CHICAGO CLIMATE ACTION PLAN

CLIMATE CHANGE AND CHICAGO

PROJECTIONS AND POTENTIAL IMPACTS

CHAPTER SIX – INFRASTRUCTURE

11-07-2007

This research was commissioned by the Chicago Climate Task Force in the development of the Chicago Climate Action Plan. It does not represent official City of Chicago policy.

Convening Lead Authors

Katharine Hayhoe, Texas Tech University, ATMOS Research
Donald Wuebbles, University of Illinois at Urbana-Champaign

Chapter Lead Authors

Jessica Hellmann, University of Notre Dame (Ecosystems)
Barry Lesht, Argonne National Laboratory (Water)
Knute Nadelhoffer, University of Michigan (Ecosystems)

Contributing Authors

Max Aufhammer, University of California at Berkeley (Energy)
Keith Cherkauer, Purdue University (Water)
Thomas Croley II, NOAA Great Lakes Research Laboratory (Water)
Scott Greene, University of Oklahoma (Health)
Tracey Holloway, University of Wisconsin Madison (Air Quality)
Louis Iverson, United States Forest Service (Ecosystems)
Laurence Kalkstein, University of Miami (Health)
Jintai Lin, University of Illinois at Urbana-Champaign (Air Quality)
Momcilo Markus, Illinois State Water Survey (Water)
Stephen Matthews, United States Forest Service (Ecosystems)
Norman Miller, Lawrence Berkeley Laboratory (Climate, Energy)
Jonathan Patz, University of Wisconsin Madison (Health)
Matthew Peters, United States Forest Service (Ecosystems)
Anantha Prasad, United States Forest Service (Ecosystems)
Marilyn Ruiz, University of Illinois at Urbana-Champaign (Health)
Nicole Schlegel, University of California at Berkeley (Climate)
Scott Sheridan, Kent State University (Health)
Scott Spak, University of Wisconsin Madison (Air Quality)
Jeff Van Dorn, ATMOS Research (Climate, Water)
Steve Vavrus, University of Wisconsin Madison (Climate, Water)
Lew Ziska, USDA Agricultural Research Service (Ecosystems)

CHAPTER

Six

INFRASTRUCTURE

Extreme temperature and precipitation impacts on infrastructure and the economy

People often talk about the costs of reducing greenhouse gas emissions, forgetting that there also are costs of inaction. As the climate changes, the number of heavy rainfall events, heat waves, and floods in the Chicago area will increase. These events will impact the city's infrastructure as well as insurance premiums, tourism revenues and energy costs. According to research done by Oliver Wyman for the City of Chicago, over the century the aggregated costs of higher emissions could be as much as 3.5 times greater than those of lower emissions. The difference between the higher and lower emissions scenarios indicates there is a compelling advantage to pursuing activities that lead to lower emissions. Even partial success in minimizing climate effects could have a disproportionately large impact on reducing negative economic impacts on the City. The research presented in the Oliver Wyman report is summarized here.

Air Conditioning Costs

As the average temperature and number of extreme heat days increases, the cost to retrofit buildings with cooling capabilities, and the subsequent energy cost of cooling buildings will increase. By the end of the century, the number of days per year requiring air conditioning could double under the lower emissions scenario and triple under the higher emissions scenario. Annual energy costs are nearly fourteen times higher in the high emissions scenario than in low emissions scenario. Additionally, with more frequent, severe, and longer heat waves, energy demands will be greater, and could increase the likelihood of electricity shortages, leading to brown-outs or black-outs.

Higher Cost Maintenance for Roads, Transit and Emergency Vehicles

Road repairs and maintenance will double under the higher emissions scenario due to changes in planting and maintenance costs, road replacement and repair related to increased heat and more severe storms. Today the more adaptive materials needed for hotter and stormier weather cost 2.2 times more than traditional materials. Costs will rise for maintaining parking lots to manage flooding. Public bus-related maintenance costs will rise because of addition stress to the bus system caused by increased average temperatures. There will also be increased demand for cooling buses to provide heat relief for people during heat waves. It is also anticipated more workers will be absent due to extreme heat stress. Emergency vehicles such as fire engines, police cars, and ambulances will need to be replaced more rapidly due to heavier usage and wear.

Higher Building Capital and Maintenance Costs

Building infrastructure effects related to temperature include heating and cooling buildings and roof and façade repairs. These costs rise in the low and high emissions scenarios and for all time periods. Our research based upon just city buildings suggests the costs in the higher emissions scenario are ten times higher than in the lower emissions scenario. All non-cooled facilities will need retrofits so they can continue to be used in extreme heat. Roofs will have higher repair costs due to the sun breaking down petroleum-based roofing materials. Facades may also need more maintenance and repairs.

Building losses due to storm damage could be a much larger expense. The city of Chicago and the Park District hope to recoup $6.6 million through federal disaster relief that was spent by city government on overtime and material to clean up after the August 23-24, 2007 storm that damaged trees, homes and buildings, flooded basements, streets, and viaducts, and left thousands of Chicagoans without power.[1] In two days, State Farm Insurance Co. receive more than 7,144 home claims and more than 1,027 vehicle claims from Chicago area policy-holders whose property was the damaged in the storm.[2]

Higher Landscaping Costs

Landscaping costs related to maintenance of trees, plants, and flowers will increase as temperatures increase. This is due both to a longer blooming season and more required maintenance and replacement. Trees will have a shorter lifespan because of increase stress due to higher temperatures. These costs are projected to be 2 times higher for the Chicago Park District under the high emissions scenario than the low emissions scenario.

A More Stressed Police, Fire, and Medical Response System

A doubling in 90 degree days is estimated to result in 5-10% more fires in the Chicago area. The increase in extreme heat days would cause an increased run volume due to increased fires, power outages, well-being checks, and transportation to cooling facilities. The medical response system will be more stressed, which will cause a need for more ambulances and engines to be dispatched to provide necessary support. As hospitals become overwhelmed during heat waves, they may reject ambulances and send them to non-local hospitals, which also will raise costs and impacts the effectiveness of the emergency response system. It is estimated the total economic impact would be 2 times greater under the high emissions scenario than the low emissions scenario.

Police costs are also likely to rise with the heat. Police emergencies generally occur when Chicago hits the heat trigger of 98 or 99 degrees. Calls include electrical outages, loss of air conditioning in high-rise buildings and subsequent evacuations, and other heat related problems. Police also see more calls during extended heat waves. The Police Department also strains its resources during extreme storm events, which will be much more frequent in the high emissions scenario. Diverting police from crime fighting to weather emergencies also could hurt crime deterrence. It is estimated the high emissions scenario would be 4 times more costly than the low emissions scenario.

Higher Harbor Dredging Costs

The Chicago Park District could see harbor dredging costs that are twice as high under the higher emissions scenario than the lower emissions scenario. It also will experience higher costs for algae treatment due to increased temperatures.

Higher Business Costs for Absenteeism

People who work outside will be under increasing stress. Workers will be vulnerable to increasing heat stress and exacerbation of respiratory diseases.

Higher Property Insurance Costs

With gradual increases in temperature and precipitation, as well as events of extreme heat and rainfall, our researchers expect to see increasing insurance premiums for coverage applicable to weather-related events; potential exclusions for certain losses such as flooding, hail damage, or business disruption; and increased deductibles or risk sharing.

Reduced Summer Tourism

Chicago will have a longer summer, but under the higher emissions scenario, it will be a much hotter and more humid summer too. An increase in average temperatures will create a more uncomfortable climate. This is expected to lead to a decrease in the number of events held in Chicago because it will be harder to attract non-resident attendees.

Avoiding Negative Impacts of Inaction on the Chicago Economy

The Oliver Wyman research shows that there is a compelling economic advantage to pursuing activities that lead to a lower emissions scenario. As temperatures and extreme precipitation rise, so will the economic costs, which will be offset only in small part by savings due to warmer winters. We only have a complete cost estimate of the costs of climate change for City government, not for all of the people and businesses of Chicago. The costs just for City government are 3.7 times higher under the higher emissions scenario than under the lower emissions scenario. They are in the billions of dollars. The magnitude of the difference in impact indicates that there is a compelling advantage to pursuing activities that lead to a lower emissions scenario. Even partial success in minimizing climate effects will reduce the large negative impacts of climate change for all Chicagoans.

Shifts in energy demand for heating and cooling

Since 1980, U.S. electricity demand has increased by more than 75%, with the largest increases in the residential and commercial sectors for space heating and cooling. As extreme heat days become more frequent, electricity demand will continue to rise. A 2005 Government Accountability Office report[3] on meeting energy demand in the twenty-first century states that the United States accounts for 5% of the world's population, yet consumes 25% of the annual energy used worldwide. The GAO report concludes that due to the consumer choices of high consumption, all major fuel sources face environmental, economic, or other constraints or trade-offs in meeting projected demand. Clear and consistent policy is therefore needed to guide energy markets, suppliers, and consumers.

The nation's energy infrastructure, its refinery capacity, and electricity line transmission system have not adequately kept up with peak demand, and electricity supply shortfalls have resulted. Electricity generation and transmission deregulation have compounded these problems, as remote transmission and energy gaming have pushed electricity flow up to and beyond the capacity limit, often resulting in electricity supply failure. This has already occurred during extreme summer heat events over the last several years, most notably in the summer of 2003, when a system failure resulted in the largest blackout in U.S. history, leaving as many as 50 million people without power for several days.

In addition to increasing electricity demand, significant increases in the frequency, intensity, and duration of summertime extreme heat days are also projected due to climate change[4,5,6,7.] Extreme heat days are defined here as the 10% warmest days of the summer, calculated as 1961–1990 warmest days exceeding the 90% probability of the summertime daily maximum temperatures (T90) for a given location or region. The correlation between daily mean near-surface air temperature (Ta) and peak electricity demand during such T90 heat extremes suggests the potential for significant temperature-driven increases in future electricity demand for air conditioning[8]. Although this would be expected in the heavily air-conditioned South, such increases may also occur in northern cities. For example, the frequency of extreme heat and electricity demand for nine Canadian cities under a warmer climate based on a doubling in atmospheric levels of heat-trapping gases[9] suggests that a 3^{o}C increase in the daily maximum temperature would lead to a 7% increase in the standard deviation of current peak energy demand during the summer.

World demand for energy is approximately equivalent to a continuous power consumption of 13 trillion watts (i.e., 13 TW). With aggressive conservation and energy efficiency, an expected global population of 9 billion accompanied by rapid technology growth is projected to more than double energy demand to 30 TW by 2050 and to more than triple to 46 TW by 2099. The same Government Accounting Office report on meeting energy demand in the 21st century concludes that due to the consumer choices of high consumption, all major fuel sources face environmental, economic, or other constraints or trade-offs in meeting projected demand. Energy shortfalls are already occurring in China and other emerging economies, where the economic expansion has led to a surge in the adoption of household appliances, including air conditioners. If our economies continue on a high-energy consumption trajectory into the future, projected temperature increases over the coming century may further strain energy providers, resulting in electricity shortages and health and economic impacts.

To quantify the impacts of extreme heat days on peak electricity demand, the historical 1961–1990 maximum temperature exceedance threshold for the 10% warmest June through September (JJAS) days (averaging approximately 12 days per year over the historical period) is calculated and referred here as T90. The number of projected future JJAS days with maximum temperatures at or above the historical T90 values are then calculated. T90 values are an important metric used in energy capacity analyses, and are often described as the 1-in-10 JJAS high temperature days. In addition to the T90 values, JJAS cooling degree days (CDD) are also calculated, defined by the National Climatic Data Center[10] as CDD = (Ta - Tac)*days, where Ta is the daily mean near-surface air temperature, Tac = 65^{o}F (18^{o}C) is an average daily-mean temperature threshold for human thermal comfort, and days is the number of days with temperatures exceeding Tac. Intensity is simply the difference between Ta and Tac, but it can be further broken down into daytime (maximum) and nighttime (minimum) temperature intensities.

During the historical period (1961–1990), by definition T90 events occurred an average of just over 36 times per year, 36 being equal to 10% of the total number of days per year. Using the T90 threshold defined by the historical 90th percentile temperature threshold, the number of days projected to exceed this threshold in the future were then evaluated.

As average temperatures rise, the historical T90 threshold will be exceeded more frequently. Moreover, T90 events are expected to be more intense (i.e., hotter), last longer, and occur earlier in the season relative to the 1961–1990 reference period. As early as mid-century, the total number of T90 days is projected to *double* relative to a historical mean under the higher emission scenario and increase by more than 50% under the lower. By the end of the century (2070–2099), the number of T90 days are projected to increase an average of two times under the lower emissions scenario and more than three times under the higher (Figure 6.1). Similarly, annual CDD values for a 18^{o}C (65^{o}F) mean temperature threshold currently average about 900^{o}C-days per year for the period 1961–

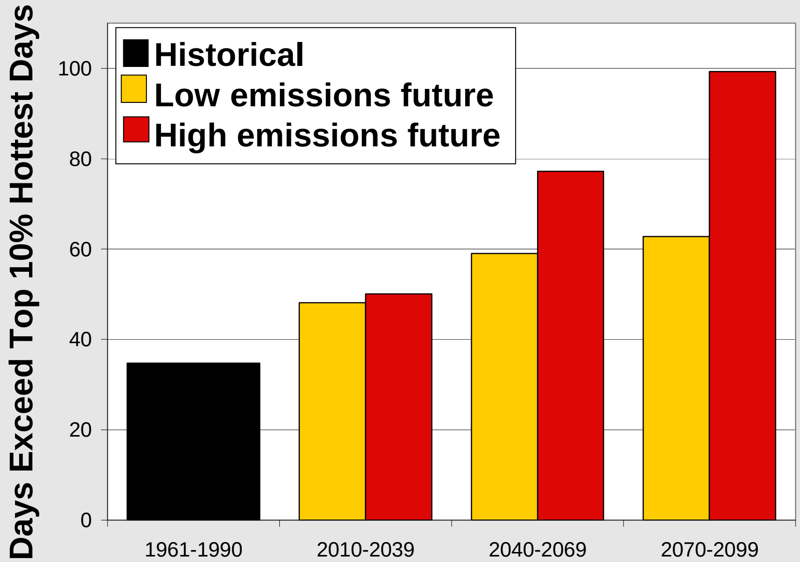

Figure 6.1. Projected average number of JJAS T90 days per year. Values are shown for the SRES A1fi (higher, red) and B1 (lower, yellow) emission scenarios.

1990. These are projected to increase to over 1400°C-days by end-of-century under lower emissions and 2200°C-days per year under higher (Figure 6.2).

Projected increases in extreme temperatures characterized by a T90 threshold, cooling degree days, and direct estimates of electricity demand all suggest that electricity demand is likely to continue to rise over this century. Although Chicago's installed electricity capacity will also continue to grow over time, its current rates of growth suggest frequent summer electricity shortages may occur by the end of this century, when all model/scenario combinations indicate an increase in region-wide extreme temperature conditions of a severity associated with electricity shortages under the current configuration of the electric power system and patterns of demand.

Some measure of the adaptive potential for reducing projected increases in CDD and the subsequent rise in residential and commercial electricity demand can be obtained through comparing projected increases in CDD values calculated based on the standard 65°F (18°C) threshold with CDD values calculated using a higher threshold of 75°F (24°C). Raising the CDD threshold by 10°F through more efficient cooling with fans and ventilation would greatly reduce the projected increase in CDD values and related electricity demand (Figure 6.3). This simplified assumption suggests potential savings through adaptation.

Considering that significantly higher CDD values and related electricity demand result from higher (as compared with lower) emission scenarios, and that most affordable near-term options for increasing electricity supply via fossil fuels also involve simultaneous increases in GHG emissions, these estimates of adaptation potential have important implications for decision making at the city and state level.

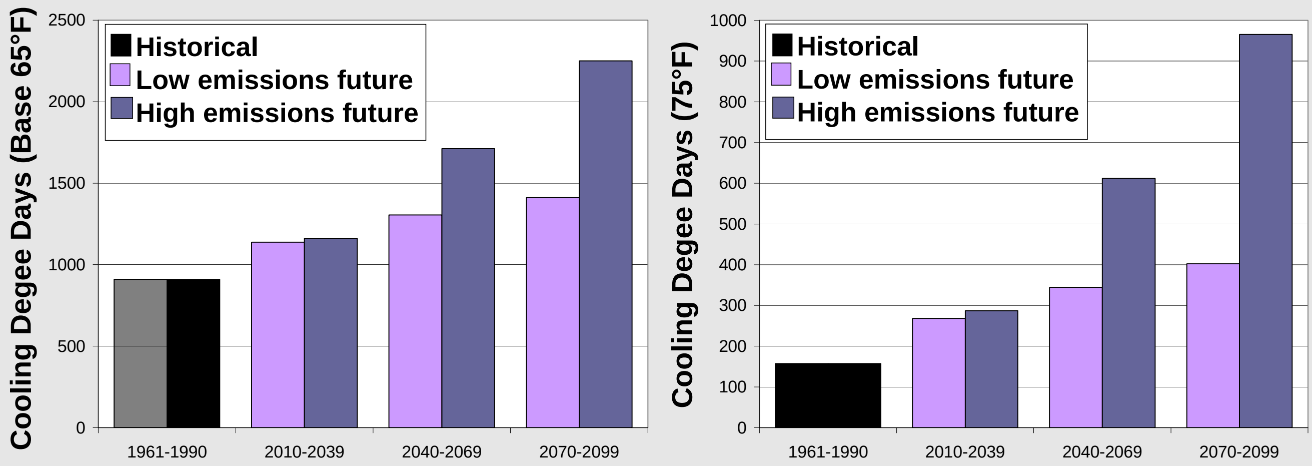

Figure 6.2. Projected average cooling degree days for Chicago using a threshold of (a) 65°F and (b) 75°F. Values are shown for the higher (dark purple) and lower (light purple) emission scenarios as simulated by the three climate models used in this analysis, downscaled to the Chicago University, Midway and O'Hare weather stations.

Understanding the relationship between temperature and hourly electricity demand is important, in order to be able to examine the impact of climate change on both annual electricity demand as well as peak load. The highly non-linear relationship between electricity demand and temperature has been shown to reflect increasing electricity consumption at the lower and higher temperature extremes. Humans respond to extreme cold and heat induced discomfort and health risks by heating or cooling. For this report, we have examined the correlation between hourly reported electricity load and average hourly temperature for Commonwealth Edison.

Commonwealth Edison, ComEd, is a unit of Exelon Corporation, one of the nation's largest electric utilities with a customer base of 5.2 million. ComEd maintains more than 78,000 miles of power lines that make up the electric transmission and distribution system in Northern Illinois. Further, it also provides customer operations for more than 3.7 million customers across the region, or 70 percent of the state's population. Commonwealth Edison's service territory borders Iroquois County to the south, the Wisconsin border to the north, the Iowa border to the west and the Indiana border to the east.

We use hourly electricity load data as reported on FERC Form 714 from 1993 until 2004 combined with average temperature across three hourly temperature monitors in the ComEd service territory. We extract the impact of temperature on load, by statistically separating out the impacts of factors, which also affects

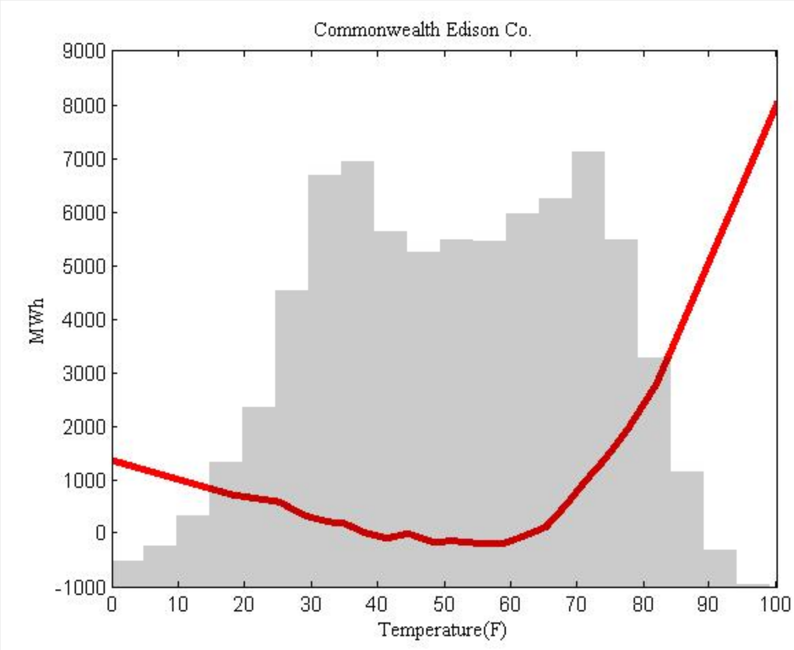

Figure 6.3. Estimated Load-Temperature relationship, using 20 knot spline function. The red line depicts the increase in hourly load due to one period spent at each ambient temperature. The grey histogram displays the distribution of 3-hourly average temperature over the sample period, excluding weekends.

loads and vary across the hours of the day, days of the week and seasons. Figure xx displays the estimated relationship between hourly temperature and hourly electricity load for ComEd, which displays the classic U-shaped temperature electricity load relationship.

The figure displays the drastic increases in electricity load at high temperatures. One hour at an average ambient temperatureof approximately 90 degrees is likely to result in a 8,000 MW higher load than an equivalent hour at approximately 55 degrees. Climate change will affect electricity consumption two ways. First, by shifting the mean of the temperature distribution to the right, annual consumption will increase. But maybe more importantly, by increasing the mean and standard deviation of the temperature distribution, peak events will occur more frequently and peak demand will increase.

In order to simulate what annual electricity consumption will be throughout the coming century, we linked the estimated relationship shown in figure xx to a climate model, which provides predictions at three-hourly intervals. We forced the PCM by the National Center of Atmospheric Research in Boulder using the SRES A1f1 scenario to obtain predicted annual demand as well as peak demand for the periods 2021-2040, 2041-2060, 2061-2080 and 2081 – 2100. Figure xxxx below shows the predicted increase in annual consumption relative to the 2000-2005 period for the four future periods.

This simulation has held constant the size and composition of the population, as well as frozen income, industrial production and technology at current levels. Uncertainty over changes in any of these factors may dominate uncertainty over

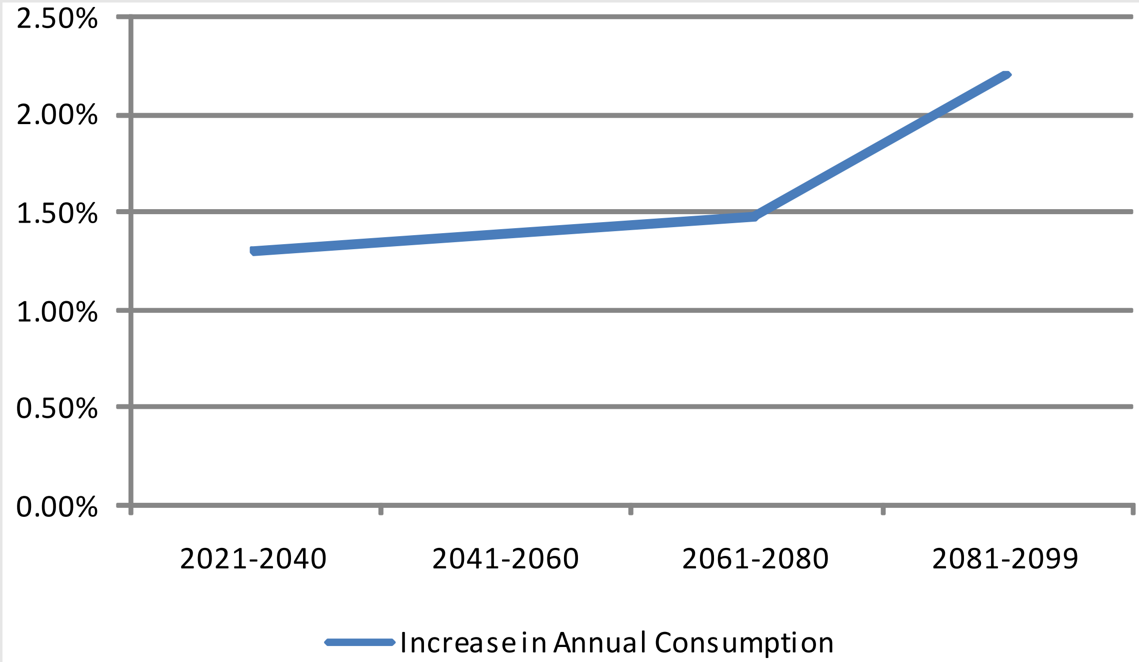

Figure 6.4. Simulated Increases in Annual ComEd Territory Electricity Consumption over 2000-05 consumption using the NCAR PCM forced by the SRES A1f1 scenario

changes in electricity consumption due to climate change induced higher temperatures. This simulation may underestimate the impacts of climate change, if people start changing their behavior from their current habits in order to offset some of the negative impacts of climate change. Increased adoption of air conditioning and increased frequency of existing air conditioner use may lead to additional increases in electricity consumption.

In the opposite direction, warmer winters are likely to result in lower heating requirements. While the overall predicted effect in electricity consumption from decreased heating requirements and increased cooling requirements is predicted to increase aggregate electricity consumption, other sources of energy may experience a drop in demand. Natural gas and heating oil are sources of energy, which would likely see a decrease in use, since they are mainly used for heating, especially in the case of heating oil. Further, adoption of more efficient cooling technology, both voluntarily and induced through appliance standards may decrease the total amount of electricity used, both at peak times and overall. Finally conservation programs similar to California's Flex Your Power programs may offset some of the predicted increases in consumption.

Annual aggregate demand is simulated to increase by 1.30% initially but up to 2.19% by the end of the century. Table xxx displays the increase in 99th and 99.9th percentile 3hour heat periods for each of the four periods. The number of extreme heat 3-hor events is predicted to increase by 258% for 99th percentile periods and up to 685% for the 99.9th percentile events by the end of the century. This increase in the predicted frequency of extreme heat goes hand in hand with occurrences of extreme electricity demand.

All indicators point to increases in summer electricity demand, even when confounding factors such as increased population and market saturation of air conditioning are disregarded. Through calculation of projected increases in extreme heat and electricity demand, the difference in potential impacts resulting from lower and higher emissions scenarios can be quantified. Model uncertainties notwithstanding, extreme heat and associated human health risks and electricity demands under the B1 lower emissions scenario are significantly lower than those projected to occur under the A2 and A1fi higher scenarios. Calculations of electricity demand under a range of human comfort levels also highlight the potential for adaptation to play a major role.

Increasing concerns regarding increases in peak electricity demand is the fact that many common energy-savings strategies for cooling (e.g. passive strategies such as natural ventilation, night cooling, etc.) work best in Chicago's spring and autumn seasons, but not so well at the peak of summer heat. Increase in extreme summer heat events will further reduce the hours that these strategies are useful. Moreover, these strategies don't contribute to peak demand reduction, as more traditional air conditioning is typically required during peak demand.

To respond to this concern, Chicago needs to more seriously evaluate both utility-scale and building-scale cooling strategies that avoid heat rejection to the atmosphere. Alternative cooling methods such as lake-source and ground-source colling wouldl both dramatically increase the energy efficiency of cooling, while avoiding even further increase of local ambient temperatures during peak cooling events. Although there are many building-scale examples of the latter currently, there are not any current examples of lake-source cooling, which is most effective as a utility-scale solution.

Percentile	1990-2000	2021-2040	2041-2060	2061-2080	2081-2099
99.9th	2.00	10.60	9.10	10.35	15.70
99th	20.82	51.10	52.65	57.40	74.60

Table 6.1. Number of extreme heat 3-hour periods relative to 1990-2000 period (weekdays only). These are simulated for grids covering ComEd's service territory using NCAR's PCM forces by the SRES A1f1 scenario

Alternative technologies such as solar photovoltaic electricity generation represent an important future technology for this region, with electricity production being proportional to solar radiation and thus closely matching summer peak electricity demand[11]. Technologies such as these have the potential to reduce the cost associated with increased demand for cooling under a warmer climate without increasing emissions of GHGs that are causing the problem in the first place.

In conclusion, the influence of climate change on extreme heat and electricity demand is likely to challenge current-day providers, spur conservation and adaptation measures, and raise questions regarding the potential for mitigation to reduce projected increases through following a lower emissions pathway worldwide.

[1] Fran Spielman, Storm Cleanup Costs City $6.6 Million; But Chicago Hopes to Recoup, Chicago Sun-Times, Sept 18, 2007

[2]

[3] Government Accountability Office (GAO). 2005. Meeting energy demand in the 21st century. GAO□05□414T, 34 pp. www.gao.gov

[4] Hayhoe, K., D. Cayan, C. B. Field, P. C. Frumhoff , E. P. Maurer, N. L. Miller, S. C. Moser, S. H. Schneider, K. Nicholas Cahill, E. E. Cleland, L. Dale, R. Drapek, R. M. Hanemann, L. S. Kalkstein, J. Lenihan, C. K. Lunch, R. P. Neilson, S. C. Sheridan, and J. H. Verville. 2004. "Emissions pathways, climate change, and impacts on California." Proc. Natl. Acad. Sci. 101: 12422–12427.

[5] Tebaldi, C., K. Hayhoe, J. Arblaster, and J. Meehl. 2006. "Going to the extremes: An intercomparison of model□simulated historical and future changes in extreme events." Climatic Change 10.1007/s10584□006□9051□4.

[6] Miller, N. L., and K. Hayhoe. 2006. Emissions scenario□based analysis of projected extreme heat
and energy costs in California, Forum on Risks and Impacts on Society, 86th Annual AMS Meeting, 29 January–2 February 2006, Atlanta, Georgia.

[7] Alley, R. et al. 2007. Climate Change 2007: The Physical Science Basis: Summary for Policymakers.
Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 21pp. Available online at: http://www.ipcc.ch/SPM2feb07.pdf.

[8] Belzer et al. 1996; Amato et al. 2005; Mendelsohn and Neumann 1999; Rosenthal and Gruenspecht 1995; Henley and Peirson 1998; Cartalis et al. 2001; Valor et al. 2001

[9] Colombo, A. F., D. Etkin, and B. W. Karney. 1999. "Climatic variability and the frequency of
extreme temperature events for nine sites across Canada." J. Climate 12: 2490–2502.

[10] Owenby, J., R. Heim, M. Burgin, and D. Ezell. 2005. Climatology of the U.S. No. 81 □ Supplement
3, Maps of Annual 1961–1990 Normal Temperature, Precipitation and Degree Days, Online Document Library,
http://www.ncdc.noaa.gov/oa/documentlibrary/clim81supp3/clim81.html.

[11] Borenstein, S. 2005. Valuing the Time□Varying Electricity Production of Solar Photovoltaic Cells.
University of California Energy Institute Working Paper 142 (CSEM WP□142).