and caps have been proposed as methods for mitigating the effects of global climate change. A wide range of proposals to impose mandatory caps on U.S. greenhouse gas emissions have been

introduced in the U.S. Congress (Paltsev et al., 2008). A carbon tax on carbon dioxide emissions could be somewhat simply implemented into MARKAL, as carbon content of fossil fuels used are easy to calculate and trace (Fullerton, 2001). The burden of such a tax would be distributed over all areas (residential, commercial, industrial, etc.) and will help environmental protection (Pehlivan and Demirbas, 2008). By raising the variable costs of producing electricity from fossil fuels an incentive will be established to shift towards cleaner technologies (Green, 2008).

On January 1, 1991, Sweden enacted a carbon tax, \$100 per ton, on the use of fossil fuels. In this case the tax was neither broadly based nor equally distributed. For political reasons, industrial users paid between a quarter and half the rate while certain high-energy industries (mining, manufacturing and the pulp and paper industry) were exempted from these taxes. In 1997 the rate was raised to \$150 per ton of CO₂ released (Brannlund, 1999; Brannlund and Gren, 1999; Ekins, 1996). Although this type of treatment may not be politically acceptable in this country, it illustrates the flexibility of the carbon tax. The MARKAL model can accommodate these sector-specific tax policies.

There have been numerous assessments of the impacts of carbon taxes at the national level. Jeong, et al (2008) investigated a carbon tax on Korea's utilities comparing coal and LNG in the presence of a carbon tax. Masui, et al (2006) investigated a carbon tax in Japan, as a mechanism to achieve a 2% CO₂ reduction of 1990 emissions, in order to comply with Kyoto targets.

The MARKAL model can accommodate both emissions caps and taxes. We have characterized a carbon tax scenario using the Long Island MARKAL model. Results of this scenario can be used to determine carbon emissions and costs, and to assess the impact of 0and have been used to examine environmental justice issues. As seen by the Long Island MARKAL model, the presence of a carbon tax leads to the closing of a heavily polluted central power plant and calls for smaller cleaner distributed electricity generation, thus reducing the impacts on one group (Friedman, Klein, and Sun, 2012).

Minimum Renewable Portfolio Standards:

Another possible policy scenario could be the implementation of minimum renewable energy sources, as per the NYS Renewable Energy Portfolio Standard (RPS). According to NYS Public Service commission mandate, enacted by Governor Paterson by 2015, 30% of all retail electricity must be from renewable sources (<http://www.nyserda.org/rps/index.asp>). This number was increased from a previous level of 25% by 2013. MARKAL allows for analyzing the impacts of minimum renewables by incorporating a constraint equal to the desired minimum renewable and defining each electricity generating technology as renewable or non renewable. The model is flexible in allowing the standard to

change over time, for example, 25% renewable by 2013 and 30% renewable by 2015. This is frequently done in MARKAL models, but has yet to be carried out in regards to a specific sustainability plan.

Efficiency Standards:

Goals for market penetration of new efficient goods, legal changes such as banning incandescent light bulbs, or mandating standard minimum efficiencies for various demand devices: MARKAL is a bottom up model and as such great detail can be included in the demand side of the problem. Demand devices or end use devices, such as specific types of lighting or air conditioning, can be specified by the model. Newer, more efficient devices may be included into the analysis with set market penetrations going forward in time. Further, the elimination of various types of technologies may be analyzed, such as phasing out incandescent light bulbs, as is being done in the European Union (European Commission on Energy) and in California (AB 1109, signed into law October 12, 2007).

By establishing sustainability plans and analyzing the results with MARKAL, it is possible to determine the impacts on vulnerable populations, such as the elderly, infants and children, low-income and minority populations, and asthma and heart-disease patients. A reduction in peak electricity demand may reduce the need for heavily-polluting peaking plants, thus improving air quality in adjacent communities. Similarly, the displacement of current transportation technologies by cleaner ones (e.g., hybrid, diesel, clean diesel, natural gas, etc), one could improve ambient air quality in urban asthma hot spots. By improving sustainability, the economy, environment, and equity of a region improve (Campbell, 1996). Unfortunately, few cities or regions combine environmental justice with sustainability (Warner, 2002). MARKAL provides the analytical framework to characterize these technology and policy changes.

IV. The Long Island MARKAL: Results and Future Work

The regional impacts of a national policy change, in the form of a carbon tax, have been examined by the Long Island MARKAL. Using the baseline LI MARKAL, two possible carbon tax scenarios were established and analyzed. The first scenario was a \$10 per ton CO₂ flat tax initiated in 2010. The second scenario was a tax that begins at \$10 per ton in 2010, increasing \$10 per ton over a period of 9 years, and then held constant at \$100 per ton over the planning horizon. We find that a flat \$10 tax reduces electricity sector costs by 3.1%, and CO₂ emissions by 6.4%, relative to the base or business as usual scenario. These economic and environmental impacts have social and environmental justice implications as well. The reduced reliance on older, dirtier power plants means certain communities, and, in particular, vulnerable populations, will be less

impacted. In contrast, the incremental tax maintains a nearly identical cost as the base or business as usual scenario, and the same 6.4% cumulative drop in CO₂ emissions. Figure 2 shows the CO₂ emissions for the three scenarios.

Figure 2: Indexed Total CO₂ Emissions

The environmental justice implications of a policy change can be seen in the case of the Northport Power Plant (1,564 MW Capacity), one of the largest oil burning plants on the East Coast. Under the base or business as usual scenario, the facility continues to run, producing 24,064TJ of electricity each year, until 2040. By running a carbon tax scenario of \$10 per ton, the facility begins to phase out by 2010; shedding 10,000+ TJ of primarily oil-based capacity, in favor of cleaner natural gas. By 2030, newer, smaller capacity technology natural gas combined cycle facilities that are over 60% more efficient are substituted into the mix. The impacts of these facilities can be spread over a larger area, thereby allowing for equitable sites to be determined and not solely influencing one group. Although Long Island's largest power plants are in areas that are neither low income nor minority communities, the model may be used in other locations where problems do in fact exist.

The policy change scenario carried out on the Long Island MARKAL model is a response to climate change, which historically is accompanied by sea level changes (Alexander, et al, 2013). The question is then posed, by how much will sea level rise? Two approaches may be used to determine the answer: physical models and semi-empirical models (Rahmstorf, 2012). Physical models examine and incorporate the impacts of contributors to global sea level change,

including: thermal expansion, addition of water mass, and changing depths of ocean basins. Unfortunately when modeled components are summed, the results fall short of recently observed sea level rise (Rahmstorf, et al, 2007). Semi-empirical models are used to predict future trends by linking observed sea level changes and observed global temperature changes. These models reproduce past sea level rise, but cannot definitively ensure what was observed in the past will hold true going forward (Rahmstorf, 2012).

Locally, sea level change may deviate from global changes for many reasons, including: winds, gravitational pull, and vertical land movement (Rahmstorf, 2012). As temperatures rise there will lead to serious ramifications for low lying coastal communities (Nicholls and Cazenave, 2010). Citizens, governments, and policy makers need to understand the potential impacts that may result from climate change in order to protect their communities (Slangen, et al, 2012).

Superstorm Sandy Impact on Long Island:

Low lying areas, such as the South Shore of Long Island, which was greatly impacted by Tropical Storm Irene in 2011 and Super Storm Sandy in 2012, pose interesting case studies for the benefits of improved planning. Had the region been better prepared, damage may have been mitigated and electricity restored more quickly. Sandy showed us that flooding of power plants may become the "new normal". It is likely that if global temperatures and sea level continue to rise, regions like this will suffer the same fate going forward. MARKAL may be used to study the impacts of loss of generation from power plants that will be impacted by sea level rise. On Long Island, they may include power plants like E.F. Barrett, a 362 MW natural gas/oil fired electricity generating facility (Kimble, 2009), which was greatly damaged by Sandy.

Long Island's Power Sector Vulnerability:

According to the report, "Synthesis of Climate Change Drives and Responses in Long Island Sound", the Intergovernmental Panel on Climate Change (IPCC) predicts sea level rise will be up to 2 feet by 2100 and particular locations such as New York will be more impacted than other locations. In particular, the south shore areas of Long Island will be more vulnerable to sea level rise because the land elevation in the south shore is lower.

In Figure 3, the map depicts the locations of power plants throughout Long Island. The table provides place name locations and elevations. The power plants are typically clustered near the north or south shore of the island to take advantage of the water intakes from the ocean. Out of the many power stations on Long Island, five represent a substantial slice of the power generation for the

region. It is important to remember that certain power plants such as the one located in the north shore along the Long Island Sound are typically less impacted by natural forces. Unfortunately, there are more power plants located in the south shore of Long Island where the elevation is the lowest in most parts. In Figure – 4, certain power plant locations such as the southwest Nassau County are more vulnerable to sea level rise and associated hazards. Four power plant locations lie within areas that the effects of a category 1 hurricane storm surge could severely impact the operations of these facilities. If these power plants were completely shut down due to an event, it would represent a large percent of energy that is produced on Long Island. A powerful storm could have unprecedented impacts on Long Island. But the effects of climate change upon the power sector are not limited to storm impacts but also rising water temperatures that in 2012 shut down Dominion Resources Millstone Nuclear Power Station in Connecticut. The facility could not continue to operate because the rising temperatures of the water exceeded design specifications (Rogers, J. et al., 2013; United Press International, 2013). Other power plants on the Island could be vulnerable to this problem.

Figure 3. Locations of large scale electricity generating facilities on Long Island, NY.

Power Station	Location	Elevation(ft)
E.F Barrett Power Station	Hempstead/Island Park	8
Caithness Long Island	Yaphank	90
Northport Power Station	Northport	3
Port Jefferson Power Plant	Port Jefferson	15
Richard M. Flynn Power Plant	Holstville	93

Table 1: Locations and elevations of large scale electricity generating facilities on Long Island, NY.

Figure 4: Four electricity generating facilities in Southwest Nassau County, NY with elevation above sea-level and hurricane storm surge.

MARKAL is an instrumental tool that could be utilized to model the impacts of the closure of these power plants over a period of time if they are susceptible to storms. Presently, regional energy plans specific to Long Island do not take into account the effects of Climate Change upon the power sector. Therefore, it is important to understand the ramifications to the environment, economy and social impacts of the elimination of a power plant. Furthermore, new plans have to be drafted to increase the energy supply for the region. In this case scenario, the elimination of power plants would likely cause the price of electricity to rise compared to the current costs and emissions would likely rise, at least short term, as smaller less efficient plants quickly replace other facilities. Other power plant facilities would also likely have to increase their power production to satisfy future energy consumption. And from a social perspective, the closure of these power plants would reduce the exposure of emissions from this area but it would increase it in other locations.

Therefore, sustainability objectives are not limited to energy production but have far ranging impacts. The closure of these plants would change the energy production pattern for the area and could lead to the reduction of emissions for certain communities. From an environmental justice perspective, the elimination of these power plants that produce harmful emissions would be another reason that sustainability should take more into account climate change effects. From 2000 to 2002, new energy infrastructures that were installed were placed in low-income communities and minority communities (New York State Department of Environmental Conservation, 2009). The most vulnerable climate change infrastructure could be replaced with energy production that is cleaner and less vulnerable to storms.

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