POLICY CHANGE, SUSTAINABILITY, AND ENVIRONMENTAL JUSTICE: APPLICATIONS OF THE LONG ISLAND MARKAL MODEL

by

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Abstract

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The objective of this study is to develop a robust and sustainable energy (electricity) path for Long Island. Waste water management and solid municipal waste have been incorporated into a MARKAL energy-planning model for the short through long term (50 years) planning horizons. In addition, an analysis of the impacts on the local scale, of a carbon tax has been carried out. By examining the Long Island MARKAL the nexus of sustainability and environmental justice is elucidated. Suggestions for examining, testing, and improving sustainability plans are also provided.

Acknowledgments

To all of those that have helped me academically reach this point I give my heartfelt gratitude. Those include, but are not limited to: Dr. Yehuda Klein, Dr. Art Langer, Dr. William Solecki, Dr. Guodong Sun, Dr. John Lee, Mr. Vatsal Bhatt, Mr. Ed Linkey, and Dr. Jeff Osleeb. To my coworkers for encouraging me, I thank you for your support. To all my friends that have been there when I needed a hand (Super Storm Sandy) or a sounding board, thank you. To my students who have been a source of encouragement and motivation over the years, especially my research and APES students, thank you.

Most importantly I would like to thank my family. It sounds trite, but I couldn't have done it without you. Special thanks to my mother and father for their unconditional love, my wife Melanie for putting up with years of this never ending project, and most importantly my two beautiful children, Matthew and Samantha. Simply thinking of you brings a smile to my face. Matthew and Samantha, I used to read journal articles to you when you were first born and now you are in 4th grade and kindergarten respectively- amazing! I love you both so much.

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I. Problem Statement:

The modern concept of *sustainable development* is traditionally dated to the Brundtland Commission Report (World Commission on Environment and Development, 1987), which defined it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Over the past twenty-five years, the concept of sustainability has penetrated society at many levels. Fortune-500 corporations like BP, Wal-Mart, and Dell have enacted sustainability plans. Colleges and universities both large and small have established sustainability committees and plans. States, counties, towns and cities have established long term sustainability plans. In the New York metropolitan area New York City has proposed "PlaNYC 2030", a plan to meet 10 key goals in five areas (land, water, transportation, energy, air, and climate change) targeted to make the region a more sustainable entity. (PlaNYC, 2011)

Green Levittown, in suburban Nassau County, New York, is a private-public partnership, with participation of Levittown, New York, Nassau County Citizens Campaign for the Environment, a local non-government organization (NGO), and private corporate partners. This initiative strives to improve the environment by maximizing energy efficiency and creating a more sustainable future. (Suozzi, 2007) All of these plans aspire to achieve economic, ecological, and social sustainability[1].

Long Island has a storied history with regards to the environment and sustainability issues. One area of great contention is the Long Island Sound, which was

[1] Social sustainability may involve: basic human rights, labor rights, human health issues, education, and social relationships. (Littig, Beate, and Griessler, 2005)

heavily polluted during the early industrial development of the region and has since seen a new era of protection (Long Island Sound Study - Sound Health, 2008). In 1957, Robert Cushman Murphy, curator emeritus of the Museum of Natural History, led a battle against the USDA for its aerial spraying of DDT over Long Island in its quest to combat gypsy moths. Five years before Rachel Carson's publication of *Silent Spring*, Murphy charged, in an unsuccessful lawsuit, that DDT harmed a variety of plants and animals, and could ultimately cause health problems in humans[2]. (Meiners and Morriss, 2001)

Long Island has been the scene of battles against electricity generating facilities, the most dramatic example being the Shoreham Nuclear Power Plant. Shoreham was hotly contested from the time the project was proposed in 1965 until construction was completed in 1984. The plant was finally fully decommissioned in 1994, after it was determined that it would not be possible to successfully evacuate the *ten-mile* emergency planning zone (EPZ) around the plant in the event of an emergency, as later mandated by Nuclear Regulatory Commission (NRC) regulations established in the wake of Three Mile Island. (Fagin, 2007)

A local Long Island daily newspaper, proposed the "Top 10 Environmental Challenges Facing Long Island," on Earth Day. (Newsday, 2009) The top two challenges were judged to be energy, specifically electricity generation and Long Island's dependence on fossil fuels and aging power plants. Yet other challenges, such as clean drinking water, the decline of Long Island fisheries, air pollution, sewage, polluted bays and rivers, wetlands, solid waste disposal, preserving open space, and climate change, are

[2] It should be noted that through the 1950s and 60s the World Health Organization used DDT heavily in order to effectively combat malaria in many regions of Africa (and around the world). This was temporary, as health concerns of its improper use grew. Today, approximately one million people die from Malaria each year. (van den Berg, 2008) In 2006 the World Health Organization reversed its stance on DDT by recommending that it be used as an indoor pesticide in locations where malaria remains a major problem.

all either heavily impacted by or strongly related to electricity generation. (Smith, 2009) The salience and environmental impacts of electricity generation, among the issues of concern to the public on Long Island, makes it imperative that we carefully examine all our energy, and specifically electricity generation options in the context of regional sustainability.

The term “think global, act local” has been increasingly used by planners, policy makers, and scientists. In this regard, establishing an energy development plan for Long Island that is both more sustainable and resilient is a must. This study is an innovative effort to balance our energy requirements and environmental needs. The approach we have chosen is to determine the optimal (least cost) mix of electric generating facilities on Long Island, New York, subject to environmental, resource availability, and system reliability constraints. The National Energy Policy Development Group recommended, in 2001, that the US include in its national energy policy “a clean and diverse portfolio of domestic energy supplies.” Using the MARKAL (MARKet ALocation) program, (www.hydrogen.energy.gov/analysis_repository/index.cfm), a bottom-up technology-driven linear programming model an optimal and sustainable mix (minimum cost) of multiple energy sources for generating electricity (natural gas and petroleum, coal, wind, solar, fuel cells, demand–side management, etc…) to satisfy Long Island’s electricity needs was determined. The importance of this analytical work is highlighted by global energy supply and environmental concerns, including continued Middle East tensions, post 9/11/01 energy independence initiatives, limits on domestic production of fossil fuels, and the risks posed by global climate change. Further, there has been a movement toward “green energy” research by the U.S. Department of Homeland Security, Department of Defense, Department of Energy, State Department, and National Aeronautics and Space Administration. (Makower, 2003) Although this seems reminiscent of the 1970's energy crisis that came and went, the current reality seems here to stay, especially in the light of what currently appears to be "peak oil." For these reasons factors such as minimum renewable energy portfolios, carbon trading, and carbon taxes can be taken into consideration and run as scenarios for which Long Island should prepare. Policy makers and other various groups could use the results to determine how to best plan for sustainability of future energy development.

This dissertation stems from an effort to develop appropriate analytical tools to support all elements of sustainability planning on Long Island. To that end an integrated version of the MARKAL energy system model for Long Island has been constructed. The Long Island MARKAL provides a comprehensive and integrated systems planning and management methodology capable of:

- Assessing and comparing technologies for electricity generation, wastewater treatment, and solid waste management;
- Evaluating the impacts of policies, regulations and alternative plans in urban development programs (e.g., power system expansion, source reduction, and green house gas (GHG) emission targets);
- Providing linkage to other decision support tools (e.g. EnergyPlus[3], MOVES[4]) that hold the promise of influencing the current environmental regulatory regime,

[3] EnergyPlus is a modeling program which allows for whole building analysis of heating, cooling, lighting, ventilation, other energy flows, as well as water use. (US Dept of Energy, 2012)
[4] MOVES is a mobile source (cars, trucks and motorcycles) emission modeling system that estimates emissions covering a broad range of pollutants and allowing for analysis at multiple scales. (EPA, 2012)

including multi-media aspects of carbon control, at multiple spatial scales, from local to national.

The innovative structure of the Long Island MARKAL is a "proof of concept" for analyzing policies and plans representing electricity supply/demand, wastewater treatment, solid waste management, and green house gas (GHG) reduction programs. Electricity supply, solid waste management, and wastewater treatment are three vital area services that are inter-linked, and are of concern to rural, suburban and urban communities alike. Electric power plants require huge quantities of treated fresh water for cooling. Wastewater treatment plants are significant electric energy users. Similarly, municipal solid waste requires energy throughout the collection, processing and transportation process. The methane gas generated from sludge treatment and solid waste landfills can be processed into cleaner fuel for electricity generation or combusted directly for electricity generation. For optimal sustainable operation of an area, long-term strategic planning and management are required to deal with these cross-cutting issues and respective interactions among these vital services. This is particularly true if the GHGs emitted from this integrated systems become a measurement of urban sustainability.

<u>Contributions</u>:

This dissertation makes the following significant contributions:

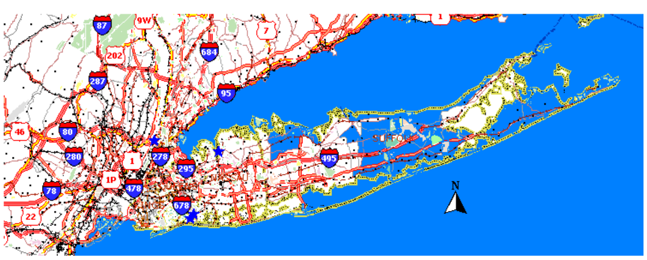
1. An incorporation of waste water management and solid municipal waste into a MARKAL energy-planning model.
2. An analysis of the impacts of a carbon tax on the local scale. Long Island, the area under investigation, is unique in that it is isolated, requires on island generation, and has an aging infrastructure.
3. An answer to the literature's need for an analytical solution capable of combining environmental justice considerations with sustainability parameters.

II. Background:

A. LONG ISLAND:

Long Island is located off the coast of New York State and Connecticut and is approximately 118 miles long and between 12 to 20 miles wide (Figure 1). There are well over 200 miles of coastline that border primarily, the Atlantic Ocean and Long Island Sound. The study area is restricted to the service area of Long Island Power Authority (LIPA), i.e. Nassau County, Suffolk County, and the Rockaway Peninsula of Queens County. KeySpan Energy Corporation (now National Grid) provides a large portion of Long Island's electricity and 25% of New York City's needs through its 6,400 MW of generating capacity. (KeySpan | corporate overview, 2003) Through the use of US Census data and records of residential electric meters, LIPA estimates, as of January 1, 2002, the population of Nassau County to be 1,340,289 persons, Suffolk County to be 1,440,810 persons. In the ten years from the 1990 to 2000 Census Nassau has seen a 3.6% rise in population and Suffolk has seen a 7.3% rise. (LIPA 2002 Long Island Population Survey)

Figure 1: Map of Long Island



According to the New York Independent System Operator (NYISO), the electric grid manager that oversees New York State's power transmission system and administers

New York State's wholesale electricity market, Long Island has 4,983 MW of generating capacity available for an average load requirement of 4,607 MW. A NYISO operating committee vote in 2003 mandated that 95% of Long Island's demand for electricity must be met from on-island sources. The stated electricity demand was an average and did not take into account peak usage days. The NYISO contends that New York's current electric system will be stretched to and beyond its capacity with increasing frequency in the near future, as a result of capacity constraints and transmission bottlenecks. This has created an imperative that additional capacity is developed and energy efficiency (demand side management) improvements be made on Long Island. (NYISO, 2003) According to the Long Island Power Authority's 2001-2002 Consolidated Financial Statements, the highest historic peak load was hit on July 3, 2002 when 5,030 MW of electricity were being consumed. On July 29th a new record was established at 5,059 MW. The blackout of 2003, which caused a large portion of the Northeast electricity grid to lose power, shows us that although areas may be interconnected, there is still a need to be self sufficient in times of potential catastrophic emergencies or extremely high peak demand (usually due to abnormally high temperature/humidity days).

According to LIPA's "Approved 2002 Operating Budget Approved 2002 and 2003 Capital Budget," electricity sales are forecasted to increase by 1.97% above 2001's original budget and reach 18,792,819 MWH, by 2003. This would consist of a 2.4% commercial and industrial market growth of 2.4% and residential increase of approximately 1%. Approximately 45% of electricity (MWh) is produced for residential sales, 52% for commercial and industrial sales, and approximately 2% for sales to Public authorities (i.e., street lighting).

B: Electricity Generation Options:

1.Nuclear Energy:

Often, governments have turned to nuclear power as a major electricity generator, as France does, but there are major well-known risks associated with the production of the energy and the removal of waste products. One need only look at disasters such as Chernobyl, in present day Ukraine, and the recent Japanese catastrophe (Fukushima Daiichi Power Plant) to realize the possible danger of this source and the public's perception of risk, which tends to drive policy. Further, nuclear energy has not been shown to be economically viable in this country. Perhaps in the future, fusion power will be the ultimate answer to our energy needs. A fusion power plant would likely use a deuterium and tritium mixture, which could be raised to thermonuclear temperatures (one hundred to two hundred million degrees Celsius), and allowed to react thereby producing ^{4}He and energy. (Princeton Plasma Physics Laboratory, 2003) Yet at this juncture, nuclear fusion is still, as it has been for the past fifty years, in its developmental stage and the NEPD recommends further funding of fusion research. (National Energy Policy Development Group, 2001)

Long Island has flirted with the concept of nuclear power and began construction (1973 – 1984) of a nuclear power plant located at Shoreham, L.I. The plant never became operational for a number of reasons, most notably the lack of an acceptable evacuation plan for residents of the ten-mile emergency planning zone (EPZ). It should be noted however that LIPA has an 18% stake in Nine Mile 2 (located 5 miles North East of Oswego, NY) nuclear reactor which provides 207 MW of electricity for Long Island.

2. Natural Gas and Oil:

Approximately 25% of the world's primary energy production is provided with natural gas. Despite recent rises in prices, natural gas is still inexpensive and is thought to have large reserves especially with the use of new hydraulic fracturing ["fracking"] technologies. As reliance on natural gas increases, the price increases as do its environmental impacts, such as carbon dioxide release. Although natural gas is "clean burning" it still releases carbon dioxide when it combusts approximately 360 – 500 g of CO_2/kWh of electricity is emitted. (Jean-Baptiste and Ducroux, 2003) Natural gas has gone from less than half of the dual fuel power plant market in 1976 to 80%. In fact, fuel oil consumption for power plants dropped 82% from 1973 to 1995 and 62% from 1989. (Bradley. 1997) New York has become increasingly reliant on natural gas because of its energy efficiency and reduced emissions. Almost all new generation facilities proposed in New York State, aside from some wind projects, are natural gas fired. New York could be exposing itself to operational and financial risk with its heavy dependence upon natural gas. (NYISO, 2003)

3. COAL:

Coal is the most abundant fossil fuel source in the U.S. (25% of the known coal reserves in the world). At our current usage rates, the country has a 250 year supply.

Ninety percent of the coal mined in the US is used for electricity generation. In fact coal transportation is the biggest source of revenue for the rail system. Fifty seven percent of all US electricity is coal-generated. Coal costs approximately one half the amount of natural gas or oil per British Thermal Unit. (www.nyserda.org/sep.html) Constraints on transportation of coal (limited rail lines) and barge ports, as well as environmental constraints precludes coal as a viable option for Long Island

<u>*4.* RENEWABLES:</u>

We must remember that emissions are indeed a serious problem and must be limited, but must not lose sight of the fact that supplies of fossil fuels are also limited and there availability is tenuous, especially when one thinks of current Middle East tensions, Venezuelan and Nigerian unrest, and the events of September 11, 2001. Since this time, there has been a movement of spending into "green" energy research by the US, from agencies such as the Department of Defense, NASA, and the Department of State, as part of the Homeland Security effort. (Makower, 2003) Due to current limits on domestic drilling and exploration, the implementation and increased usage of clean renewable energy sources is needed to ensure the sustainability of our environment and decrease our dependence on non-renewable fossil fuels. The United States currently uses fossil fuels to produce approximately 67% of its electricity. This is clearly unsustainable considering limited supplies and availability, as well as its various negative externalities (Ronen, 1998).

In the future, and even now, we will begin to rely more heavily on technologically advanced renewable energy sources. The ideas behind these sources date back many years, but technology has brought them to the point that they are “competitive with, if not superior to, their conventional counterparts.” (Makower, 2001) Fuel cells were conceptualized in 1840 by Sir William Grove, and produced in 1960s by GE for the U.S. space program. Photovoltaics were discovered by Edmund Becquerel in 1839, and explained by Einstein in 1921who won the Nobel Prize for his contributions regarding the photoelectric effect. Bell Labs invented the first solar cell silicon device in the 1950s and by the 1960s solar cells were utilized in our space program. By the late 1990s, they had become cost-competitive with some conventional sources of energy. (Makower, 2001) This became increasingly true as oil and gas hit historic levels in 2008 (subsequently falling dramatically in 2011-2012). Although the United States attempts to be a leader in almost all technology fields, it has fallen greatly behind many nations in regards to the energy sector. Japan and Germany have taken the photovoltaic and fuel cell systems lead, while Denmark leads in wind systems. (Herzog, 2001)

a. WIND:

Wind energy has been used for over 2,000 years as a power source for pumping water and grinding grains. Today it is a cost-competitive energy source. (Baird, 2001) Wind is caused by differences in surface heating by the Sun. As long as the sun shines, winds will blow. Areas that are warmer than others will have a lower pressure; those that are cooler will experience higher pressure. Air will flow from high pressure to low pressure, thus causing winds. Areas by the coast and at high elevations tend to have the greatest average winds. In total, winds could supply 80 times the energy the US consumes. Realistically though, we can only capture a minute portion, since we can't cover the entire surface with turbines which are not 100% efficient (Baird, 2001). Over the course of a year an average wind power plant produces 30-35% of its peak rated capacity. In New York a 100MW wind plant could produce on average 30-35MW, enough electricity for 44,000 homes. (Wind energy- a guide for wind site development, 2003)

On April 22, 2002, LIPA announced results of a study to determine the potential for offshore wind farms off Long Island's South shore and Montauk Point. It was determined "that a maximum [given current technology] of about 5200 megawatts (MW) of electricity could be produced by wind generators placed in a 314 square-mile band that stretches three to six nautical miles off Long Island's south shore and east of Montauk Point." A 100 MW off-shore farm of 25 to 50 turbines has been proposed. This could only supply approximately 30,000 homes with power.

b. SOLAR:

Solar energy (photovoltaic) is still expensive and will likely remain a backup source, with fantastic future potential (Jean-Baptiste and Ducroux, 2003) There is currently a 10% business tax credit for solar equipment, to help promote its use, as well as a 15% residential tax credit (up to $2,000) for home owners who purchase photovoltaics (PV) and solar water heaters. (Sissine, 2003) In addition, if a solar system serves as part of a building structure, the increase in property value added by the system multiplied by the incremental cost (increased cost of the system above a conventional system) is currently exempt from general municipal taxes and school taxes. (Global Energy Concepts, 2002)

Customer sited, grid connected PV systems currently cost between $6 to $7 per watt. Because of tax credits, grants, and a net metering option, according to the National Renewable Energy Laboratory, New York State is ranked as the number one market for PV systems based on a break even price system for a 20 year time frame. (www.nrel.gov/ncpv/documents/cust-sited.html) According to the Earth Policy Institute, even with low priced oil, solar growth was approximately 15% per year from 1984 through 1996. The late 90s and early 2000s have seen a staggering 20-30% growth according to the Energy Information Administration (EIA).

c. GEOTHERMAL:

Worldwide geothermal energy accounts for 49 TWh/year of electricity (geothermal electricity is not viable on Long Island, but is a usable resource on the demand side for space heating), with twenty-one countries as of 2000 generating geothermal electric power and approximately 53 TWh/year for direct use (Kaygusuz and Kaygusuz, 2002). Geothermal energy, however, plays a relatively small part in the energy mix of the United States. Approximately 30 million barrels of imported oil are displaced by geothermal energy each year (McLarty and Reed, 2003). Direct use of geothermal energy (heating/cooling) in the US accounts for the majority of its use. Approximately 6,029 GWh/year of energy is drawn on by direct heat use. The energy is used for heating pools, spas and greenhouses, as well as space heating. Direct use and geothermal heat pumps save over 10 million barrels of fuel oil per year. This has displaced 1.35 million tons of carbon emissions from oil or 0.32 million tons from natural gas. As a space cooling system, geothermal has saved over 6 million barrels of oil, displacing 0.81 million tons of carbon emissions. (Lund, 2003) LIPA promotes geothermal heating and cooling and have highlighted its efficiency, cost savings, and durability. (LIPA-Geothermal Power, 2012) A number of locations have taken advantage of geothermal direct use on Long Island including: Atlantis Marine World, The Inn at Foxhollow, The Theodore Roosevelt Center, and Danford's Inn. (LIPA-Geothermal Customer Testimonials, 2012)

d. Tidal Power:

Tides are the daily rise and fall of ocean water levels that result from earth, sun, and moon gravitational interactions. The Moon has the greatest impact because of its close proximity to earth. The Moon and the Sun exert a gravitational force on the earth that pulls on the entire Earth, including oceans and seas. This causes the waters to bulge outward towards the gravity center of these bodies. As the Earth rotates beneath the water a cyclic rise and fall of our ocean water levels ensues. There are generally two high tides and two low tides that occur just over a twenty-four hour period. The greatest difference between high and low tide occurs when the earth, the Sun, and the Moon are lined up (180°) during full and new moon phases, this is called a Spring tide. The lowest total difference between high and low tides are called Neap tides. These occur when the Earth, the Sun and the Moon are at right angles (90°) during the half moon phases (Baird, 2004).

The New York State Energy Research and Development Authority (NYSERDA), The Massachusetts Renewable Energy Trust, and The Connecticut Clean Energy Fund have been conducting research to determine the feasibility of tidal systems and wave energy potential for Long Island. E3, Inc (2007) points out the "infancy" of tidal technology, future promise, and need for more detailed analysis. Their reports conclude that present day technology is not appropriate for Long Island-based sites (given its low to moderate tidal range), but that the technology may be suitable in the future. (www.nyserda.org/sep.html) This technology would be available beyond the time horizon of this project.

e. 1. Waste to Energy:

As the population of Long Island grows, so to does the quantity of municipal solid waste (MSW). For years, garbage was buried in unlined landfills or dumps, or incinerated without pollution abatement controls (pre Clean Air Act). Today, garbage can be sent to sanitary landfills, recycling facilities (paper, aluminum, glass, and plastic), or incinerated at waste to energy (WTE) facilities. The concept of waste to energy is not a recent development, the first documented facility that converted garbage to electricity through a steam generator was in Hamburg Germany in 1896 (Korzun, 1990). The obvious benefit of waste to energy (WTE) facilities is their ability to turn refuse into a needed commodity, electricity, while vastly reducing volume. Interestingly, waste to energy facilities were not considered renewable energy sources by the NYS Renewable Portfolio Standard, but the IPCC considers them as renewable and its carbon emissions should not be taxed or capped. Although older technology WTE facilities were heavy polluters of NOx, SOx, dioxins, furans, volatile organic compounds (VOCs), as well as particulates; newly constructed WTE facilities have scrubbers and filters that remove more than 98% of many of these pollutants. (Swanson, 1993)

There are "resource recovery" (WTE[5]) energy producers in Babylon, Huntington, Islip, and Hempstead. The Hempstead facility, American Ref-fuel, has a capacity of 72MW to 80MW. The facility uses 8MW in order to run the entire facility, and sells the remaining 64MW to 72 MW capacity to LIPA. The facility processes 2,500 tons of refuse per day from the Town of Hempstead and parts of Brookhaven. The resultant ash (90% volume reduction) is sent to the Brookhaven landfill. (Motschman, 2003) According to the "Municipal Solid Waste Assessment of Nassau and Suffolk Counties, Long Island, New York, 2006," released by Stony Brook University's Department of Technology and Society, Long Island produced approximately 3.5 million tons of Municipal Solid Waste (MSW) in 2005. Forty-three percent of which was incinerated, 27% recycled, and 30% hauled off island. The base year will maintain these percentages, but an upper bound of 70% of waste will be available for waste to energy projects. MSW growth will grow at the rate of population growth (1.5% growth for Long Island from 2001 to 2006, as per Long Island Index), as is the convention.

e. 2. Landfill Gas Energy:

Garbage can be sent to sanitary landfills, recycling facilities (paper, aluminum, glass, and plastic), or incinerated at waste to energy facilities. Until recently land filling dominated Long Island's waste disposal. As of 1992 all landfills on Long Island were

[5] WTE or Waste to Energy facilities incinerate or burn solid municipal waste (or other forms of trash) with the energy from this process being used to produce electricity, metals may also be recovered for recycling. (WTERT, 2012)

ordered to be capped and closed. As waste decomposes in landfills it produces methane. If this gas is not captured and burned it would eventually rise into the atmosphere. Although waste combustion produces carbon dioxide, itself a greenhouse gas, the methane has a 20 times greater greenhouse potential. Combusted methane can in fact be used to produce electricity and Long Island currently has these types of facilities in Oceanside and Brookhaven. There were numerous other potential landfills that could have been tapped but were not. In fact, the Riverhead Town landfill was ordered to be closed, as all other Long Island landfills in 1992.

It was not until the summer of 2008 that the 32 acre Riverhead site began to be capped. Ground water monitoring will continue, as will methane testing, but since the landfill was closed to new dumping there has not been significant methane developed. (Gannon, 2008) The EPA estimates that 25% of all anthropogenic methane results from landfills. (Rather, 2008) This methane also represents 3% of all U.S. greenhouse gas emissions. (Jaramillo and Scott, 2005) It is estimated that for each ton of landfill gas (LFG) captured and combusted, there is a net savings of 20 tons of carbon dioxide released (Simon et al, 2007). This savings offsets carbon emissions from landfill gas combustions.

Although LFG is considered to be a renewable resource, there are many critics of its being labeled as such. Reasons for debate include its air emissions, potential for groundwater contamination, and public health issues. It's interesting to note that more electricity is currently produced from LFG in New York and New Jersey than from solar panels. (Weeks, 2005)

f. FUEL CELLS:

Fuel cells convert chemical energy into electrical energy, in much the same way a household battery would. They combine a fuel, such as hydrogen, and an oxidant to produce electricity without combustion and in so doing significantly minimize pollution and increase efficiency. (www.nfcrc.uci.edu/fcresources/FCexplained/FC_howItWorks.htm) According to the National Fuel Cell Research Center, there are six types of fuel cells: alkaline (used for early manned space flights), phosphoric acid (200kw systems currently available), molten carbonate (60% to 80 % efficient when used as a cogenerator), proton exchange membrane (can operate at the lowest temps, 90°C), solid oxide (currently 1-250kw systems with multi-MW systems in the works), and direct methanol (currently very low performance). (www.nfcrc.uci.edu/fcresources/FCexplained/FC_Types.htm) The cost per kilowatt is currently $4,000+, and would only be truly competitive if it dropped to $1,500 or less per kilowatt. (www.nfcrc.uci.edu/fcresources/FCexplained/challenges.htm)

LIPA has partnered with Plug Power Inc., a fuel cell manufacturer, to possibly connect 75 fuel cells in West Babylon. The project would provide power for approximately 100 homes (1 million kWh of electricity). (www.lipower.org/projects/fuelcell.html) Although this has been discussed for years, to date this has not occurred. Additional fuel cell systems running on natural gas are proposed for setup at Babylon Town Hall, an off campus Hofstra University dormitory, the East Hampton Town Hall, the US Merchant Marine Academy, and a McDonald's store. (www.lipower.org/cei/rd.fuel.html)

5. Purchasing Power from off Island Sources:

The NYISO requires Long Island to provide 95% of its base electricity from on island locations. The remaining 5% and peak load may be provided by off-island sources. There are a number of connections to neighboring systems that can import power to Long Island. The costs involved with importing the electricity include the cost of generating the electricity, transporting it (cable cost, installation, and maintenance), and transmission losses. The actual cost to LIPA of purchasing this power from off Island is a commercially sensitive trade secret that has been protected in a number of cases such as: Arrow Electronics, Inc. v. Long Island Power Authority, Sup. Ct. Suffolk Co., Index No. 03-2002 (February 28, 2002); Matter of Encore College Bookstores v. Ancillary Service Corp. of the State Univ. of New York, 87 N.Y.2d 410 (1995); Matter of Glens Falls Newspapers v. Counties of Warren and Washington Ind. Dev. Agency, 257 A.D.2d 948 (3d Dep't 1999); Matter of New York State Electric & Gas Corp. v. New York State Energy Planning Bd., 221 A.D.2d 121 (3d Dep't 1996).

A brief description of imports is listed below:

1. New York Power Authority Blenheim-Gilboa: LIPA has contractual agreements with New York Power Authority to purchase 50 Megawatts (upper bound 1576.8 TJ) of capacity from this Catskill Mountains-based hydro pumped storage plant. (LIPA's Energy Plan 2004-2013)
2. Nine Mile Point 2: LIPA holds an 18% (~207 MW) stake in this Syracuse area nuclear power plant. The second of two reactors in the area has a 1,148 MW capacity and began operation in 1988. (LIPA's Energy Plan 2004-2013)

3. Cross Sound Cable: This hotly contested 330 MW, 25 mile long cable connects Shoreham, Long Island to New Haven, Connecticut, providing Long Island with less costly New England electricity. This project was completed in 2002, but various lawsuits stymied the usage until the August 2003 blackout, when it was ordered on, until May 2004. In June of that year it was permanently operational. (LIPA- Powering Long Island, n.d.)
4. Neptune Cable: This 65 mile cable connects Sayreville, New Jersey with New Cassel, Long Island. It provides 660 MW of electricity and began operations in May 2007. Less expensive electricity can be purchased from New Jersey, Pennsylvania and eleven other states in the mid-Atlantic and Ohio River Valley regions. (LIPA- Powering Long Island, n.d.) In its first 8 months of operations it supplied over 2.8 million MWh of electricity for Long Island (Personal Correspondence with L. Nicolino, 10/10/2008)

C. DEMAND-SIDE MANAGEMENT (DSM), CONSERVATION AND ENERGY EFFICIENCY:

Conservation and improved efficiency techniques must play a role in energy optimization modeling. Strategies to conserve energy may include the purchase and installation of more energy efficient equipment and/or the increase in insulation for homes and buildings with electric heat. Models have shown that higher insulation standards for new buildings lead to large overall savings. Creating minimum insulation standards for newly constructed homes and businesses would be a major step toward increased efficiency. This may therefore be a legislative move that could be somewhat easily passed. (Luthra and Fuller, 1990)

LIPA has been involved with a "Clean Energy Initiative" (CEI) and will spend $185 million over five years (2004-2009) toward energy conservation and efficiency programs, as well as alternative energy technologies, according to the 2004-2005 Operating Budget. This program was instituted in 1999 and in its 10 year existence it is estimated that $355 million will have been spent. According to NYSERDA from 1999 to 2001 LIPA spent $41.5 million of their CEI funds solely on conservation and efficiency programs, not peak load management or alternative energy programs. This program saved a cumulative reduction of 112.7 GWh and a decrease in peak demand of 29.5 MW

Other methods for improving efficiency include the guidelines set forth by Governor Pataki's Executive Order 111, which requires a 35% reduction in energy use in buildings of all State agencies, and public authorities, by 2010 relative to 1990 levels. All existing buildings will be required to strive to meet ENERGY STAR® building standards. All new products used in State agencies will be required to be of the ENERGY STAR® label. Further methods include revising the NYS Energy Conservation Code, which was established in 1979 and not substantially altered since 1989. Expected changes will make the code one of the most progressive in the nation. The NYS Green Building Tax Credit was established in 2000-2001. The $25 million tax credit was intended to promote the use of advanced materials and technologies in construction and renovation projects by companies, utilities, and individuals. New buildings could use no more than 65% of the State's Energy Code allowance, while renovated buildings could use no more than 75% of the allowance.

(www.nyserda.org/sep.html)

III. Modeling Background :

The purpose of this dissertation is to determine the optimal mix of electricity generating facilities for Nassau and Suffolk Counties, on Long Island, New York and the impacts of two policy changes. This is an operations research type problem that will require the establishment of a *Long Island* MARKAL model. Many organizations have used operations research (O.R.) applications to solve assignment and scheduling problems that share a common approach: minimizing cost or maximizing profit, subject to a set of linear and nonlinear constraints. For example, airlines (such as United Airlines and American Airlines) have used such models to schedule shifts for workers to minimize cost and meet customer needs, and to design fare structures, and coordinate flights to maximize revenues. The U.S. military used O.R. to coordinate aircraft and associated personnel and equipment to effectively run the Desert Storm airlifts. (Hillier and Lieberman, 1995) Numerous governments, organizations, and companies have used O.R. to optimize various energy systems, as previously mentioned, and as follows.

OPTIMIZATION MODELS:

Charpentier (1974, 1975) and Beaujean and Charpentier (1978) provide detailed reviews of the first generation of energy models. Energy models were categorized as single-fuel vs. multiple-fuel, national vs. international in scope, and with respect to the nature of the posited linkages with the economy: 1, national, single-fuel models (Category A): 2, international, single-fuel models (Category B); 3, national, multiple-fuel models (Category C); 4, international, multiple-fuel models (Category D); 5, national, multiple-fuel models with linkages to the macro-economy (Category E); and 6, international, multiple-fuel models with linkages to the macro-economy (Category F). Numerous modeling techniques including linear programming were used in the various papers. The models that follow are more recent and focus on the types of models (Beaujean and Charpentier Category C type models) that will be expanded upon to solve the problem of optimal mix and facility location to minimize cost and maximize equity.

Kavrakoglu (1981) developed an optimization model to plan for Turkey's future energy needs. It specifically looked at the impacts of petroleum prices, delays in hydro project development, the shadow price of foreign currency, faster economic growth, and the substitution between petroleum and coal. The model was later used for determining nuclear energy possibilities for Turkey.

Anderson (1972) reviewed models that were created for the electricity supply sector. The use of linear and non-linear programming was included in various objectives, including: least cost investments, minimum discounted costs, optimum replacement, and optimal storage capacities. Kavrakoglu (1982) studied the planning of the entireTurkish power system. Only coal, hydro, and nuclear options were considered as sources of energy. The economics of a plant included: investment and operating costs, environmental impacts, and potential unforeseen damage. The three objective functions were:

$$Zc = \sum_{t=1}^{T} (1/(1+r))^{t} \sum_{j=1}^{3} (C_{1j} P_{jt} + C_{2j} E_{jt})$$

$$Ze = \sum_{t=1}^{T} \sum_{j=1}^{3} C_{3j} E_{jt}$$

$$Zp = \sum_{t=1}^{T} \sum_{j=1}^{3} C_{4j} P_{jt}$$

where,

Z_c = economic cost
Z_e = environmental impact
Z_p = potential damage
C_1 = unit capital cost
C_2 = unit generation cost
C_3 = unit environmental impact
C_4 = unit potential damage
r = discount rate
t = time period up to T (max time horizon)
j = type of plant

The constraints for the model included:

1. demand for energy and power must be met
2. generation cannot exceed production capacity
3. building of a plant cannot exceed or surpass technological/manpower capabilities
4. development maximums for each source could be set

Luthra and Fuller (1990) devised a model using linear programming to determine the least costly energy system for Ontario, Canada. The economic and air pollution impacts were determined using several different scenarios. Conservation through improved building design was included, as were combinations of space heating energies, including wood and solar devices with natural gas backup systems. They found improved insulation to be very cost effective, with Canadian R2000 Standards to be the most cost effective for heating and cooling. This in turn leads to lower emissions of gases such as CO_2. The Canadian government Office of Energy Efficiency can certify an individual home as meeting these R-2000 Standards, which on average reduce energy usage by 30% over non- R-2000 homes (http://r2000.chba.ca/index.php).

Sinha and Kandpal (1991) created a linear programming model for cooking, irrigation, and lighting in rural India with an objective function of annual cost minimization, constrained by resource availability and demand. Joshi, et al (1991) created a model for rural Nepal with cost as the objective function and supply/efficiency as the constraints. The model consisted of a mix of sources and conversion devices including biomass, LPG, kerosene, and hydroelectric plants.

The actual or presumed high cost of renewables is a common criticism of the industry and the usage of such technology. Neij (1997) found that renewable technologies, especially wind turbines and photovoltaics are more similar to mass-produced technologies than to conventional power plants in terms of production costs. The experience curve (cost per unit as a function of output) is more progressive for small scale plants and products such as mass-produced electronics. This is known as economies of scale in terms of producing goods. When a good enters a market the cost of production drops as more are sold and built. Think of the cost of a television, video cassette recorder, or DVD player when they first came to market (very expensive), as compared to just a few years later (very inexpensive). Renewable technologies are more similar to the mass produced electronics industry than to large scale power plant production. In fact, coal burning and nuclear power plants have shown an increase in construction costs over the years, while a decrease in costs has been seen with renewable energy technologies. Gas turbines have also realized cost reductions, but Neij notes that the rate of cost reduction will likely decrease with time, and that fuel prices (which are increasing) must be considered. Wind turbines have shown a decrease in cost, the technology has improved and electricity generation has become more cost effective and efficient (from 35%-40% efficient in the 1980's to 45%-48% in the early 1990's). Photovoltaics have shown a tremendous cost reduction but remain relatively inefficient (15%-20% efficient for crystalline silicon and 6%-10% for amorphous solids). Neij notes that as new materials are developed the costs will likely decrease, but for now these photvoltaics are a niche market (i.e. locations far from the electric grid with high intensity and duration of sunlight).

Rana (1998) determined the optimal mix of electrical generation which minimized cost and used renewable sources in Madhya Pradesh, India. Technologies included: biomass, biogas, and solar photovoltaics. Biogas and biomass provided the lowest cost electricity, but not all regions in the study area had sufficient supplies and therefore had to rely more heavily on PV. The cost per kwh ranged from 4.1 Rupees (biogas/biomass) to 21.3 Rupees (PV).

Carlson (2002) determined the impact of externality costs (environmental and health damage) on the optimal mix of energy systems. The evaluation focused on heating single family and multi-family buildings and homes, nonresidential areas, and district heating systems. The externalities included: CO_2, NO_x, SO_x, and particulates. MODEST, a linear programming model for optimizing energy systems, was used to help construct a regional model for three areas of Sweden. By using externality costs from the literature pertaining to Sweden, it was determined that it would be less costly to take externalities into account during planning, than to ameliorate damage after it has been done. Further, the use of wood chips for heating was found to be cost effective and should be used more widely in the study area.

Iniyan and Sumathy (2003) developed an optimal renewable energy mathematical (OREM) model for substituting renewable energy sources in India from 2010-2011, 2015-2016, and 2020-2021. The model allocates specific sources for various uses. The objective was minimization of cost/efficiency based upon social acceptance, reliability, demand, and potential constraints. This model used a Delphi study, a technical means by which experts in a field are questioned repeatedly and their ideas and opinions are collected and organized and redistributed anonymously so as to reach a consensus. Iniyan et al (1998) had sought to ascertain the best method for popularizing renewable energy sources in India and to determine the associated problems. Renewable sources were determined to be a key component to solve environmental problems and a minor component for a sustainable development.

Cormio, et al (2003) devised a bottom up energy optimization model that would help promote the use of renewable energy sources by including environmental constraints. A bottom up model is commonly used by energy optimization models such as MARKAL, while top down models are a market equilibrium approach. Cormio's study was for the rural Apulia region of Southern Italy. The methodology provides for regional energy planning on a multiple decade interval. The supply sector includes: fossil fuels, industrial by-products, and local renewables. This study included end use in the form of electricity, gas and solid fuels for transportation and other uses, and oil products. It was found that when externality costs were included there was a shift to less polluting facilities, such as cogeneration plants, and renewables, such as wind. Yet many renewables, such as PV were still not competitive because of their high capital costs.

Antunes, C. H., et al (2004) devised a multi-objective mixed integer linear programming model for power generation expansion planning. The three objectives were the minimization of total cost, environmental impact, and environmental cost. Total cost included: investment costs, operating costs, and maintenance charges. Environmental impact was determined by taking a weighted average of the impact criteria (land use, accidents, and effects on an ecosystem) associated with generation facilities. Using monetized environmental externalities, Antunes included the environmental cost of various technology choices. Interestingly, only fossil fuel technologies and demand side management (DSM) were studied and were used in this model.

MARKAL

One frequently used optimization model for energy systems analysis is MARKAL (MARKet ALlocation). This is a bottom up linear programming model that was conceived by the Energy Technology Systems Analysis Programme of the International Energy Agency. The model shows the supply and demand sides of the energy system. MARKAL has been used by over 50 countries and over 110 institutions. This model is able to address the interactions and competition between many energy forms and technologies, from conventionals such as oil and natural gas to renewables such as, wind and solar. (www.epa.gov/cleanenergy/pdf/model_sum%20_markal_100202.pdf) Some uses of MARKAL are: to identify least-cost energy systems, to identify cost-effective responses to restrictions on emissions, to evaluate new technologies and priorities for R&D, to evaluate the effects of regulations, taxes, and subsidies, and to project inventories of greenhouse gas emissions. (http://www.etsap.org/Tools/MARKAL.htm) Because of MARKAL's great flexibility, it was chosen over other existing models.

There are several extensions based on the standard MARKAL model: MARKAL-MACRO (macro-economic model), MARKAL-MICRO (micro-economic model), MARKAL with multiple regions (includes emissions permit trading), and MARKAL with materials flow (in addition to energy flows this includes recycling of materials. The MARKAL model is particularly useful to answer energy policy and planning questions. One such application is the least cost solution for meeting energy demands subject to limits to emissions such as CO_2 and/or other greenhouse gases. The choice of variables may include: technologies, policies, and various market based instruments, i.e. taxes and permits. Gielen, et al. (2000) used MARKAL MATTER 4.2, an extension of the standard MARKAL model to show that biomass strategies could be used to reduce CO_2 emissions by 400Mt in 2030. The use of biomass for transportation fuels and energy recovery from waste were determined to be the best options for greenhouse gas emission reduction over the long term.

Kanudia and Loulou (1998) used Extended MARKAL to describe a stochastic model for an energy plan for Quebec Canada. The model presumed a 45 year time period from 1993 to 2037. The three decision variables were: the initial investment, the capacity, and the type of the technology. The objective function was expected cost, which was defined as the probability-weighted sum of the capital and operating costs, given a range of demand and energy prices The model showed that the use of a hedging strategy lowered costs over a “perfect foresight” method with differing demand and pollution (primarily GHG) mitigation levels.

Gielen and Kram (2000) used MARKAL to determine optimal policy selection for European Union Kyoto compliance. It was determined that the control of non-CO_2 GHG emissions, specifically methane reduction are a key method for complying with the standards set forth. The sources of these emissions are, surprisingly, primarily from the agricultural sector. The use of taxes for controlling GHG emissions on industry was determined to have a sizable impact on the structure and location of industry. The effects depend of course on the exact policy implemented, but overall it was noted that taxes on polymer and petrochemical industries would lead to shifting of jobs to developing nations without such taxes. This would happen despite the possible use of technology to reduce emissions within the home nation (least cost choice used by industry). The authors suggest governments allow as many technical and materials options for limiting GHG emissions, set long range goals or targets that give adequate time to adjust practices of business and integrate other environmental policies with GHG abatement.

Northeast States for Coordinated Air Use Management (NESCAUM) and the EPA have begun working on a project to build a Northeast regional MARKAL Model (NE-MARKAL), covering New Jersey, New York and New England. NESCAUM will include the commercial, residential, industrial, transportation, and power generation sectors. Individual states will provide available commercial energy data. Most sectoral energy demand data will be compiled from EIA State Energy Data Summary (available at: http://www.eia.doe.gov/emu/states/_use_multistate.html), the Commercial Building Energy's Consumption Survey (CBES) [http://www.eia.doe.gov/emeu/cbecs] and the Residential Energy Consumption Survey (RECS) [http://www.eia.doe.gov/emeu/recs/contents.html]. Transportation data is difficult to find at the state level. R.L. Polk and Associates will provide data on light and heavy-duty vehicles, the FAA will provide aircraft data, and sources of rail and marine data have not yet been identified. The industrial sector is also a difficult area to obtain needed information. The Department of Energy lists the 5,000 most energy-consuming facilities in New England and New York; this database will be useful.

Power generation data may be obtained from the EPA e-GRID database at http://www.epa.gov/cleanenergy/egrid.htm which provides information about generation technologies and their efficiencies. Other such data will be obtained from the National Renewable Energy Laboratory (NREL) at: http://analysis.nrel.gov/repis/whatisRepis.html. A limit to MARKAL, and all models, is finding available data that is consistent and complete. The robustness of modeling results is limited by such data availability. (Bronze.nescaum.org/projects/nemarkal/DATA_AVAILABLITY_SURVEY.doc)

Most applications of the MARKAL literature have failed to incorporate waste water treatment and solid municipal waste treatment plants. This dissertation project, through an EPA grant in cooperation with CUNY, Stony Brook, and Brookhaven National Laboratory, addresses this issue. Since electricity generation, waste water treatment, and solid municipal waste disposal, are so greatly interconnected, this work is a major contribution to the existing literature.

IV. BASELINE LONG ISLAND-MARKAL METHODOLOGY:

The objective of this study is to develop a robust and sustainable energy (electricity) path for Long Island. The Long Island MARKAL model is a tool which has been developed to select an optimal portfolio of electricity generating technologies and policy instruments. The minimum cost solution will be determined which takes into account various conventional and renewable sources and technologies, as seen in Cormio, et al (2003), as well as importing electricity, and conservation and efficiency (DSM) practices as seen in Martins, et al (1996).

The Long Island MARKAL model will determine how policy changes impact long term electricity planning. A carbon tax policy change will also be investigated in this study. This particular scenario is likely to be taken into consideration by policy makers as a result of continued Mid-East tensions, the realization of peak oil and accompanying record oil prices (Summer 2008), and the specter of global warming (IPCC's 4th Assessment Report). Although the United States has not been a party to the Kyoto Accord, a series of regional initiatives, such as RG 91, suggest that the U.S. will begin to control greenhouse gases, (Linky, Bhatt, and Lee, 2008). For these reasons carbon dioxide was chosen as a target of policy change for this project. Fullerton (2001) developed a simple model to show how different policies, regarding pollution abatement, will ultimately lead to the same net gain ("efficiency effect" or extent to which social marginal cost exceeds social marginal benefit for each unit of pollution from the optimal level to any unregulated point), but with different distributions of costs and benefits.

A carbon tax on CO_2 emissions would be easy to implement, as carbon content of fossil fuels used are relatively 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) For these reasons a carbon tax will be the principal scenario chosen for the model.

A Reference Energy System (RES) was established in order to show the energy producing, transforming, and consuming processes as a network. Three typical RESs are found in Figures 2 (electricity), 3(wastewater), and 4 (municipal solid waste).

Figure 2: MARKAL Building Blocks- Data Categories (Source: Loulou, Goldstein, and Nobel, 2004)

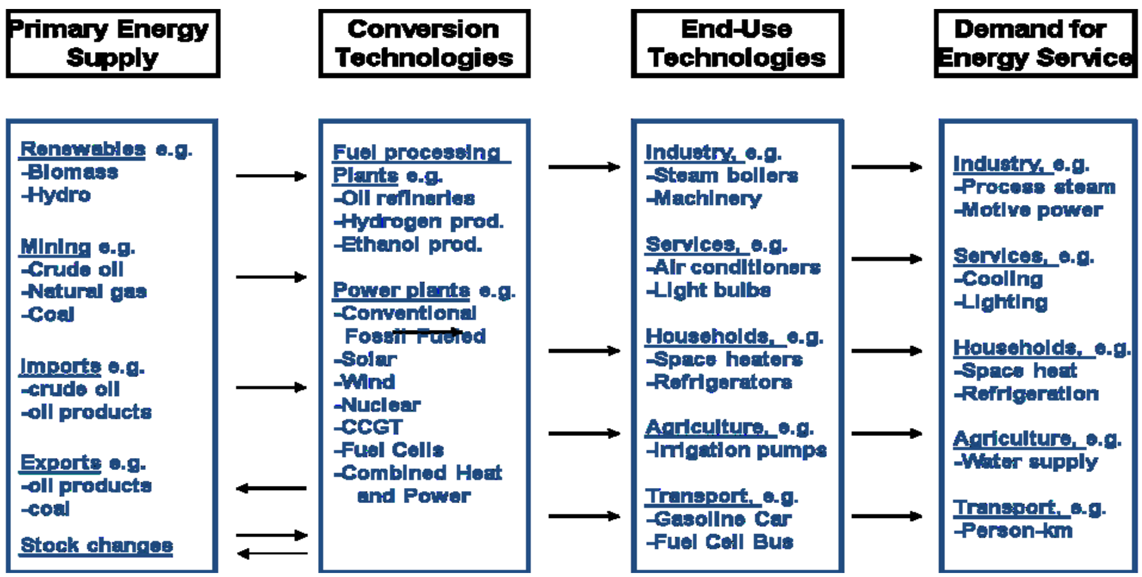


Figure 3: Sample Reference Energy System (RES) for waste water (Source: Lee, 2006)

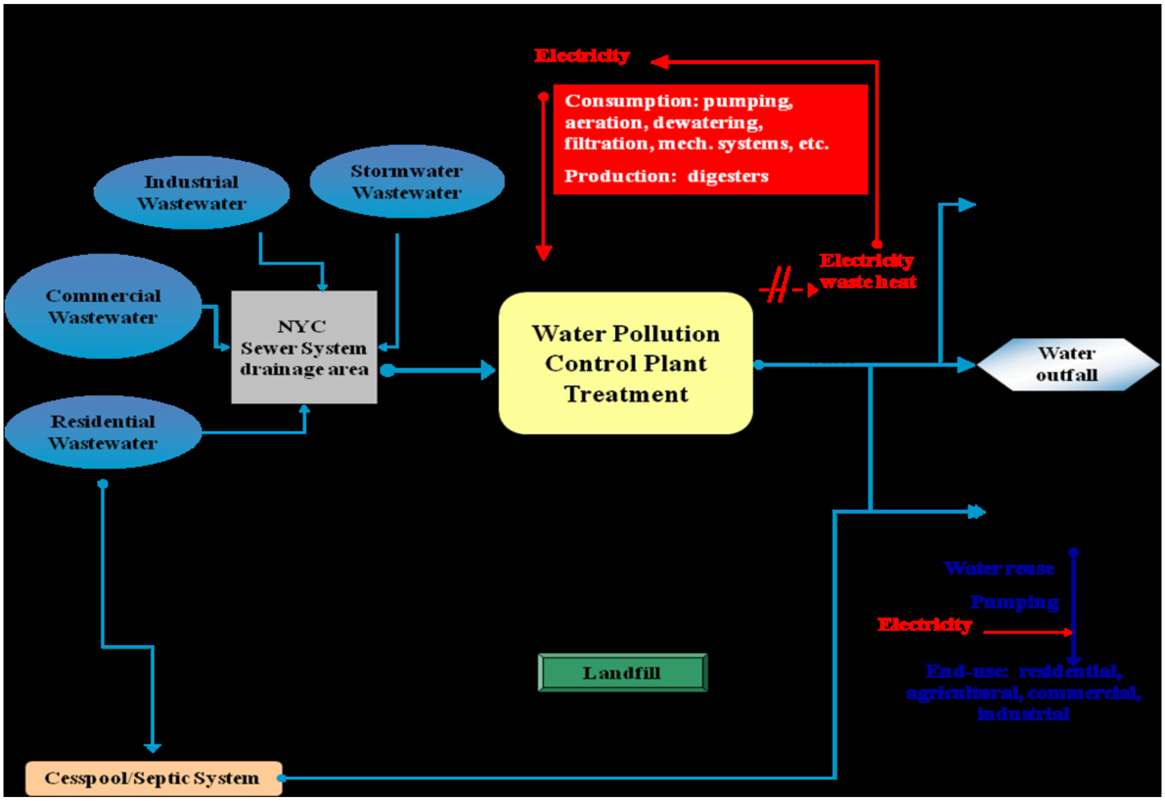
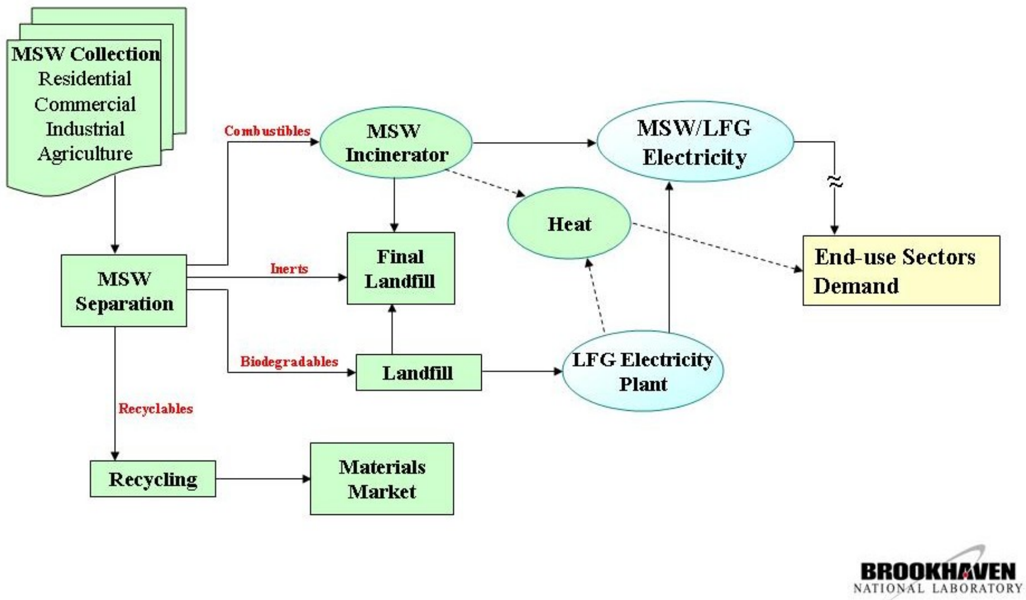


Figure 4: Sample Reference Energy System (RES) for municipal solid waste (Source: Lee, 2006)



For the Long Island MARKAL model, dummy processes were constructed within the RES in order to allow greater flexibility. As depicted in Figure 5, a dummy process was created that "converts" a fuel to a name that is specific to a power plant. This allows for greater flexibility of the model in dealing with policy issues. When multiple fuels are used a dummy process is created to establish a fuel mix, as exemplified in Figure 6. This allows for greater flexibility of the model in dealing with policy issues and fuel blends. Not all electricity generation is carried out on Island, so out of region generation can be dealt with by producing sub regions or by splitting the facility into its capacity (Conversion Technology) and the actual electricity imported (Resource Import) as seen below in Figure 7. A simplification of the actual Long Island MARKAL RES is depicted in Figure 8.

Figure 5: Dummy Process

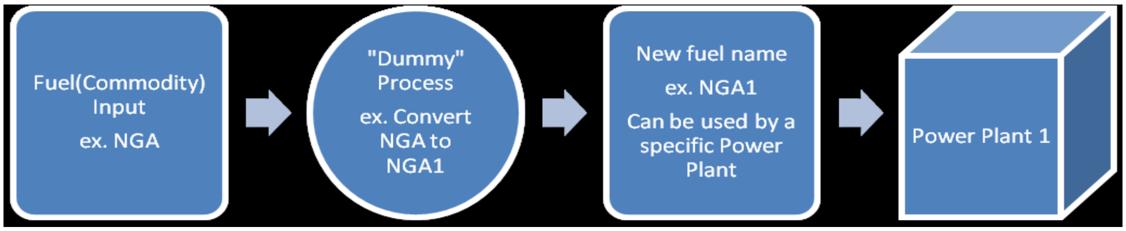


Figure 6: Multiple Fuels Dummy Process

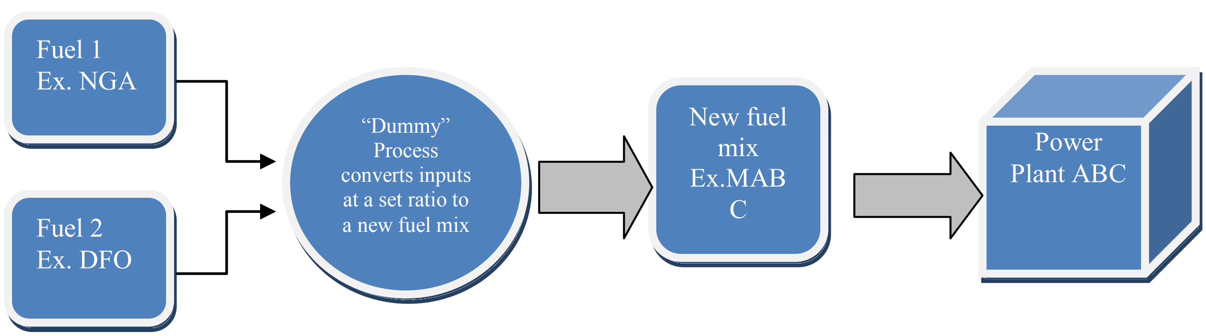


Figure 7: Import splitting technique

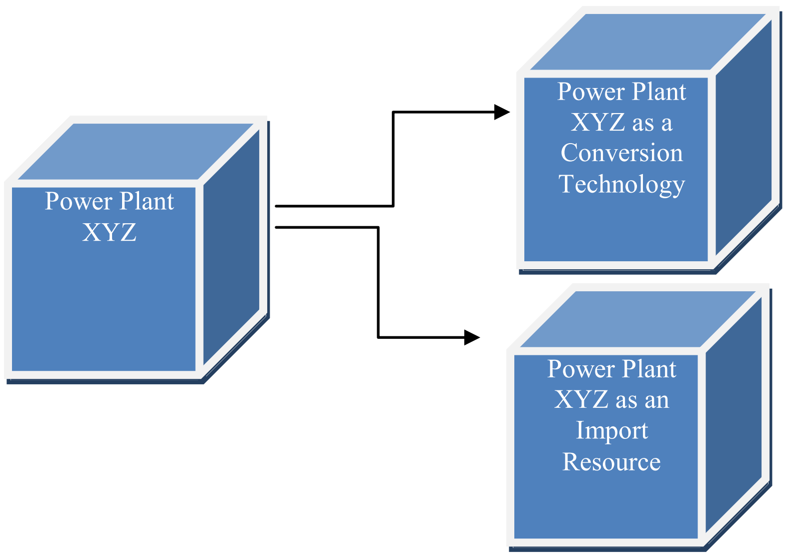
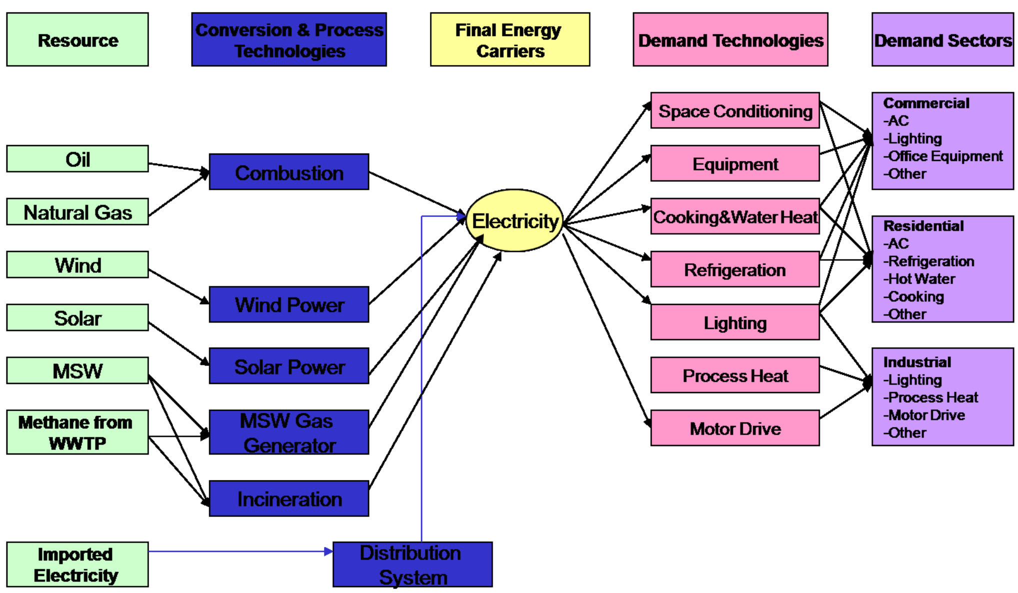


Figure 8 - A simplified Long Island MARKAL Reference Energy System



V. BASELINE DATA:

It is important to remember that although the goal of a model is to understand the real world, a model can never reflect it completely. As Daskin (1995) points out, “parsimonious models are generally better than complex inscrutable models.” Further, “the ability to know what must be incorporated into a model… is both an art and a science.” Much research is required to determine capital costs, fixed operations and maintenance, and variable operations and maintenance costs. Various sources are used to gather supply side and demand side data, including: EPA, NYSERDA, the U.S. DOE, EIA, and the available literature.

ELECTRICITY and POWER SYSTEMS:

In 2005, the total installed generating capacity available to Long Island Power Authority (LIPA) was 4,983 MW, to meet an average load requirement of 4,607 MW. As previously stated New York Independent System Operator (NYISO), the body which oversees New York State’s power transmission system and administers its wholesale electricity market, mandates that 95% of Long Island’s demand for electricity must be met from on-island sources. NYISO contends that New York’s electric system will be stretched to and beyond its capacity with increasing demand in the near future, as a result of capacity constraints and transmission bottlenecks. This has created an imperative that additional capacity should be developed and energy efficiency (demand side management) improvements are made on Long Island to meets its future demand in power and electricity (NYISO, 2003). The remaining 5% and peak load are met by off-island sources. Neighboring systems from which LIPA has contractual agreements to purchase power include: New York Power Authority (50 MW), Nine Mile Point 2 (200 MW), Cross Sound Cable (330 MW), and Neptune Cable (660 MW). In terms of fuel use for generation, natural gas has gone from less than half of the dual fuel power plant market in the 1970s to approximately 80% in recent years. In fact, fuel oil consumption for power plants dropped over 90% in the last two decades. New York has become increasingly reliant on natural gas. Almost all new generation facilities proposed on Long Island, aside from some renewable (wind and solar) projects, are natural gas fired because of its energy efficiency and environmental qualities. In 2005, the total electricity sales on Long Island amounted to over 20 billion KWh. The residential sector was the largest end-user, consuming about 50% of this total. The commercial and industrial sectors combined accounted for the remaining 50% of the electricity sales, with a small amount used by public authorities (e.g., street lighting).

Supply side data:

All power plants and facilities that provide electricity to LIPA are included.

Model Inputs: EPA e-Grid 2006 v.2.1

EIA 906, 920, & 860 Reports

RESID: The name plate capacity of the plant.

INP(ENT)c: Energy carrier input: conversion technology. Plant's nominal heat rate (BTU/kWh)/3413 BTU. Plants with multiple fuel (commodity) inputs require multiple entries.

AF: Annual availability. Capacity factor of a plant varies year to year, but EIA sets an average of .80 for large scale power plants, as seen on Long Island.

IBOND(BD): Bound on investment in new capacity. This is set to 0 for all existing and committed plants/facilities, as the capital is in place or sunk.

BOUND(BD)O: Bound on activity: conversion/process technology. Total annual electricity output (MWh) * 3.6*10^9(J)

VarOM and FixOM: Variable and Fixed Operations and Maintenance Costs

Transmission efficiency set to 90%

Reserve Capacity: 18% as per NYS-ISO

There are various constraints that must be taken into account for supply side technologies, especially in regards to renewable sources. According to a LIPA/NYSERDA feasibility study conducted in 2002, there is significant potential for wind power on Long Island. It was determined that a 314 square-mile band from the south shore of Nassau County to a point east of Montauk Point could house 5,200 MW of wind driven generating capacity. Since such a project is considered to be highly improbable within the planning horizon of this study, a smaller 235 square-mile band was studied that could produce 2,250 MW. This study took into account the impact on the area in terms of fishing, bird migration, aesthetics, and other limitations. An optimal location off Long Island's South Shore was proposed for a 100-150MW wind farm.

A 2007 Pace Global Energy Services study estimated that a 150MW facility placed in this location would generate 438,292 MWh. This is based upon NYISO recognizing offshore capacity at 38% of its name plate capacity and onshore wind turbines at 20% of its nameplate rating. As pointed out by a 2006 National Grid report on wind power, reliable and sustainable power is of utmost concern to customers. We want electricity available when we need it. As with other renewables, wind is sporadic, and thus intermittency may become an issue. An overall constraint on wind power generation for Long Island will be set at 10%. There are a number of varying findings for reliability and wind power. Although some European countries produce 25% of their electricity from wind power, there needs to be backups and contingencies. A GE Power Systems report for NYS from 2004 and 2005 found that a 10% penetration would have no effect on reliability, given mandated reserves, in the event of rapid production drops from wind turbines. Several English studies have found that anywhere from 10%-20% penetration would not lead to intermittency or expensive backup plans. (UK Research Center, 2006; Dale, et al, 2004; House of Lords Science and Technology Committee, 2004) In abiding by the precautionary principle and erring on the side of caution, 10% will be a maximum wind constraint.

Demand side data:

Using available data from LIPA's annual budget and EIA data on demand and demand devices (demand technologies) in NYS, the demand side of LI-MARKAL was established. The demand side structure is divided into: a) Residential, b) Commercial c) Industrial, and d) Public authorities and street lighting.

Residential Demands:

Residential demand (DM) was determined to be 9,705,753 MWh as per LIPA's 2005 Operating Budget, and represents the largest segment of demand. This demand is used to satisfy any number of various end uses or demand devices (technologies), ranging from lights to appliances. Detailed data is lacking for end uses at local levels, and as such, NYS and North East US regional EIA data was used. Long Island's population growth was used as a driver for energy demand (DM) growth, while North East US EIA data was used to determine the breakdown for various demand devices (DMD). In order to determine residential energy demand growth Long Island's population for 2008 (2,863,849) was established from LIPA's Population Survey and Regional Planning Associations estimates of a nominal growth of +461,000 people by 2035, while baseline 2005 data was garnered from the US Census. The geometric annual growth rate was determined and applied to the years of the study.

Baseline and projected population:

Figures 9 and 10 present Long Island's estimated population growth from 2005's census data through 2055, based upon Regional Planning Association (RPA) data.

Figure 9: Long Island's 2005 US Census population, RPA 2035 estimate, and growth rate

Census Population	RPA Est. Population	
2005	2035	
2810000	3324849	
	Growth Rate	1.005623747

Figure 10: Long Island's population from 2005 (Census) estimated through 2055

2005	2010	2015	2020	2025
2810000	2889907	2972087	3056604	3143524

2030	2035	2040	2045	2050	2055
3232915	3324849	3419397	3516634	3616635	3719481

Industrial Demands:

Industrial and commercial demand is reported by LIPA as an aggregate, as little heavy industrial electricity demand is currently present on Long Island. According to Andrew McCabe of the LIPA FOIL (Freedom of Information) Department it is estimated that 862,433 MWh of this demand is used by manufacturing, the balance being "commercial". Classification of industrial (manufacturing) demand devices proves difficult as was reported in the NYS MARKAL (1994). Data for industrial purposes is not reported by end-use, and as such will be reported as "Misc. Industrial Electricity Demand".

Commercial Demands:

Commercial demand (DM) was determined to be 9,244,514 MWh as reported in LIPA's 2005 Operating Budget, and represents the second largest segment of demand. This demand is used to satisfy any number of various end uses or demand devices (technologies), in locations including: office buildings, stores, hotels, etc. There is little data available for end uses at local levels, and as such, NYS and North East US regional EIA data was used. New York State level data was used to determine commercial useful energy demands (DM), while North East US EIA data was used to determine the breakdown for various demand devices (DMD).

Public Authority and Street Lighting (PA/SL) Demands:

PA/SL demand (DM) was determined to be 437,368 MWh as per LIPA's 2005 Operating Budget, and represents a small segment of demand. This demand is used to satisfy any number of various end uses, the breakdown of which is not clear. Data for PA/SL purposes is not reported by end-use, and as such will be reported as "Misc. PA/SL Electricity Demand".

Energy Service Demands:

Energy service demands (Figure 11) are not the same as the end-use energy and they should not be compared with the end-use data. The energy service demands represent the need for which energy is required (i.e. a person demands light to illuminate their home at night, rather than electricity). They use a mix of units and the values cannot be added. The units include: terajoules (TJ) of final energy demand, terajoules (TJ) of useful energy, and tera lumen-seconds, etc.

Figure 11: 2005 Energy Service Demands

Energy Service Demand	Unit	2005
Commercial: Space Heating	TJ	6,655.3730
Commercial: Air Conditioning	TJ	11,392.3960
Commercial: Ventilation	TJ	481.9940
Commercial: Water Heating	TJ	1,371.7680
Commercial: All Lighting	Tera lumen-seconds	658,240.8580
Commercial: All Office Equipment	TJ	5,095.4850
Commercial: All appliances	TJ	4,150.6280
Industrial: All Demand	TJ	3,104.7588
Misc. Demand	TJ	5,585.8241
Residential: All - Space Heating	TJ	2,291.0330
Residential: All – Lighting	Tera lumen-seconds	161,412.4550
Residential: Air Conditioning	TJ	7,302.6200
Residential: All – Refrigeration	TJ	6,655.3730
Residential: Water Heating	TJ	25.6480
Residential: Electric Appliances	TJ	13,774.3020

Solid Waste Management

The Long Island Landfill Law of 1983 and the Solid Waste Management Act of 1988 guide the waste management activities on Long Island. In 2005, Long Island residents, institutions, commercial businesses and industries generated over 2.7 million metric tons of solid waste. About a quarter of these wastes went into various recycling processes. Over a million tons were used in the region's four waste-to-energy facilities (incinerators). The resulting ash was sent to the Island's landfills. With all these facilities operating at capacity, the remaining waste had to be trucked off of Long Island to states such as Virginia and Ohio (Tonjes, 2006). This practice of long haul trucking comes at an enormous cost of nearly $100 per ton. In the face of this price tag and other infrastructure bottlenecks, there exists an urgency to reduce the Island's waste production through new technologies, more aggressive recycling and reuse programs, and financial incentive/penalty programs (e.g., volume based fee). Further, the incineration of waste on-island provides a needed commodity in electricity. By merely shipping the waste off

Island you have the added vehicular emissions, land fill methane emissions, and issues related to environmental justice in regards to what area is accepting the waste.

Wastewater Treatment

In 2005, the total wastewater treated on Long Island is estimated at over 60 billion gallons. In Nassau County, two sewage treatment plants process 85% of the sewage collected within the County. These two plants each treat approximately 58 millions of gallons per day (mgd), operating below their respective permitted capacities of 70 and 72 mgd. Both plants have installed recovery/purification/storage facilities for the methane generated from sewage and used it to generate electricity for on-site application (Personal Communication, Nassau County sewage plants). Ten other small and independent treatment facilities process the remaining 15% of the sewage in the County. The County's Sewer and Storm Water Authority are responsible for the management and operations of most of these facilities. The structure of wastewater treatment system in Suffolk County is drastically different from that of Nassau County. Over 184 small treatment facilities process between 33-35 mgd of wastewater generated in the County (Personal Communication, Suffolk County). This represents a much smaller flow rate as only 24.7% of Suffolk County residents have sewer access. The biggest facility among them is the Bergen Point Plant. Rated at 33 mgd, this facility is one of the most efficient facilities of its kind after a recent upgrade.

VI. Base Scenario

Energy Use in Electricity Generation

The total energy use in electricity generation on Long Island, for the Baseline Case is projected to increase from about 160 million TJ in 2005 to 176 million TJ in 2050, i.e. at an annual growth rate of 0.22% during this period. In terms of fuel fix, natural gas used in high efficiency combined cycles is expected to grow at annual growth rate of 1.66% between 2005- 2050, replacing oil based generating plants with their fuel consumption decreasing at 1.76% per year during this period. Figure 12 depicts the projected energy use by type, for projected electricity generation between 2005 and 2050. The dip in total energy use in 2040 is due to the simultaneous decommissioning of less efficient oil based plants, replaced by advanced gas combine cycles. MSW used by incinerators, methane from wastewater treatment, and other renewable (solar and wind) are assumed to stay at the current level.

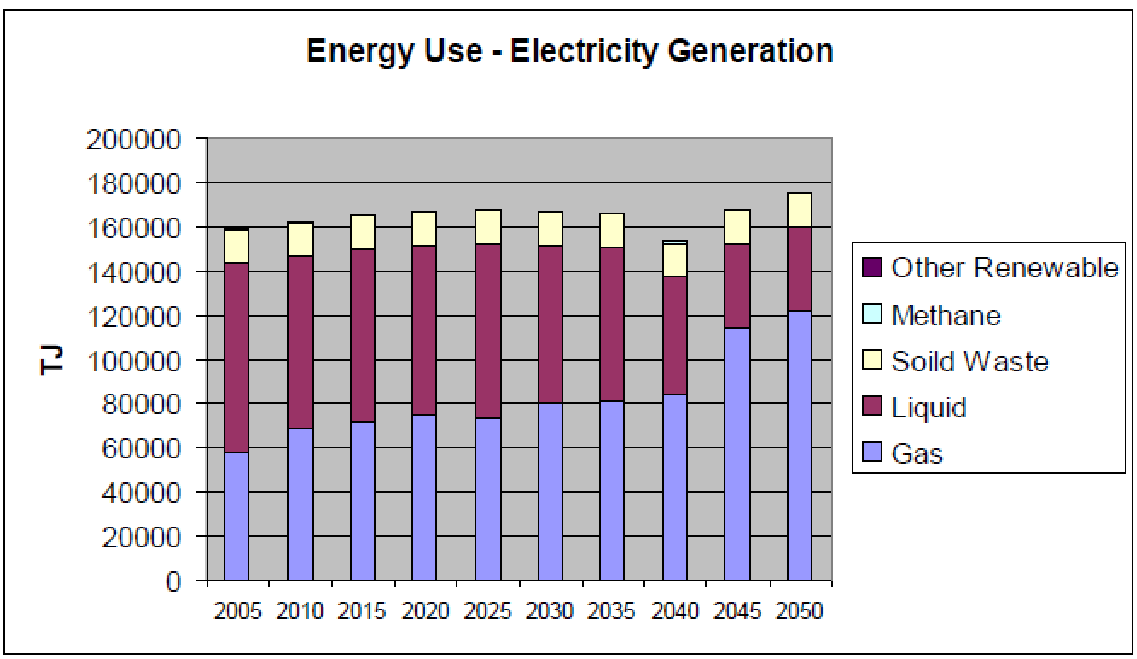


Figure 12: Projected Electricity Generation by Source

On/Off Island Electricity Supply:

The total electricity supply to Long Island is projected to increase from approximately 23 million KWh in 2005 to approximately 28 million KWh in 2050, at an annual projected growth rate of 0.43%. The Baseline Case assumes that this growth in supply is met by in-island generation, which is projected to grow from 15 million KWh in 2005 to about 19 million KWh (0.55% annual growth rate). The balance of the supply is met by imports from neighboring systems, which is presumed to remain at the current level of slightly below 9 million KWh. Figure 13 shows imports and on-Island generation of electricity.

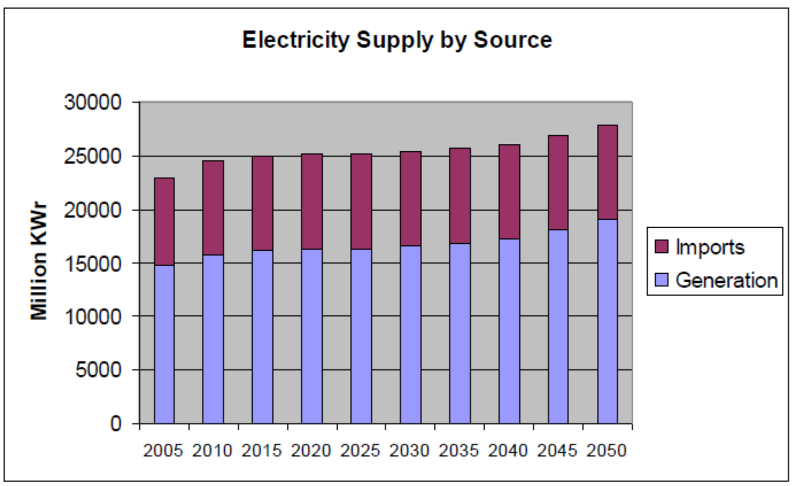


Figure 13: Imports and On-Island Generation of Electricity

Electricity Demand by Sector

The total electricity demand at end-use on Long Island, in the Baseline Case, is projected to increase from about 20 million KWh in 2005 to 27 million KWh in 2050, using a projected annual growth rate of 0.6% during this period. Figure 14 depicts the projected trend of electricity demand by end-use sector. Residential demand is currently the largest electricity consumer on Long Island. At over 9 million KWh, it accounted for 45% of the total electricity use in 2005. However, this demand is projected to stay at the present level in 2050 as improving efficiencies and on-going conservation programs are expected to offset the increase in future residential electricity service demands. The 15 commercial-sector demand is projected to grow at a relatively high rate of over 1% per year between 2005 and 2050 and account for over 50% of the total electricity demand by 2050. Although the industrial demand is projected to grow at annual rate of over 1.1% per year, its share of the 2050 total remains small (5%). Electricity demand in transportation, public authorities, and activities such as street lighting, accounts for the remaining demand in 2050 (8%).

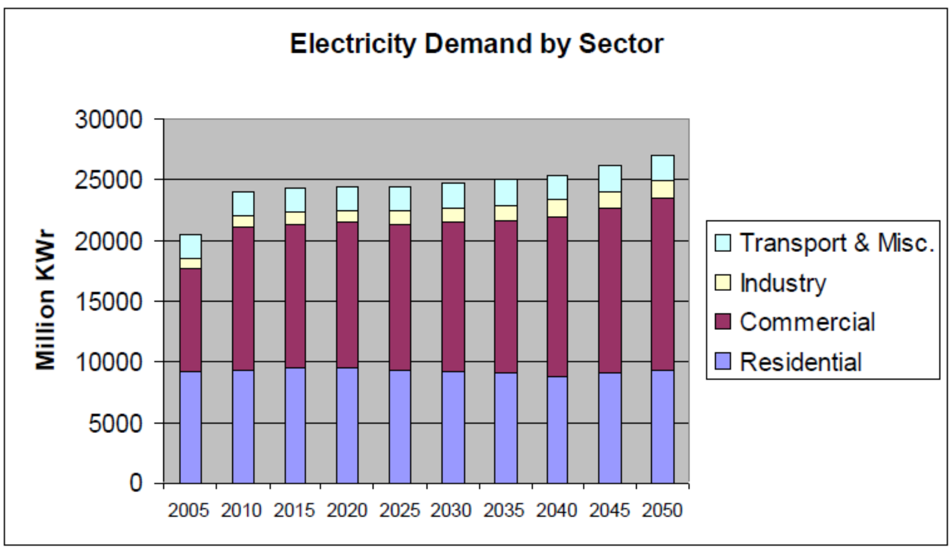


Figure 14: Electricity Demand by End-Use Sector

Potential of MSW as an Energy Source

Total MSW generated on Long Island is projected to grow from 2.7 million tons in 2005 to over 3.2 millions in 2050. This projection is made on the assumption that MSW will increase at the same rate as the Island's population. Less than about 27% of this total for recycling, the total energy imbedded in the available MSW is projected to be almost 25,000 TJ. This implies that by 2050, there will be 10,000 TJ in additional MSW energy over the current 15,000 TJ used in existing WTE facilities. Moreover, the cost of investing in new WTE facilities to use this potential will largely be offset by the avoidance of the enormous cost of long haul trucking of the MSW to out of state facilities.

Potential of Methane from Wastewater Treatment as an Energy Source

At present, a large part of the methane generated in the wastewater treatment plants on Long Island is collected, stored, and purified for use as a fuel for on-site electricity generation. The amount of electricity generated in this way has met about one-half of the energy needs in these plants with methane utilization capability. The uncollected methane generated in wastewater treatment is projected to reach 300 TJ by 2050. Although relatively small in quantity, this amount is significant in the reduction of energy use in the wastewater treatment processes, which are very energy intensive.

VII: CARBON TAX SENARIO: AN APPLICATION OF THE LONG ISLAND MARKAL MODEL[6]

INTRODUCTION:

The demand for energy is intertwined with many of our most pressing environmental threats. Among these threats, the risk of climate change is perhaps the one that looms largest. Other environmental issues associated with our energy systems have an impact at local or regional scales, including acidification and the dispersion of metals from mining and burning fossil fuels. (Johansson and Lundqvist, 1999) Although there are a number of sources of criteria air pollutants (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) 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 has been understood since Arrhenius in 1896. Approximately 29 billion tons of carbon dioxide is added to the atmosphere each year through human activity, of which 23 billion tons is the result of fossil fuel burning and industrial activity. (Jean-Baptiste and Ducroux, 2003) 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)

As our technology advances, our need for energy seems to expand at an even greater rate. This is caused by increases in everything from vehicles to electrical and

[6] This chapter has been published in a peer reviewed journal: Friedman, D., Klein, Y., and Sun, G. (2012) Environmental and economic impacts of a carbon tax: An application of the Long Island MARKAL model *Middle States Geographer* 45:18-26.

electronic appliances and tools. But simply building power plants and generators may not solve the problem of supplying electricity efficiently; it may actually cause more of a problem. (Teresko, 2001) Although there are numerous greenhouse gases (GHGs), carbon dioxide is generally focused upon because it is the major byproduct of fossil fuel combustion, from which the majority of our electricity generation is derived. The bulk of the other GHGs are related to the combustion of fossil fuels. (Gielen and Kram, 2000) Further, it has been noted that CO_2 emissions reductions simultaneously reduces other criteria pollutants (SO_2, NO_x, PM_{10}), as has been seen in Shanghai China. (Chen et. al., 2001) The impact on climate change of methane nitrous oxide, and fluorinated gases are comparable in magnitude to the impacts attributable to carbon dioxide. (Hansen and Sato, 2004; IPPC, 2007) Since the non-CO_2 emissions are falling below the IPCCs scenarios, the current focus of climate change policy is on emissions of carbon dioxide. (Hansen, et. al., 2008)

Global increases in carbon dioxide are being seen 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 type of increase may be responsible for the bleaching of coral reefs, cause a shutdown of the thermohaline circulation in the Atlantic Ocean, and lead to a rise of sea level. (Hoffert, 2002)

The United Nations, at the Earth Summit held in Rio in 1992, called for a worldwide stabilization of greenhouse gases as to avoid, "dangerous anthropogenic interference with the climate system." (UN Framework Convention on Climate Change, 1992) The most recent 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 CO_2 emissions will continue to contribute to warming for more than a millennium. With rapid climate change impacting Earth systems within a century or less (Hansen, et. al., 2007) there is growing realization that an Earth energy balance no longer exists and further warming lies down the road. (Hansen, et al, 2005) Many politicians, scientists and even industrial leaders have called for action. Rex Tillersin, CEO of Exxon Mobil has called on Congress to enact a "lucient" and efficient carbon tax. (Gold and Talley, 2009)

A wide range of proposals to impose mandatory caps on U.S. greenhouse gas emissions have been introduced in the U.S. Congress. (Paltselv 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 neighbors. Examples of these actions include the Regional Greenhouse Gas Initiative (RGGI) and Western Regional Climate Action Initiative (WRCAI). Pew Center (2009) provides a detailed inventory of state initiatives. Other initiatives have been implemented by local governments (see Linky, et al., 2008). It seems that climate change programs implemented at the regional, state and local levels will create pressure for action by the U.S. Congress and federal agencies. Jason Grumet, an energy expert and head of the Bipartisan Policy Center, recently stated that "setting a price on carbon in the power sector is the most significant opportunity we have to achieve domestic greenhouse gas reductions." (Leonhardt, 2010) 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. This developed-nation funded 10 billion-dollars-a-year, three-year program starting in 2010 will fund developing nations' projects to deal with drought, floods and other impacts of climate change, as well as develop clean energy. It also set a longer term "goal" of providing 100 billion dollars a year by 2020. The Accord also seeks to cap temperature rise to 2°C and reduce CO_2 emissions. In 2011, the EPA began regulating carbon emissions under the provisions of the Clean Air Act. On December 30, 2010, the U.S. Environmental Protection Agency (EPA) established an implementation strategy for the issuance of carbon permits. (EPA, 2010) Legislation to suspend EPA authority to regulate greenhouse gases has been introduced in the U.S. Senate (S. 231, 2011).

GREENHOUSE GAS MITIGATION POLICIES:

There are a number of environmental policies that can be enacted, and have been proposed to reduce pollution levels, including carbon dioxide emissions. Command and Control (CAC) instruments include emissions restrictions and design standards. Examples of CAC include catalytic converters on cars and scrubbers on power plants. Permit policies may be implemented whereby the right to pollute is established with permits that are either handed out to firms at a rate equal to some fraction of a previous year's emission level or sold by the government at auction. These permits can then be sold or traded at some market rate. (Fullerton, 2001) Examples of these trading systems include the U.S. SO2 trading program, which has been very successful and has had a significant impact on environmental quality and the E.U. European Trading System for CO_2 which has seen volatility in market price and limited emissions impact. (Anthoff and

Hahn, 2009) While many have proposed carbon taxes (Baranzini, 2000), others have called for “green” credits or subsidies. (Painuly, 2001; Schaeffer, et al, 1999) These policy instruments are Pigouvian solutions. (Pigou, 1932) Pigouvian solutions are taxes levied against activities with negative externalities, at a rate equal to the cost of these externalities. (Baumol, 1972) Unfortunately, subsidies such as those provided to farmers in the U.S. lead to a market which is no longer competitive and pays firms to “cut production, raise price, and make profits.” There are no true Pigouvian taxes on pollution in the U.S. There are environmental taxes on petroleum, chemical feed stocks, ozone depleting chemicals, and motor fuels, but these fund environmental programs such as Superfund and Leaky Underground Storage Tank fund, and are not meant to directly discourage pollution. (Fullerton, 2001)

A carbon tax on carbon dioxide emissions would be a powerful policy mechanism that could address market failures, such as hidden externality costs. (Wu, et al., 2006) Further, it would be easy to implement, 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) Taxes, by their nature, raise revenues. Becker and Mulligan (2003) show that governments who find more revenue tend to spend it rather than lower other taxes. It is possible, however, to create a revenue-neutral carbon tax by using the revenues it generates to offset other taxes. (Metcalf, 2009). Parry et al. (1999) found that a carbon tax, which “cut distorting labor tax rates”, was less costly than a carbon permit system. If the policy is carefully crafted, the revenue from a carbon tax can offset other taxes and improve economic efficiency. For all these reasons a carbon tax is the scenario chosen for the model.

The literature and established world-wide tax systems may be used to begin to understand their impacts. There are many different estimates of the social cost of carbon (net benefits and costs). Peer-reviewed estimates of these costs have an average value of $12 per ton of carbon dioxide with a large range around this mean. In a survey of 100 estimates, the values ran from $ 3 per ton of carbon dioxide up to $95 per ton of carbon dioxide. (Tol, 2005) According to the Carbon Tax Center (a nonprofit started by economist Charles Komanoff and attorney Dan Rosenblum), 88 estimates of the marginal costs of carbon dioxide from 22 published studies were analyzed. The modal cost of carbon dioxide was determined to be $5/tC, the mean $104/tC, and the 95 percentile $446/tC. When incorporating assumptions about aggregation and discounting, the marginal costs of carbon dioxide emissions is unlikely to exceed $50/tC, and is probably much smaller.

William Nordhaus, a Yale economist, in A Question of Balance: Weighing the Options on Global Warming Policies concludes that a carbon tax starting at $7.40/ton of CO_2 is optimal, so long as it increases by 2-3% a year after inflation until 2050, with even steeper increases after that. Metcalf (2007) has called for an optimal CO_2 tax rate of $16.60 with no annual adjustments. Shapiro, et al (2008) has called for an optimal rate of $15 per ton of carbon dioxide, with an increase of $2/ton each year. The Carbon Tax Center has proposed a $10/ton tax increasing $10/year for at least the next 10 years ($100 tax) and held constant, or more aggressively continued to increase for 20 years ($200 tax).

On January 1, 1991, Sweden enacted a carbon tax, $100 per ton, on the use of fossil fuels which is not 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 CO_2 released. (Brannlund, 1999; Brannlund and Gren, 1999; Ekins, 1996) This type of treatment may not sit well in this country, but provides another example of the burden and/or complexity of a carbon tax.

Numerous studies have been carried out in regards to the impacts of carbon taxes at the national level. Jeong, el 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% CO_2 reduction of 1990 emissions, in order to abide by Kyoto targets. This thesis determines the local impacts of two proposed carbon tax policies in an "isolated" region (Long Island, NY) with an aging electric utility infrastructure.

THE MARKAL MODEL: A TOOL FOR POLICY ANALYSIS

A commonly used optimization model for energy systems is MARKAL (MARket Allocation). This is a bottom up linear programming model that was conceived by the Energy Technology Systems Analysis Programme of the International Energy Agency. The model shows the supply and demand sides of the energy system. MARKAL has been used by over 50 countries and over 110 institutions. MARKAL is able to address the interactions and competition between many energy forms and technologies, from conventional such as oil and natural gas to renewable such as, wind and solar. Some uses of MARKAL include: to identify least-cost energy systems, to identify cost-effective responses to restrictions on emissions, to evaluate new technologies and priorities for R&D, to evaluate the effects of regulations, taxes, and subsidies, and to project inventories of greenhouse gas emissions. (http://www.etsap.org/Tools/MARKAL.htm)

There are several available extensions based on the standard MARKAL model: MARKAL-MACRO (macro-economic model), MARKAL-MICRO (micro-economic model), MARKAL with multiple regions (includes emissions permit trading), and MARKAL with materials flow (in addition to energy flows this includes recycling of materials. The MARKAL model is particularly useful to answer energy policy and planning questions. One such application is the least cost solution for meeting energy demands subject to limits to emissions such as CO_2 and/or other greenhouse gases. (http://www.etsap.org/Tools/MARKAL.htm) MARKAL has been widely applied to studies of the energy and environmental impacts of climate change. (Zhang, Z. and Folmer, H., 1998; Morales K.E.L.S.R., 2004; Rafaj, P., and Kypreos, S., 2007; Sukla, P. R.; Dhar, S.; Mahapatra, D., 2008)

THE LONG ISLAND MARKAL MODEL: METHODS AND RESULTS

A 2005 baseline Long Island MARKAL model was established in order to investigate the impacts of policy changes on Long Islands electricity generating future (see, Lee, J., Bhatt, V., and Friedman, D., 2009, for details of baseline). A basic reference energy system (RES) showing energy flows from supply to end use, can be found in

Figure 15. In 2005, the total installed generating capacity available to Long Island Power Authority (LIPA) was 4,983 MW to meet an average load requirement of 4,607 MW.

The New York Independent System Operator (NYISO) that oversees New York State's power transmission system and administers New York State's wholesale electricity market mandates that 95% of Long Island's demand for electricity must be met from on-island sources. NYISO contends that New York's electric system will be stretched to and beyond its capacity with increasing demand in the near future, as a result of capacity constraints and transmission bottlenecks. This has created an imperative that additional capacity should be developed and energy efficiency (demand side management) improvements are made on Long Island to meets its future demand in power and electricity (NYISO, 2003). The remaining 5% and peak load are met by off island sources. Neighboring systems from which LIPA has contractual agreements to purchase power include: New York Power Authority (50 MW), Nine Mile Point 2 (200 MW), Cross Sound Cable (330 MW), and Neptune Cable (660 MW). In terms of fuel use for generation, natural gas has gone from less than half of the dual fuel power plant market in the 1970s to around 80% in recent years. In fact, fuel oil consumption for power plants dropped over 90% in the last two decades. New York has become increasingly reliant on natural gas. Almost all new generation facilities proposed on Long Island, aside from some renewable (wind and solar) projects, are natural gas fired because of its efficiency and environmental qualities. In 2005, the total electricity sales on Long Island amounted to over 20 billion KWh. The residential sector was the largest end-user, consuming about 50% of this total. The commercial and industrial sectors combined accounted for the remaining 50% of the electricity sales, with a small amount used by public authorities (e.g., street lighting).

Using the baseline LI MARKAL, two possible carbon tax scenarios were established. The first was a \$10 per ton CO_2 flat tax that initiates in 2010. The second was a tax that begins at \$10 per ton in 2010, increasing \$10/year for at least the next 10 years (\$100 tax) and held constant beyond that point. Though there is much discussion in the literature regarding types of taxes which should be enacted, there is little discussion in regards to how local/regional areas are impacted by these Federal decisions.

The impacts of carbon taxes are generally discussed at national levels, as they would be implemented at that scale. Clearly there is a need to understand the impacts at the local level. Figures 16 and 17 provide an indexed cost for years 2005 (base year) through 2050, and a summation of those years indexed costs. Figures 18 and 19 provide the indexed total CO_2 emissions for 2005 (base year) through 2050, and a summation of those years indexed emissions. These values are indexed to the 2005 base year considering the results of modeling analysis; it is most useful to focus on the difference between scenarios than on the absolute numbers of a single scenario. It is the differences that form a basis for analyzing policy changes and not absolute numbers.

Figure 15: Simplified Long Island Reference Energy System

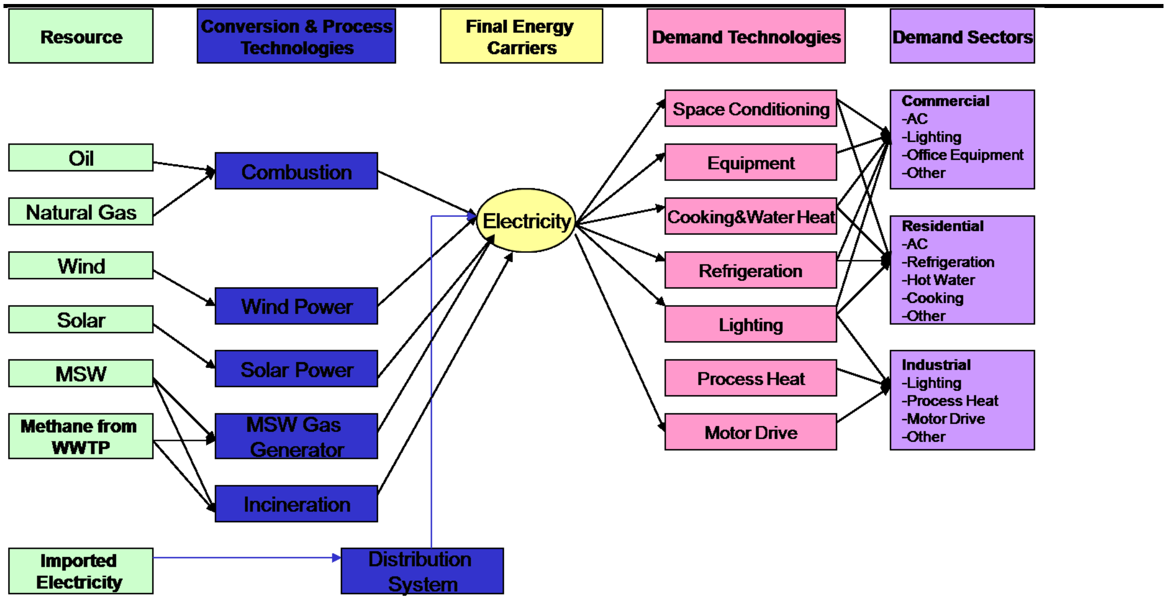


Figure 16: Indexed Total Undiscounted System Cost

	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	Sum
Base	100.00	240.18	105.77	105.51	231.45	113.93	128.76	241.39	150.25	119.85	1537.09
Flat Tax	100.00	240.14	105.73	105.48	231.43	112.93	124.28	237.96	130.61	101.17	1489.73
Incremental Tax	100.00	240.14	105.73	105.48	231.43	113.64	128.93	241.30	150.24	119.85	1536.74

Figure 17: Indexed Total Undiscounted System Cost

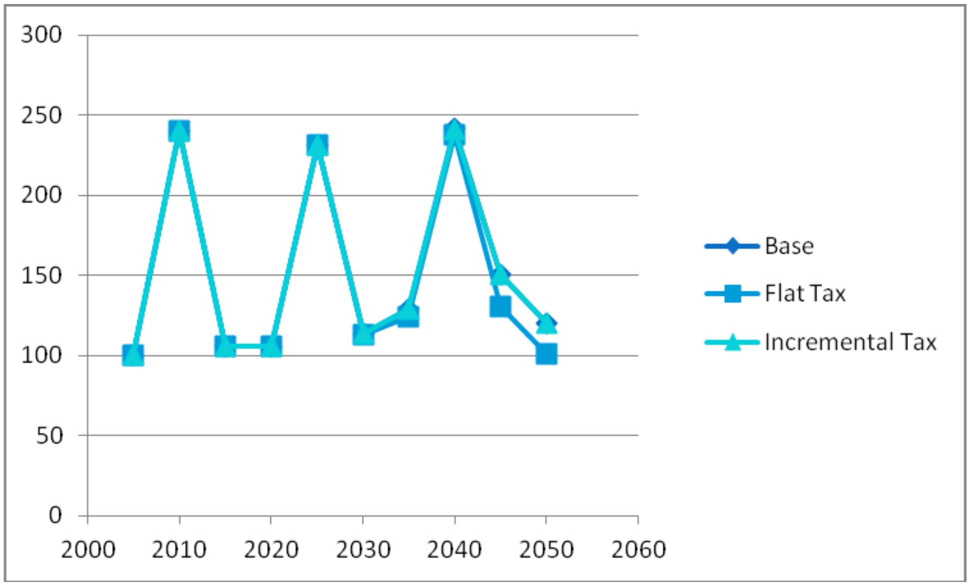
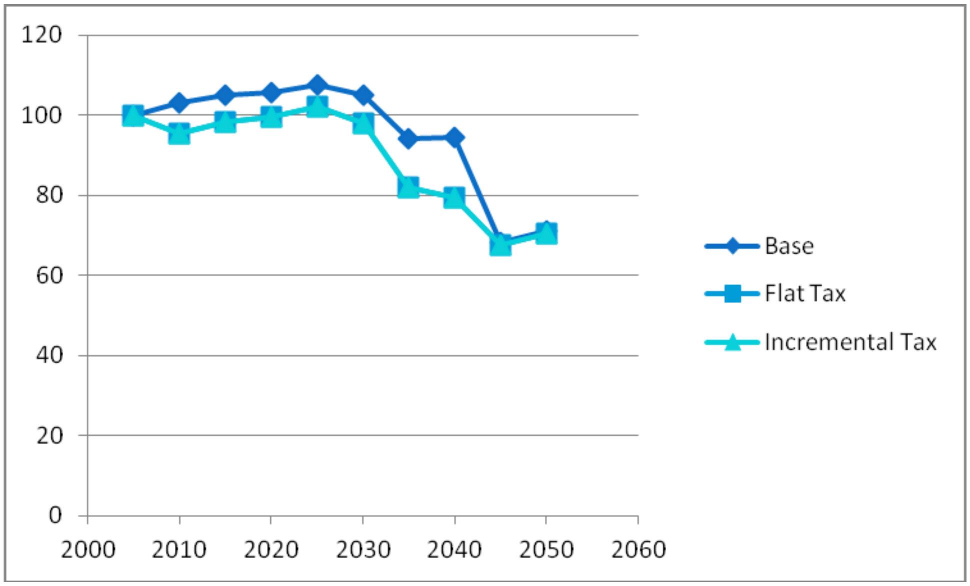


Figure 18: Indexed Total CO_2 Emissions

	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	Sum
Base	100.00	102.93	104.88	105.61	107.55	105.11	94.17	94.53	68.15	71.15	954.08
Flat Tax	100.00	95.57	98.38	99.71	102.15	97.93	81.99	79.37	67.57	70.57	893.24
Incremental Tax	100.00	95.57	98.38	99.71	102.15	97.93	81.99	79.37	67.57	70.57	893.24

Figure 19: Indexed Total CO_2 Emissions



Conclusions

The values of cost and CO_2 emissions are presented as indexes, as this allows for simpler and clearer comparisons. The baseline scenario represents a "business as usual" path. As noted by the difference between the flat tax and baseline values, a flat $10 tax yields a 3.1% lower cumulative cost and 6.4% cumulative drop in CO_2 emissions. In contrast, the incremental tax maintains a nearly identical cost and the same 6.4% cumulative drop in CO_2 emissions. Since Long Island has many older electricity generating facilities, during the short term planning period there is the immediate drop off of CO_2 emissions, as older facilities are quickly phased out. Increasing the tax during the medium range and long term planning horizon does not initiate further CO_2 reduction, it only increases total system costs. The reduction of emissions was carried out by reducing distillate fuel oil dependence and increased usage of efficient natural gas combined cycle facilities.

Another result from this work was the maintained dependence on waste to energy facilities. This is important and possibly somewhat unique to Long Island, as land filling has been banned on Island and waste must be incinerated or carted off Island at a large cost. This analysis clearly shows that a major issue for climate change action by way of a carbon tax is not necessarily how high the tax is, but when and where the tax is implemented. In an area like Long Island, with older facilities, short term regulations or policies will have a long standing effect. One of the major limitations of this study is that we have information on only a limited range of future power plant designs. We would expect that the introduction of a carbon tax on power plant emissions will drive the technology for carbon reduction (or sequestration), which might potentially amplify the environmental and economic effects of such policies.

VIII: SUSTAINABILITY PLANNING and ENVIRONMENTAL JUSTICE: An APPLICATION OF LONG ISLAND MARKAL[7]

INTRODUCTION

The aphorism "think globally, act locally," attributed to René Dubos, reflects the vision that the solution to global environmental problems must begin with efforts within our communities. We are called upon to consider the global impact of environmental issues such as acid rain, climate change, deforestation and ozone depletion while participating in grassroots actions in our own communities that can have a cumulative impact at a global scale. We can understand the injunction to embed environmental awareness within our daily lives in the context of the urgent goal of economic, environmental and social "sustainability." First used in this context by the United Nations Brundtland Commission (1987), sustainability is defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." 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, such as forests and fisheries, not exceed regeneration rates; our use of non-renewable resources, such as fossil fuels and minerals, should not outpace the rate at which we can develop renewable substitutes; our discharge of pollutants into the biosphere should not exceed the rate at which the environment can safely absorb and decompose them.

The past twenty years since the Brundtland Report have 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 towns, and cities. One active area of

[7] This chapter has been published in a peer reviewed journal: Friedman, D. and Klein, Y. (2010) Urban/Suburban Sustainability Planning: MARKAL as an Analytical Tool. *Middle States Geographer* 43: 1-7. 2010.

research has explored the numerous sustainability initiatives undertaken by U.S. cities (Portney, 2003; 2005). One such example emerged in Levittown, New York, America's first suburb. In cooperation with Nassau County, the Citizens Campaign for the Environment and private corporate partners *Green Levittown* had been established. This initiative strived to improve the environment by improving energy generation efficiency and creating a more sustainable future. This initiative was ultimately unsuccessful, perhaps due to the failure to establish clear, measurable goals. Another example is PlaNYC 2030, a New York City initiative aimed at creating a sustainable New York City. This initiative, which incorporates a set of clear metrics, is ongoing, and has achieved the cooperation of a number of local stakeholders, among them the major universities within New York City. Common to these initiatives are the goals of economic, ecological, and social sustainability.

Many of these plans set forth seemingly arbitrary goals without setting forth a clear standard for determining the "best" choices from among available options. In the words of Parris (2003), sustainability has "broad appeal and little specificity." 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 quantifiable sustainability goals and to identify policies and technologies that will enable us to reach these ends.

In this study we examine the potential use of an urban MARKAL model (MARKet ALlocation model) as a tool to quantify sustainability standards and foster rational, cost-based decision making. The objective of this exercise is to develop and make more sustainable our energy system, a major component of any sustainability plan. At the same time we will consider the implications of energy choices on environmental justice.

Beyond energy planning, the MARKAL model can accommodate waste water treatment and solid waste disposal, two key components of the energy nexus. (This has been done with the

Long Island MARKAL, an EPA funded project, carried out as a joint effort by Brookhaven National Laboratory, City University of New York, and Stony Brook University.) It is anticipated that these analytical tools will be of use to policymakers and other stakeholders in determining how to best plan for the future.

MARKAL AS AN ANALYTICAL TOOL TO IMPROVE SUSTAINABILITY

MARKAL is a dynamic and highly flexible, bottom up model which would be beneficial to policy makers investigating the possible impacts of various sustainability plans. Often noted in sustainability plans, such as PlaNYC 2030, are minimum renewable portfolios, emissions caps and taxes, and demand side management ranging from peak shaving to efficiency standards (e.g., Energy Star). MARKAL provides a framework for analyzing the impacts to these types of policy changes over various planning horizons.

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 our best projection of energy use and emissions over the planning horizon. The backbone of this model is captured by the MARKAL Reference Energy System (Figure 1). The Reference Energy System requires input data (actual and projected) from primary energy supply (e.g., diesel fuel imports), intermediate conversion and process (e.g., electricity generation), to end-use technologies (e.g., computer) that satisfy energy service demands (e.g., office equipment). Every component in the RES (Reference Energy System) is characterized by three groups of data: technical (e.g., efficiency), economic (e.g., capital cost), and environmental (e.g., carbon emission coefficient).

Long Island specific and regional historical energy demand-supply data were used to establish the base year (2005) RES in the Long Island MARKAL model. This model represents a "proof of concept" that MARKAL can be used to jointly model waste water, municipal solid waste and energy systems. These linkages provide policy makers with an invaluable tool for addressing a broad range of energy and environmental policies. The base year RES provides a balanced stance (partial equilibrium) based on which future energy-environmental-economic scenarios can be formulated. If no Long Island specific data were available (characteristics of a specific technology, existing or future), they were taken from many existing MARKAL databases in the world community as a starting point.

The baseline case (2005-2050) is driven by the projected energy service demand (DM) in the Model. The projections of these energy service demands utilize the econometric equations estimated in New York City MARKAL. This involves the incorporation of the latest or updated projection values (2010-2050) of the explanatory variables (drivers) into the energy end use projection equations. Although the Baseline Case projects a “business as usual” energy system path by incorporating existing and planned measures and development programs into the model, it should not be taken as the prevailing energy market for the future in the absence of additional mitigation policies and measures. Rather, it only provides a reference basis to evaluate impacts of additional alternative scenarios representing recommended policies and measures. Figures 18, 19, and 20 display the output of the base case scenario run on the Long Island MARKAL, in regards to energy use in electricity generation, electricity supply by source, and electricity demand by sector, respectively.

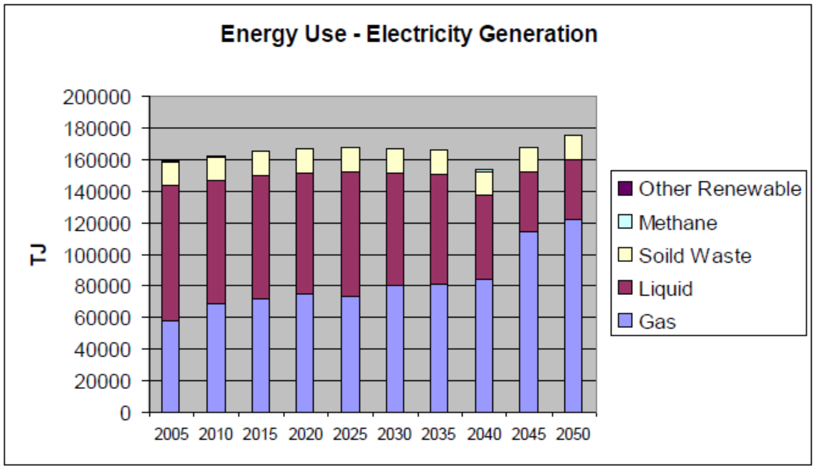


Figure 20. Energy use by electricity generation from LI MARKAL.

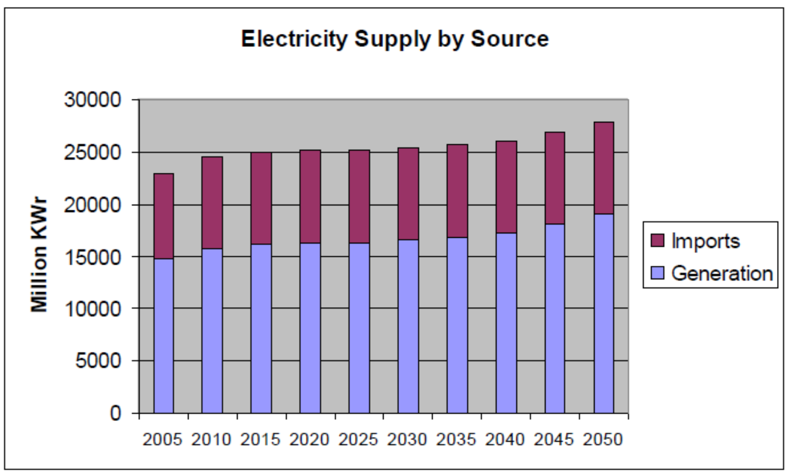


Figure 21. Electricity supply by source from LI MARKAL

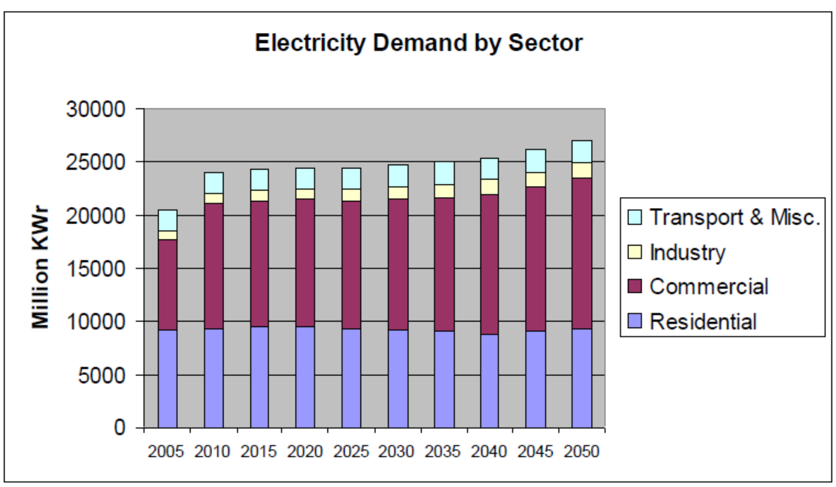


Figure 22. Electricity demand by sector from LI MARKAL

Once the base case has been established, scenarios called for in sustainability plans can be run and analyzed. Possible scenarios include:

- Carbon Tax or Cap and Trade policies: Both taxes and caps on carbon dioxide emissions have been proposed as a method for combating possible human induced global warming. 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). MARKAL allows for both caps and taxes to be incorporated into the model. This specific scenario has been run on the Long Island MARKAL model. Results of this scenario can be used beyond carbon emissions and cost. The environmental justice section of this paper explains how these results have been used to examine equity issues on Long Island.
- Minimum Renewables 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. Currently there are 24 states, in

addition to the District of Columbia, that have enacted RPS policies. These states account for half of US electricity sales. (http://apps1.eere.energy.gov/states/maps/renewable_portfolio_states.cfm)

MARKAL allows for 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.

- 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).

An example of an Urban Sustainability Plan that could be modeled using MARKAL is PlaNYC 2030. PlaNYC has six major areas of focus in regards to sustainability: land, water, transportation, energy, air, and climate change. Although each of these areas is interconnected, the key is energy. Energy is the driving force of transportation, has a major impact on our land, water, and air, and plays a role in climate change. Many of the 14 initiatives in PlaNYC's energy initiatives can be modeled in MARKAL to help policy makers establish and meet their goals, for example:

- Initiative 2: "Reduce energy consumption by City government - We will commit 10% of the City's annual energy bill to fund energy-saving investments in City operations." The PlaNYC 2030 report states that LED stoplights are one investment that will lead to energy-savings. There are countless end uses that can be incorporated into MARKAL's bottom up structure. By running scenarios with varying market penetrations a greater savings could be achieved, at a lower cost.
- Initiative 3**:** **"**Strengthen energy and building codes for New York City." This initiative calls for the establishment of regular building code reviews on a three year cycle. Scenarios could be run on the incorporation of something as small as mandating CFLs, or establishing rules for new construction related to LEED or Energy Star standards.
- Initiative 8: "Facilitate repowering and construct power plants and dedicated transmission lines." This calls for one of three scenarios:

repowering existing power plants, building new power plants, and/or building new facilities outside of NYC. All three of these options, with varying technologies and facility sizes can be placed into the MARKAL model.

- Initiative 9: "Expand Clean Distributed Generation (Clean DG)." Much like in initiative 8, MARKAL allows for varying technologies to be pitted against one another, with the optimal solution being chosen.
- Initiative 11: "Foster the Market for renewable energy." Within MARKAL, a minimum renewable scenario can be run. As NYS is mandating 25% of its electricity be derived from renewables, by 2013, a local NYC minimum renewable scenario can be run. Further, should the City establish projects for various sized renewable, such as solar, once incorporated into the model, the impacts on the rest of the sector can be determined.

Another area of concern is waste-to-energy and wastewater treatment. MARKAL has recently been shown to be able to model wastewater treatment, municipal solid waste, and energy in the Long Island MARKAL (Lee et al., 2009). This could be carried out in NYC as well.

ENVIRONMENTAL JUSTICE

Oran Young stated that environmental equity is "a matter of taking steps to ensure that the rich and powerful do not insulate themselves from environmental harm largely by displacing problems on to the poor and weak." The Environmental Justice Movement is generally agreed to have been developed in the US during the 1970s primarily as a result of racially motivated siting of environmental risks, waste management being the major issue (Harvey, 1996; Dobson, 1998; Agyeman, 2002). The United Church of Christs Commission for Racial Justice report in 1987 is seen as a seminal paper that pushed environmental justice to the mainstream, 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 were established, it is important that no one group feels the unfair brunt of their effects.

Environmental justice is “more than just 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).

By establishing sustainability plans and analyzing the results with MARKAL, one can determine the impacts on environmental justice in a given area. For example, if peak demand is lowered, more heavily polluting peaking plants may not have to operate. By comparing various transportation technologies (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 combine environmental justice with sustainability (Warner, 2002). MARKAL provides an opportunity to analytically do this. An example of this is seen in a carbon tax scenario run on the Long Island MARKAL. The results of a $10 flat tax on carbon emissions is a 3.1% lower cumulative cost and 6.4% cumulative drop in CO_2 emissions. The first plants to be dropped by the model are older, more heavily polluting technologies. This allows for even a relatively small tax to have the same effect as a larger tax, as seen in the previous chapter.

The impacts on environmental justice 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 and which has been grandfathered to not meet Clean Air Act standards, as it was built in the 1960s and 70s. When the baseline model is run, 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.

CONCLUSIONS

Sustainability and sustainability plans are generally nonspecific and lack clear analytical data and often ignore or fail to provide clear data in regards to environmental justice. MARKAL provides a possible solution to these problems. By using MARKAL policy makers, utilities, and other interest groups can determine the impacts of a variety of proposed policies suggested or proposed by sustainability plans, or help provide ideas that should be incorporated into such plans. The Long Island MARKAL has been used to test the impacts of a specific policy change, a carbon tax, on the electricity generating system of the local area. By studying the impacts on operating generation technologies, it has been used to determine the impacts on environmental justice in regards to electricity generating facility locations. This paper provides ideas for using MARKAL to test, develop, and improve sustainability plans at varying special scales.

IX. CONCLUSIONS AND FUTURE WORK

Based on the results of the Long Island MARKAL model, it is clear that natural gas plays an important part in Long Island's short, mid, and long range planning. The incorporation of municipal solid waste and waste water treatment technologies in the MARKAL model demonstrates the potential of non-conventional energy sources to displace fossil fuels in the electric generation sector, and do satisfy on-site electricity demand at waste-water treatment plants. These findings point toward a number of further applications of the Long Island MARKAL model, as classified in Figure 23.

Figure 23: Applications of Long Island MARKAL
(Source: Lee, J., Bhatt, V., and Friedman, D., 2009)

Economic Sector/Activities	Policy and Measures	Government/Public Programs
Residential/Commercial Buildings	Energy Star Portfolio Manger and Water Sense Improved Energy End-use Efficiency	Energy Star; Water Sense DOE Re-Building America; Commercial Building Initiative
Passenger Transportation	Improved Energy End-use Efficiency; Alternative Fuels	EPA and DOT Smart Way RPA America 2050 DOE Clean Cities
Energy Resource/MSW	Enhanced Methane Recovery & Use	Landfill Methane Outreach Program
Power Generation	Expanded Use of Renewable and Integrated power systems + micro and mini grids	EPA Green Power Partnership and Combined Heat and Power Partnership
Water Supply	Improved Water Efficiency in Appliances	EPA Water Sense
Wastewater Management	Improved Process Efficiency, Enhanced Recovery in Methane & Sludge Energy	Waste Water-to-energy Applications
Bio-fuels	Solid-waste-methane to CNG, Waste Edible oil to Biofuels	Alternative Fuels Standard
Hydrogen	Hydrogen Economy	Replace Imported Oil – Increase Energy Security
Peak-load Management	Distributed Generation and Demand-side Management	NYSERDA or Local Initiatives
Urban Energy and Sustainability Planning	Reduce Energy use, GHGs, etc.	Sustainability Plans (e.g. PlaNYC 2030 or GreenWorks Philadelphia)
Green Jobs	Deployment of Energy Efficiency and Renewable Technologies in Cities	Stimulus Plan (ARRA) and related activities
Economic Development	Increase local production of energy efficient and renewable technologies	Local Economic Development Strategies and International Collaboration
GHG Mitigation	Cap & Trade	Regional Greenhouse Gas Initiative (RGGI)+ SIP+REC

As noted in this dissertation, sustainability and sustainability plans are generally non-specific data needed for analysis, and often ignore or fail to provide clear results in regards to environmental justice. Specific ways for using MARKAL to test, develop, and improve sustainability plans at varying special scales have been provided. This allows us to determine the environmental equity of a region, and to explore the impact of various changes to the current system.

An example of this is demonstrated in a carbon tax scenario run on the Long Island MARKAL. A $10 flat tax on carbon emissions results in a 3.1% lower cumulative cost and 6.4% cumulative drop in CO_2 emissions. The first plants to be dropped by the model are older, more heavily polluting technologies. Exploring the short, mid, and long term effects could prove to be interesting and valuable to policy makers and special interest groups (i.e. environmental justice and sustainability groups).

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