

**PREPARING FOR CLIMATE CHANGE IN THE  
METROPOLITAN EAST COAST REGION:  
THE POTENTIAL CONSEQUENCES OF  
CLIMATE VARIABILITY AND CHANGE**

**ENERGY SECTOR**

**INTRODUCTION**

Climate change will affect the need for energy in the Metropolitan East Coast Region. The questions addressed here are:

1. What are the potential *impacts* of climate change on the energy system?
2. What *adaptation* strategies may be effective as potential responses?

This chapter presents information on current trends in energy supply and demand, particularly electricity, and projections of electric peak demand. The potential impacts of climate change on electricity demand are examined, primarily as those have been characterized in forecasting models. Measures by which the energy system can adapt to climate change are described. Finally, the interaction of energy adaptation measures and the effect of summer heat waves on public health are examined.

In keeping with the mandate of the *U.S National Assessment of the Potential Consequences of Climate Variability and Change*, this chapter is not primarily aimed at mitigation, i.e., reduction of greenhouse gas emissions. However, some of the principal measures needed to adapt to climate warming – namely, greater energy efficiency and energy conservation – are the preeminent means of reducing these emissions.

The largest part of energy consumed in the Metropolitan East Coast Region is divided about equally between transportation, on the one hand, and on the other, residential, commercial and public use. Only a small fraction is for industrial use. In this assessment, we concentrate on the built environment, and focus on residential and commercial buildings. The main concern therefore is electricity.

The *impacts* of climate change on the region's built environment are likely to be: (a) reduced demand for winter heating, and (b) increased demand for summer cooling, especially for electricity.

An assessment of the future of the energy sector in the Metropolitan East Coast Region confronts two major uncertainties: uncertainty in the extent of future climate change, and uncertainty in future energy prices because of steps that may be taken to reduce the use of fossil fuel. These uncertainties are compounded by the present fluid nature of the energy industry itself. Following the deregulation of the natural gas industry, the electric power industry is now being deregulated. State by state, companies that formerly had a regulated monopoly in their service areas are now becoming subject to competition from other electricity suppliers. This is encouraging decentralized electric generators operated

by independent power producers, and a convergence of the electric and gas industries. In the energy sector, climate is not the only thing that is changing.

## BACKGROUND

The pattern of electricity use is quite consistent among the three states in which the Metropolitan East Coast Region is located. About three-quarters of electrical energy is consumed in the residential and commercial sectors, with the larger share in the latter. (Table 1).

**Table 1. Electric utility retail sales by state and sector (millions of megawatt-hours), 1998. (Source: K. Wade, U.S. Energy Information Administration, State Electricity Profiles, personal communication, 13 March 2000.)**

	<b>New York</b>	<b>New Jersey</b>	<b>Connecticut</b>	<b>Total</b>	<b>Percentage</b>
Commercial	53.2	31.1	11.7	96.0	42%
Residential	40.2	23.2	10.9	74.3	33%
Industrial	25.1	13.3	5.8	44.2	19%
Other	12.7	0.5	0.5	13.7	6%
<b>Total</b>	<b>131.2</b>	<b>68.2</b>	<b>29.0</b>	<b>228.2</b>	<b>100%</b>

Fossil fuel is supplied to the Metropolitan East Coast Region in the form of petroleum arriving by sea and pipelines, natural gas arriving by pipelines, and coal arriving by train. In addition, a substantial portion of the electricity generated for the region is based on nuclear power. The metropolitan region has virtually no indigenous fossil fuel resources. Locally, there is a small amount of renewable energy supplied by landfill gas, and negligible amounts of solar and wind power.

Northern New Jersey is the site of six petroleum refining plants which receive crude oil from overseas and distribute refined products to the northeastern states. Oil products also arrive from the Gulf Coast and southwestern U.S by two pipelines. In addition, there are several oil depots along the East River and at ports on Long Island Sound, which receive refined products for local distribution. Oil-fired electric generating plants along waterways in New York receive light distillate and residual oil shipped by barge. Residual oil originates at both domestic and overseas refineries.

Natural gas arrives in pipelines from the Gulf Coast, the southwestern U.S., and western Canada. Because of its competitive price and preferable environmental characteristics, there is a growing appetite for natural gas, which is limited by the capacity of existing pipelines. Under federal legislation, states may provide consumers with the opportunity to buy natural gas from sources other than the local distribution company, a process called “unbundling.” New York and New Jersey now provide this option, but Connecticut as yet does not.

Electricity supply in the Metropolitan East Coast region is controlled by three different power networks. The fourteen counties in the New York portion are served by utilities

supported by the New York Independent System Operator (NYISO – formerly the New York Power Pool), which has a summer peak capacity of 34,650 megawatts. The fourteen counties in New Jersey are served by utilities that are part of the PJM Interconnection, L.L.C. with a peak capacity of 56,000 megawatts. The three counties in Connecticut are served by utilities that are part of ISO New England (formerly New England Power Pool).

For the three states that the region overlaps, the energy sources used for electricity generation are shown in Table 2. The largest share of utility generation is from nuclear power. However, a significant amount of power now comes from nonutility sources; these are independent power producers other than the traditional franchised utilities. As most nonutility power is gas-fired, the major fuel used to generate electricity in the three states is natural gas.

**Table 2. Electricity generation by state and primary energy source (billions of kilowatt-hours), 1998. (Source: K. Wade, U.S. Energy Information Administration, State Electricity Profiles, personal communication, 13 March 2000.)**

	<b>New York</b>	<b>New Jersey</b>	<b>Connecticut</b>	<b>Total</b>	<b>Percentage</b>
Nuclear	31.3	27.0	3.2	61.5	28%
Coal	23.5	5.6	1.5	30.6	14%
Hydro	26.6	-0.1	0.4	26.9	12%
Gas	19.9	2.9	1.0	23.8	11%
Oil	14.5	0.5	8.6	23.6	11%
Other	-	-	0.4	0.4	-
<b>Total Utility</b>	<b>115.8</b>	<b>35.9</b>	<b>15.1</b>	<b>166.8</b>	<b>77%</b>
Nonutility	28.7	17.7	4.5	50.9	23%
<b>Total industry</b>	<b>144.5</b>	<b>53.6</b>	<b>19.6</b>	<b>217.7</b>	<b>100%</b>

**Note: “Nonutility” consists of independent power producers sources other than the traditional franchised utilities.**

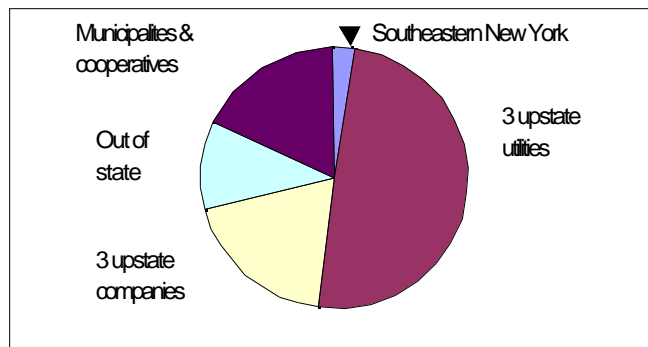
The dominant fossil fuel for electric generation has changed from oil to natural gas in the past decade, but there are short-term switches between the two (as in 1998) as the relative prices fluctuate; many power plants can burn either. About two-thirds of the natural gas is consumed by independent power producers who produce one-quarter of the power generated in the state (New York State Energy Research and Development Authority, 1999). Since 1990, there has been rapid growth in the share generated by independent power producers.

*New York electricity:* Electricity in the New York metropolitan region is now supplied by three franchised utilities – Consolidated Edison, Orange & Rockland Utilities, and Long Island Power Authority – as well as by the New York Power Authority. In this region, the New York Power Authority provides electricity primarily for the Metropolitan Transportation Authority, New York City public buildings, New York City Housing Authority, Port Authority of New York and New Jersey, New York State Office of General Services, Westchester County, and the governments of various towns and villages. In 1999, Con Edison merged with Orange & Rockland Utilities. The Long Island Power Authority (LIPA) is a recently established New York State entity that owns

the distribution system of the former Long Island Lighting Company (LILCO). For the next five to ten years, it is committed to purchase most of its electricity from the former LILCO generating plants on Long Island now owned by KeySpan Energy. KeySpan was formed by the consolidation of the Brooklyn Union Gas Company and LILCO.

About one-fifth of the state’s electric power is generated by nuclear reactors at four sites: James A. Fitzpatrick, Ginna, Nine Mile Point 1 and 2, and, in the Metropolitan East Coast Region, Indian Point 1 and 2.

New York Power Authority has major hydroelectric plants on the Niagara and St. Lawrence Rivers. This renewable energy constitutes almost one-quarter of the state’s utility-generated power. However, only about 3 percent of this inexpensive public power reaches the metropolitan region (Figure 1).



**Figure 1. Distribution of New York Power Authority hydroelectricity. (Source: NYPA Annual Report, 1994.)**

The supply of electric power to New York City and Long Island is severely constrained by the capacity of transmission lines into the region. Transmission lines from other places represent only about one-quarter of the region’s capacity to deliver electricity, which limits the ability to import power at times of peak demand. Long Island is more isolated from the national grid than any other part of the country (Perez-Pena, 1999).

Long Island Power Authority is evaluating the economics of installing an additional major transmission line across Long Island Sound to connect it more strongly with the New England grid. Con Edison is limited in its transmission ties with upstate New York by the width of its right-of-way through Westchester County, although conceivably new technology such as superconducting cable could increase the capacity of this corridor.

Con Edison has two 345 kilovolt (kv) transmission lines across the Hudson River, from Brooklyn to Hudson County, New Jersey, and one 345 kv line across The Narrows by way of Staten Island to Linden, New Jersey (Northeast Power Coordinating Council, 1989). These provide a link with the PJM Interconnection, a system with 60 percent more generating capacity than New York’s. The NYISO requires that 80 percent of the power supplied to New York City be generated locally, and Con Edison is not considering building new transmission lines to import more power from outside the region.

For the first time since the late 1980s, however, a substantial number of companies are presently seeking to build new power plants in New York including five in New York City (Perez-Pena, 1999). A 1,080 megawatt (mw) plant in Athens, New York, has just been approved for construction by the state (Perez-Pena, 2000). Another fifteen, amounting to 9,567 mw of power, are in process. Of these, eleven are in the Metropolitan East Coast Region, and almost all are expected to be in service in 2002-03 (Table 3). For perspective, the total capacity of these eleven plants is 6,977 mw, equivalent to about 85 percent of Con Edison's total generating capacity as of January 1999.

**Table 3. Applications for electric power plants in the New York portion of the Metropolitan East Coast Region, May 2000. (Source: New York State Public Service Commission, 2000)**

Project	Power (megawatts)	Developer	Location	Estimated In-Service Date
Bowline Unit 3	750	Southern Company	Haverstraw, Rockland	2002
Ramapo Energy Project	1100	Ramapo Energy, LP	Ramapo, Rockland	2002-03
Torne Valley Station	827	Sithe Torne Valley, LLC	Ramapo, Rockland	2002-03
Astoria Energy, LLC	1000	SCS Energy	Astoria, Queens	2003
East River Repowering	360	Con Edison	Lower Manhattan	2002
Grassy Point	550	Haverstraw Bay, LLC	Haverstraw, Rockland	2003
Poletti Station Expansion	500	New York Power Authority	Astoria, Queens	2002
Ravenswood Cogeneration Project	250	KeySpan Energy	Long Island City, Queens	2002
Sunset Energy Fleet, LLC	520	SEF	Brooklyn	2002
Brookhaven	580	Brookhaven Energy, LP	Brookhaven, Suffolk	2003
Wawayanda*	540	Calpine Corporation	Wawayanda, Orange	2004

\*Publicly announced project, expected to apply for application.

In addition, there is a trend toward decentralized electric power generation where commercial and industrial establishments generate their own power on site. New and emerging technology, such as microturbines and fuel cells, are small units that lend themselves to these applications. These will add to the power generated within New York City and in the metropolitan region.

Electricity prices of Con Edison and Long Island Power Authority are among the highest in the country (New York City Office of the Comptroller, 1999). Electricity prices have recently declined in the New York metropolitan area, but not as much as the national average, so that the price gap is widening (New York Academy of Sciences, 1999).

Judged by energy consumption per capita or per unit of Gross State Product (GSP), New York is the most energy-efficient state in the continental U.S. This is due principally to the efficiency of moving people by mass transit in the metropolitan area, and the fact that very little of the GSP is due to heavy manufacturing.

*New Jersey electricity:* Northern New Jersey is supplied by Public Service Electric & Gas Company (PSE&G) and GPU Energy (formerly Jersey Central Power & Light Company). Electricity generation within New Jersey has been characterized by rapid growth in nonutility sources, amounting to 33 percent (in 1998). However, in 1996 almost half of its electrical power was imported from out of the state (Energy Information Administration, 2000a).

New Jersey has nuclear plants located at Oyster Creek, Hope Creek, and Salem 1 and 2, none of them in the Metropolitan East Coast region. New Jersey has the highest percentage of utility-generated electricity within the state by nuclear power, about 75 percent, when all units are operating. However, the share dropped to 29 percent when PSE&G took its Salem plants in southern New Jersey out of service in 1995 (Energy Information Administration, 2000a).

Electricity prices in New Jersey are the fifth highest in the nation. These high prices were one of the forces leading to New Jersey taking an aggressive approach to electrical industry restructuring (Energy Information Administration, 2000a).

*Connecticut electricity:* The three nearby counties in Connecticut that are within the metropolitan region are supplied with electricity by Northeast Utilities, Connecticut Light and Power Company, and United Illuminating Company. (A proposed merger between Northeast Utilities and Con Edison has been approved by the stockholders of both companies.) In 1986, more than half of the electricity generated in the state was from nuclear power. By 1996, however, the share of nuclear had been reduced to 31 percent as a result of the permanent shutdown for safety reasons of the Connecticut Yankee plant and the shutdown of the Millstone plants, one of the three units permanently. There is also a nuclear plant at Haddam Creek. Connecticut is normally a net exporter of electricity, principally to the rest of New England, but in 1996 almost 30 percent of its power was imported due to the nuclear shutdowns.

Although less a proportion than New Jersey, Connecticut like New York has one of the highest levels of nonutility generation at 23 percent in the country (in 1998).

Connecticut has been one of the leaders in the move toward deregulation. Utilities are required to sell non-nuclear generation plants by January 2000 and nuclear plants by January 2004.

*Energy-related pollution:* All three states are in the Ozone Transport Region, which covers eleven northeastern states, as well as Washington, D.C. and northern Virginia. In this region, the electric utilities are affected by the federal requirement that requires the states to enact regulations to achieve region-wide reductions in nitrogen oxides (NO<sub>x</sub>) from May through September. Ozone is formed in the atmosphere by the reaction of nitrogen oxides with volatile organic compounds in the presence of sunlight. Due to the movement of air masses, this is a regional problem. To address it, an emissions trading program has been established to encourage the reduction of nitrogen oxide emissions from sources where it is most economical to do so. However, Gov. Pataki recently announced even more stringent regulations for New York State, requiring that the same Clean Air Act targets for NO<sub>x</sub> be met year round

Sulfur dioxide restrictions more stringent than those required by the Clean Air Act are also being imposed in New York State (New York Times, October 14, 1999). Sulfur aerosols in the atmosphere have been found to have an important effect in screening the earth's surface, thus lowering the surface temperature (Houghton et al., 1996).

### **Current trends in electric energy demand**

During the decade from 1988 to 1998, the combined electric energy demand in New York, New Jersey and Connecticut grew at the low rate of 0.6 percent per year, as shown in Table 4. The commercial sector, which comprised 42 percent of total electricity demand in 1998, was the fastest growing at 1.6 percent per year. The residential sector, accounting for 32 percent of electricity demand in 1998, grew at a rate of about 0.8 percent per year. Industrial energy use declined in all three states.

**Table 4. Growth in utility retail sales in New York, New Jersey and Connecticut by sector (millions of megawatt-hours), 1988, 1993, and 1998. (Source: K. Wade, U.S. Energy Information Administration, State Electricity Profiles, personal communication, 13 March 2000.)**

<b>Sector</b>	<b>1988</b>	<b>1993</b>	<b>1998</b>	<b>Growth rate*</b>
Commercial	81.7	86.9	96.0	1.6
Residential	68.5	72.5	74.3	0.8
Industrial	52.3	50.4	44.2	-1.7
Other	12.2	13.3	13.7	1.2
<b>Total</b>	<b>214.6</b>	<b>223.0</b>	<b>228.2</b>	<b>0.6</b>

\*Growth rate in percent per year, 1988-1998

## **Current trends in energy supply**

The energy supply structure is changing because of new technology, the availability of inexpensive natural gas, changing demand, but most of all due to the deregulation of the industry.

Until recently, electric power throughout the country was generated and delivered by local companies with a franchised monopoly overseen by state public utility commissions. By the early 1990s, a number of developments had begun to make local competition among several different electricity suppliers possible.

- The notion that ever larger power plants running constantly to meet the minimum daily electric load (base load) would necessarily provide the cheapest electricity had been dispelled, in large part by experience with nuclear reactors
- New efficient technologies had appeared small enough to be manufactured in units (“modules”) in a factory, gaining the economies of large-scale production, and then transported to the generation site.
- Deregulated natural gas prices were low.
- New information and control technologies were emerging.
- Changing regulatory policies facilitated competition among electricity suppliers.

By the end of 1992, competitive bidding for new power supplies was approved in 20 states. Also, the Federal Regulatory Commission (FERC) approved “market-based” pricing for some wholesale power sales, and Congress broadened the scope of wholesale competition with the passage of the Energy Policy Act of 1992. In 1992, for the first time, generating capacity added by independent power producers exceeded that added by traditional electric utilities (Energy Information Administration, 2000b).

As a result of deregulation, the traditional vertical structure of franchised public utilities is disappearing. For example, Con Edison has sold the bulk of its generating plants and become a “wires” company primarily providing local distribution of electricity.

The electricity and gas industries are converging. In metropolitan New York, Brooklyn Union Gas and Long Island Lighting have combined as KeySpan Energy. As gas becomes the dominant fuel for both power generation and domestic heat and cooking, there is an overlap between the supply and retail functions of electricity and gas suppliers, and it becomes logical for the two to combine.

Deregulation does not guarantee that the price of electricity will go down. With competition, the price will respond rapidly to changes in supply and demand, as oil prices do now. When supply is short, for example, to meet peak demands during summer hot spells, the unregulated cost of electricity may increase sharply. During the past two summers, prices have spiked as high as \$7,000 per megawatt-hour, compared to a typical price of \$35 to \$45 per megawatt-hour (Lynch, 2000). This can be expected more frequently with climate change.

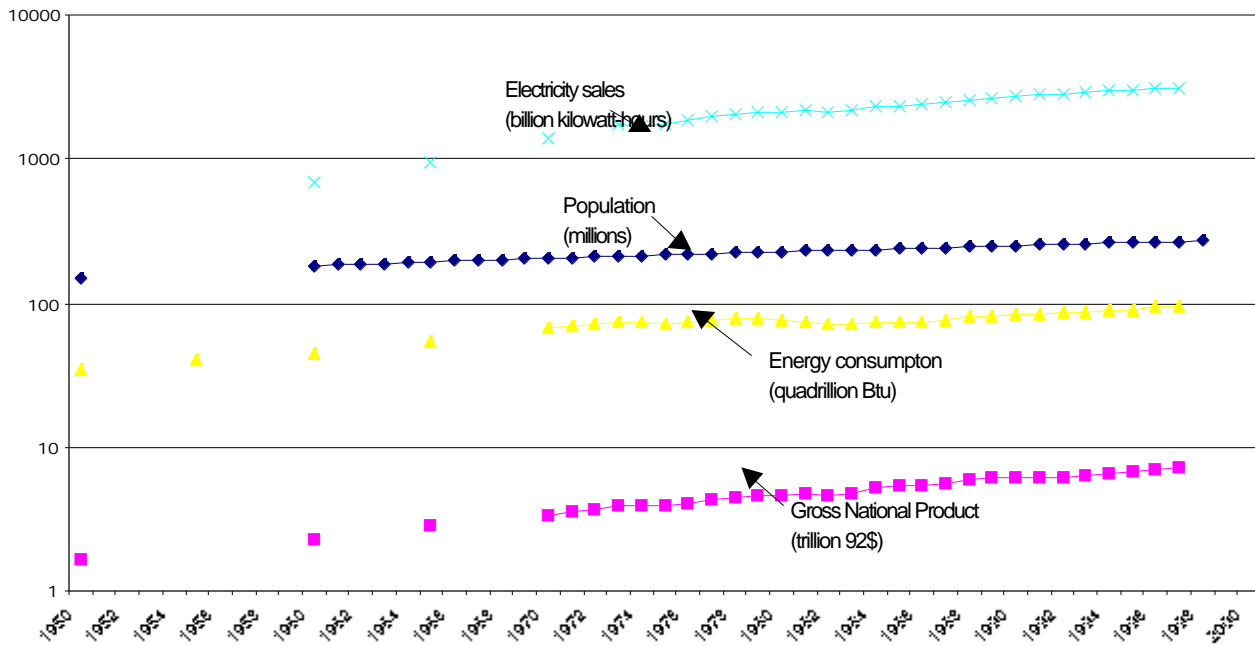
Although there are short-term fluctuations as comparative prices vary, natural gas is replacing oil as the fossil fuel of choice to generate electricity. It generally contains fewer impurities, burns cleaner and more efficiently, does not risk oil spills, and produces less carbon dioxide. Oil-fired plants can be converted to burn natural gas, and new construction is dominated by gas-fired combined-cycle gas turbine generators.

Except for hydroelectricity in New York State, renewable energy is a very minor source of electric power and is unlikely to be a major local source of energy for decades to come (Morris et al., 1996).

*Aging infrastructure.* Aside from these trends in new directions, there is the fact of constantly aging infrastructure. Particularly with ever increasing summer peak loading, failures may become more frequent. An example is the blackout in the Washington Heights area of Manhattan on July 6-7, 1999 (see Box 1 below).

**Determinants of energy demand**

On the national level, the two primary determinants of energy demand are population and the level of economic activity, the latter usually measured as Gross National Product. The relationship is illustrated in Figure 2 which shows the annual growth in population, Gross National Product, energy consumption, and electric power sales over the past few decades. The data are shown on a logarithmic grid so that proportional changes over time appear as parallel lines. The relative position of the curves vertically has no significance.



**Figure 2. History of trends in population, Gross National Product, energy consumption, and electricity. (Source: U.S. Bureau of the Census, Statistical Abstract, various dates)**

Over the long term, growth in energy consumption has generally paralleled population growth, between 1973 and 1997 at a rate of 1 percent per year. Electricity sales have generally paralleled the higher rate of growth of the Gross National Product, 2.5 percent per year during that period. On the other hand, between 1973 and 1986, conservation and efficiency measures helped to keep U.S. energy consumption at nearly constant levels while the country's Gross National Product grew by 35 percent. This demonstrates the significant potential for reducing the use of energy without hurting the economy.

Final end-use energy consumption is usually classified by economic sector – principally commercial, residential, industrial, transportation. On this level, electricity demand in the residential and commercial sectors may be estimated by the number of households, manufacturing and non-manufacturing employment, the number of buildings with electric cooling and heating, and the energy-efficiency of those buildings. The effect of climate on energy demand is discussed in detail in the next section.

At the end-use level, energy demand forecasting models have been developed by Lawrence Berkeley National Laboratory (LBL) separately for commercial buildings and the residential sector for the Electric Power Research Institute (EPRI). The numerous factors that influence energy demand in a building are shown for residences in Figure 3.

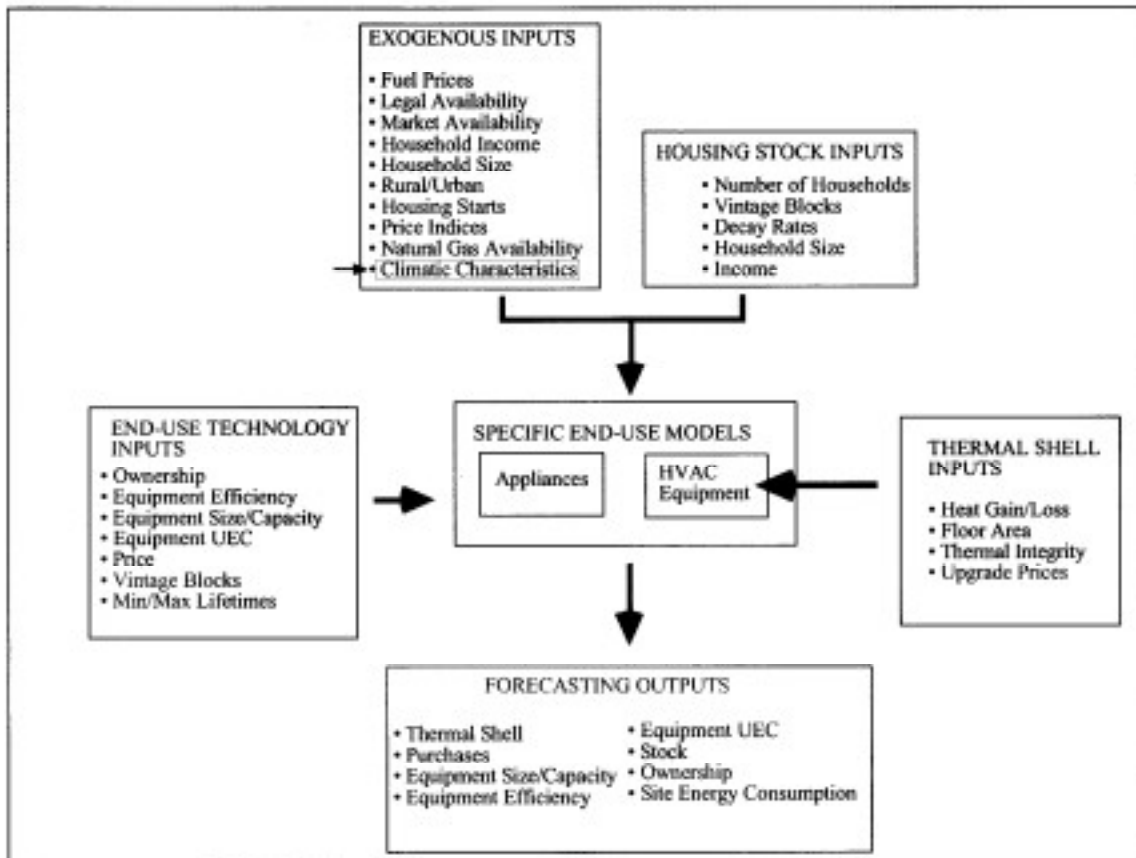


Figure 3. Factors affecting energy consumption at a residence. (Source: Koomey et al., Lawrence Berkeley Laboratory, LBL-34044, December 1995.)

The figure shows the various building characteristics and other inputs that are required to forecast energy consumption at a residence. Climate is one of many.

An example of the direction and extent of changes in energy demand due to various residential end-uses is shown in Figure 4. The forecasts of the LBL REEPS (Residential End-Use Energy Planning System) model offer a picture of how much energy will be used for what purposes in the residential sector over time.

The figure compares forecasted growth in primary energy by end use from 1995 to 2010 for both the REEPS forecast and that of the 1995 Annual Energy Outlook (AEO) prepared by the Energy Information Administration. The end uses are ranked according to the REEPS forecast with highest growth at the top and the lowest at the bottom. The largest growth in primary energy use is due to space heating with electricity and natural gas, followed by the use of electricity for “miscellaneous,” space cooling, and lighting. Energy for water heating, refrigerator, and freezers is expected to decline primarily because of efficiency standards now in place for these end uses.

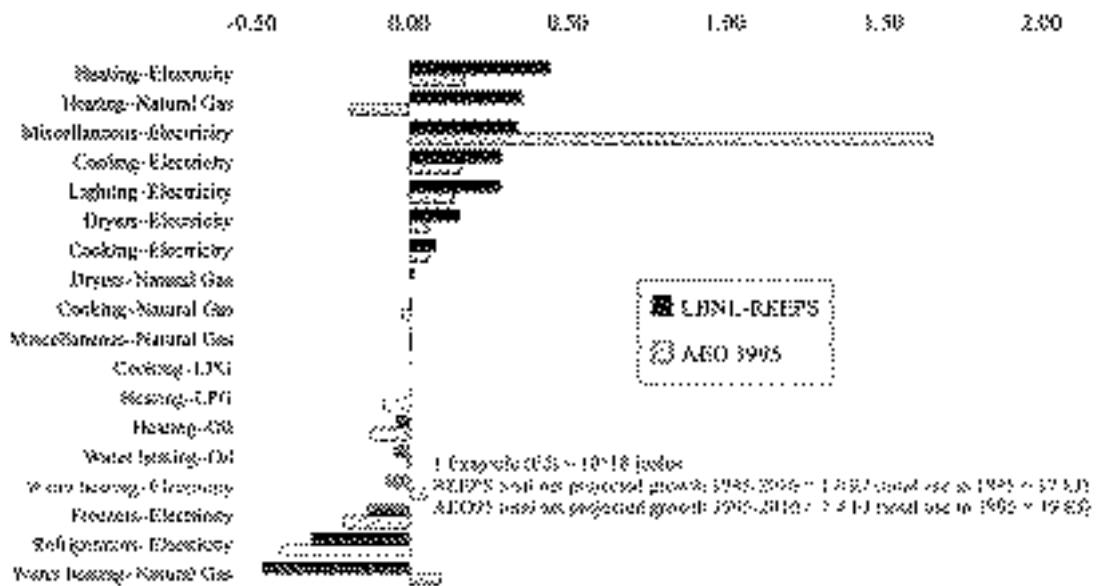
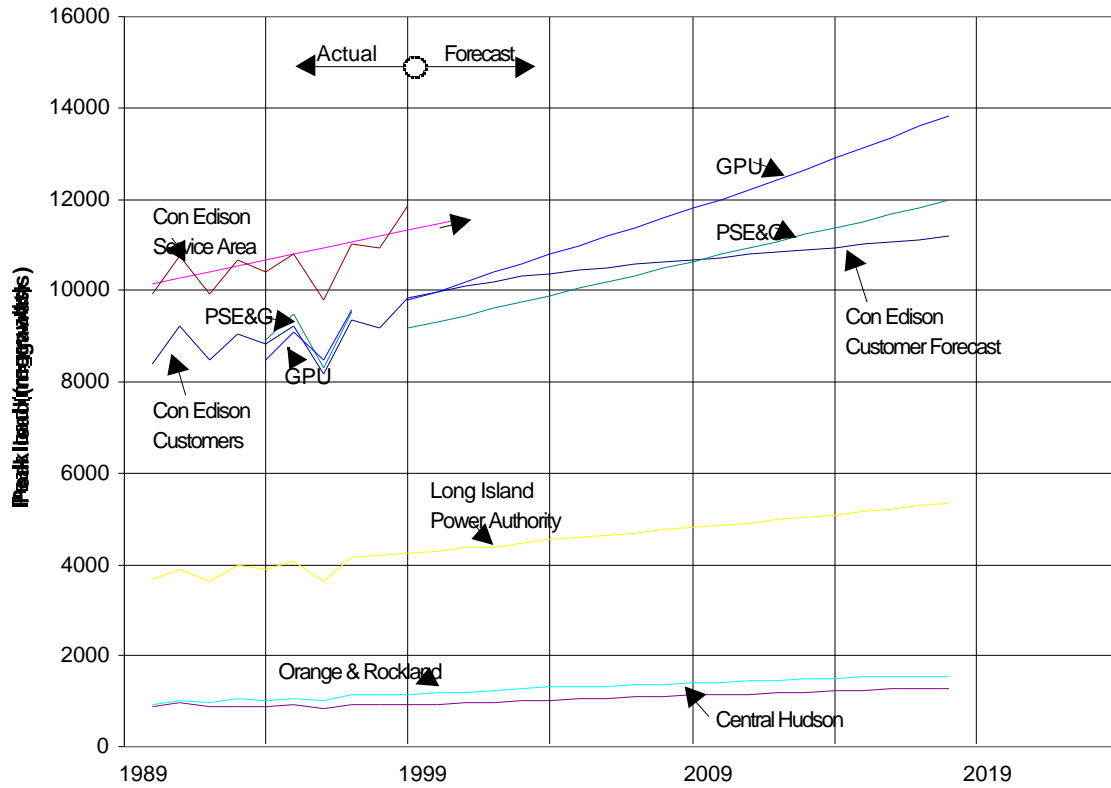


Figure 4. Projected changes in U.S. primary energy use due to various residential end-uses, 1995-2010. (Source: Koomey et al., Lawrence Berkeley Laboratory, LBL-34044, December 1995.)

### Projections of electric energy demand

Both the New York Independent System Operator and the PJM Interconnection forecast demand for future electric generating capacity for individual utilities or service areas twenty years ahead. Peak load projections for the major utilities in the Metro East Coast

region are compared with recent history in Figure 5. The NYISO projection for Con Edison applies to Con Ed customers. The peak load in the Con Edison service area is



**Figure 5. Comparison of growth in peak loads for utilities or service areas in the Metro East Coast region. (Sources: New York Power Pool, Load & Capacity Data, 1999, Tables I-1, I-2. Con Edison Annual Reports, 1995, 1999. PJM Interconnection, L.L.C. [www.pjm.com](http://www.pjm.com))**

larger because the company delivers power in the region for the New York Power Authority and other sources.

**Table 5. Comparison of growth rates in peak loads among Metro East Coast utilities.**

	Time interval	Growth rate per year
GPU forecast	1999-2018	1.84%
PSE&G forecast	1999-2018	1.40%
Con Edison service area trend	1989-1999	1.26%
LIPA forecast	1999-2018	1.22%
Con Edison customer forecast	1999-2018	0.67%

The growth rates in peak load represented in the figure are compared in Table 5. The growth rates anticipated for the three major suburban utilities are all higher than that for Con Edison customers. Probably this is because of higher projected population growth in the suburbs. However, the actual growth rate in the Con Edison service area from 1989 through 1999, shown by the trend arrow (the linear regression calculated for the eleven points), is almost double that projected for future growth in Con Edison customers.

New York State forecasts growth in electricity “sendout” – total energy – of 0.6 to 1.2% for the state as a whole during the next 20 years (New York State Energy Planning Board, 1998). The New York Power Pool (now the New York Independent System Operator) forecasts growth of about 1.1 percent for the utilities within the Metro East Coast region (New York Power Pool, 1999).

The variation in monthly peak loads projected for the PSE&G area is shown in Figure 6. The summer peak load remains 40 percent higher than the winter peak two decades hence according to these projections, although the actual summer peak in 1997 – not an unusually warm year – was more than 50 percent higher than the winter peak. In other words, no worsening of summer cooling requirements due to climate change seems to be anticipated by the utility in this time period.

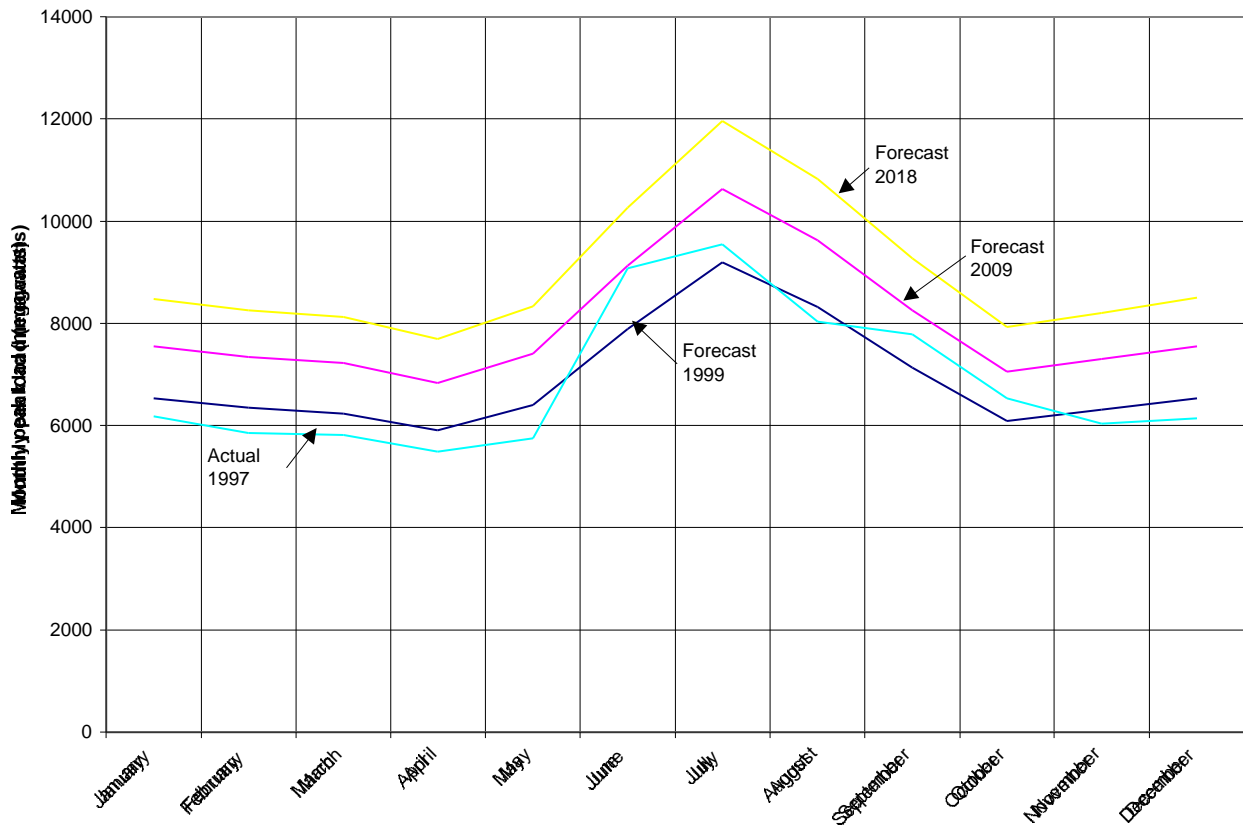
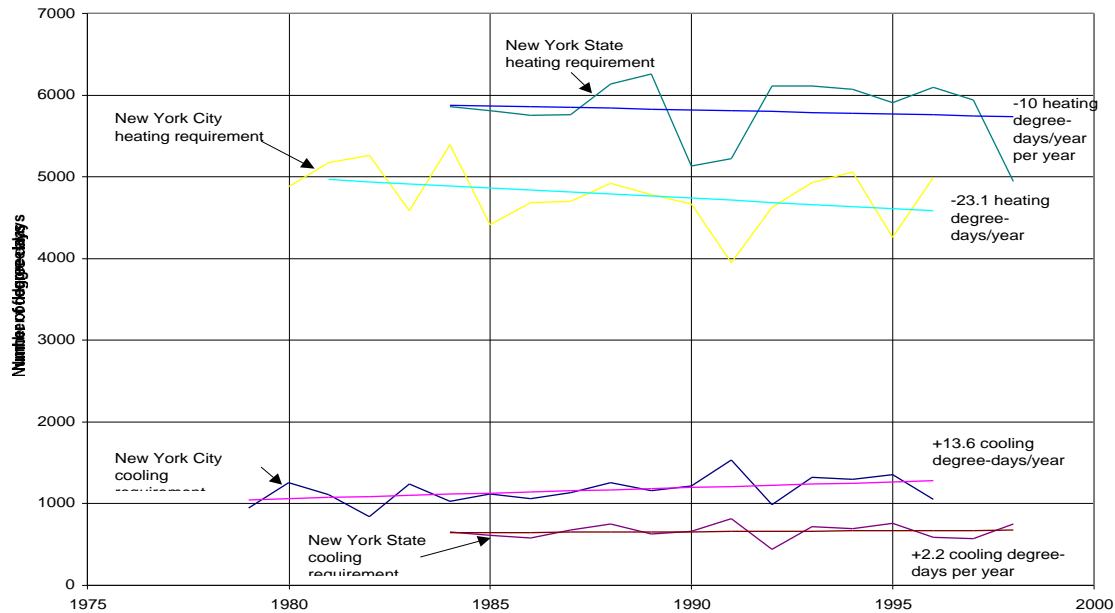


Figure 6. Actual and forecast monthly peak loads in the PSE&G service area for 1997, 1999, 2009, and 2018. (Source: PJM Interconnection.)



**Figure 7. Cooling and heating degree-days in New York City and New York State. (Sources: National Weather Service and New York State Energy Research and Development Authority).**

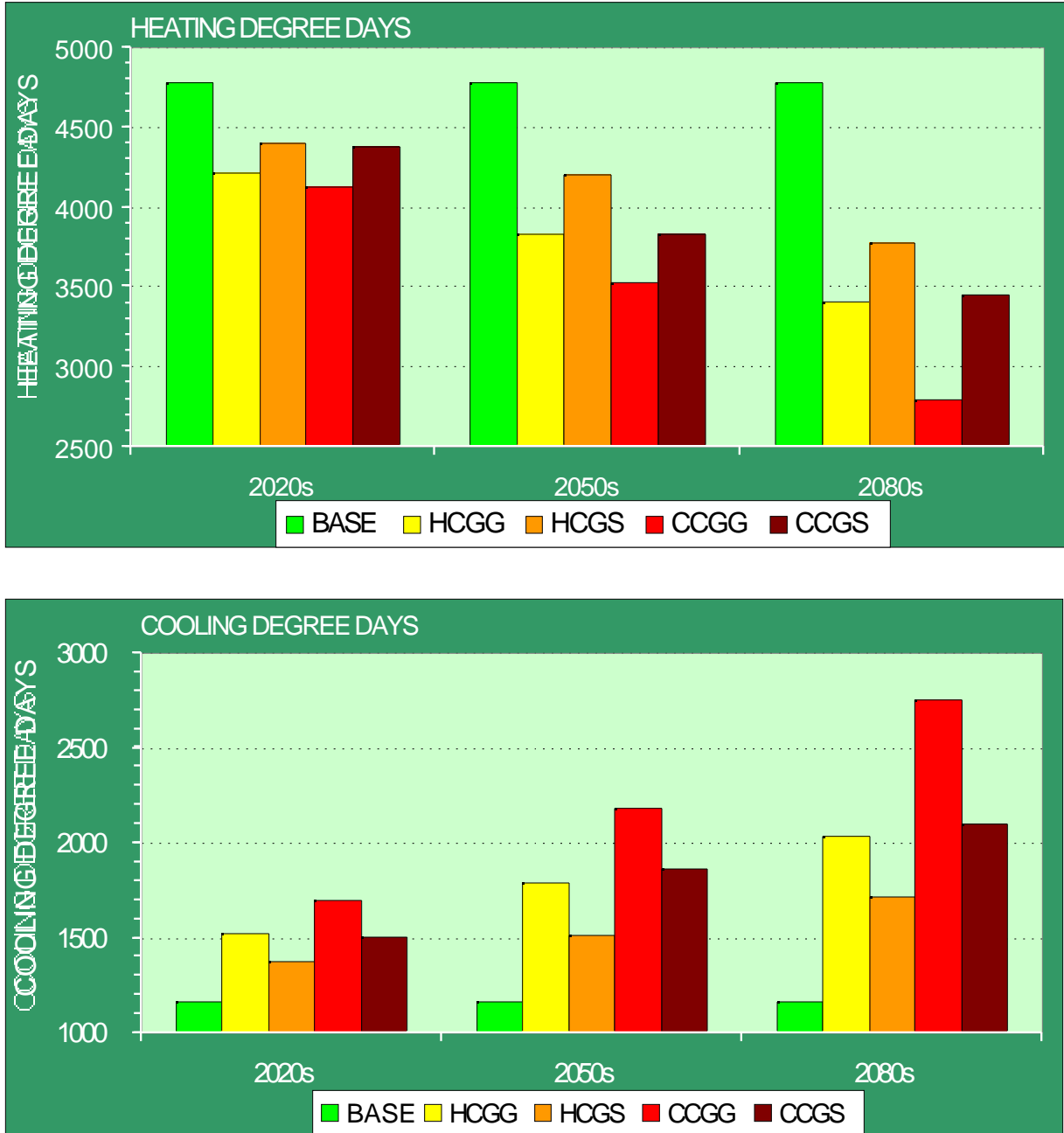
## A. CLIMATE IMPACTS ON ENERGY DEMAND

Although the major drivers of energy demand in the U.S. are population and economic activity, climate makes itself felt at the margins. In particular, a warming climate is likely to increase summer peak electricity loads, straining the generation, transmission and distribution systems to their limits. (See Box 1) This section describes analyses to quantify and project the impact of climate on energy demand, especially under peak conditions.

The 20-year projections made by the utilities may not take into account expected changes in climate, but their *short-term* demand forecasts – for the next few days – do take into account expected changes in the weather. These short-term forecasting methods provide a basis for estimating the effect of long-term climate change, because they relate demand to climatic factors.

The impact of climate on energy demand is determined by changes in winter heating and, more importantly for electricity demand, summer cooling. Energy peak demand increases with extremes of cold and heat. Total energy demand is roughly proportional to heating and cooling degree-days. A degree-day is the difference between a reference temperature, usually 60 or 65 degrees F, and the average temperature for the day.

Heating degree-days in New York City are less than those in New York State as a whole, and since 1980-85 they have declined at twice the rate, as seen in Figure 7. On the other hand, cooling degree-days in New York City are more than in New York State as a whole, and in the same time period they have increased at six times the rate.



Notes: Base time period is 1979-96. Degree-days are calculated from a base value of 65°F. Bars represent high and low range of two general circulation models, the Canadian Climate Model (CC) and the Hadley/UKMO Model (HC).

**Figure 8. Projected heating and cooling degree-days in the Metropolitan East Coast region.**

These trends are expected to continue or become more pronounced. The declining number of heating degree-days and the rising number of cooling degree-days in the metropolitan region are shown projected using two general circulation models in Figure 8. Compared to the base time period of 1979-96, heating degree-days may decline by 20 to 40 percent by the 2080s. Cooling degree-days may increase by 45 to 135 percent, that is, by almost half to more than double the recent values.

A decline in heating degree-days reduces the impact on the energy system, whereas an increase in cooling degree-days worsens the impact. Relatively little electricity is used to provide heating, whereas air cooling is principally provided by electricity. Thus, it is the effect of a rising requirement for air cooling, especially on the electrical system, that is the principal climate change impact of concern in the energy sector.

### Response of electric energy demand to change in temperature

The response of electric energy demand to a change in temperature can be measured by its elasticity. The elasticity of residential electricity demand to cooling and heating degree-days in California was calculated by month from 1977 through 1995 (McMenamin, 1997).

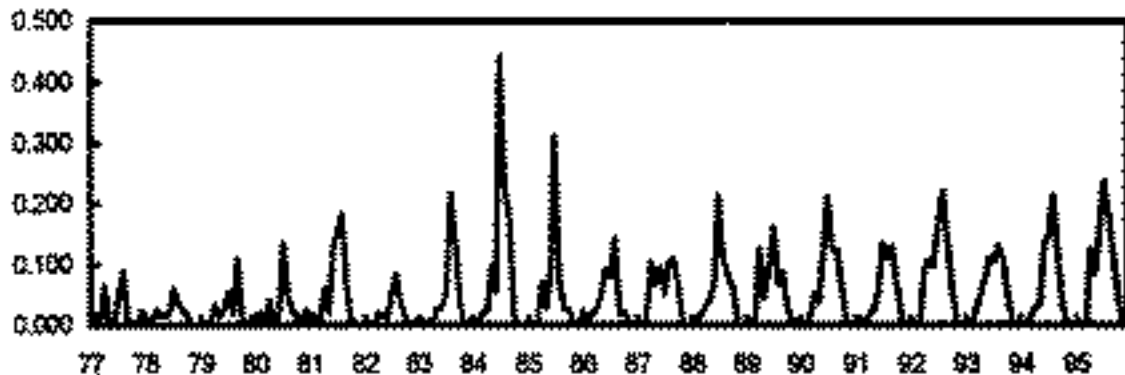
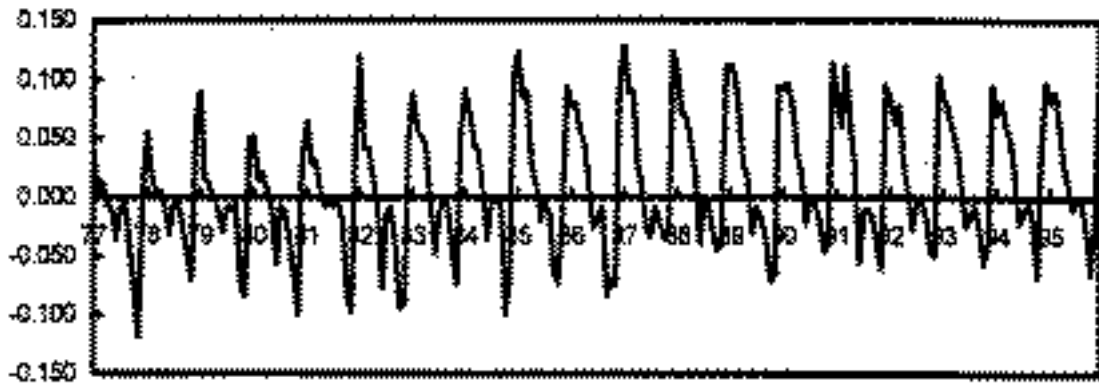


Figure 9. Elasticity of residential electric energy demand with respect to cooling degree-days, calculated by month from 1977 to 1996. (Source: J.S. McMenamin, 1997.)

Electricity consumption was compared with cooling and heating degree-days, measured by the difference between the daily average temperature and 65 degrees Fahrenheit.

The elasticities of electricity demand with respect to cooling degree-days was most evident in summer months, as indicated by the peaks in Figure 9. In these months, the “typical value” was found to be 0.2, indicating that a 10 percent increase in cooling degree-days will cause a 2 percent increase in monthly electricity use. The summer peak values for elasticity ranged from about 0.05 to 0.45. The elasticity builds up from zero in winter months to its summer peak. Thus, the elasticity of electricity demand is a function of the average monthly temperature, rising with higher temperatures. The hotter it gets, the greater will be the increase in electricity demand with an additional degree of temperature.



**Figure 10. Elasticity of residential electric energy demand with respect to heating degree-days.**  
(Source: J.S. McMnamin, 1997.)

In contrast, the elasticity of electric energy demand with heating degree-days in the California sample, shown in Figure 10, switches sign. In winter months, cold weather increases heating loads. However, since most heating systems are not electric, the elasticity is modest, at about 0.1. In the summer months, the elasticity is negative, indicating that cool weather reduces electricity loads.

### **Energy Demand Models**

Cooling and heating degree-days provide only a rough indication of energy demand. Weather conditions other than temperature have been found to be important in influencing energy demand on a given day, namely humidity, wind speed, cloud cover, and the previous day's weather (Consolidated Natural Gas Company, 2000). For more precise projections of energy demand, therefore, models have been constructed that take into account these other factors.

On the local scale, the COMMEND model used by EPRI to characterize heating and air conditioning in commercial buildings, for example, requires users to enter service demand data (Sezgen et al., 1995). Service demand is characterized by the annual heating and cooling loads in a base year, peak-heating and peak-cooling requirements in the base year, the sensitivity of heating and cooling loads to changes in efficiency of other end uses, building occupancy, and environmental factors such as weather conditions. The latter consists of average heating and/or cooling degree-days in the region.

### **New York Power Pool Zone Forecasting Models**

The New York Power Pool Zone Forecasting Modeling system consists of a set of advanced neural network and regression models to forecast hourly loads, daily peaks, monthly peaks, and energy demand for the New York State electric system.

Three types of data are used: load, weather, and calendar (New York Power Pool, 1999b). The weather data include:

- Dry bulb temperature
- Wet bulb temperature
- Wind speed, and
- Cloud cover.

Calendar data include individual days of the week, all major United States holidays, sunrise-sunset tables, and seasonal variables.

To account for regional differences, the models were developed individually for eleven regions of the state, shown in Table 6 with the weather stations used for data. The New York metropolitan region consists of regions G through K: mid-Hudson, Millwood, SPR Dunwoodie, New York City and Long Island. In total, these correspond generally with the service areas of Con Edison, Long Island Power Authority, Orange & Rockland, Central Hudson Gas & Electric, and the retail customers of New York Power Authority. Once the weather data were obtained, the relationship between energy loads and weather was examined.

The model was developed in a series of steps:

- Load and weather data were examined for consistency and quality
- Weather stations were mapped to zones and combined to produce aggregate weather variables for each zone
- Economic trends for the state and eleven zones were developed to forecast both energy and peak demand for the state
- Neural network and regression models were developed to forecast both energy and peak demand for each of the eleven zones.

Three economic drivers/indices were developed to capture long-term changes in energy demand: residential energy consumption, manufacturing segment growth, and non-manufacturing segment growth. For the residential index, the energy consumption in each zone was developed from the 1998 *Annual Energy Outlook* of the Energy Information Administration. Space heating and cooling shares were developed from the 1996 Gas Research Institute *Baseline Projection Data Book* for the New England region.

The long-term forecast using the models projected a state electric system with peaks growing at 1.15 percent annually and total energy consumption growing at 1.4 percent annually. For the state, summer peaks grow at 1.15 percent annually, faster than the 1.0 percent annual growth in winter peaks. By 2010, summer peaks are estimated to be 20 percent higher than winter peaks, compared to 5 percent in 1996.

The eleven zone models are forecast with a combination of the individual zone models and the system load model. These models were combined using a “share-out” approach to produce the load forecast by load zone. In this approach, the model result for each zone is used to develop the zone’s percentage of the entire load for New York State. This percentage is then applied to the result from the New York State system model to estimate the final forecast for each zone.

Zone	Weather Stations	Weight
A: Frontier	Buffalo	91%
	Elmira	5%
	Syracuse	4%
B: Genessee	Elmira	5%
	Rochester	85%
	Syracuse	10%
C: Syracuse	Binghamton	23%
	Elmira	14%
	Syracuse	55%
	Watertown	9%
D: Adirondack	Plattsburg	100%
E: Utica	Binghamton	20%
	Massena	17%
	Monticello	13%
	Utica	35%
	Watertown	15%
F: Capital	Albany	76%
	Binghamton	3%
	Plattsburg	5%
	Poughkeepsie	6%
	Utica	10%
G: MID Hudson	Newburgh	68%
	Poughkeepsie	27%
	White Plains	4%
	Albany	2%
H: Millwood	White Plains	100%
I: SPR Dunwoodie	White Plains	100%
J: New York City	JFK	21%
	LaGuardia	79%
K: Long Island	Islip	100%

Table 6. Zones in New York Power Pool Zone Forecasting Models, determined by local power grids. Zones in the Metropolitan East Coast Region are G, H, I, J, and K. (Source: New York Power Pool, 1999b).

### Climate impacts on downstate New York electricity

For this study, the New York Power Pool Zone Forecasting Model was used to estimate the effect of future extreme weather conditions on electricity demand in the five downstate zones that are part of the Metropolitan East Coast region.

To put these estimates in context, the daily electric energy load in New York State as a whole is shown in Figure 11 for the years 1996 and 1997. Each point represents the daily energy sendout (gigawatt-hours) and the average dry bulb temperature for the day. The distribution of points for both years bottoms out in the range of 50 to 65°F. As the average daily temperature *decreases* from this range, it is evident that the daily sendout increases at a slightly increasing rate. As the temperature *increases*, the daily sendout increases more sharply, again at a slightly increasing rate. For the lower boundary of the distribution of points to appear convex, it must be an increasing rate of change in both directions.

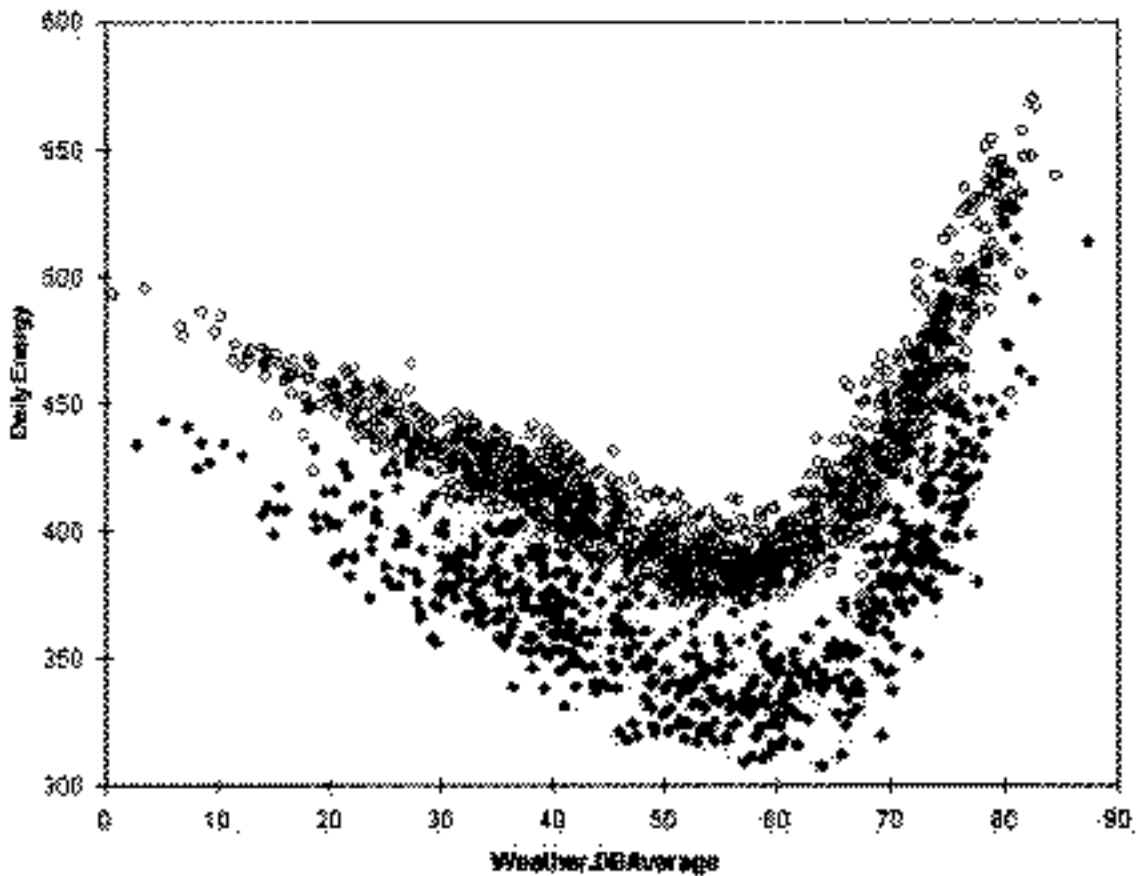


Figure 11. Daily electric energy load (gigawatt-hours) in New York State vs. average dry bulb temperature (degrees Fahrenheit). Solid points are 1996, open points are 1997. (Source: New York Power Pool, 1999b.)

At extremely high temperatures, however, the daily sendout would increase at a *decreasing* rate as the point is approached where there are no more air conditioners to

turn on. There is therefore a transition zone where the rate of increase in the daily sendout goes from increasing to decreasing. With summer peak cooling loads expected to increase in the future, the question is how to extrapolate electricity demand under these peak conditions.

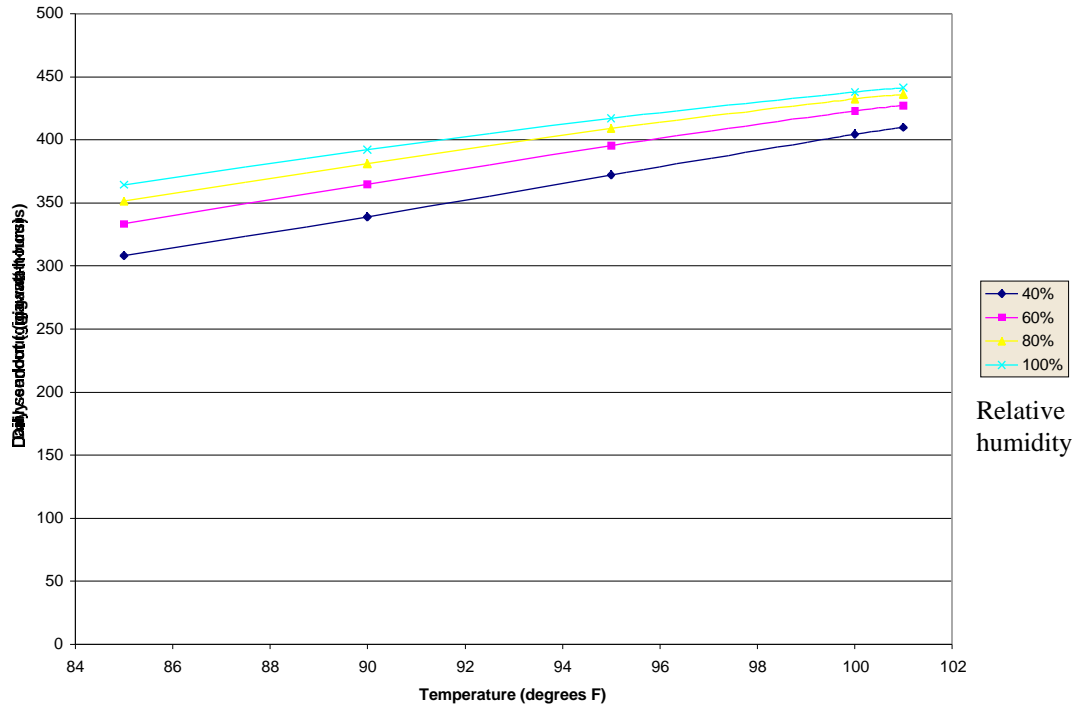
To answer this question, the New York Power Pool Zone Forecasting Model was used to calculate what the electricity demand would be under a set of assumed extreme conditions for temperature and humidity. The results for daily peak (megawatts) and daily sendout (gigawatt-hours) are shown in Table 7.

**Table 7. Calculated midweek electricity demand in July for the New York State portion of the Metropolitan East Coast region for assumed values of temperature and humidity, with other conditions those of July 1999. (Source: John Pade, New York Independent System Operator, 2000)**

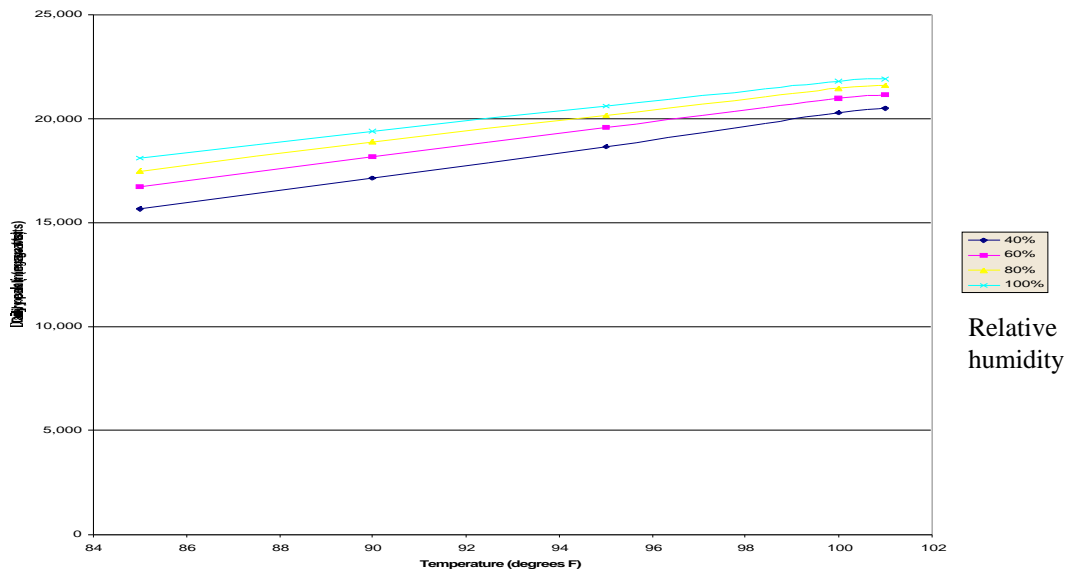
		<u>Daily Peak (MW)</u>			
Relative Humidity		40%	60%	80%	100%
Temperature (°F)	85	15,655	16,717	17,489	18,089
	90	17,140	18,168	18,872	19,409
	95	18,655	19,565	20,158	20,604
	100	20,296	20,997	21,457	21,799
	101	20,490	21,143	21,596	21,923
		<u>Daily Sendout (GWH)</u>			
Relative Humidity		40%	60%	80%	100%
Temperature (°F)	85	308	333	351	364
	90	339	365	381	392
	95	372	395	409	417
	100	404	423	432	438
	101	410	427	436	441

To represent extreme conditions, the peaks and sendouts in the table are average values for Tuesday through Thursday in July. The non-weather data was the same as that for 1999. These results for daily sendout are plotted in Figure 11 and for daily peak in Figure 12.

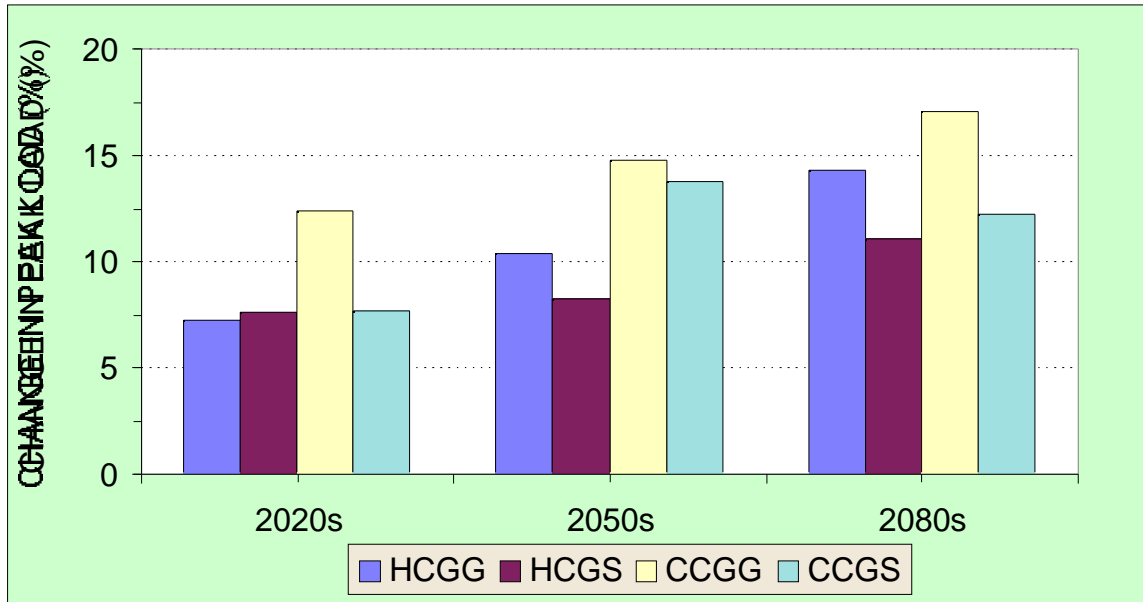
In both cases, the increase in electricity demand with increasing temperature at constant relative humidity is virtually linear. In the case of daily sendout, the curve is slightly concave at humidities above 40 percent. In the case of daily peak, some concavity appears above 100°F. This may be explained in both cases by a saturation of the capacity for air conditioning discussed above. For the case of daily peak, however, the points are



**Figure 12. Parametric relationship of daily sendout with temperature and relative humidity in the New York portion of the Metropolitan East Coast region calculated with the New York Power Pool Zone Forecasting Model.**



**Figure 13. Parametric relationship of daily peak with temperature and relative humidity in the New York portion of the Metropolitan East Coast region calculated with the New York Power Pool Zone Forecasting Model.**



Note: Bars represent high and low range of two general circulation models, the Canadian Climate Model (CC) and the Hadley/UKMO Model (HC).

**Figure 14. Increase in peak electricity demand under July 1999 conditions with temperatures and relative humidity projected for future decades.**

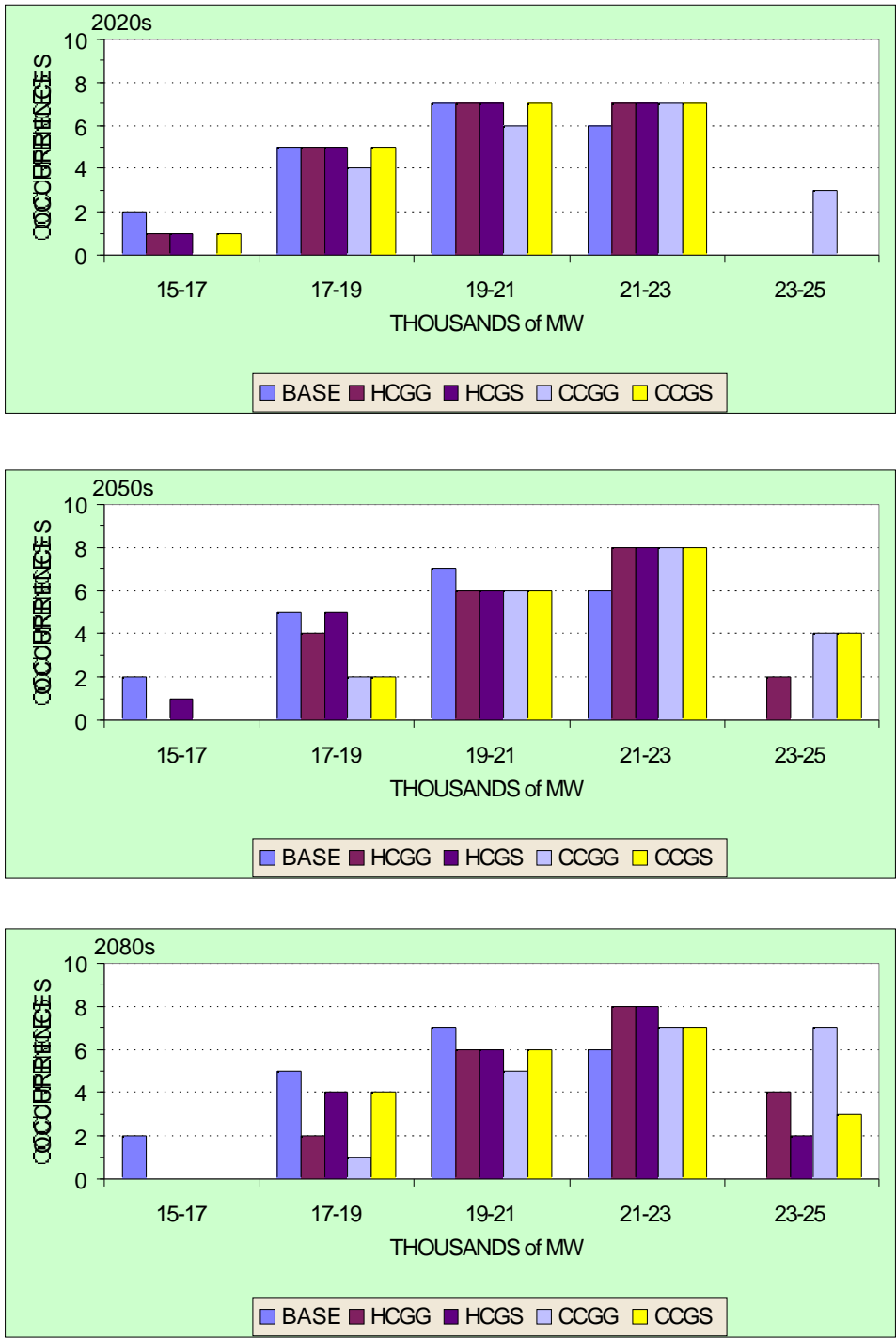
so close to perfectly linear that they can be represented by a linear equation calculated by regression analysis with a correlation coefficient of 0.99.

This does not mean that the transition zone between 85 and 101°F is necessarily linear. If there is a systematic increase in relative humidity with temperature, for example, the energy demand curves would be convex, that is, increasing at an increasing rate. If there is a systematic decrease, they would be concave. In either case, it is consistent with the necessity for a transition zone at some point on the energy-temperature curve for them to be close to linear.

For future daily peaks, it therefore appears valid to use the linear regression equation to extrapolate beyond 101°F. This assumption is used to estimate the future daily peaks shown in Figures 14 for the 2020s, 2050s and 2080s. These estimates are determined by the future values of temperature and relative humidity calculated in the two general circulation models. The percentage increase in the daily peak load ranges from 7 to 12 percent in the 2020s, 8 to 15 percent in the 2050s, and 11 to 17 percent in the 2080s.

The distribution of increases in the daily peaks is shown in Figure 15. The progressively higher peaks in future years appear as a shift from the 15,000-17,000 mw range to the 23,000-25,000 mw range. The base distribution for the year 1999 shown for comparison is the same in all three figures. The numerical values in megawatts of the peaks referenced to 1999 serve only as an index. In future years, the absolute values will be different according to the growth in all electricity. In the near term, the incremental change

from one range to the next should remain valid. In the longer term, however, as the technology consuming electricity changes, this increment may also change.



Note: Change in distribution of peak loads indexed by July 1999 system. Bars represent high and low range of two general circulation models, the Canadian Climate Model (CC) and the Hadley/UKMO Model (HC).

Figure 15. Projected change in the distribution of July peak electric loads based on GCM models.

## B. ADAPTATION OF ENERGY TO CLIMATE CHANGE

Adaptation of the energy sector to climate change consists of measures to reduce energy consumption, particularly space cooling in summer. Aggregate energy consumption is the product of millions of individual decisions on the type and level of energy services required, the type of equipment and fuel to use, the types of buildings in which we live and work, and the kinds of commercial services and manufactured products that we buy.

Many measures to reduce energy consumption were part of the demand-side management programs instituted by state public service commissions through the electric utilities in the early 1990s. In the future, the promotion of such measures will depend in part on how the system benefit charges now collected from utilities by New York and New Jersey will be allocated.

In this section, adaptive responses are identified, in particular technical approaches and policy options for improving energy efficiency and reducing energy use. Such adaptive responses include:

- *The “Cool Communities” program.* This federal program, initiated by the Environmental Protection Agency and now administered by the Department of Energy, promotes the idea of reducing the “heat island effect” in cities through the use of high-albedo surfaces on roofs and pavements and by extensive tree planting. (Akbari et al., 1992). Mesoscale meteorological modeling results indicate that New York City may reach 2-3 degrees C higher temperatures than the suburbs on a summer afternoon. With high-albedo surfaces and urban forest strategies, the model suggests that the temperature could be reduced by up to 2 degrees C. The 20 percent decline in New York City’s trees in the past decade should be reversed (U.S. Department of Energy, 2000). Simulations of buildings indicate that energy savings of 3-35 percent are attainable. Wintertime penalties in heating energy use are very small or negligible in most cases (Taha et al., 1995).
- *Low-energy cooling in structures.* As alternatives to electric air conditioning, the following technologies have been identified as the most promising for cooling commercial buildings: evaporative cooling, cooled ceiling (with and without displacement ventilation), and night and slab cooling (Huang, 1993). In residences, ceiling fans offer an important alternative to air conditioning by raising the critical temperature at which air conditioning is needed and by pre-cooling homes prior to the use of an air conditioner (Meier and Pon, 1993). Gas air conditioning, with approximately 88 percent efficiency, is a viable alternative to electricity, when net efficiency of electric generation is accounted for (Lynch, 2000).
- *Natural ventilation in new buildings.* A revolutionary design for a commercial building in London uses an external, corkscrewlike bracing structure rather than the conventional steel core. The design uses natural air pressure differences around the building’s face to circulate air efficiently once it is taken in through vents or open windows. This will minimize the energy needed to run air-conditioning units (American Society of Civil Engineers, 1999).
- *“Weatherization” of low-income housing.* With federal support, states weatherproof, insulate, and upgrade the energy efficiency of low-income housing to reduce winter

heating bills. The legislation does not now authorize other measures, such as high-albedo roofs, that provide summer cooling. In the Chicago heat wave of 1995, most fatalities were old people living without air conditioning on the top floors of old, uninsulated buildings, probably with black tarpaper roofs. (See “Integration Across Sectors” below.)

### **Demand-side measures**

Between 1973 and 1986, conservation and efficiency measures helped to keep U.S. energy consumption at nearly constant levels while the country’s gross national product grew by 35 percent. Many believe that opportunities for further demand reduction are still available using existing and newly developed conservation and efficiency measures.

Demand-side management (DSM) is the term for programs that focus on getting consumers to consume less energy or to consume less in peak periods. Basic types include: building or business audits to identify potential energy savings; performance-based rebates; technology-based rebates; reduced interest payments to finance energy-efficient investments; direct installation of energy-efficient equipment; energy load management programs; educational and advertising campaigns; and end-use fuel substitution.

From 1989 through 1993, there was a steady increase in utility DSM spending and in energy and demand savings. Since then, however, DSM has declined with the deregulation of the electric power industry. Even at their peak, however, demand-side management programs were often slow to take hold. According to the EPA, the problem is rooted in a set of common institutional and political barriers. These include: perceived high initial cost and delayed return on investment in energy-efficient technology; lack of information; low priority given to energy consumption; low energy costs; limited availability; popular attitude and consumer habits; and inaccurate price signals. In the future, state promotion of demand-side measures will be determined by their allocation of system benefit charges paid by the utilities (Kushler and Witte, 2000).

### **Technical approaches for improving energy efficiency and reducing energy use**

Technical measures to reduce the use of energy may simultaneously reduce both conventional air pollution and greenhouse gases using what are sometimes called “harmonized strategies.” (STAPPA and ALAPCO, 1999). Technical approaches to achieve energy-efficiency improvements can be divided along three lines: building measures (*e.g.*, building shell measures to reduce heating/cooling requirements), equipment improvements, and process changes (U.S. Environmental Protection Agency, 1998).<sup>1</sup>

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<sup>1</sup> In existing residential and commercial buildings, energy use for heating and cooling accounts for about 57 percent of carbon dioxide emissions, appliances account for about 20 percent, lighting for about 14 percent, and hot water about 9 percent (OTA, 1991).

- *Building shell measures.* Approaches to improve the efficiency of building shells include a wide variety of building design, construction, landscaping, and retrofit actions. Major decreases in energy use can be achieved by increasing insulation levels, installing improved window technologies, orienting the building to take advantage of the sun for heating, using thermal mass for storing energy, and minimizing north-facing window area. Interior design can emphasize minimizing of ventilation energy requirements. While many building shell approaches are practical only during the design and construction of buildings, significant energy savings are available through shell retrofit measures designed to reduce infiltration and heat loss. *Four Times Square*, the new office tower in New York City, provides an example of “green” building practices that include lighting, energy efficiency, indoor air quality, and waste management.
- *Device or equipment measures.* These measures replace existing energy-using equipment with more efficient technologies, and are available for every kind of energy end use at efficiencies substantially above current levels. High-efficiency gas air conditioning systems are, on a fuel cycle basis, more efficient than electric air-conditioning systems, even without considering line losses of electricity during transmission. Other examples are given in Table 8. The applicability of energy-efficient equipment, however, can be limited by technical, operational or economic barriers.
- *Process measures.* Substantial energy-efficient gains can be achieved through changes in the processes used to produce goods and services. Processes can range from substituting an energy-efficient fax machine or electronic mail system to the adoption of electric arc systems to make use of waste heat in industrial and other facilities.
- *Load shifting.* Load shifting changes energy consumption patterns to different times of the day to reduce energy demand at peak hours. Load shifting does not directly increase energy consumption efficiency, but it can lead to more efficient operation. Electric utilities make significant use of programs to electronically cycle air conditioners during peak periods, and peak load pricing programs to shift consumption to off-peak hours.
- *Cogeneration and district heating.* Making use of the waste heat from electricity generation – cogeneration of heat and power – raises the overall efficiency of the process. Many independent power plants serving local building complexes provide cogeneration, in some cases also providing cooling. Con Edison’s steam-electric generation system in Manhattan – the largest in the world – is another and older example on a much larger scale. The steam district heating system extends from the lower tip of Manhattan to 96<sup>th</sup> Street on the west side of Central Park and to 89<sup>th</sup> Street on the east side. About 60 percent of Con Edison’s steam sales are for both heating and air conditioning. The company’s plans for expansion of the steam system at the margins would require customers to use the steam for air conditioning as well

as heating, specifically to reduce summer electricity peak loads (Consolidated Edison, 1990).

**Table 8. Projected annual savings of residential energy efficiency upgrades (Source: USDOE, Lawrence Berkeley Laboratory.)**

**Projected Annual Savings of Energy Efficiency Upgrades\***

Energy Efficiency Upgrade	Purchase Price <sup>a</sup>	Amount Bill Savings <sup>b</sup>	Simple Payback (years)	Annual Rate of Return
Fluorescent Lamps and Fixtures	\$200	\$80	2.5	41%
Duct Sealing	\$250	\$95	2.6	41%
Energy Star Clothes Washer	\$194	\$66	2.9	37%
Energy Star Programmable Thermostat	\$107	\$29	3.7	30%
Water Heater Tank Wrap (R-12)	\$85	\$23	4.2	27%
Energy Star Refrigerator	\$97	\$23	4.2	27%
Energy Star Heat Pump	\$692	\$126	5.5	19%
Energy Star Dishwasher	\$29	\$5	5.5	18%
Air Sealing	\$522	\$38	13.7	9%
Increase Wall and Attic Insulation	\$1,784	\$111	16.1	8%
Total	\$3,960	\$597	6.6	16%
Total Bill Savings as % of Baseline Bill <sup>c</sup>		36%		

\*Assumes typical house with air-source heat pump, electric water heating, clotheswasher, clothes dryer, and dishwasher. Purchase prices and annual bill savings for efficiency measures are nominal 1997 dollars. The rate of return assumes 3% annual inflation in residential energy prices. After-tax rates of return assume a 28% marginal income tax rate.

- a. Purchase price of clotheswasher, dishwasher, thermostat and heat pump measures its incremental to the price of existing NAECA appliance standards. All other prices reflect the full cost of the measure, including installation.
- b. Bill savings assume average electricity cost of \$0.068 per kWh. Bill savings of equipment measures are relative to a NAECA standard unit.
- c. Heating and cooling consumption values are from LBNL energy modeling using DOE-2, other end-use consumption's are from the U.S. DOE's Residential Energy Consumption Survey (RECS).

Source: DOE, Lawrence Berkeley Laboratory.

- *Fuel switching.* Substitution of one energy source for another is often an effective way to reduce greenhouse gas emissions. This can occur not only at sites that provide power, such as large electricity generating stations, but on a much smaller scale such as a home. Substituting gas for electricity, for example, can lead to a reduction in

power plant fuel consumption and emissions. Alternatively, replacing current gas technologies with very efficient electric technologies can produce net system reductions in energy use and emissions, even after accounting for the losses in the generation and transmission of electricity. As with load shifting, the energy and emissions reductions realized by fuel switching depend heavily on the specific situation.

Two general factors influence whether a given technical approach is feasible. The first concern is whether an approach can be implemented in new, retrofit, and/or replacement situations. Some approaches are feasible only when a building is being constructed since they are key elements of a structure's design. Other measures are feasible when existing equipment is replaced due to failure, while still other options can be retrofitted at any time. Energy used in heating buildings, for example, is determined in large part by the type of building, the quality of its construction, and level of thermal integrity. Although building thermal integrity can be improved by retrofitting it with better insulation, once built, the building's basic heating and cooling requirements can seldom be changed. They therefore apply for the building's remaining life which is measured in decades.

Most primary heating and cooling systems, residential or commercial, undergo major maintenance every 20 to 30 years. Upgrading boilers/furnaces and/or air-conditioning can generally be undertaken without significant structural change. Targeting of pre-1970s buildings would be appropriate (Lynch, 2000).

The second factor affecting the feasibility of the technical approaches listed above is that some energy-efficiency options are not compatible with existing equipment or energy service needs. Replacing electric resistance heating in a home with an efficient heat pump, for example, may be impractical if the home does not contain any duct work. Certain commercial HVAC (heating, ventilating, and air-conditioning) systems are suited only to certain applications and/or climate zones, or the lighting needs of a retail store may not be compatible with the most efficient type of lighting systems available. The key to successful implementation of energy-efficient options, therefore, is to target the selected approaches to those segments of the market in which the specific approaches are practical, feasible, and economic.

In New York City, there have been several obstacles to improving energy efficiency in buildings. Codes and regulations have had limited success in promoting energy efficiency in buildings because they are behind the technology and because they do not apply to most renovations. At present price levels, energy costs are not a large enough fraction of anyone's operating costs to be concerned. Landlords pass through energy costs to renters; renters often do not control the heating. There is no incentive for builders to pay more to make a building more energy efficient (Audin, 1996).

### **Policy options for improving energy efficiency and reducing energy use**

Policy options are instruments through which one or more technical approaches are promoted. Policy options recommended to states preparing action plans by the

Environmental Protection Agency for improving energy efficiency and reducing energy use are as follows (U.S. Environmental Protection Agency, 1998):

- *Provide financial incentives for efficiency improvements.* States can provide financial incentives for accelerating equipment replacement rates through tax credits or low-interest loans on efficiency improvements. They can tax inefficient appliances and equipment, or work with utilities to sponsor rebate programs that induce customers to buy efficient products.
- *Develop institutional planning and support structures.* State agencies established to deal with energy issues may conduct planning and analysis, administer programs, and provide support for utilities, industry, and consumers. Many such agencies are instrumental in facilitating energy-efficiency measures. The New York State Energy Office, considered by many to be a model of such activities, was terminated by Governor Patacki. However, many of its most effective functions continue to be performed by the New York State Energy Research and Development Authority.
- *Institute long-range planning.* Many states, including New York but not New Jersey or Connecticut, mandate an energy agency to provide assessments of state energy consumption as well as potential ways to increase efficiency and reduce energy use. These plans provide valuable focal points for policy development through time and across the economic sectors that affect energy consumption.
- *Facilitate interaction between DSM program sponsors and potential customers.* States, for example, are in a good position to act as a liaison between federal energy-efficiency programs and local industries and governments, or between utilities and potential commercial or industrial energy-efficient clients.
- *Rationalize state tax policy.* Although practice varies from state to state, tax policies often favor energy consumption over energy efficiency. For example, purchases of gas and electricity may be exempted from state tax, while energy-efficiency instruments (more efficient equipment, insulation, etc.) are not.
- *Provide information and education.* States and local governments can gather and disseminate information, often working with utilities, on the energy and financial implications of energy-efficiency projects in certain types of buildings and facilities, and promote research, development and demonstration projects. Through their university systems, states may also promote energy-efficiency training in professional planning and urban design programs.
- *Take direct action to reduce energy consumption in government facilities.* States and local governments can reduce energy consumption on their own properties, including schools and low-income housing projects. Such programs may involve retrofitting existing buildings, changing building and procurement practices to require energy-efficiency investments, and modifying building design requirements.
- *Establish and enforce efficiency standards and codes.* More integrated and aggressive approaches to promoting energy efficiency in buildings may be encouraged by strengthening outdated building codes. There must also be enforcement of the codes they adopt. The Energy Policy Act of 1992 encourages states to adopt energy-efficient provisions at least equal to ASHRAE (American Society of Heating, Refrigeration, and Air-conditioning Engineers) standards for commercial buildings, and the 1992 model Energy Code from the Council of American Building Officials for residential structures.

- *Demonstrate building efficiency measures and facilitate energy-efficient programs.* States and local governments are well situated to initiate energy-efficiency demonstration projects in buildings, often using their own facilities, and to publicize resulting information on energy and cost savings. Similarly, they are often well situated to coordinate interactions between landlords and tenants, especially in the commercial sector, in order to facilitate improvements in existing buildings. Programs to include these goals can include innovative approaches such as setting minimum efficiency standards for rental properties, or developing shared savings programs where landlords and tenants both benefit from energy-efficient investments.

A modeling study to evaluate measures to reduce carbon dioxide emissions in New York found that energy efficiency measures, together with fuel switching to natural gas, led to the largest share of carbon dioxide emission reductions (Morris et al., 1996). Although energy conservation and efficiency improvements are described here as the principal steps to adapt to climate change, they are also preeminently the steps needed to reduce greenhouse gas emissions.

## **INTEGRATION ACROSS SECTORS: ENERGY AND PUBLIC HEALTH**

The factors that determine summer energy demand are much the same as those that cause heat stress: temperature, humidity, wind speed, cloud cover, and antecedent weather conditions (see Box 2). When it gets hot, people turn on their air conditioners, which demand electricity. The hotter it gets, the more the air conditioners work, demanding more electricity.

A number of studies have compared ambient climate conditions to mortality during a heat wave. The duration, high humidity, high minimum temperatures, and low wind speeds all contribute to increased mortality, and a time lag exists between the peaks in the heat index and deaths, as illustrated for the 1995 Chicago heat wave in Figure 16 (Huang, 1996). Many health researchers have found that deviation from the mean temperature is a better predictor of heat stress mortality than absolute temperature (Kinney et al., 2000), just as cooling degree-days – a common predictor of summer energy demand – are measured by the difference in daily temperature from 60 or 65 degrees F.

Extremely high temperature and humidity over successive nights is a crucial factor in heat-related deaths. Over the last half century, these conditions have become more frequent (Stevens, 1998).

Epidemiological studies of heat-wave deaths have given little attention, however, to the role of the building and its interior conditions. Simulations of these conditions in the Chicago heat wave of 1995 indicate that some of the structural measures that would save lives are the same as those that would reduce energy demand. An exception is the use of electric air conditioners, which are estimated to have prevented probably 3,600 deaths in New York City from 1965 to 1988 (Kalkstein, 1995). Unfortunately, when electric air conditioners are used, they add to the electricity peak load and contribute to worsened

global warming by causing more carbon dioxide to be emitted. As recently as 1995, twenty percent of residences in the Con Edison service area lacked air conditioners.

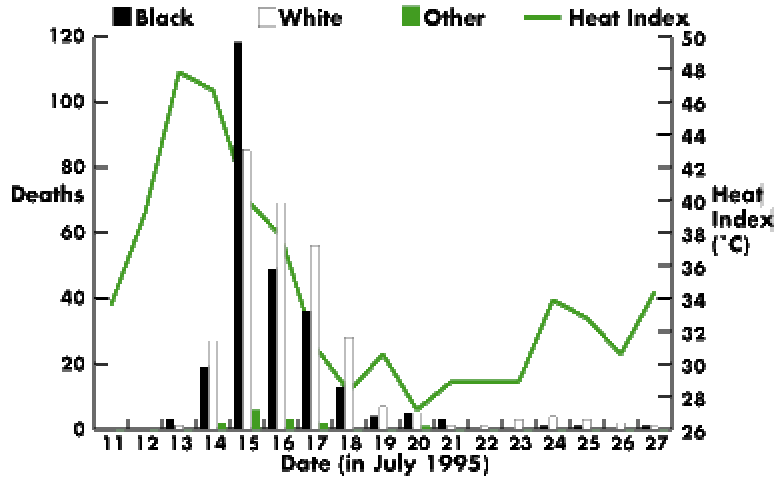


Figure 16. Heat index related to the bars indicate the numbers of deaths by race each day of the July 1995 heat wave in Chicago. (Source: J. Huang, Lawrence Berkeley Laboratory, 1996.)

The number of deaths from heat stress has been higher over a period of time in New York City than in Chicago or any other American city, as shown in Table 9. With a doubling of the concentration of carbon dioxide in the atmosphere – a common measure of the climate change in the next century – the annual toll would increase fivefold (Kalkstein, 1995).

Table 9. Death toll from heat stress in some major cities. (Source: Kalkstein, 1995)

	Annual toll (1964-1985)	Annual toll with atmospheric CO <sub>2</sub> doubled
Shanghai	418	3,587
<b>New York</b>	<b>320</b>	<b>1,743</b>
Philadelphia	288	938
Cairo	281	1125
Chicago	173	412
St. Louis	113	744
Los Angeles	84	1,654
Montreal	69	430

In these heat waves, worsened air pollution exacerbates the unhealthy conditions. For reasons of electric system reliability, the New York Independent System Operator requires that at least 80 percent of New York City’s electric power be generated locally, a higher percentage than most other cities. All electric generating plants will be operating at peak power, adding nitrogen oxides, sulfur dioxide, particulates, and other pollutants as well as heat to the atmosphere.<sup>2</sup> The higher air temperatures accelerate the formation of ozone which causes asthmatic attacks and worsens other respiratory diseases. At night,

<sup>2</sup> Because of their low efficiency, the combustion turbines turned on by Con Edison and KeySpan that burn distillate oil under peak load conditions produce more carbon dioxide per kilowatt-hour of energy than does coal in New York State.

the pollution lying over the city inhibits heat loss and contributes to the heat island effect. On these hot days, the association between mortality and airborne particulates also increases dramatically.

An estimate of the increase in mortality and respiratory hospital admissions is shown in Table 10 (Kleinman and Lipfert, 1996). The causes of respiratory hospital admissions are divided about evenly among ozone, airborne particulates, and temperature. Temperature, however, is by far the leading cause of death.

**Table 10. Health effects of a temperature increase in New York City of 2 degrees C. (Source: Kleinman and Lipfert, 1996.)**

	Mortality	Respiratory hospital admissions
From temperature alone	0.61%	0.45%
From ozone	0.02%	0.58%
From airborne particles	0.04%	0.32%
Total effect	0.67%	1.3%

These 1996 results must be accompanied by a number of caveats, all relating to uncertainties. The rate of increase in mortality with temperature varies among cities and over time. There are large differences between actual pollution exposure and outdoor air quality. Ozone is greatly attenuated indoors, while particulate matter may increase. Thus, if climate change forces people to spend more time in air-conditioned spaces, outdoor air quality becomes less important than indoor air quality, except for the unfortunate few who can't afford air conditioning. It can be argued that the change in daily temperature is more important than the absolute level, which says that at least some portion of the population will adapt to higher temperatures (Lipfert, 2000).

In the Chicago heat wave, more deaths occurred in inner-city areas and disproportionately among older, infirm residents on the top floors of apartments without air conditioning. The mortality pattern appears to correlate with the thermal response of different building types to a heat wave, as well as current conditions in the housing stock (Huang, 1996).

A building simulation program was used by Lawrence Berkeley Laboratory to simulate indoor conditions without air conditioning in four prototypical multifamily buildings of different vintages during the 1995 Chicago heat wave. The buildings were simulated first with windows closed, and then with windows opened for ventilation whenever the outdoor temperatures were lower than inside. To study the benefits of potential energy conservation strategies, the simulations were repeated with additional ceiling insulation, light-colored roofs, and lowered window-shading coefficients.

If the buildings were unventilated, as was reported often to be the case, the simulation indicated that indoor temperatures could reach 108°F (42°C) on the top floors of buildings built in the 1940s (Figure 17). They were hotter than the human body temperature for 80 percent of the hours during the peak three days. Conditions in the 1970s apartment buildings were even worse, with temperatures averaging 108°F (42°C) over the three-day period. Because of their greater mass and moderate insulation, these

buildings would remain hot for days after the peak temperature had passed. The heat index reached 129°F (54°C) in the 1940s apartments and 134°F (57°C) in the 1970s apartments over the period.

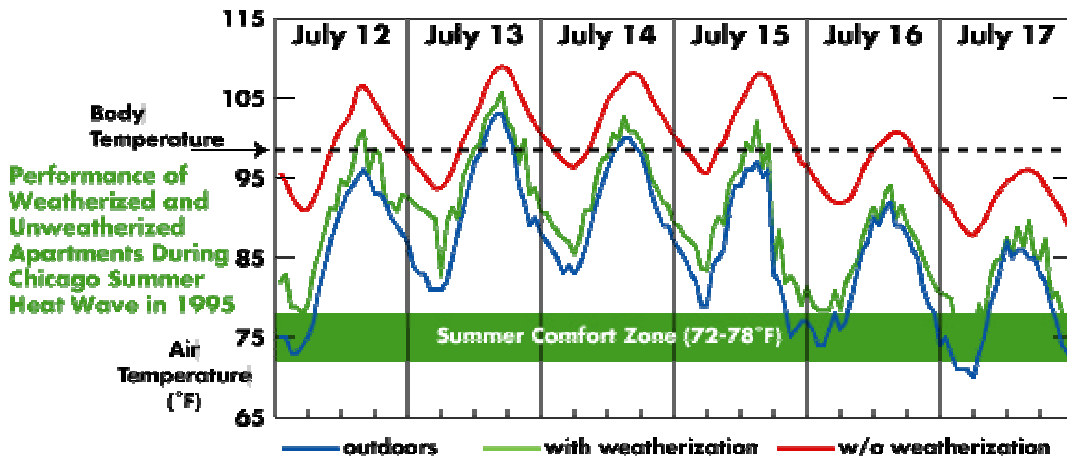


Figure 17. Computer-simulated indoor temperatures in the top floor of a prototypical 1940s two-story apartment building in Chicago during the July 1995 heat wave. (Source: J. Huang, Lawrence Berkeley Laboratory, 1996).

The simulations showed that the single most important strategy to prevent excessive building overheating during a heat wave is ventilation. (The victims of the 1995 Chicago heat wave were reported to have been found in sealed apartments because they were afraid to go out to seek relief.) In older, uninsulated buildings, however, adding ceiling insulation and lightening the roof color will have an appreciable impact on conditions in top-floor apartments.

Most of these kinds of improvements in low-income housing are made under the Weatherization Assistance Program for Low-Income Persons (10 CFR 440 and U.S. Department of Energy, 1999) of the U.S. Department of Energy (USDOE). Most of the weatherization funding in New York State comes from this program and the Low-Income Home Energy Assistance Program (LIHEAP) administered by the U.S. Department of Health and Human Services (Campaign to Keep America Warm, undated).

The USDOE mission statement for the Weatherization Assistance Program is “to reduce heating *and* cooling costs for low-income families, particularly the elderly, people with disabilities, and children, by improving the energy efficiency of their homes and ensuring their health and safety.” However, the program is weighted toward relative cold-weather conditions. Cooling assistance consists of providing fans and air conditioners for extremely hot weather only in warm weather climates.

More than 385,000 dwellings have been weatherized in New York State since 1977, but the backlog is 1.5 million and at the current reduced rate of funding only 10,326 units were to be weatherized in 1999 (New York State Division of Housing and Community Renewal, 1999). At the present rate, therefore, the great majority of these units will never

be weatherized. The maximum average cost per unit was estimated to be \$2,032. State funding is allocated to counties by a formula that takes into account both the number of income-eligible persons and climate, with climate measured only by *heating* degree-days. In New York, a portion of the public benefit charges administered by the Public Service Commission will be allocated to a low-income program that includes weatherization (Kushler and Witte, 2000).

While weatherization measures that provide insulation from the cold also insulate dwellings from the heat, the additional steps of providing fans, air conditioning, and light-colored roofs, which would provide summer cooling are not authorized under the New York Weatherization Assistance Program.

Immediately following the July 1999 heat wave (see Box 1), the federal government released \$100 million in LIHEAP emergency funds to states on the Atlantic seaboard, including \$3 million to Connecticut, \$9 million to New Jersey, and \$28 million to New York. For New York, this after-the-fact funding compares to the \$29.9 million in regular funds from USDOE and LIHEAP for the 1999 program (U.S. Department of Health and Human Services, 1999).

There would seem to be good reason to extend the weatherization program in northern urban areas to account for the growing threat of summer heat stress before these heat waves occur.

## **INFORMATION AND RESEARCH NEEDS**

The major conclusion of this review is that worsening summer heat waves will stress both people and energy systems. The most direct solution to protecting people is to provide air conditioning for everybody. To provide the electricity that would be needed, the power industry is responding, as it knows how: by building more generating units. A question for research is: how much will more local power under peak conditions increase the stress on energy distribution systems, contribute further to global warming, worsen local air pollution, and further raise the temperature of the urban heat island?

To break this cycle, the principal research need is how to promote means of cooling that can be widely used and that demand less or no energy: passive cooling of buildings and the community.

Some places are hotter than others; they can be identified with satellite imagery and aerial photography with computer enhancement. This information could be used to direct the extremely limited funding for weatherizing buildings and cooling the community to where it is most needed.

In an unregulated market, electricity prices may skyrocket in these hot spells. Mechanisms need to be found to prevent these costs from further burdening the low-income residents of the inner cities who suffer most from heat waves: the castaways on

the urban heat island. Even without such price increases, measures need to be strengthened to keep these people from dying from the heat.

## **POLICY RECOMMENDATIONS**

The gradual increase in summer cooling requirements in the Metropolitan East Coast region is straining the electric power industry's ability to meet increasing summer peak loads. This is evident in declining reserve margins and overstressed local distribution networks. The energy investments being made now will be with us for many decades to come. *The industry should take climate change into account now for better long-term solutions to providing electric power.*

As the climate warms, the industry can adapt through some combination of four solutions:

- Construction of local power plants to keep up with the rising demand
- Construction of additional transmission lines to bring more power into the metropolitan area
- Upgrading of local power lines that distribute electricity to customers
- More aggressive energy efficiency improvements, particularly to reduce summer peak electric loads.

The industry's present response to rising peak demand is to build additional power plants, especially within the metropolitan region. New high-efficiency plants will be used year round, but the old inefficient plants are likely to be retained for service under these peak conditions.

This cannot be regarded as a satisfactory long-term solution for several reasons. With summer peak loads 40 to 50 percent higher than winter peaks, the system is inherently inefficient and therefore costly because much of its capacity is idle most of the year. The older plants brought into service during summer peaks add to local air pollution at the worst possible time, add heat to the urban heat island, and add disproportionately to carbon dioxide emissions. Moreover, additional power adds to the stress on local distribution systems. Finally, simply generating more and more power adds to carbon dioxide emissions.

A portion of additional power to New York City can be provided with increased transmission capacity. This can be through the New York system, trading seasonally with sources to the north that have winter peak loads, or with stronger interconnections with the adjoining systems in New Jersey and Connecticut. Indeed, the promise of a wider electric power market through deregulation requires greater access to more sources. *The adequacy of transmission interconnections in the metropolitan region therefore needs to be assured.*

However, the adverse impact of climate change on the energy sector is not simply a matter for the electric utilities. It is the public that must reduce the demand for energy, and public policy must respond.

*The broadest solution must be to reduce the need for electricity through improved energy efficiency, primarily in commercial and residential buildings. The technologies for doing this are well established and continually improving. The policy options for improving energy efficiency and reducing energy use, identified earlier in this report, are well known. An important new element will be how the system benefit charges now collected from the electric distribution companies will be allocated by the states among research and development, low-income programs, and energy efficiency.*

Measures to adapt to climate change by reducing energy use will at the same time reduce greenhouse gas emissions. In the past several years, companies participating in voluntary energy reduction programs sponsored by the U.S. Environmental Protection Agency have found that these measures also save money. However, *stronger incentives are needed to achieve broader participation.*

The crux of the energy problem is the need for summer cooling, virtually all of which is now provided by electric air conditioning. Gas-fired air conditioning is a practical and economic alternative that would reduce peak electricity loads, but it would not decrease emissions. *Priority should be given to promoting passive means of cooling in buildings and in the community.*

Summer heat in New York City is higher than the surrounding suburbs because of the heat island effect. This situation can be partially relieved with extensive tree planting and the use of light-colored surfaces on roofs and pavements. *These measures are specified in the Cool Communities program of the Federal government, which should be aggressively promoted.*

As the climate in the Metropolitan East Coast region warms, access to cool air will become more necessary for some to survive summer heat waves. The victims of heat waves in the city are mainly older, infirm, poor people living on the top floors of old buildings without air conditioning. For those with air conditioning, deregulated electric rates are likely to increase sharply during heat waves, putting poor people at a further disadvantage. *The “weatherization” program that exists to save energy costs in housing for low-income people should be extended to provide summer cooling in urban areas as well as winter heating, and should be much more generously funded. This would save lives as well as energy.*

#### **BOX 1**

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##### **July 6, 1999 Power Failure**

The summer of 1999 brought unusually high temperatures and humidity to much of the eastern half of the United States. Many electrical systems set records for energy output during several extended heat waves. On July 6, the PJM Interconnection, which serves New Jersey and much of the Eastern seaboard, experienced a voltage drop by as much as 5 percent which lasted several hours. A blackout occurred in the Washington Heights section of Manhattan and parts of the Lower East Side and Long Island.

The low voltage in the PJM system occurred because demand exceeded supply. Demand was exceedingly high due to record usage of electricity resulting from high temperatures, high humidity, a strong economy,

and from increased transmission losses created by high transfer levels across the system. Electricity was supplied into PJM from sources as far away as Florida, the Midwest, and Canada. Nevertheless, supply was insufficient to meet the demand because some generators were unavailable or unable to meet their rated capability due to ambient conditions, and some capacitors were not in service (PJM Interconnection, 2000). By using a number of emergency procedures, however, PJM did not have to resort to system-wide rolling blackouts, and was able to supply emergency energy to the New York Power Pool (PJM Interconnection, 1999).

The New York Independent System Operator, a consortium of the state's electric utilities, requires that each of its members be able to deliver at least 18 percent more power than customers use at peak periods. On July 6, Con Edison for the first time fell below that standard, to 17 percent. The Long Island Power Authority had just a 10 percent cushion, and Public Service Electric and Gas in New Jersey came within 5 percent of its capacity (Perez-Pena, 1999).

Con Edison, with its power distribution system underground, has one of the lowest rates of power failure in the industry, and by far the lowest of any New York State utility, according to the New York State Public Service Commission. Nevertheless, blackouts have occurred in 1993 in Brooklyn and 1996 in Queens because "feeder cables" that supply communities become overheated as more energy is pushed through them and as the ground becomes hotter. In many cases, the cables were installed decades ago. Con Edison is installing new cables with greater capacity and better insulation, but company officials say that it will take years to replace them all (Perez-Pena, 1999).

Con Edison's decision to shut down the Washington Heights network resulted from a combination of factors stemming from record high electrical loads and heat, according to The New York Times. These caused a concentration of an unusually high number of component failures in the network, resulting in the outage of 8 of the 14 feeders in the Washington Heights network just prior to the shutdown. This culminated in a fire in the Sherman Creek substation which serves the Washington Heights network. The fire caused two additional feeders to be removed from service, which resulted in the decision to shut down the network (Con Edison, 1999).

With the shutdown, power was cut off to two of Columbia University's four laboratory buildings in Washington Heights when the university's backup generators were either not in place or failed. According to Columbia researchers, hundreds of experiments were destroyed or set back by months, and hundreds of thousands of dollars worth of enzymes and other chemicals were ruined when refrigerators lost power (Kennedy, 1999).

On April 10, 2000 a group of 100 small businessmen filed suit against Con Edison, joining 60 bodega owners and the City of New York in suing. To date, Con Edison has compensated 1,266 businesses up to \$2,000 each for losses during the blackout, but the businessmen say that they have not been adequately compensated (Barnes, 2000).

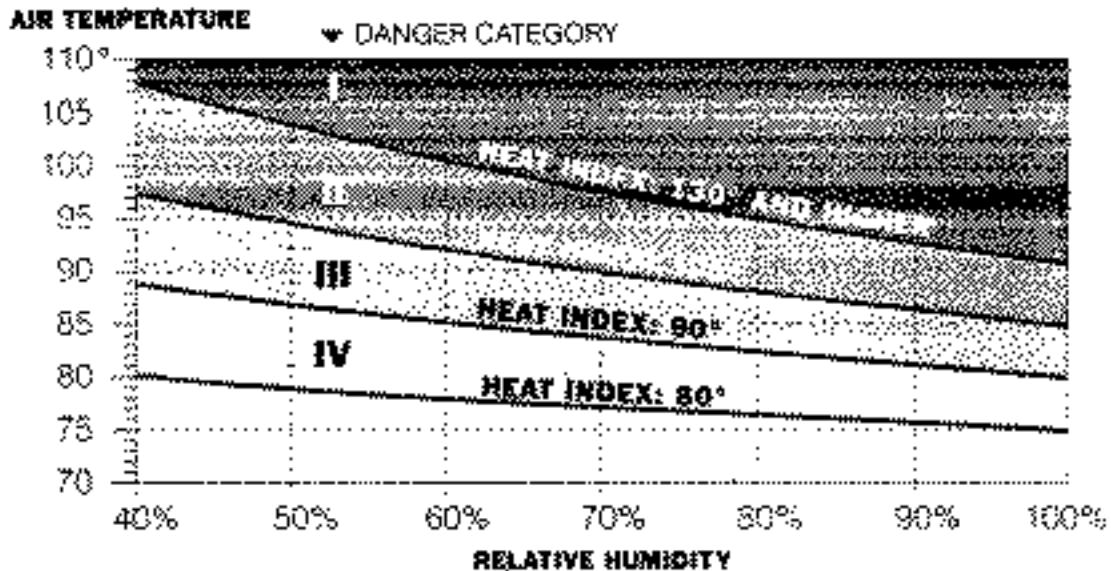
Investigations by the New York State attorney general and the Public Service Commission found that the Washington Heights network was maintained no differently than any other network (Barnes, 2000). Nevertheless, the perception persists among part of the public that the region was neglected because, except for Columbia, it is a low-income neighborhood.

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**END OF BOX 1**

## BOX 2

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The National Weather Service combines temperature and humidity to find the heat index – an “apparent temperature” measuring the discomfort of people during a heat wave. However, other factors – sunlight, wind and even body type – also affect the way one feels the heat.

Category I. Heatstroke (caused when the body loses its ability to cool itself during excessive exposure to high temperatures) and sunstroke (a form of heatstroke caused by excessive exposure to sun) highly likely with continued exposure.

Category II. Sunstroke, heat cramps, or heat exhaustion likely, and heatstroke possible with prolonged exposure and/or physical activity.

Category III. Sunstroke, heat cramps and heat exhaustion possible with prolonged exposure and/or physical activity.

Category IV. Fatigue possible with prolonged exposure and/or physical activity.

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**END OF BOX 2**

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