Chapter 10

Telecommunications

Authors: Klaus Jacob,[1] Nicholas Maxemchuk,[2] George Deodatis,[2] Aurelie Morla,[2] Ellen Schlossberg,[2] Imin Paung,[2] Madeleine Lopeman,[2] Radley Horton,[4] Daniel Bader,[4] Robin Leichenko,[3] Peter Vancura,[3] and Yehuda Klein[5]

[1] Sector Lead (formerly at Columbia University)
[2] Columbia University
[3] Rutgers University, Department of Geography
[4] Columbia University Earth Institute, Center for Climate Systems Research
[5] City University of New York, Brooklyn College, Department of Economics

Contents

Introduction

The telecommunications and broadcasting industries are vital elements of New York State's economy. Their combined direct economic contributions to the state's gross domestic product are on the order of $44 billion.[1] Telecommunications capacity and reliability are essential to the effective functioning of global commerce and of the state's main economic drivers, including the finance, insurance, information, entertainment, health, education, transportation, tourism, and service-based industries. It is essential to the daily life of every business, farmer, and citizen across the state, from rural to urban regions, and is especially vital during emergencies. Reduction in communication capacity for an extended period results in commercial and economic losses. This is a critical concern especially in the financial-service markets concentrated in and around the New York City area (The New York City Partnership, 1990).

The communications industry, perhaps more than any other sector, has undergone and continues to undergo a perpetual rapid technological revolution. It has experienced major deregulation and institutional diversification and functions in a state of fierce internal competition. In large part due to rapid technological changes, the planning horizons and lifespans for much of its infrastructure are at best on the order of a decade. This is a very short time horizon relative to the significant climate changes taking place over the scale of multiple decades to centuries. It is also short compared to that for other sectors, for example the public transportation sector, in which some rights of way, bridges, and tunnels have useful lifespans of 100 years or more. That is not to say that some parts of the communication infrastructure cannot be quite old. There are oilpaper-wrapped copper cables hung from poles or in the ground in some places, including New York City, many of which are older than 50 years.

The rapid technological turnover of communication infrastructure versus the pace of climate change gives rise to several inferences and issues:

In the context of the industry's vulnerability to weather and climate, it is essential to focus on its present vulnerability and to ensure its resilience vis-à-vis extreme weather events (and power failures) to provide the highest possible standard for continuity and uninterrupted service under extreme conditions. This, however, depends on the extent to which the market is willing to pay for such reliability and/or the extent to which the State and society at large demand and support higher reliability, including resilience to extreme events. The key questions are: What is the tolerable balance between reliability and cost? And who will bear the costs?

If service reliability and continuity are achievable at an acceptable cost for current weather extremes and if service disruptions can be better decoupled from electric grid power failures, there is good reason to expect that the industry could maintain high reliability vis-à-vis the additional hazards caused by climate change and be able to adapt to such changes with the help of new technologies.

Therefore, unlike many of the other sectors in the ClimAID report, addressing future climate change is arguably less important than addressing the communication industry's vulnerability to the current climate extremes. Additional hazards are expected from climate change in the sense that the frequency and severity of some extreme events are more likely to increase than not. Such events include excessive wind and lake effect snow in the coming decades, bringing down power and communication lines and even some wireless facilities. Some recent events have caused extensive and prolonged service failures with substantial economic and social impacts. Also, where centralized communications infrastructure is located at low elevations near the coast or near rivers and urban flood zones, climate change will pose additional risks that need to be managed comprehensively (see Chapter 5, "Coastal Zones," and Chapter 4, "Water Resources"). The areas at risk of flooding are expected to become larger, increasing the extent of flood zones as well as extending to higher elevations at the currently designated flood zones. In other words, the risk will increase in frequency and severity because of sea level rise and more extreme precipitation events. But these additional climate-change-induced risks are likely to be manageable in the future if currently existing vulnerabilities can be reduced.

There are a number of factors that make reducing vulnerability to extreme climate events challenging, including the following:

- The industry is experiencing strong internal competition and market pressures, which tend to limit redundancy to what dynamic free markets and profit motives are willing to pay for—on both the customer's and service provider's side. Market pressures and the short lifespan of certain telecom technologies result in an industry tendency to replace infrastructure as it becomes damaged, rather than to "harden" existing facilities. This would appear to be a reasonable response to lesser climate threats but it leaves critical components of the network vulnerable to rare but catastrophic events.
- Regulation and related mandatory reporting of service outages are limited and unequal among the different service modes and technologies.
- Customers have little accessible data to make choices based on reliability and built-in redundancy of services; instead, decisions are based largely on convenience, accessibility, marketing, and price.

Reducing current vulnerability while these factors prevail requires balance of policies between providing incentives to and regulation of the telecommunications industry. It can be argued whether it is valid to compare the risk-taking and aversion to regulation that has prevailed in the financial services sector to that of the technology-intensive communications sector. But such a comparative assessment may yield insight into changes to both business and public governance and policies that can guarantee the industry's reliable and continuous delivery of services—even during external shocks from climate-related (and other) extreme events. This could be for the benefit of the sustained economic health of the industry itself as well as of its customers and society at large.

A focus of the telecommunications infrastructure sector—including that of the service providers, the government, and the customer—is on how to ensure that the ongoing introduction of new technologies enhances the reliability and uninterrupted access to services, rather than degrading the reliability of these services. Such a focus is essential both now and in the future, when the impacts from climate change may increase.

The ClimAID telecommunications sector research team interacted with stakeholders from industry and government. A description of this process and the list of stakeholders are contained in Appendix A.

10.1 Sector Description

Telecommunications is one of the fundamental infrastructure systems on which any modern society depends. Its technological sophistication, availability, accessibility, broadband capacity, redundancy, security, and reliability of services for the private and public sectors are telling indicators of a region's economic development and internal social equity.

According to a report by the Federal Communications Commission (2009), the penetration rate for telephone service (land and cell combined) for all New York households was 91.4 percent in 1984, 96.1 percent in 2000 and 93.7 percent in 2008. Nationwide, the penetration rate was 95.2 percent in 2008, 1.5 percent higher than that of New York State. Demographic factors and level of aid to low-income households contribute to the differences in telephone service penetration among states. There is also considerable variance for income groups around the average of 93.7 percent within New York State.

At present, the telecommunications infrastructure sector comprises point-to-point public switched telephone service; networked computer (Internet) services, including voice over Internet protocol (VoIP), with information flow guided by software-controlled protocols; designated broadband data services; cable TV; satellite TV; wireless phone services; wireless broadcasting (radio, TV); and public wireless communication (e.g., government, first responders, special data transmissions) on reserved radio frequency bands.

The various domains are highly interconnected, overlapping, and networked. The boundaries between the different media are fluid and shift rapidly, often in concert with changes in technologies. Increasingly, the boundaries between technology providers versus content providers are also in flux.

Ongoing telecommunications innovations include the transition from analog to digital communication, introduction of networked computers, the Internet, broadband services, satellites, fiber optics, and the rapid expansion of wireless communication (including mobile phones and hand-held devices). Fourth-generation (4G) wireless technologies, such as Long Term Evolution (LTE) and WiMAX (Worldwide Interoperability for Microwave Access), provide an advanced IP-based

(Internet protocol) wireless platform for telephony, broadband Internet access, and multimedia services. These are some of the technologies that have transformed telecommunications in the last few decades. Some of these technologies have the potential to expand wireless voice and broadband coverage in unserved and underserved areas of the state.

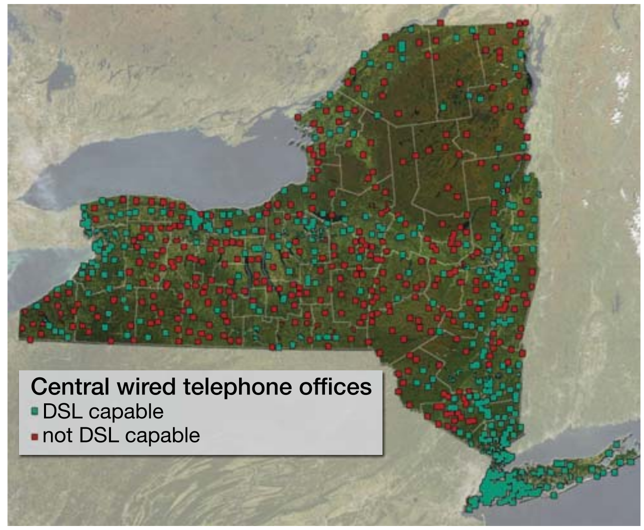
In concert with technology, the institutional landscape of the industry has changed radically. Telecommunications giants, operating as regulated utilities with quasi-monopolies, were broken up in the United States in the mid-1980s to foster competition and innovation. The breakup was paired with considerable deregulation fostering robust intermodal competition followed by more deregulation. Among all types of service infrastructure on which society has come to rely, the telecommunications industry is almost entirely privately owned. It functions more competitively than most basic services that require large infrastructure, including electric power distribution (but not generation), transportation, and water and waste.

10.1.1 Economic Value

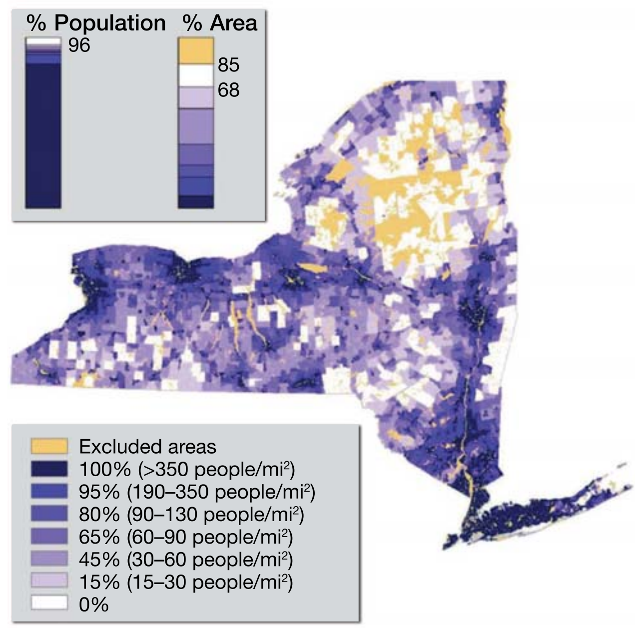
Telecommunications is an important sector in New York State's economy. Its total annual revenues contribute some $20 billion to the state's economy, about 2 percent of New York's entire gross state product of about $1.1 trillion (2007 dollars). Telecommunications is critical to the success of many of New York's largest industries and to many of the industries that will drive the state's growth in the future. New York City's status as a global financial center, for example, is heavily dependent on the capacity and reliability of its telecommunications networks. The New York Clearing House processes as many as 26 million financial transactions per day, at an average value of $1.5 trillion per day, for 1,600 financial institutions in the United States and around the world (NYCEDC et al., 2005).

10.1.2 Non-Climate Stressors

Not all areas of New York State have equal access to broadband wire services. **Figure 10.1** (top) shows a map of central offices (where subscriber lines are connected on a local loop), differentiating between those that are DSL-capable (digital subscriber line) and those that are not. **Figure 10.1** (bottom) shows the cable-modem availability for 2009 as determined by the New York State Office of Cyber Security and Critical Infrastructure Coordination (CSCIC). Note that these are CSCIC's own projections and not based on data provided by service providers.[2]



Distribution in 2010 of central offices for wired telephone in New York State. Those in green are capable of providing digital subscriber lines (DSL, 2009). Source: http://www.dslreports.com/comap/st/NY; basemap NASA



Source: Redrawn from NYS GIS, 2009

Figure 10.1 Distribution of central offices for landline telephone in New York State, 2010 (top); Predicted cable modem broadband availability, 2009 (bottom)

The Federal Communications Commission (FCC) has oversight of the industry on the federal level, and the New York State Public Service Commission (PSC) exercises oversight on the state level. The stated mission of the PSC is "to ensure safe, secure, and reliable access to electric, gas, steam, telecommunications, and water services for New York State's residential and business consumers, at just and reasonable rates. The Department seeks to stimulate innovation, strategic infrastructure investment, consumer awareness, competitive markets where feasible, and the use of resources in an efficient and environmentally sound manner."[3]

This mission implies that part of the Public Service Commission's role is to see to it that the telecommunications industry adapts to climate change, as the latter poses new challenges to maintaining "safe, secure, and reliable access to telecommunications … at just and reasonable rates." The PSC mission has always included oversight for reliability and continuity of telecommunications services related to natural or man-made events. Climate change adds more urgency to this ongoing mission.

The increased competition that has evolved since diversification and deregulation in the mid-1980s has had consequences for how the industry as a whole (albeit not all of its components) tends to plan and operate. Although redundancies tend to be inefficient most of the time, in emergencies they serve to provide alternative means of communication and much-needed extra capacity. It is in this context that climate change poses new challenges, in addition to those the industry is facing already (e.g., cyber security).

Apart from the commercial communications sector, there are other entities within the state that operate communication systems. For instance, public operators (e.g., police, emergency services, first responders, public safety agencies) communicate internally using mobile and handheld devices, either via trunking systems with multiple channels or via designated channels and reserved bands across the VHF and UHF radio spectrum. In trunking systems, only a small percentage of the users are expected to be active on the network at any given time. In the near future, public safety answering points (PSAPs), which receive and dispatch 911 calls, will need to upgrade their equipment to handle next generation 911 (NG911) calls that accommodate the transmission of wireless information enhanced with text, graphics, and video. Because the county PSAPs in New York operate independently, it is likely that NG911 will not be deployed uniformly across the state.

New York State has made an attempt to build the $2-billion New York State Statewide Wireless Interoperable Communications Network, which was originally commissioned in 2004. This centralized plan was cancelled in its originally designed form in January 2009 because tests showed unreliable performance.[4] The new version of a statewide interoperable network will rely more on existing and planned county and city communications networks in order to achieve operational interagency communications on the local, city, county, state, and federal levels. The difficulties of multiple services not being able to communicate effectively with each other during emergencies has been a long-standing problem, and the new cooperative efforts on the federal, state, and local levels through this state-guided program are aimed at overcoming these problems.[5]

10.2 Climate Hazards

The climate hazards and their expected changes for the various regions of New York State are described in detail in Chapter 1, "Climate Risks." We summarize here briefly some key features of these hazards relevant to the Telecommunications sector. Examples of extreme weather events and their impact on telecommunications are presented in Section 10.3 (Vulnerabilities).

10.2.1 Temperature

ClimAID projections for the number extreme hot days per year show that the number of these events is expected to increase as this century progresses. In addition to more frequent hot days, the frequency and duration of heat waves, defined as three or more consecutive days with maximum temperatures above 90°F, are also expected to increase. In contrast, cold temperature extremes, such as the number of days per year with minimum temperatures below 32°F, are projected to become less frequent. The extreme event temperature projections shown in Table 1.8 of Chapter 1 are based on observed data from stations within each climate region. Because the higher latitude zones of each region experience a cooler baseline climate, they will probably experience fewer future heat events than those shown in the tables.

10.2.2 Precipitation

ClimAID projections for annual precipitation are for a relatively small increase through the century. However, larger percentage increases are projected in the frequency, intensity, and duration of extreme precipitation events at daily timescales. Extreme precipitation events are defined here as days with greater than 1, 2, and 4 inches of precipitation. This ClimAID projection is consistent both with theory and observed trends nationally over the last century. Intense precipitation may cause more street and river flooding and may affect low-lying infrastructure, if it is not well protected. Drought is of little consequence for telecommunications infrastructure.

10.2.3 Sea Level Rise, Coastal Floods, and Storms

Coastal flooding associated with storms is very likely to increase in intensity, frequency, and duration as sea levels rise. Changes solely in sea level rise will cause a change in coastal flood intensity, as shown in Table 5.4 (Chapter 5). More frequent future flood occurrences relative to the current 10-year and 100-year coastal flood events would occur with any increase in the frequency or intensity of the storms themselves. By the end of this century, sea level rise alone suggests that coastal flood levels, which currently occur on average once per decade, may occur once every one to three years (see Chapter 1, "Climate Risks," and Chapter 5, "Coastal Zones").

The more severe current 100-year flooding event is less well characterized than the 10-year event, because there is the possibility that the flood height may vary on century timescales. Due to sea level rise alone, the 100-year flood event may occur approximately four times as often by the end of the century. The current 500-year flood height is even less, since the historical record is shorter than 500 years. By the end of the 2100s, the 500-year flood event is projected to occur approximately once every 200 years (see Chapter 5, "Coastal Zones").

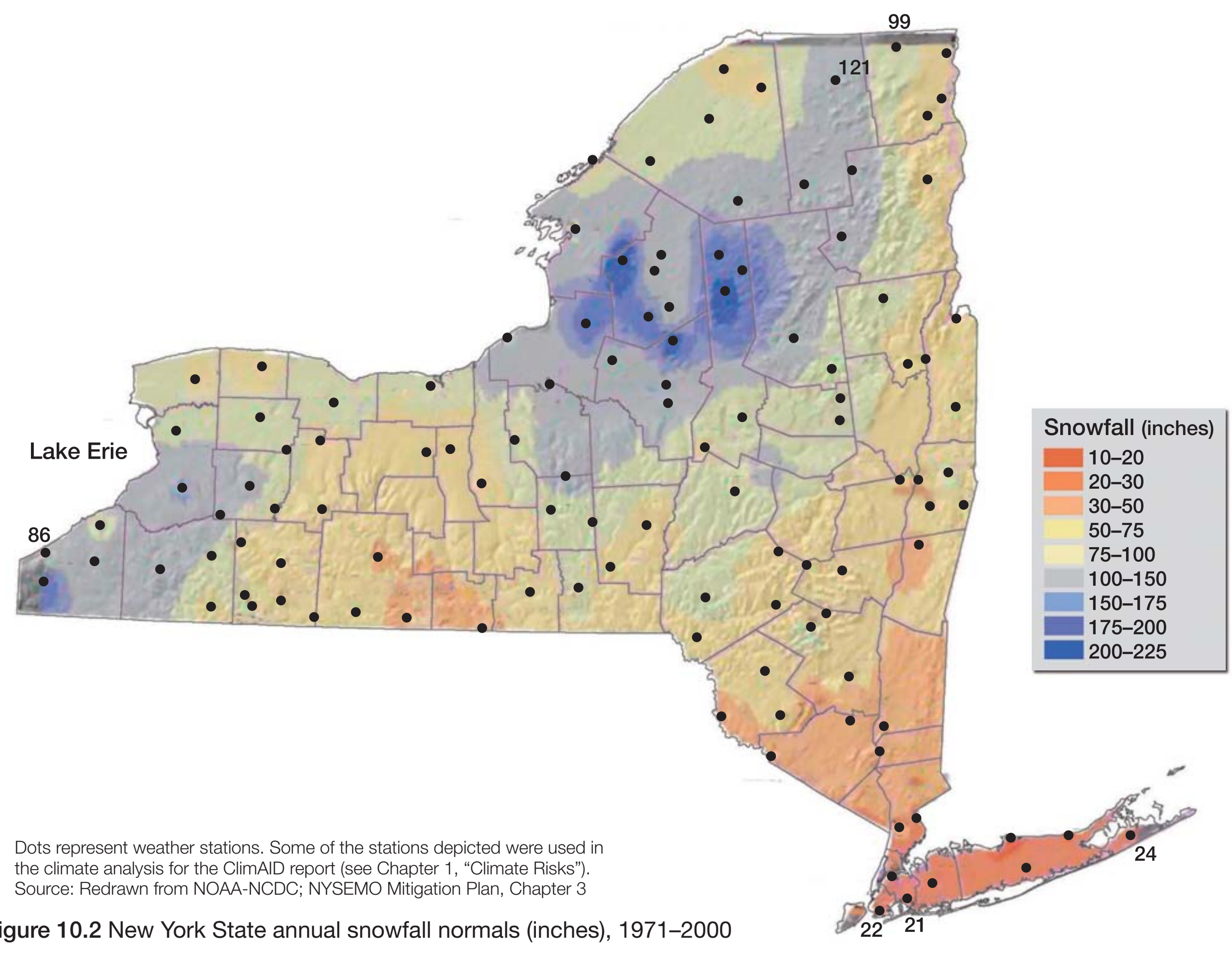


Figure 10.2 New York State annual snowfall normals (inches), 1971–2000

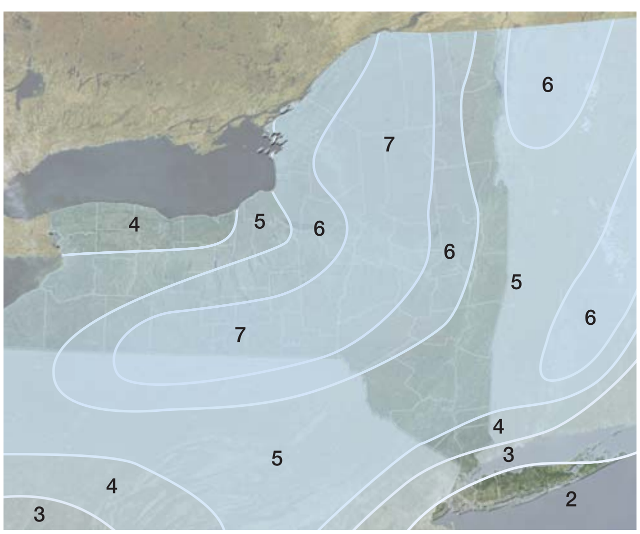
10.2.4 Other Extreme Events

For some types of extreme climate events that may have a large impact on telecommunications infrastructure, future climate changes are too uncertain at local scales to allow quantitative projections. In these cases, ClimAID provides qualitative information. These largely storm-related events include:

- frozen precipitation (snow, ice, and freezing rain);
- large-scale storms (tropical storms/hurricanes and nor'easters) and associated extreme winds;
- intense precipitation of short duration (downpours of less than one day); and
- lightning.

Snowfall

Snowfall is likely to become less frequent for much of the state in the coming decades, with the snow season decreasing in length. However, the coldest areas and the areas directly downwind of the Great Lakes may experience more snowfall due to greater moisture availability during the cold season when the lakes are not covered as much by ice as they once were. **Figure 10.2** shows the annual snowfall normals for New York State, with the highest accumulations in the Adirondacks (exceeding 200 inches per year), and in western New York. The lake effect on snow accumulations is clearly visible on the eastern shores of both Lake Erie and Lake Ontario.



Source: Redrawn from Changnon and Karl, 2003; basemap NASA

Figure 10.3 Contours of the average number of days per year with freezing rain for the 1948–2000 period

Ice Storms and Freezing Rain

Ice storms and freezing rain have disproportionate effects on communication infrastructure and on society at large. During the 52-year period from 1949 to 2000, freezing rain caused more than $16.3 billion in total property losses in the United States (Changnon, 2003).

New York has the highest average occurrence of ice storms of all the lower-48 U.S. states (Changnon and Karl, 2003). **Figure 10.3** shows the contours for the average number of days per year with freezing rain, based on data for the 1948–2000 period. There are, on average, seven days per year of freezing rain conditions in a curved band from western through central to northeastern New York. The number of days with freezing rain per year trails off to lower values (around five days per year of freezing rain) toward Lake Ontario. Even fewer days with freezing rain (two to three days) are observed toward New York's Atlantic coast.

Hurricanes

Hurricanes are a form of tropical cyclone. They need warm ocean surface temperatures to gain strength, and they diminish in power when they move over colder oceanwater or over land, becoming tropical storms or tropical depressions. ClimAID projects that intense hurricanes and associated extreme wind events are more likely than not to become more frequent due to expected warming of the upper ocean in the tropical cyclone genesis regions (where storms, including hurricanes, form). However, because changes in other critical factors for tropical cyclones are not well known, there is the possibility that intense hurricanes and their extreme winds will not become more frequent or intense. It is also unknown whether the most probable tracks or trajectories of hurricanes and intense hurricanes may change in the future.

Downpours and Other Events

Downpours—defined as intense precipitation at sub-daily, but often sub-hourly, timescales—are likely to increase in frequency and intensity. Changes in nor'easters and lightning storms are currently too uncertain to support even qualitative statements.

10.3 Vulnerabilities and Opportunities

The following provides examples of specific extreme weather events that have affected telecommunications, illustrating current vulnerabilities.

10.3.1 Ice Storms

One climate extreme that telecommunications is vulnerable to is ice storms. This section describes some of the major ice storms that have affected New York State and their impacts to telecommunications.

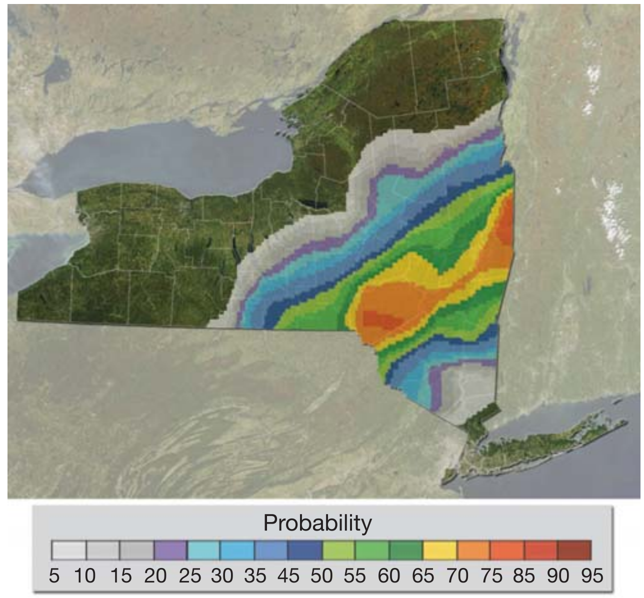
New York and New England: December 11–12, 2008

The December 2008 ice storm in New England and Central and Upstate New York formed late on December 11 and meteorologically dissipated by December 12. Its impact, however, lasted for more than a week in New York and in large portions of New England. The forecast probability for freezing rain associated with this storm is shown in **Figure 10.4.**

The band of icing from the storm traversed some populated areas and, as a result, caused a large amount of damage, even though the ice thickness generally stayed below 1 inch. More than 1.4 million customers lost power in six states. Several days after the storm, more than 800,000 customers were still without power; almost a week after the storm, more than 100,000 customers were still without power, affecting the holiday-shopping season and crippling the business and transportation sectors in many Northeast cities. Some 85 percent of customers had power restored within five days, and full restoration was accomplished within eight days for the entire affected region.

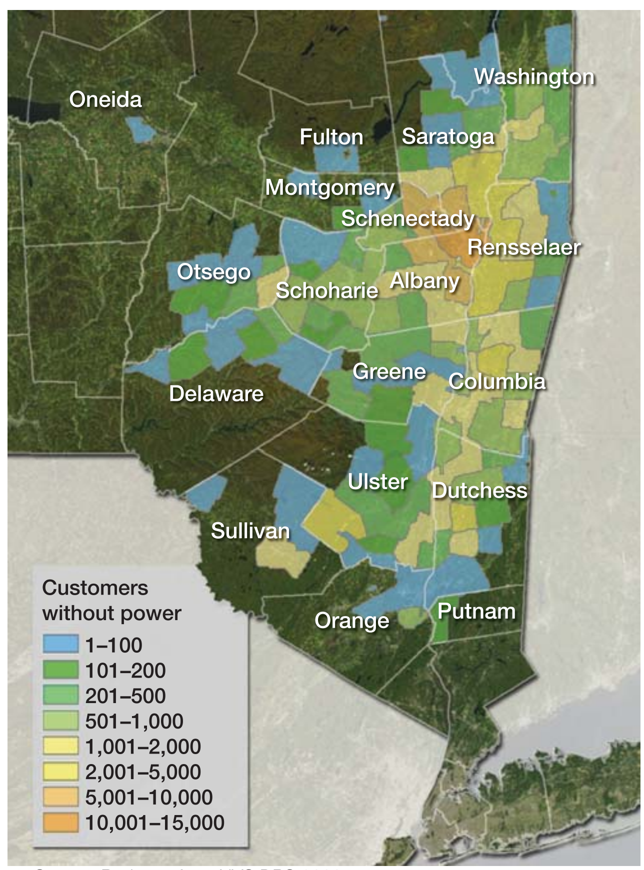
Telecommunications services were disrupted as a result of damaged lines, and electronic equipment in homes lost power. Cable-provided voice, video, and data services had problems at twice the normal levels during the week following the storm. Damage was primarily a result of fallen trees, utility wires, and poles, which were coated in a heavy layer of ice. The slow return of power in the aftermath of the storm resulted in a great deal of controversy about why the utilities could not restore services more expediently, if not avoid outages in the first place.

New York declared a state of emergency in 16 counties. Up to 300,000 utility customers lost service (**Figures 10.5** and **10.6**) in an area largely centered on Albany. By Sunday evening, December 14—three days after the beginning of the storm—an estimated 126,000 people were still without power. Power in the area was not fully



Source: Redrawn from NOAA-NWS 2008

Figure 10.4 Forecast of freezing rain probabilities for December 12, 2008



Source: Redrawn from NYS DPS 2009a

Figure 10.5 Areas with electric power outages in New York State as a result of the December 12, 2008 ice storm restored until December 19, over a week after the storm began (**Figure 10.7**).

The American Red Cross of Northeastern New York opened multiple shelters around Albany to give residents a warm place to stay and eat. At least four deaths were attributed to the storm. Three of the deaths (two in New York) were caused by carbon monoxide poisoning, the sources of which were gas-powered generators used indoors.

Hotels, hardware stores, malls, and restaurants that either had power or had a generator saw a boom in business during that weekend, as many residents finished holiday shopping, ate, and sought warmth. Most schools closed on Friday, December 12, and some colleges ended the semester early due to the severity of the storm.

Federal disaster aid topped $2 million for the nine New York counties that suffered damages from the December 2008 ice storm. Aid distributed to these counties and the State of New York is listed in **Table 10.1**.

Several weeks after the New England storm, a similar ice storm struck the midwestern United States, knocking out power to a million people and leading to at least 38 deaths.

Of note is that most outage reports cover the failure of power. Only some of these outages lead to telecommunications failures, which more commonly are experienced by consumers and less often by service providers. No consistent data for the failures of telecommunications services are in the public domain for the 2008 ice storm nor are such data available for many of the other storms described below, unless otherwise indicated.

Western New York State: April 3–4, 2003

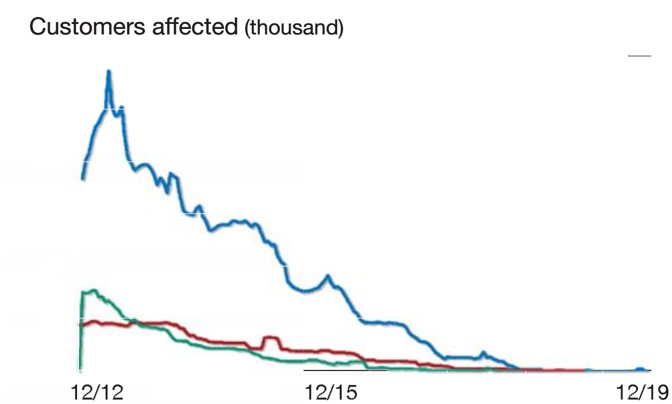
During this ice storm, 10,800 telecommunications outages were reported. It took 15 days from the beginning of the storm to return conditions to normal. More than $25 million in federal aid was provided to help in the recovery (FEMA, 2003).

Northeast United States and Canada: January 4–10, 1998

The extent, thickness of accumulated ice, duration, and overall impact of the January 4–10, 1998, ice storm are

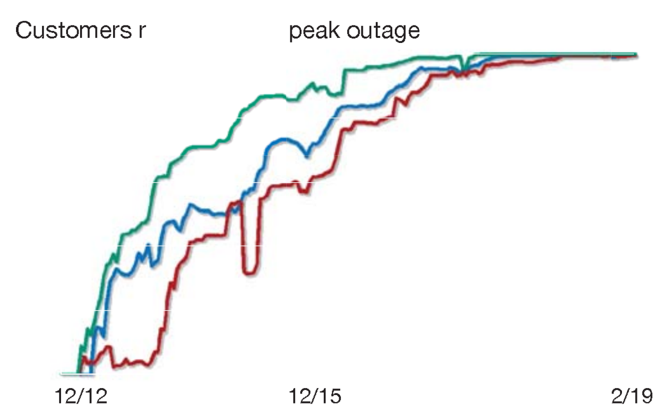
County	Federal Aid
Albany County	$295,675
Columbia County	$123,745
Delaware County	$324,199
Greene County	$203,941
Rensselaer County	$203,079
Saratoga County	$166,134
Schenectady County	$300,599
Schoharie County	$324,569
Washington County	$173,393

Table 10.1 Federal aid distributed to New York Counties as a result of the December 2008 ice storm



Source: NYS DPS 2009a

Figure 10.6 Number of reported customers with power outages versus time during the December 12–19, 2008 ice storm



Source: NYS DPS 2009a

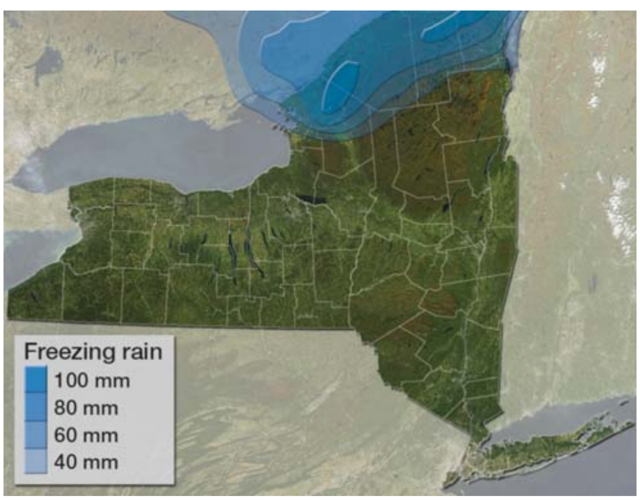
Figure 10.7 Percentage of customers with restored power versus restoration time during the December 12–19, 2008 ice storm considered the most severe of any ice storm to hit eastern North America in recent history (DeGaetano, 2000). The storm affected both Canada and the United States (**Figure 10.8**).

In northern New York, tens of thousands of people living in isolated rural areas lost power and/or telephone service. Power was not restored in all parts of Jefferson County until 25 days after the start of the storm. It took another two to three weeks for services to be fully restored. Approximately 129,000 telecommunications problems were reported to one company (Jones and Mulherin, 1998; NYS PSC, 2007).

Emergency communications systems became stretched beyond capacity as a result of the ice storm. There was a sudden increase in emergency radio communications, and a number of calls were blocked because of overload of lines (**Figure 10.9**).

Pre-1998 Ice Storms Affecting New York State

Between 1927 and 1991, at least seven severe ice storms affected New York and/or New England states. Descriptions of their effects are given in USACE (1998). **Figure 10.10** depicts one of these storms, which devastated western and northern New York, Vermont, New Hampshire, and Massachusetts in 1991.



The blue-shaded areas represent freezing rain accumulations of more than 1.5 to nearly 4 inches (40–100 millimeters; 20-millimeter gradient). Affected areas reached from Lake Ontario to Nova Scotia, including four U.S. states (New York, Vermont, New Hampshire, and Maine) and four Canadian provinces (Ontario, Quebec, New Brunswick, and Nova Scotia). Source: Redrawn from Federal Communications Commission Spectrum Policy Task Force: Report of the Spectrum Efficiency Working Group. November 15, 2002; basemap NASA, based on data from Environment Canada

Figure 10.8 Distribution of ice accumulations between January 4 and 10, 1998

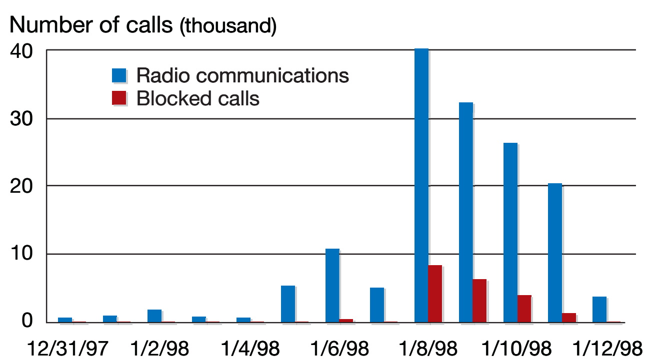
Six additional reported severe ice storms during this period occurred on the following dates:

- February 14–15, 1986
- January 8–25, 1979
- March 2–5, 1976
- December 22, 1969–January 17, 1970
- December 4–11, 1964
- December 29–30, 1942
- December 17–20, 1929

10.3.2 Hurricanes

To have maximum effect on the New York City metropolitan area, a hurricane would have to make landfall on the New Jersey coast, between Atlantic City and Sandy Hook. Since New York has not been directly impacted by a serious hurricane for the past several decades, this analysis uses hurricanes that have hit in the Gulf States as examples of the potential impact such a hurricane could have on telecommunications infrastructure in New York.

In 1938, the highest-category storm New York State has experienced made landfall in central Long Island, east of New York City (Hurricane Saffir Simpson 3). New York City was spared from the storm's worst effects, because the eastern side of the storm did not directly hit the city. (In the Northern Hemisphere, the eastern side is associated with the highest wind speeds and storm surges.)



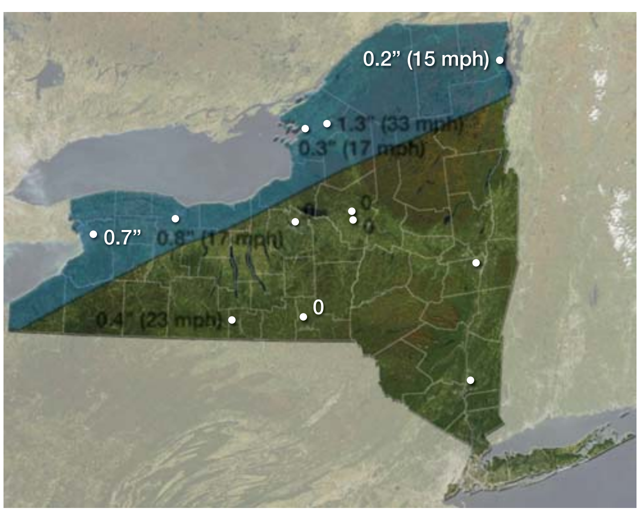
The first five days show normal background traffic, prior to when the storm hit. Source: http://www.stanford.edu/~rjohari/roundtable/sewg.pdf

Figure 10.9 Number of emergency radio communications per day and blocked calls because of overload in a single New York State county during the 1998 ice storm

Hurricane Katrina: August–September 2005

An excellent source of information on telecommunications vulnerabilities that became apparent with Hurricane Katrina, which made landfall as a category 3 storm, is FCC (2006). Hurricane Katrina struck the Gulf Coast in August 2005 and caused widespread flooding and wind damage, both of which affected telecommunications infrastructure. The duration of power outages during Hurricane Katrina exceeded the length of time that back-up batteries and fuel to power generators could supply communications. There were no means nor any plans and too many obstacles to restock fuel and batteries. Fuel to power the base stations lasted 24–48 hours, and batteries for portable radios lasted 8–10 hours. Thirty-eight 911 call centers went down and lacked an advance plan for rerouting calls. Most call centers in the low-impact areas took 10 days to restore. More than 3 million customer telephone lines lost phone service due to damage to switching centers and the fiber network and lack of sufficient diversity in the call-routing system.

Figure 10.11 shows the spatial distribution of causes of wired telephone system failure; lack of fuel supply for standby power features prominently. **Figure 10.12** indicates the failure mode for wireless services. In the area that experienced the largest service loss, diesel fuel ran out for back-up generators and supplies could not be replenished in time. It took 10 days to restore 90 percent of phone service.



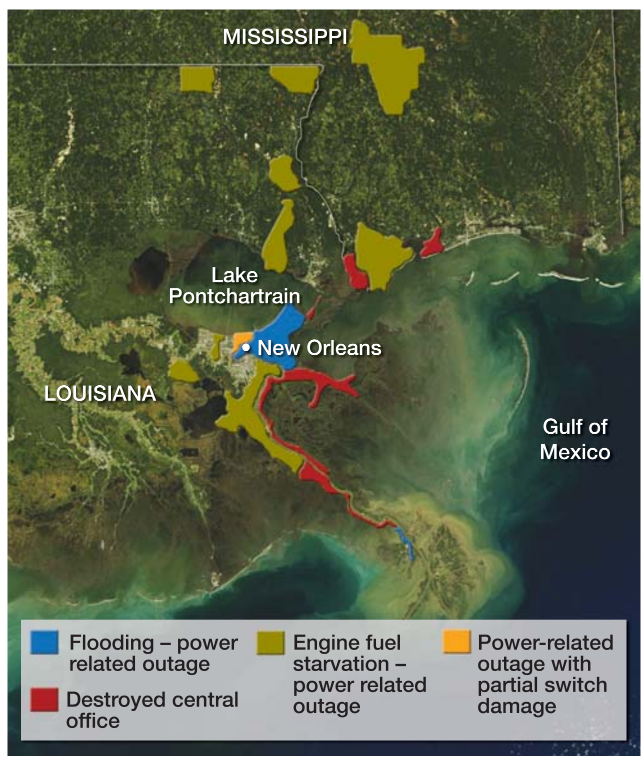
Source: Redrawn from (USACE, 1998), basemap NASA

Figure 10.10 Ice loads (inches) and wind speeds (mph) reported for the March 3-6, 1991 ice storm

In all, 35 broadcast radio stations failed, and only 4 stations worked during the storm. Also, 28 percent of television stations experienced downtime in the storm zone.

Hurricane Ike, September 2008

Hurricane Ike made landfall as a strong category 2 hurricane on September 13, 2008, near Galveston, Texas. On September 15, 2008, 75 percent of one company's customers in coastal Texas did not have service. Service was restored over the following days, with 60 percent lacking service on September 17, 48 percent on September 23, 30 percent on September 24, and 20 percent on September 26. As much as seven weeks later, some TV channels were not operative in severely hit areas. Most satellite TV customers also lost service. In the greater-Houston region, the functionality of cell phone services, on average, ranged between 60 and 85 percent in the days immediately following the storm in September 2008.



Note: Central office is where subscriber lines are connected to a local service loop. Source: Redrawn from: https://netfiles.uiuc.edu/akwasins/www/ Intelec06_Katrina.pdf; basemap: Jeff Schmaltz, MODIS Rapid Response Team, NASA/GSFC

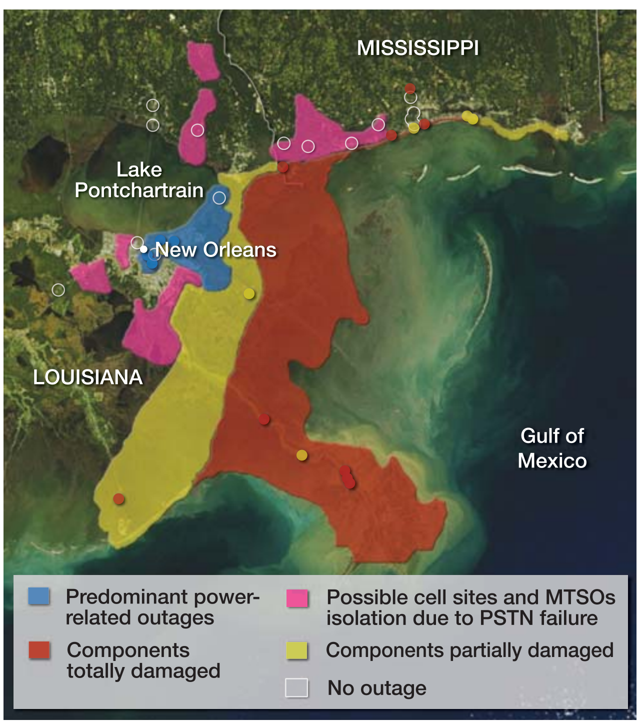
Figure 10.11 Failure modes of the wired telephone systems after Hurricane Katrina

10.3.3 Rain, Wind, and Thunderstorms

Rain is generally of little consequence for communications facilities, except when buried facilities or central offices are flooded during urban flash floods or by overflow from nearby flooding rivers. Wind and thunderstorms are more substantial hazards to above-ground communications facilities, in part from falling trees and downed wires.

Nationally, an example was a windstorm in Washington State on December 16, 2006. Approximately 15,000 customers lost high-speed Internet for up to 48 hours. Rural areas in Kitsap and east King Counties experienced service disruptions. More than 46,000 customers lost telephone service between December 16 and 22; distribution-plant and power problems interrupted service for another 100,000 telephone customers, 400,000 Internet customers, and 700,000 television customers.

Closer to home, New York State experienced, for instance, the 1998 Labor Day thunderstorm affecting the Rochester to Syracuse and Utica regions. Approximately 37,000 telecommunications trouble reports were filed. It took 16 days from the start of the storm for service to return to normal.



Circles show the locations (cell towers) included in the sample. MTSO stands for mobile-telephone switching office (which connects all individual cell towers to the central office); PSTN for public switched telephone network (which connects landline services).
Source: Redrawn from https://netfiles.uiuc.edu/akwasins/www/Intelec06_Katrina.pdf; basemap credit: Jeff Schmaltz, MODIS Rapid Response Team, NASA/GSFC

Figure 10.12 Zones of predominant failure type of wireless phone services

10.3.4 Extreme Heat and Heat Waves

Most heat-wave-related outages for the telecommunications sector are related to power outages that, in turn, are related to unmet peak power demands for air conditioning. Because of these similarities, see the example discussed below in Section 10.3.6, "Electric Power Blackouts."

10.3.5 Snowstorms

Several recent noteworthy snowstorms that affected either power or telecommunications systems, or both, in New York revealed considerable vulnerabilities of the telecommunications systems, often in connection with power failures.

Western New York: October 2006

Wet snow fell on October 13, when there was still foliage on the trees and many of them snapped under the heavy load (NYSDPS, 2007). From October 13 to November 10 (29 days), there were 93,000 reported disruptions to telephone service affecting one company's customers out of the roughly 475,000 access lines (i.e., an outage rate of about 19.6 percent) in the area affected by the storm. The company replaced about 350 downed poles and about the same number of distribution and feeder cables, and it repaired about 46,000 drop wires (i.e., wires connecting poles to homes or other buildings). **Figure 10.13** shows customer-reported service disruptions and the service restorations over the 29-day period that it took to fully restore wired phone services.

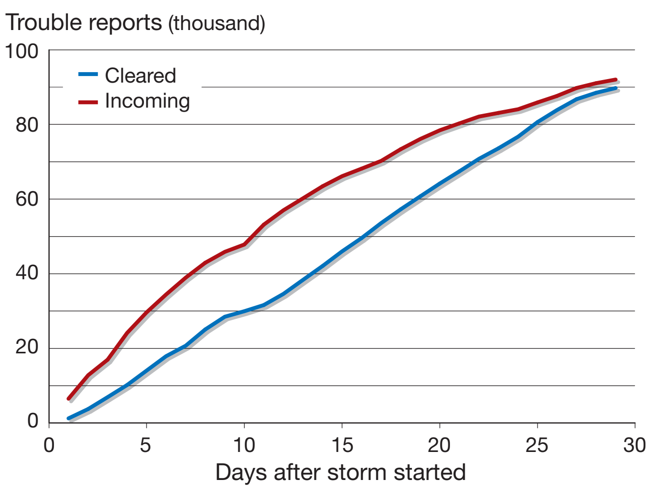
Power failures on Friday, October 13, affected approximately 400,000 customers as a result of the storm. The power companies completed restorations to full electrical service in 10 days. It took almost three times as long to complete restoration of wired telephone and cable TV services. From October 13 to November 10 (29 days), one company reported 149,000 cable television outages and repaired 46,000 lines. Most of the cellular services functioned normally during the storm, except when the back-up power was depleted and when cables that connect the cellular facility to the wired network went down. Cellular service was restored within six days after the storm, although some customers could not recharge their cell phone batteries until day 10 when power was restored fully.

New York: 1987

An early season snowstorm hit New York State in October 1987. Areas from Westchester County to Glens Falls received heavy, wet snow, with accumulations of over 20 inches observed in parts of the Catskills. This storm was the earliest measurable snowfall in Albany, which recorded 6.5 inches of snow. The heavy, wet snow fell onto leaved trees, causing numerous telecommunications outages. There were approximately 43,000 telecommunications trouble reports from this storm. The duration from the start of the event to normal conditions was 14 days.

10.3.6 Electric Power Blackouts

Although not directly linked to weather, recent electric power blackouts in the Northeast can serve as examples that show the relationship between electric grid outages and telecommunications outages.



The total number of service outages amounted to ~93,000. The difference between the two lines is the number of customers known at any given day to have no service. Note the drawn-out reporting of outages. The largest number of known, not-cleared outages (about 21,000) falls on Day 12. Restoration of wired phone services was completed on Day 29.
Source: Raw data taken from October 2006 Western New York Snowstorm Report (NYSDPS, 2007)

Figure 10.13 Total number of incoming trouble reports of customers without service (red), and number of cleared troubles (blue), versus days after start of the storm

Northeastern United States: August 14, 2003

This event had no direct weather-related cause, but demonstrates the relationship between telecommunications and electric grid outages—especially if they persist for some time. The grid power was out for 12 to 36 hours in virtually the entire northeastern United States and parts of adjacent Canada (NYSDPS, 2004).

The blackout affected an estimated 45 million grid customers in the United States and 10 million in Canada. According to the relationship between the annual frequency of outage occurrence versus number of affected customers (**Figure 10.14**), the extent of the blackout was the equivalent to a 20-year event in the United States.[6] The loss of electricity to 6.3 million customers in New York State left approximately 15.9 million people, or 83 percent, of the state's 19.2 million residents without power.

Less than 5 percent of telephone subscribers in New York State lost their "dial tone." Most losses occurred in Manhattan, where two central offices lost back-up power. During the event, approximately 19,000 lines were out of service, the duration of which lasted from 15 to 60 minutes. For competitive local exchange carriers (CLEC), switch failures caused 714 business customers in New York City to lose their service. About 14,000 CLEC customers lost their service statewide. For wireless carriers, back-up generators at cell sites initially functioned normally, but were unable to sustain operation for the long duration of the outage. Approximately 20 percent of cell sites lost service within four hours of the blackout, and about 30 percent of cell sites lost service within 12 hours. Most cable television services were out due to the lack of power.

10.3.7 Causes of Telecommunications Outages

Communication networks are complex and vulnerable to many different types of failure.

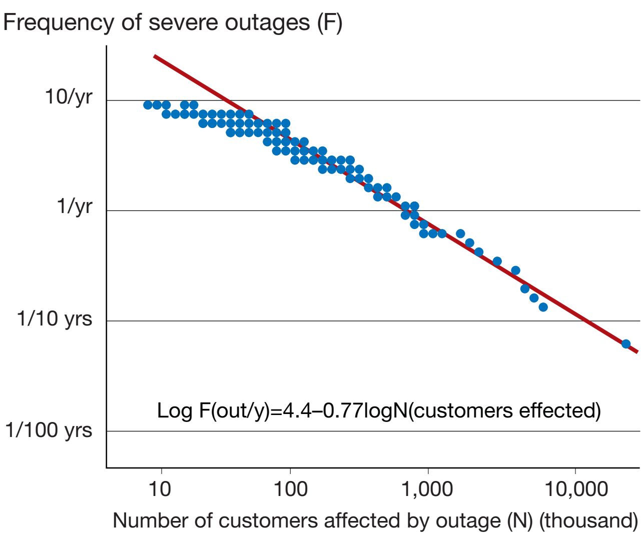
Figure 10.15 depicts the types and occurrences of failures of telecommunications networks, based on a national survey and sample period from 1993 to 2001. It indicates that power-related failures are a major cause of telecommunications outages.

Power outages, in turn, are often weather-related. **Figure 10.16** shows the rapid increase in weather-related power outages since 1992, as well as the various weather conditions that contributed to the power outages (based on a national survey). Windstorms and hurricanes dominate, followed by thunderstorms, with ice and other winter storms as the third most important contributing cause. Some of the rise in outages may be related to electricity deregulation and related dramatic decreases in tree trimming and maintenance budgets.

> The portion of all events that are caused by weather-related phenomena has tripled from about 20 percent in the early 1990s to about 65 percent in recent years. The weather-related events are more severe, with an average of about 180,000 customers affected per event compared to about 100,000 for non-weather-related events (and 50,000 excluding the massive blackout of August 2003). Data includes disturbances that occur on the bulk of electric systems in North America, including electric service interruptions, voltage reductions, acts of sabotage, unusual occurrences affecting electric systems, and fuel problems. Eighty to 90 percent of outages occur in the local distribution network and are not included in the graph. Although the figure does not demonstrate a cause-effect relationship between climate change and grid disruption, it does suggest that weather and climate extremes can have important effects on grid disruptions. We do know that more frequent weather and climate extremes are likely in the future, which poses unknown new risks for the electric grid (Karl et al., 2009).

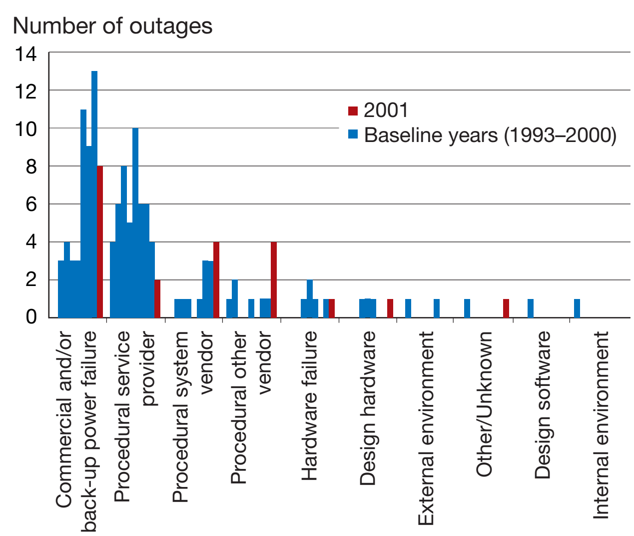
The electricity grid is vulnerable to climate change effects, ranging from temperature changes to severe weather events (see Chapter 8, "Energy"). The most familiar effects of severe weather on power lines (and telecommunications lines on the same poles) are from ice and snowstorms, thunderstorms, and hurricanes. Heat waves are associated with concurrent brown- or blackouts from overload, largely because of increased electricity demand associated with the need for air conditioning. During the summer heat wave of 2006, transformers failed in several areas of Queens, New York, due to high temperatures, causing interruptions of electric power supply.

It is not yet possible to project the effects of climate change on the power grid (or telecommunications infrastructure) at a local scale. Many of the climate effects are likely to be more localized than current climate change models can resolve. Weather-related



Based on data for the entire United States, from 1984 to 1997.
Source: Modified from https://reports.energy.gov/B-F-Web-Part3.pdf

Figure 10.14 Relationship between annual frequency of outages and customers affected in the U.S.



Note: The largest number of telecommunications outages was related to commercial grid and/or service-provider backup power failures.
Source: Bennett 2002.

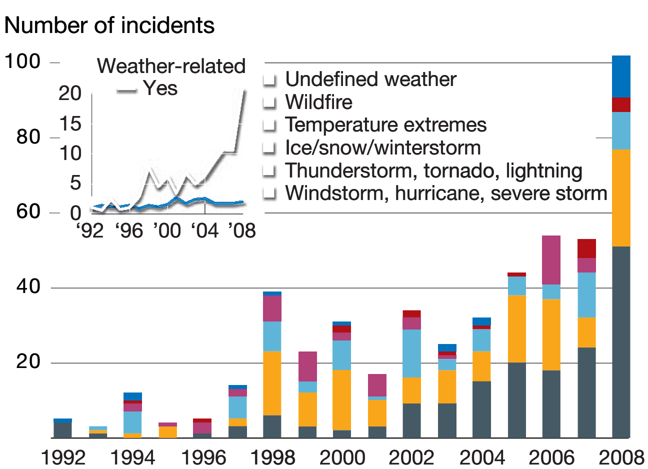
Figure 10.15 Causes of telecommunications outages from 1993 to 2001 in the U.S.

grid disturbances are recognized, however, as a challenge for strategic planning and risk management in the electric power industry primarily. Because of the interdependence between telecommunications infrastructure and power supply (**Figure 10.15**), disturbances to the power grid also affect the telecommunications infrastructure sector. This connection is expanded on in Case Study A.

Loss of communications can result in the inability to obtain assistance when needed, which can lead to the loss of life. Even brief communication outages in life-threatening situations can be devastating. During extreme weather conditions such risks are amplified. While people may not be able to communicate the need for help, the ability of responders may also be inhibited by disturbances to systems, including communication and transportation. This combination can lead to life-threatening delays.

Some of the weather-related events listed in sections above have caused telecommunication outages that have lasted two or more weeks, and in the case of Hurricane Katrina, up to several months.

The effect of the World Trade Center collapse on September 11, 2001, and the subsequent loss of communications in the Wall Street area for an extended period of time, was less costly than it might have been if recommendations to implement network relocation of facilities (by providing geographical diversity, and in some cases redundancy) had not been heeded before this catastrophic event (NYCP, 1990). An informative



Note: The number of incidents caused by extreme weather has increased tenfold since 1992. For details, see text.
Source: U.S. Global Change Research Program 2009

Figure 10.16 Significant weather-related U.S. electric grid disturbances

report was provided in the aftermath of the 2001 World Trade Center attacks. The report drew inferences about the reliability of communication systems during extreme weather conditions that can result in people being unable to obtain assistance and can lead to the loss of life (NYSDPS, 2002).[7]

10.4 Adaptation Strategies

A variety of adaptation strategies exist that can help the telecommunications sector in New York State prepare for the impacts of climate change. Described here are two types of these adaptations strategies: technical adaptations and broad-scale adaptations. Within each, specific actions that the telecommunications sector can take are discussed.

10.4.1 Key Technical Adaptation Strategies

This section explores some of the key technical adaptation strategies for the telecommunications sector. These adaptation strategies focus on changes to the physical telecommunications infrastructure and systems.

Choices: Above versus Below Ground; Wire versus Fiber Optics; Land Lines versus Wireless

Wired communication systems on utility poles are susceptible to disruption from falling trees during storms, wind and rain during hurricanes and nor'easters, and loading during ice and snowstorms. Underground communications are more susceptible to flooding. Buried and aerial fiber optics are less affected by water and water pressure than buried metallic cables, but are susceptible to freezing. Fiber optics are more dependent on power, and the regenerators need careful protection. Underground cable faults do occur less frequently, but take longer to locate and repair when they do happen.

Careful planning with due consideration of environment, climate, geography, cost, zoning laws, current plant configuration, a company's business model, etc., will determine the optimal choice for above versus below ground and wire versus fiber optics choices. Reduction of vulnerabilities can be achieved by putting the drop wires between the main wire lines and the houses of individual end-users underground. In general, the expansion of wireless services usually increases redundancy during emergencies.

Generators: Emergency Power and Strategies for Refueling

Failures of cellular systems have occurred when emergency generators are not available at cell sites and when plans are not made to store enough fuel for the generators to operate during extended climate events. The same failure mode applies to remote switching terminals or critical nodes in a wired network. In a widespread outage, companies often do not have enough generators on hand for every facility that needs one. Access to the site for refueling can be obstructed, or fuel shortages can prevent timely refueling. The same may, to a lesser extent, apply to central switching offices for wired phone services that have permanent on-site generators with contingency fuel supplies, but in extended power outages fuel may become exhausted.

Where battery banks provide the direct power equipment (48 V, DC), solar panels can extend back-up capacity. For the large power needs of urban central offices and with older switch technologies, this is not practical. But for smaller offices with the next generation of switches that promise power consumption reduction by factors of up to a thousand, this may become a practical option. The fuel supply for, and availability of, back-up power generators need to be increased at towers and at other critical locations to be able to sustain extended power outages, e.g., at wireless cell phone towers and at remote nodes in a wired network, both with potentially difficult road access.

Preventing Power Grid Failures and Loss of Central Office Functions

Strategies that can be used to adapt to power grid failures and the loss of central office include the following:

- Make a standard cell-phone-charging interface that would allow any phone to be recharged by any available charger (either powered by gasoline-fueled home generators or by cars). During extended outages, such as the recent East Coast blackouts (described in section 10.3), cell phones could not be recharged (even though commercial power or generators could be found), because the charger for one brand or model of phone was incompatible with others. A federal standard requiring all cell phones to have a standard charging interface would allow any phone to be recharged by any available charger. Since most cell phones are changed every two to three years, nearly all phones would be compatible with any charger within three years. The new generation of smart phones with charging via USB connectors promises to improve this situation. This is an action for the telecommunications industry to undertake, but state and federal agencies can help to encourage its adoption.
- Intensify the use of strategically stored mobile cells in areas where they can be quickly moved to locations where cellular towers are disabled. This solution would likely only be used when it is clear that restoration of power or telecommunications, for example to a cell site, is not faster than the deployment of mobile cells.
- Use the network to relocate communications centers or distribute the normal operation of the centers among different centers. This is an option to reduce disruptions to the economy when communication services are lost in an area. Network capacity is routinely redeployed or augmented to adapt to changes in traffic patterns, both in business-as-usual situations and following disasters. For instance, following the World Trade Center collapse, the communications destined for Wall Street were re-routed to New Jersey. This reduced the economic effects that would have resulted from an extended suspension of trading for several weeks.
- Encourage the deployment of passive optical networks that are less reliant on commercial and back-up powering in the field. A passive optical network (PON) is a point-to-multipoint fiber to the network architecture of a quality in which unpowered optical splitters are used to enable a single optical fiber to serve multiple premises.

Developing and Expanding Alternative Technologies

It is quite likely that alternative networking technologies will be developed to provide diversification across another dimension. Some networking technologies that may or may not add diversity or robustness include:

- **Free-space optics** (FSO), an optical communication technology that uses light propagating in free space to transmit data between two points. The technology is useful where the physical connections by means of fiber optic cables are impractical due to high costs or other considerations. Free-space optics is only good for a few hundred yards to maintain high reliability (i.e., better than 0.999 or 0.9999). Any longer distances will produce circuit errors in heavy rain or fog.
- Commercial versions of ***ad hoc* networking** techniques typically relying on wireless communication. *Ad hoc* networks lack a designed infrastructure and form cooperative links between users to forward data. The structure of the network reflects the bandwidth requirements of the users in an area and the availability of access to the network infrastructure. However, ultimately they depend on the connection to the backbone wired network infrastructure, except in some relatively localized settings, which may be limited to urban environments.
- **Transmission via power lines**, which would reduce redundancy and couple power and communication failures more than they are currently.
- **Delay-tolerant networking techniques**. These networks can provide emergency communications during weather-related disasters, but are limited in data rate and quality. They include, for instance, those being proposed to provide communications to nomadic reindeer herders in Arctic latitudes. They are typically applicable to e-mails and text messages that are delay-tolerant.
- **Satellite phones and ham radio operators**, which have played important roles in emergency situations. The United Nations regularly distributes satellite phones in disaster regions internationally. These phones were in high demand during Hurricane Katrina. Satellite phones continued to operate following Hurricane Katrina and more than 20,000 satellite phones were used in the Gulf Coast region in the days following Katrina. Amateur ham operators have been the lifeline in many disasters and, perhaps, should be better organized. Not only should first responders be tied to them (some local emergency offices have such arrangements), but utilities should be organized to link with them as well.

10.4.2 Larger-Scale Adaptations

This section focuses on broader adaptation strategies for the telecommunications sector.

Diversification of Communications Media

Cable television and telephone distribution networks were originally different. Telephone systems used twisted wire pairs to connect to a central office, while cable television used coaxial-cable-based tree topology. A major difference between the cable company hybrid fiber-coax networks and the traditional telephone networks is that the former are more reliant on commercial power in the field and on electronic relays and amplifiers that have no back-up capability. They are not designed to operate in a power loss or blackout. Traditional telephone networks are designed to work even after a loss of commercial power. This critical reliability difference still exists today.

To some degree, the technologies in both networks have become more similar. They both use a fiber-optic network from a central location that connects to a customer's neighborhood with a short coax (cable television), twisted pair of wires, or a fiber connection (telephone systems) from the neighborhood node to a customer's premises. Both systems provide the same services to the end users (voice communications, high-speed data, and video distribution). The more recent technologies are more power-dependent, which affects reliability, resiliency, and recovery, although some use passive optical fiber technology requiring no power for "the last mile" (i.e., the last segment of telecommunications delivery from provider to customer).

It is possible that separate cable and telephone networks may evolve into a single monopoly distribution network that may be provided by a separate private or public utility company. Companies similar to the current cable and telephone companies may compete as service providers. If this occurs, a redundancy that currently exists in the multiple distribution networks may disappear, and the network may become more susceptible to failures caused by weather-related events. However, telephone and cable lines, while separate, are not really redundant in the sense that they are located on the same poles; if the poles are damaged in a storm, both cable and telephone lines may fail.

The Hurricane Katrina communications panel recommended more diversity of call routing in wireline networks to avoid reliance on a single route. The Public Service Commission instituted such diversity requirements following the September 11, 2001, outages that largely affected New York City (discussed further below) (NYSDPS, 2002; Case 03-C-0922). This approach is useful for routing traffic between switches, but does not help when the problem is in "the last mile," near the end customer. Also, the increasing use of Internet protocol for telephone services will provide routing diversity, because the information processing system will automatically search for any surviving physical routes. On the other hand, Internet-based networks often experience more widespread outages than a traditional network does when a major node or other centralized critical function location or equipment fails. This is common because these providers must leverage economies of scale to compete with bigger traditional companies and have fewer distributed facilities and less redundancy.

Natural Competition: Wired versus Wireless Networks

Wired networks provide point-to-point links that are more secure and private and can currently support much higher total data rates in a given geographic area. Improving antenna technologies, such as multiple-input and multiple-output (MIMO),[8] will continue to change this imbalance, but it is unlikely that the data rates provided by wireless technologies will exceed the rates provided by wired networks.

While wireless networks are in general dependent on wireline networks in order to backhaul data from cell sites to the backbone network, they do provide seamless communications to mobile, untethered users. They transfer information that is broadcast to a large set of receivers more naturally than wireline systems.

The current federal and state broadband initiatives could potentially encourage competition between wired and wireless media by developing both. However, major wireline companies own large portions of the wireless companies with major market shares in New York State. The development of either technology is likely to occur naturally by consumer choice, desired data rates, and considerations of quality versus price. Whether wired communications are more likely to prevail in densely populated, disadvantaged areas, while wireless communications prevail in sparsely populated rural areas, is questionable. In either case—wireline or wireless networks— in a competitive free-market telecommunications environment, commercial operators need a customer base to support the cost of infrastructure. Rural areas will continue to have more difficulty in obtaining access to high-speed broadband than urban areas, unless it is publicly supported, or prices may tend to be higher in the rural areas that often are least able to afford them.

Prior Adaptation Policy Recommendations

It is instructive to revisit what kind of measures and actions New York State agencies have already recommended vis-à-vis experiences from past extreme events, whether of natural or manmade origins. A review of these assessments reveals that nearly all proposed policy options and recommendations for reducing communications vulnerability to extreme events, made without particular reference to climate change, are directly relevant to the kind of extreme weather events discussed in the ClimAID report.

In the context of telecommunications, there is a comprehensive document that combines many of the findings, options, and conclusions for this important infrastructure sector: *Network Reliability After 9/11*, a white paper issued by the New York State Department of Public Service (NYSDPS, 2002). While it was originally inspired by the lessons learned from the September 11 events in 2001, it looked far beyond this single event and addressed fundamental systemic telecommunications vulnerability and reliability issues.

10.5 Equity and Environmental Justice Considerations

The rapid rate of innovation in telecommunications technology and the relative impermanence of the infrastructure mean the sector is potentially in a relatively good position to respond to climate change, signaled either by perceived physical risk or price changes. Yet flexibility and mobility present some challenges to enhancing social equity and ensuring that these technologies facilitate wide-ranging social resilience rather than exacerbate isolation and lack of access to information among more vulnerable people.

Because of the rapid changes taking place in the sector, monitoring equity involves examining the distribution of and access to old technology as well as rates of adoption and use of new technology. As climate risks affect decisions about types of infrastructure to deploy and where it can be built, a number of questions stand out: Are there specific regions, communities, or demographic groups that are likely to lose out? Which types of telecommunications technology and infrastructure are inherently more resilient? Will some adaptation decisions create new vulnerabilities for those using less resilient and obsolete infrastructure?

10.5.1 Landline Dependency and Adaptation Decisions

Because of enormous growth in new technologies, telecommunication companies are increasingly losing landline subscriptions. As of mid-2008, landline subscribers in the state had declined 55 percent since 2000. This is, in part, due to competition from increasing mobile phone penetration (which, in the context of storm vulnerability, may provide higher reliability where mobile services are available). The New York landline loss rate is comparable to that of the decline in landlines in New Jersey (50 percent), but surpasses the lowest rates in Connecticut (10 percent), Texas (20 percent), and California (21 percent) (Cauley, 2008). In the last year alone, one company lost 12 percent of its landlines. At the same time, the cost of maintaining the lines is increasing, and there are reports that some companies are pulling back on the upkeep of lines (Hansell, 2009; NYS DPS, 2009b).

Amid these changes, 14 percent of Americans are neither cell phone nor Internet users (Horrigan, 2009). Some of these customers are simply late adopters, but many others are households in isolated rural areas where new technologies have simply not yet penetrated. This leaves them dependent on landlines for lifeline services in emergency situations.[9] Adaptation strategies that focus disproportionately on the use of newer technologies and on implementation in areas with opportunities for greatest cost recovery may exacerbate the relative vulnerability of those reliant on landlines in more remote locations. Natural progression of technology can have a profound and beneficial impact on the reliability of networks if combined with responsible and realistic policies to address these concerns.

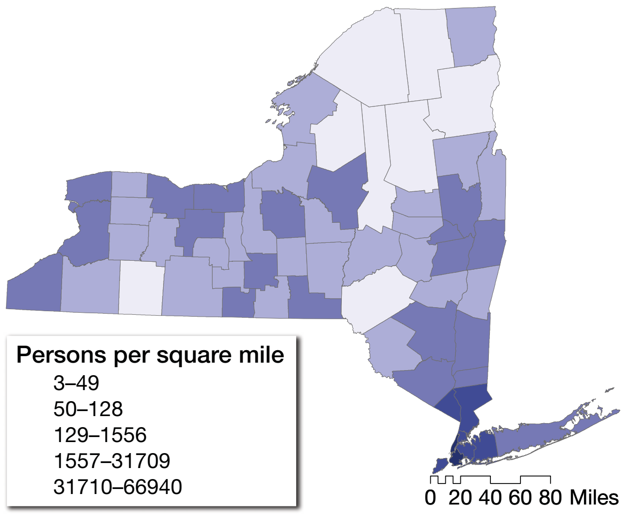
10.5.2 Cascading Inequities and Challenges

Similar to the way localized energy problems can ripple through the grid, a relatively localized disturbance to telecommunications infrastructure can create cascading impacts across regions and cripple widespread economic operations. For example, commercial transactions are increasingly reliant on credit card authorization, ATM withdrawals, and computer networks, services that are incapacitated with power and telecommunications outages (Quarantelli, 2007). Coping capacity reflects the underlying social and financial capital as well as the degree of isolation and service repair capacity. Rural and low-income communities are likely to be at a disadvantage.

On the other hand, it is possible that a progressive policy of universal service offers an opportunity to expand newer (wireless) technologies to the outer reaches of the network. This is comparable to developing nations "skipping" legacy telecommunication technologies. Cellular expansion in rural areas could make disaster recovery less burdensome (e.g., fewer drops to fix); allow utilities to pursue more efficient, centralized recovery strategies; and allow the severity of long-term power outages to be mitigated more easily. For example, rural customers are more likely to be able to use and recharge cell phones using car batteries, because vehicle ownership is more prevalent in rural areas. In contrast, modern fiber and cable networks are heavily dependent on the availability of commercial power.

10.5.3 Digital Divide

According to the 2008 State New Economy Index, New York ranks within the third quartile in terms of digital economy competitiveness (NYS Council for Universal Broadband, 2009), i.e., use of digital communication is widespread. At the same time, disparities in access to technologies and different rates of adopting them ensure that some areas and groups within New York State will benefit more than others from the potential of new information and communications technology to drive social and economic development and wellbeing. Sustainable development is an important tool for building local and regional resilience to climate stresses and shocks. Technology disparities are discussed in the next section as well as how infrastructure deployment aimed at



Source: U.S. Census 2000

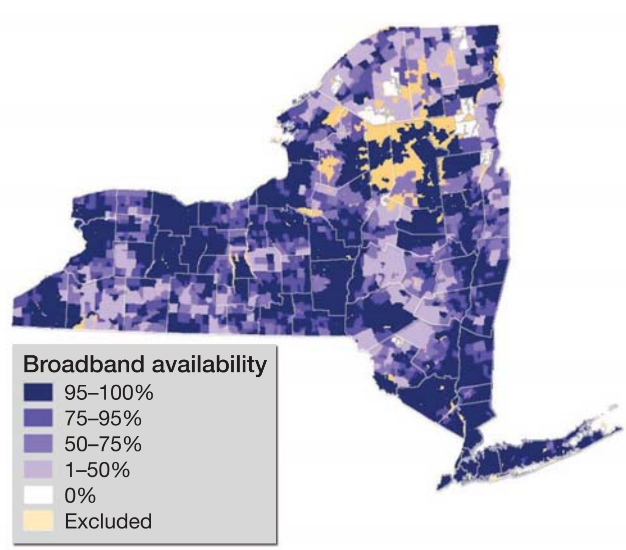
Figure 10.17 Variation in population density in New York counties

minimizing these disparities could be part of a broad adaptation strategy.

Since the 1990s, the term "digital divide" has been employed to describe persistent differences in access to digital technology based on race, gender, age, geography, and socioeconomic condition (Light, 2001). For example, in a recent survey, low-income households adopted broadband at less than half the rate of higher-income households, and a wide gap was noted between white adults and African American adults (Horrigan, 2007 and 2008).

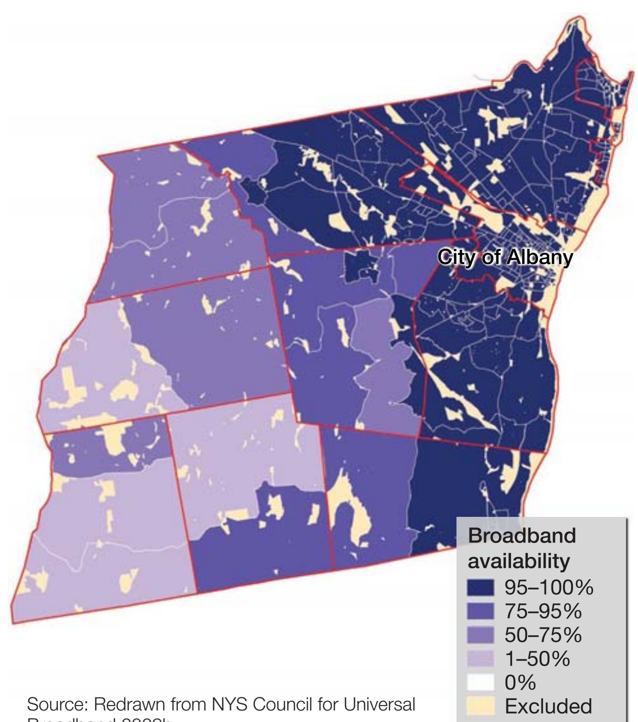
Demographic differences in rates of adopting technologies are compounded by regional differences in access to technologies. A national survey found that 24 percent of Internet users did not have broadband access because it was unavailable in their area (NYS Council for Universal Broadband, 2009a). Similarly, throughout New York State, there are communities where broadband is neither available nor affordable. The most sparsely populated counties are clustered in the Adirondack region and in Delaware and Allegany Counties (**Figure 10.17**). These areas also tend to have limited access to broadband. Notably, large parts of Franklin, Essex, and St. Lawrence have no availability at all. Compare this to the near-universal access in and around most of the state's urban centers (**Figure 10.18**). Perhaps most striking is the variation within counties. In Albany County, a noticeable division exists between urban centers such as the city of Albany, with coverage rates of 95 to 100 percent, and surrounding towns with less than 50 percent availability (**Figure 10.19**).

Access to wireless services (cell phones) is also limited in rural areas with low population densities. The same applies to the expansion of competitive wired networks, such as digital cable. Unfortunately, this is the reality of a non-regulated competitive industry. If there are not enough people to break even (much less turn a profit) on



Source: Redrawn from NYS Council for Universal Broadband 2009a

Figure 10.18 Variations in wired broadband availability (cable-modem and DSL) in New York State, February 2009



Source: Redrawn from NYS Council for Universal Broadband 2009b

Figure 10.19 Wired broadband availability (cable-modem and DSL) within Albany County, February 2009 the infrastructure required to deliver the service, it is very difficult for service providers to make that investment when other areas with higher population densities are in a similar need for additional capacity and speed. Some rural cell towers, unless they are on a highway corridor, operate at a loss. With continued downward pressure on wireless service prices, equitable distribution will continue to be a difficult problem to solve.

Introducing new technologies and maintaining equitable and reliable access are often conflicting. New technologies are introduced where they are most profitable, i.e., in high-density population areas. Noting this reality, short-term goals then could be to preserve service and access so that customers and critical services are not abandoned. The long-term solution should be to deploy a more reliable and equitable technology network that can be sustained by viable operators.

Another demographic trend is that lower-income groups drop landlines faster than higher-income groups and use wireless as their sole means of communication.[10] On the one hand, this reduces redundancy in emergency situations, but on the other, because wireless is less vulnerable to extreme weather events, it implies more continuity of services during extreme events as long as customers find a way to recharge their mobile batteries (e.g., via charges from cars).

10.5.4 Deploying Rural Broadband as an Adaptation Strategy

Broadening the penetration and use of affordable and fast information and telecommunications technology can help strengthen the types and degree of connectivity between lower-income rural communities and economic centers, educational options, business services, and health infrastructure.

As part of a comprehensive development strategy aimed at employment and business diversity, for example, deploying broadband could help build social and economic resilience in regions dependent on climate-sensitive industries such as agriculture and natural resources (see Figure 3.4 of Chapter 3, "Equity and Economics"). It also could help increase citizen capacity to respond to climate-related disasters via better communication of risks and preparedness strategies. Recently, the federal National Telecommunications and Information Administration awarded a $40-million grant for the ION Upstate New York Rural Initiative to deploy a 1,300-mile fiber-optic network in northern New York State as part of the federal government's broadband stimulus program.

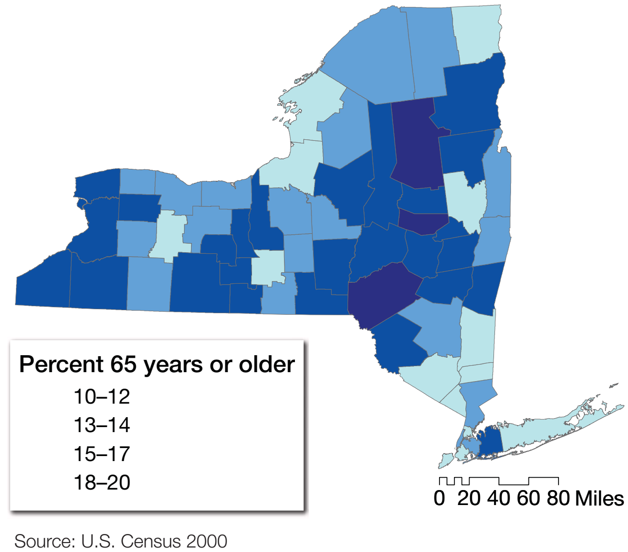


Figure 10.20 Regional variations in concentrations of population 65 years and older

Rural deployment of broadband would tend to target regions with higher-than-average rates of aggregate population vulnerabilities. For example, Delaware County, one of the state's most sparsely populated counties, is located within the high-risk zone for ice storms and was hard hit by flooding in 2006. On top of this, it is also among those counties with the highest rates of poverty outside of New York City (see Figure 3.2 of Chapter 3, "Equity and Economics") and the highest proportion of elderly people (**Figure 10.20**). In the current recession, lower-income rural, elderly populations are especially vulnerable to additional climate extremes. These extremes could multiply the burden of regional economic decline on the elderly and also could cause the state to roll back the social supports that serve them (see e.g., *New York Times*, 2009).

10.5.5 Equity and Equity-Governance

Focusing on the use of information and telecommunications technologies as part of a broader strategy of inclusive community participation and sustainable development opens a range of possible strategies for equitable social, economic, and environmental gains in communities that might otherwise be exposed and sensitive to a variety of climate stressors.

Following the framework identified by a 2008 report (MacLean, 2008), information and telecommunications technologies can be coordinated for first-, second-, and third-order effects. Applied to adaptation, first-order effects include using innovative forms of technology to monitor and research climate change and adaptation, as well as to disseminate information on best practices and critical vulnerabilities. Second-order effects include using social networking and emergent forms of cooperative dialogue that build adaptive capacity and enable modes of debating and evaluating potential adaptations and risks. Finally, third-order effects encompass a whole suite of networked government measures related to equity, ranging from those that facilitate access to and coordination across branches of government to those that increase procedural justice by encouraging active executive participation among isolated or disengaged stakeholders.

To adopt these strategies, citizens must have equitable access to affordable information and telecommunications technology networks and knowledge of how to use these resources. Equally important is equitable access for local governments, where wide disparities in technological infrastructure exist across local planning departments in New York State (for an example, see Gross, 2003).

On a more sophisticated level, governance strategy to enhance equity requires building local capacity (e.g., through education, new management practices, behavioral changes) so that communities and governments have the means to creatively use technology for information gathering, dialogue, or participation. However, no amount of access can overcome persistent ignorance about how and when to use technology. Situations in which people do not know how to use technology may generate a false sense of security or control. In some cases, this can even increase vulnerability when the equipment malfunctions at a critical stage.

Telecommunication systems are designed so that the installed capacity can handle the typical daily peak traffic load. Add in a disaster, and the system will likely be overwhelmed. As long as telecommunications companies running the networks have to pay to operate and maintain the infrastructure on a competitive basis, change is unlikely. Wireless phone technology (and, to some extent, landlines) can augment capacity fairly quickly when needed in emergency situations. Some capacity-enhancing measures can be implemented immediately, trading off voice quality for additional traffic. Adding radios and backhaul capacity can take a few days, depending on the situation.

A useful adaptation strategy is to educate people about the impacts their behavior will have on a network during a disaster. To educate customers to send a text message about the tornado, as opposed to taking a picture and sending it from their cell phone (which uses more network capacity), is one example.

10.5.6 Information and Telecommunication Technology Adaptation Strategies and Climate Change Mitigation

Any significant expansion of information and telecommunications technology services needs to be evaluated with respect to the impact of increased energy use on household budgets. The expansion also needs to be evaluated with regard to its wider impact on greenhouse gas emissions. Cooling and operating more information and telecommunications technology servers and applications will result in increased energy demands. These processes already account for 1.5 percent of the energy consumption in the United States, and it is a percentage that is growing quickly (*The Economist*, 2008). Evaluating the efficiency gains of new technologies relative to this increased energy usage is a critical area for further research.

10.6 Conclusions

As discussed in this ClimAID chapter, telecommunications is an essential sector that is vital to New York State's economy and welfare. It is largely privately operated but has important public functions. Because of rapidly changing telecommunications technology and deregulated, fiercely competitive markets, some service providers tend to focus on short-term market share and profitability rather than pursuing long-term strategies to achieve reliability and redundancy. Business planning horizons are at most five to ten years, which is short compared to projected climate change trends over many decades. Even under current climate conditions, there are serious vulnerabilities that prevent the telecommunications sector from uniformly delivering reliable services to the public during extreme events. New York State can proactively engage industry to help prepare for more severe and more frequent extreme climate events in the future.

10.6.1 Key Vulnerabilities

The telecommunications sector is vulnerable to several climate hazards, many of which are projected to change in the future with climate change. The sector's key vulnerabilities include the following:

- Telecommunication service delivery is vulnerable to severe wind, icing, snow, hurricanes, lightning, floods, and other extreme weather events, some of which are projected to increase in frequency and intensity.
- In coastal and near-coastal areas, sea level rise in combination with coastal storm-surge flooding will be a considerable threat during this century to some central offices and underground installations. This risk extends up the tide-controlled Hudson River to Albany and Troy.
- The delivery of telecommunications services is sensitive to power outages, some of which result from increased energy demands during heat waves. Heat waves are expected to increase in frequency and duration.
- Telecommunication lines and other infrastructure are vulnerable to the observed and projected increase in heavy precipitation events resulting in floods or icing during freezing rain.
- Populations in underserved areas, especially in remote rural areas, often have only one type of service and hence lack redundancy. They may have difficulty reporting outages during extreme events and potentially life-threatening emergencies. For instance, during ice or snow storms, mobility can be severely hindered.

10.6.2 Adaptation Options

There are adaptation options and opportunities that can help the telecommunications sector prepare for the impacts of climate change. Key adaptation options and strategies include the following:

- Make the backbone network redundant for most if not all service areas, and resilient to all types of extreme weather events; provide reliable backup power with sufficient fuel supply for extended grid power outages.
- Decouple communication infrastructure from electric grid infrastructure to the extent possible, and make both more robust, resilient, and redundant.
- Minimize the effects of power outages on telecommunications services by providing backup power at cell towers, such as generators, solar-powered battery banks, and “cells on wheels” that can replace disabled towers. Extend the fuel storage capacity needed to run backup generators for longer times.
- Protect against outages by trimming trees near power and communication lines, maintaining backup supplies of poles and wires to be able to replace expediently those that are damaged, and having emergency restoration crews at the ready ahead of the storm’s arrival.
- Place telecommunication cables underground where technically and economically feasible.
- Replace segments of the wired network most susceptible to weather (e.g., customer drop wires) with low-power wireless solutions.
- Relocate central offices that house telecommunication infrastructure, critical infrastructure in remote terminals, cell towers, etc., and power facilities out of future floodplains, including in coastal areas increasingly threatened by sea level rise combined with coastal storm surges.
- Further develop backup cell phone charging options at the customer’s end, such as car chargers, and create a standardized charging interface that allows any phone to be recharged by any charger.
- Assess, develop, and expand alternative telecommunication technologies if they promise to increase redundancy and/or reliability, including free-space optics (which transmits data with light rather than physical connections), power line communications (which transmits data over electric power lines), satellite phones, and ham radio.
- Reassess industry performance standards combined with appropriate, more uniform regulation across all types of telecommunication services, and uniformly enforce regulations, including mandatory instead of partially voluntary outage reporting to the regulatory agencies.

- Develop high-speed broadband and wireless services in low-density rural areas to increase redundancy and diversity in vulnerable remote regions.

10.6.3 Knowledge Gaps

The industry generally lacks computerized databases that readily show the location and elevations of installed telecommunication facilities and lifelines and their operational capacity. Such data can be crucial in extreme weather events to make rapid damage, loss, and consequence assessments in potential hazard and damage zones. For security reasons, such databases need to be fully protected to allow only restricted, authorized accessibility.

The public lacks standardized easy access to information on service outages and expected restoration times. This information can be crucial in response actions taken during emergencies, by public first responders, businesses, and private households. Some consideration must be given to what kind of information is publicly accessible and what additional information is only accessible to authorized parties (government, first responders, etc.), because of security reasons. But these concerns must not prevent the public from having ready access to information in order to minimize the potential impact of emergencies.

A sound financial model is needed for telecommunications companies to implement costly reliability and resiliency measures and to remain competitively viable, since these companies 1) have obligations to serve high-cost rural customers, and 2) provide backbone services for all other communication modes described in this report.

The ClimAID assessment suggests both technical and policy options for effective adaptation strategies and reducing vulnerability/improving resilience. The following potential responses emerge from this assessment:

- Overcome the lack of and unevenness in transparency with respect to reporting and assessing vulnerabilities to climate-related hazards for both the current and future communication infrastructure systems and operations. Attune state actions to balancing the competing needs for public safety versus concerns for free-market competition and cyber security.
- Perform a comprehensive assessment of the entire telecommunications sector's current resiliency to existing climate perils, in all of their complexities. Extend this assessment to future climate projections and likely technology advances in the telecommunications sector. This includes the assessment of co-dependency between the telecommunications and power sectors' relative vulnerabilities. Provide options and incentives to decouple one from the other while improving resiliency of each.
- Implement measures to improve public safety and continuity of communications services during extreme events. Any such actions need to be risk-informed and need to consider the benefits versus costs to both the public and the industry for increased resilience to extreme events. They need to foster security for both the public and the industry and simultaneously advance competition, technological innovation, and equitable and affordable customer access across the state.

Case Study A. Winter Storm in Central, Western, and Northern New York

This ClimAID case study analyzes the impacts of a severe winter storm in central, western, and northern New York State, concentrating on two specific climate hazards based on geographic location in the state. For central New York, the focus is on an ice storm that produces freezing rain and ice accumulation. Snow accumulation is the focus for western and northern New York.

The case study's primary focus for the societal impacts of the winter storm is on the telecommunications infrastructure. However, a secondary area of examination is the effects of the winter storm on the electric power grid.

Ice Storm Scenario

Severe winter storms in New York generally follow a certain pattern, as described in section 10.2. A low-pressure system moves up the Atlantic Coast bringing warm moist air that encounters cold dry air in a high-pressure system over Canada and extends into the northern parts of New York. The northward movement of the counterclockwise-rotating storm system causes warm air to overrun the cold air mass. This typically forms three moving bands of precipitation (**Figure 10.21**):

- a southwest-northeast band of heavy rain closest to the coast
- parallel to it but farther inland, a band of freezing rain (ice)
- farther toward the northwest, another parallel band of precipitation that gradually grades from snow pellets into snow

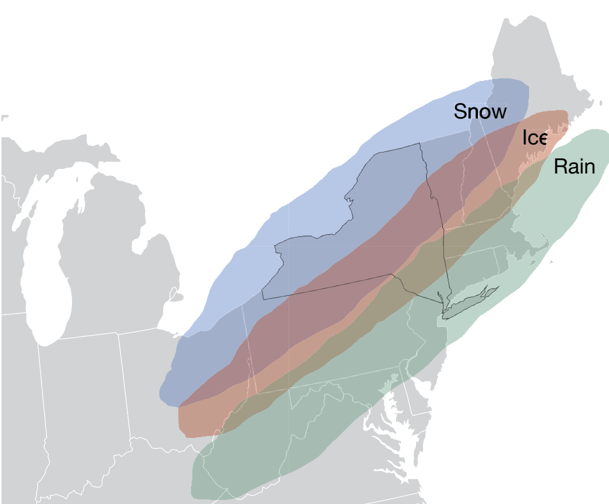
The jet stream's position, strength, and persistence, as well as other meteorological factors, determine how large the storm system is; where and how fast or slowly it moves; how much total precipitation it will produce as rain, freezing rain/ice, and snow; how wide and long the three bands of precipitation stretch; and how the bands move in time and, hence, how long each phase of precipitation lasts at any location. Any given location may go through more than one precipitation phase (from rain to freezing rain to snow pellets to snow), while other locations may be affected only by a single precipitation band.

In this case study, a hypothetical composite of historical extreme winter storms is assumed. While the three precipitation categories (rain, freezing rain, and snow) would not necessarily be expected to occur concurrently in these proportions, each of these types of extreme winter precipitation is currently expected to occur on average at least once per century:

- up to 8 inches of rain falling in the rain band in near-coastal New York over a period of 36 hours
- up to 4 inches of freezing rain precipitating in the ice band in central New York, of which between 1 and 2 inches (radial, i.e., the thickness of accumulated ice as measured outward from the collection surface, such as a twig) accumulates as ice, over a period of 24 hours
- up to 2 feet of snow accumulating in the snow band in northern and western New York over a period of 48 hours

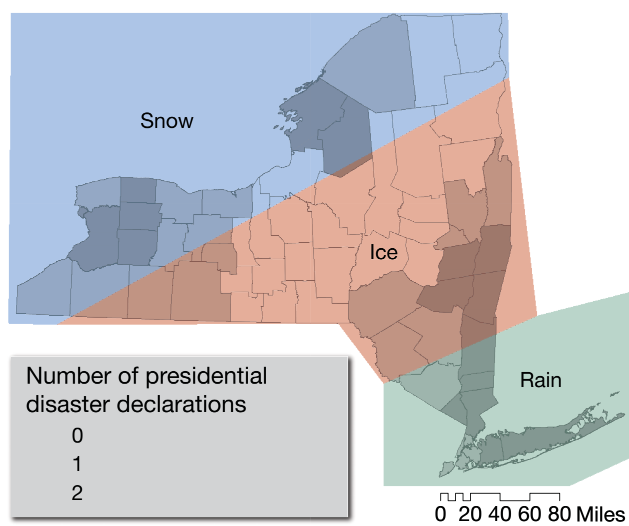
Figure 10.22 shows the three precipitation bands of the scenario storm system in relation to county boundaries within the state. The center of the ice band covers the cities of Binghamton, Albany/Troy, and Schenectady, and several rural areas in between and in their vicinity. The snow band covers Buffalo, Rochester, Syracuse, Utica, Plattsburg, and the Adirondacks. The rain precipitates over Long Island, New York City, and the mid-Hudson Valley counties to halfway between New York City and Albany.

Of New York State's 62 counties, 12 are assumed to be dominated by rain and about 20 by snow; about 30 are subjected to freezing rain. The county population density varies significantly from extreme urban (65,000



Note: The ice band includes a zone in New York State stretching from Binghamton through Albany into the Berkshires.

Figure 10.21 Typical pattern of severe winter storms in New York State



Source: Redrawn from NYSEMO historic map of presidential disaster declarations of winter storms in New York State for 1953 to 2007

Figure 10.22 Approximate overlay of the precipitation bands for the winter storm analyzed in the case study people per square mile in Manhattan) to very rural (three people per square mile in Hamilton). Of the nearly 20 million people living in New York State, about 12 million are assumed to be affected largely by heavy rains, 4 million by freezing rain and ice, and about 4 million by snow. This weather-affected population (individuals) translates into about half of the above-quoted numbers as electric grid customers (households or businesses), with 6 million electric grid customers affected by heavy rain, 2 million affected by freezing rain and ice, and about 2 million affected by snow. About 95 percent of these customers in each of the precipitation categories are connected by wire (cable), wireless services, or both.

While there may be some urban flooding in the rain band, this assessment focuses on electric grid and telecommunications outages. Thus, the analysis largely examines the approximately 2 million New York customers in the ice band and the approximately 2 million customers in the snow band.

There are an estimated 4.1 million utility poles along about 145,000 pole miles in New York State,[11] i.e., an average of about 28 poles per pole-mile. Nearly one-third (almost 1.4 million poles) would fall into each of the three precipitation zones. This implies, on average, about 0.7 poles per customer in the less populated ice and snow bands and only slightly more than 0.2 poles per customer in the metropolitan area of the rain band, which, at least in New York City, has a large portion of the electric wires and phone lines running underground. These are average numbers, and the local values of poles per customer may vary in inverse relation to the population density, with more poles per person in less densely populated areas. Therefore, on average, rural customers have a higher chance of wire line problems from snow and ice loads than do city dwellers. Of course, if an urban area is struck by power outages, each outage can affect a much larger number of customers.

But because of the much longer average wireline per rural customer, and the assumed rate of ice and snow load failure is proportional to wire length (although other factors, such as proximity to trees and wind exposure, play a considerable role), rural customers can expect longer restoration times. Another factor is that utilities may decide to bring back the largest possible number of customers at the earliest possible time with the finite number of repair crews available. For this reason, there is a tendency to make restoring lines with a high customer density a higher priority. This may leave rural areas at a lower priority, not by intent but for technical reasons. The pattern of restoration often starts from the core of the network and radiates outward from there. Also, telecommunications companies generally follow the electric grid restoration, and hence the pace and pattern of electric grid restoration largely controls the pace and pattern of telecommunications restoration.

The Public Service Commission monitors restoration plans on a regular basis and works with utility companies via post-storm reviews to improve restoration planning and performance. This information is also important for updating emergency response and assistance readiness.

The electric grid outage rate during the 2008 ice storm left about 12.4 percent of customers without power (see section 10.3.1). The percentage varied from county to county and from township to township, affecting between a few percent of customers up to almost 60 percent of customers (with the largest outages in rural Otsego County, which has a population density of only five people per square mile). The 2008 ice storm was centered on Albany County. There, it had a (radial) ice thickness that rarely exceeded 1 inch.

This analysis considers an ice storm with 1 to 2 inches of radial ice accumulation, which raises the average outage to 25 percent of customers, notwithstanding the possible strong local deviations from this average. This would imply that within the ice band a total of some 500,000 New York State customers would be without power. Fewer customers would probably be without power in the snow zone. Most customers without electricity are likely to lose communication services sooner or later due to dropped wirelines placed on the same poles as electric lines; from the inability to sustain back-up power at central phone offices when they run out of fuel; from drained batteries that cannot be recharged in customers' wireless home sets or in their wireless phones; or from drained batteries, inside the customers' homes, located at the end of fiber-optic drop lines.

Exhausted batteries in fiber loop converters that serve wireless cell sites could also contribute significantly to the loss of wireless communication. Typically, a single fiber loop converter serves all the wireless carriers at a tower. If one of the carriers cannot get generator power to the fiber loop converter, the sites of all carriers go down at the tower.

Restoration Times

Estimates of likely restorations for power and communication services are based on the recent storms described in Section 10.3.1 of this chapter regarding reported power failure and restoration times, including those times given for the 1998 Canada/United States ice storm and the December 2008 New York ice storm centered on Albany. This scenario also assumes that the ice thickness is greater than the ice thickness in two out of the three ice storms described, and that adjacent states are also affected by the scenario ice storm and, thus, need some of their utility repair crews to restore their own outages.

Restoration Time Estimates

Based on the assumptions above, the estimated restoration times for the central ice band are as follows:

- Ten percent of customers who lost power will have their electricity restored within 24 hours after the ice stops accumulating (i.e., the first 50,000 of the half million customers in the band of freezing rain/ice).
- Fifty percent of customers will have electricity restored after 10 days (i.e., 250,000 customers).
- Ninety percent of customers will have their power restored after three weeks (i.e., 450,000 of the half million customers in the band of freezing rain/ice).
- Full restoration of power will take about five weeks (i.e., for the remaining 10 percent, or 50,000 customers, who are most likely located in remote, rural locations).

The restoration times in the snow zone may be slightly shorter than in the ice band. From the trends and historic cases described earlier, it is likely that the majority of customers in most of the larger cities (e.g., Albany, Binghamton, and the Schenectady area in the freezing-rain zone, and Buffalo, Rochester, Syracuse, Ithaca, and Utica in the snow zone) will be part of the first 50 percent of customers who lost power to have it restored, i.e., within the first 10 days.

However, large uncertainties exist, and local restoration times may depend, in part, on how well prepared a utility is to cope with the consequences of the storm. Preventive tree trimming, stocking poles and wires, and arranging for outside crews to assist in the restoration can all make a difference, either by reducing the failure rate or by shortening restoration times. Tree trimming is unpopular with many homeowners, and in some areas utilities have succumbed to political pressure and reduced the clearance they ordinarily would maintain.

Economic and Social Impacts: Productivity Losses, Damage, and Equity and Environmental Justice Issues

To estimate economic productivity and damage losses, the case study uses the number of people affected and the number of customers restored per number of days until restoration from the previous section. It also uses New York State's average per-person contribution to the state's gross domestic product ($1.445 trillion per year per 19.55 million people equals about $58,600 per person per year, which is equal to $160.50 per person per day).

Loss Estimates

Based on these assumptions, the losses to the state's economy are about $600 million in the first 10 days, $240 million between days 10 and 20, and $60 million in the remaining time from days 20 to 35. In total, this amounts to about $900 million ($0.9 billion) from productivity losses alone.

In addition to costs associated with lost productivity, costs associated with direct damages must be included as well (e.g., spoiled food; damaged orchards, timber, and other crops; replacement of downed poles and electric and phone/cable wires; medical costs; emergency shelter costs). These costs are likely to be of the same order as those of the productivity losses, which would imply a total ice storm cost of about $2 billion in New York State. This estimate does not include the snow effects on the state's economy and potential economic losses in the areas covered by snow. The loss estimate of $2 billion is probably on the low side, given that the 1998 ice storm resulted in losses of about U.S. $5.4 billion in Canada alone.

Equity and Environmental Justice Issues

The equity and environmental justice analysis uses the October 2006 snow storm in western New York as a historical analogue for illustrating potential social vulnerabilities during the recovery and restoration phase. The case considers rural areas and particular segments of the population who might be especially vulnerable during a protracted recovery. A primary advantage of analyzing this event instead of the 1998 ice storm is that the 2006 storm reflects a more current state of telecommunications technology. Its similarity to other severe ice storms is confirmed by one company's report that the degree of infrastructure damage and the magnitude of the company's response for the 2006 storm were comparable to those of the historic 1998 ice storm. Also, the 2006 storm triggered a recovery lasting nearly a month (NYSDPS, 2007), which is comparable with the estimates for restoration in this case study.

Following the 2006 storm event, the New York State Public Service Commission published a report detailing the steps leading up to the infrastructure failures and the subsequent difficulties in diagnosing problems and restoring service (NYSDPS, 2007). The report did not explicitly address population vulnerabilities, but it does reveal the limits of one communication company's capacity to respond, and it suggests a number of areas where these limits could be differentially experienced across regions and groups.

Date	Opening Trouble Load	Incoming Troubles	Troubles Cleared	Repair Technicians
10/14/2006	7,004	6,539	1,305	278
10/15/2006	10,811	6,274	2,467	372
10/16/2006	11,774	4,155	3,192	453
10/17/2006	15,699	7,196	3,271	497
10/18/2006	17,373	5,473	3,799	497
10/19/2006	18,263	4,791	3,901	535
10/20/2006	19,947	4,479	2,795	509
10/21/2006	19,604	4,015	4,358	514
10/22/2006	19,100	2,896	3,400	519
10/23/2006	19,700	2,068	1,468	568
10/24/2006	20,368	5,307	1,639	589
10/25/2006	21,218	3,830	2,980	599
10/26/2006	20,674	3,191	3,735	617
10/27/2006	20,157	3,213	3,730	608
10/28/2006	18,965	2,726	3,918	606
10/29/2006	17,361	1,986	3,590	607
10/30/2006	15,397	2,064	4,028	614
10/31/2006	14,884	3,164	3,677	606
11/01/2006	14,121	2,713	3,476	603
11/02/2006	13,055	2,358	3,424	649
11/03/2006	11,652	1,844	3,247	772
11/04/2006	10,085	1,801	3,368	776
11/05/2006	8,290	1,009	2,804	758
11/06/2006	6,113	934	3,111	732
11/07/2006	3,995	1,826	3,944	675
11/08/2006	2,540	1,747	3,202	636
11/09/2006	1,779	2,133	2,894	629
11/10/2006	1,388	1,306	1,697	448
11/11/2006	1,034	968	1,322	287

Table 10.2 Daily opening trouble reports, incoming troubles, troubles cleared, and staffing levels for October 2006 snow storm

The majority of damage in 2006 (and large amounts in the 1998 ice storm) was to tens of thousands of drop wires to individual building units. Nearly 93,000 trouble reports (not all may indicate that customers are out of service) were registered over a three-week period, with the peak report load being reached nearly two weeks after the storm (**Table 10.2**). These reports are a guide to restoration activities, with extended lag times on customer response complicating such efforts. As the report notes, one reason for the widespread delays was that customers were unaware that they were responsible for reporting the outage or assumed that service would be restored in time with power. One could expect that customers with better access to communications and information or who were socially and geographically more connected would be in a better position to understand their personal responsibility and act on the situation. On the other hand, isolated or impaired individuals or those who were in disconnected households in rural areas would be at higher risk of lengthened hardship.

The New York State Department of Public Service (2007) report notes another key variable in delays to restoring service: Large numbers of affected customers may have lost the incentive to promptly report outages because they simply switched to cell phones or left their homes. Whether these individual cases of non-reporting might contribute to aggregate, systemic, communitywide misdiagnoses and delays is unclear. But it does raise the prospect of one group's coping strategies potentially exacerbating the vulnerability of less mobile or otherwise isolated individuals who are located within the same communities. The report found it credible, for instance, that use of cellular phones likely contributed to delays in the company's initial damage assessment, which is key to the above suggestion that it delayed the restoration of more vulnerable customers.

In all such emergencies, there remains one big issue: How do households in rural communities report a telephone outage when the telephone services are out?

Coping during Service Restoration

Initial concentration on centralized and reported infrastructure failures is a technically logical reaction to the magnitude of the problem, but one that inevitably favors more densely populated areas. In more general terms, restoration after an ice storm would happen first in urban areas and then in rural areas, with smaller, remote communities likely to be restored last. This pattern is reinforced by the relative inaccessibility of remote areas in the aftermath of a storm, which prevents service technicians from safely restoring lines, particularly when the latter are in unapproachable areas in backs of houses, as was noted in the 2006 storm. Both of these issues are pertinent since central New York is marked by wide variations in population density and rapid transitions between accessible urban areas and more isolated rural areas.

The ability to cope through the lifecycle of a power and telecommunications outage partly reflects access to diverse telecommunications and transport options. In the 2006 ice storm, large numbers of households did cope by leaving their homes or switching primarily to cell phones. (The cell phone network relies, however, entirely on the landline network, except for the wireless link from the tower to the mobile phone. The tower is typically connected to the network over landline facilities, so cell phone service can fail when the lines feeding the towers are damaged.) Both of these strategies (leaving homes and cell phone use) rely on physical mobility, wealth, and geographic integration. More wealthy, urban populations with access to public transportation, adaptive vehicles (e.g., sport utility vehicles, all-terrain vehicles), or affordable temporary housing are substantively more resilient than elderly, low-income, disabled, rural, or otherwise transport-disadvantaged populations.

Under some conditions, cell phones can become a coping mechanism even when other parts of the communication network are down. However, cell phone coverage varies across providers and regions, and most major companies have dead zones within parts of rural New York State. Furthermore, during localized power outages, rural households with access to power exclusively from the electric grid will be—for as long as the latter is down—unable to recharge their cell phones without supplemental solar or car phone chargers.

Special Considerations and Communication Needs

Individuals with cognitive and physical impairments are less likely to receive emergency messages and to correctly interpret the recommended actions. This vulnerability could be compounded by mismanaged or misleading information disseminated by telecom providers (or other institutions).

In 2006, providers struggled to communicate critical information regarding service restoration promptly and consistently to the local media. At times, communication with public institutions bypassed local officials on the town and village level, officials who arguably would have been best placed to spread emergency communications (NYSDPS, 2007).

Case Study Conclusions

In summary, the case study shows that with the current state of vulnerability of power and telecommunications systems to winter storms, interruption of these services in New York State can affect hundreds of thousands of customers for many weeks from a single event. The resulting business interruptions and direct losses combined tend to produce losses in the hundreds of millions of dollars. Services for remote rural customers are typically the last to be restored and pose social injustice and inequities, and in some cases life-threatening emergency conditions.

References

Belinfante, A. 2009. “Telephone Subscribership in the United States (Data through March 2009).” Report for the Industry Analysis and Technology Division, Wireline Competition Bureau, Federal Communications Commission (FCC), August. http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-292759A1.pdf.

Bennett, J. 2002. *State of the U.S. Telecommunication Networks and Root Cause Analysis: 2001 Annual Report*. ATIS Report, May.

Cauley, L. 2008. “Consumers ditching land-line phones.” *USA Today*, May 14. http://www.usatoday.com/money/industries/telecom/2008-05-13-landlines_N.htm

Changnon, S.A. 2003. “Characteristics of ice storms in the United States.” *Journal of Applied Meteorology* 42:630-639.

Changnon, S.A. and T.R. Karl. 2003. “Temporal and spatial variations of freezing rain in the contiguous United States 1948-2000.” *Journal of Applied Meteorology* 42:1302-1315.

Congress of the United States Congressional Budget Office (CBO). 2007. *Potential Cost Savings from the Pre-Disaster Mitigation Program*. http://cbo.gov/ftpdocs/86xx/doc8653/09-28-Disaster.pdf.

DeGaetano, A.T. 2000. “Climatic Perspective and Impacts of the 1998 Northern New York and New England Ice Storm.” *Bulletin of the American Meteorological Society* 81(2): 237-254.

DSL Reports. *DSL-ready map.* http://www.dslreports.com/comap/st/NY/.

The Economist. 2008, May 22. “Buy our stuff, save the planet.” http://www.economist.com/opinion/displaystory.cfm?story_id=11412495

Federal Communications Commission (FCC). 2002.

Federal Communications Commission (FCC). 2008.

Federal Emergency Management Agency (FEMA). 2003. Ice Storm Disaster Aid Tops $25 Million [Press release]. Retrieved from http://www.fema.gov/news/newsrelease.fema?id=3947

Fox, S. 2005. *Digital Divisions*. Washington, DC: Pew Internet & American Life Project.

Global Climate Change Impacts in the United States. 2009. Edited by T.R. Karl, J.M. Melillo and T.C. Peterson. U.S. Global Change Research Program. http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf

Gross, D.L. 2003. “Assessing Local Government Capacity for Ecologically Sound Management of Flowing Water in the Landscapes of the Great Lakes Basin.” Unpublished M.S. thesis, Cornell University, Department of Natural Resources.

Hansell, S. 2009. “Will the Phone Industry Need a Bailout, Too?” *New York Times*, May 8. Accessed May 20, 2009. http://bits.blogs.nytimes.com/2009/05/08/will-the-phone-industry-need-a-bailout-too/.

Horrigan, J. 2009. *The Mobile Difference.* Washington, DC: Pew Internet & American Life Project.

Horrigan, J. 2007. *Why it will Be Hard to Close the Broadband Divide*. Washington, DC: Pew Internet & American Life Project.

Horrigan, J. 2008. *Home Broadband Adoption.* Washington, DC: Pew Internet & American Life Project.

Johnson, K. 2009. “For Rural Elderly, Times are Distinctly Harder.” *New York Times.* December 10.

Jones, K.F. 1996. “Ice accretion in freezing rain.” U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory. Rep. 96-2.

Jones, K.F. and N.D. Mulherin. 1998. “An evaluation of the severity of the January 1998 ice storm in northern New England.” U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory report.

Karl, T.R., J.M. Melillo, and T.C. Peterson (eds.). 2009. Global Climate Change Impacts in the United States. Cambridge University Press.

Light, J. 2001. “Rethinking the digital divide.” *Harvard Educational Review* 71(4):709-735.

MacLean. 2008. “ICTs, Adaptation to Climate Change, and Sustainable Development at the Edges.” *An International Institute for Sustainable Development Commentary.*

Manuta, L. 2009. “New FCC Telephone Penetration Statistics Reveal Problems in New York.” *The Public Utility Law Project of New York (PULP) Network blog*, August 14. http://pulpnetwork.blogspot.com/2009/08/new-fcc-telephone-penetration.html.

McKenna, C. 2009. “New York Statewide Wireless Interoperable Communications Network Refocused on Regional Systems.” *Government Technology.* http://www.govtech.com/gt/635218?id=635218&full=1&story_pg=1.

Multihazard Mitigation Council (MMC). 2005. “Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities.” National Institute of Building Sciences. http://www.nibs.org/index.php/mmc/projects/nhms and http://www.nibs.org/client/assets/files/mmc/Part1_final.pdf.

National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS). 2008. “The Historical 11-12 December 2008 Ice Storm.” http://cstar.cestm.albany.edu/PostMortems/CSTARPostMortems/2008/12dec2008icestorm/dec2008icestorm.htm.

New York City Economic Development Corporation (NYC EDC), New York City Department of Information Technology and Telecommunications (NYC DoITT), New York City Department of Small Business Services (NYC DSBS). 2005. *Telecommunications and Economic Development in New York City: A Plan for Action*. A Report to Mayor Michael R. Bloomberg. March.

New York City Partnership (NYCP). 1990. “The $1-Trillion Gamble: Telecommunications and New York’s Economic Future.” A Report by the New York City Partnership in Collaboration with Booz, Allen & Hamilton, Inc., June.

New York State Council for Universal Broadband. 2009b. *Broadband Map, Albany County* http://www.nysbroadband.ny.gov/maps/counties/albany.htm.

New York State Geographic Information Systems (NYS GIS). 2009. *Clearinghouse*. http://www.nysgis.state.ny.us/coordinationprogram/reports/presentations/gisconf09/2009_State_of_State_FINAL.

New York State Office for Technology (NYS OFT). 2008. “Going from Good to Great.” http://www.oft.state.ny.us/News/FinalNYS2008GoalsandStrategies.pdf.

New York State Office for Technology (NYS OFT). 2009a. “Connecting New York to the World for Sustainable Adoption: New York State Universal Broadband Strategic Roadmap.” New York State Council for Universal Broadband, June. http://www.nysbroadband.ny.gov/assets/documents/Final_Broadband_Strategy_June2009.pdf.

New York State Office of Cyber Security and Critical Infrastructure Coordination. 2009. "2009 State of the State in GIS." http://www.nysgis.state.ny.us/coordinationprogram/reports/presentations/gisconf09/2009_State_of_State_FINAL.pdf

New York State Public Service Commission (NYS PSC). 2002. "Network Reliability After 9/11". A Staff White Paper on Local Telephone Exchange Network Reliability. NYS DPS Office of Communications. November 2.

New York State Public Service Commission (NYS PSC). 2003. "Case 03-C-0922: Network Reliability Proceeding." http://www.dps.state.ny.us/03C0922.html.

New York State Public Service Commission (NYS PSC). 2004. "Initial Report on the August 14, 2003 Blackout." February. http://www3.dps.state.ny.us/pscweb/WebFileRoom.nsf/Web/5FA2EC9B01FE415885256E69004D4C9E/$File/doc14463.pdf?OpenElement.

New York State Public Service Commission (NYS PSC). 2005. "Second Report on the August 14, 2003 Blackout." October. http://www3.dps.state.ny.us/pscweb/WebFileRoom.nsf/Web/DA5944111F5033A4852570B4005E778A/$File/FinalSecondBlackoutRpt-4-03-06-errata.pdf?OpenElement.

New York State Public Service Commission (NYS PSC). 2006. *Mission Statement.* http://www.dps.state.ny.us/mission.html.

New York State Public Service Commission (NYS PSC). 2007. "October 2006 Western New York Major Snowstorm: A Report on Utility Performance" May. http://www3.dps.state.ny.us/pscweb/WebFileRoom.nsf/Web/2D5910CDFE0696CA852572DD005F9D80/$File/WesternNewYorkOctober2006SnowstormFinalReport.pdf.

New York State Public Service Commission (NYS PSC). 2009a. "October and December 2008 Winter Storms. A Report on Utility Performance," June. http://documents.dps.state.ny.us/public/MatterManagement/CaseMaster.aspx?MatterSeq=30915.

New York State Public Service Commission (NYS PSC). 2009b. Case 09-M-0527. http://documents.dps.state.ny.us/public/MatterManagement/CaseMaster.aspx?MatterSeq=31654.

Quarantelli, E.L. 2007. "Problematical Aspects of the Computer Based Information/ Communication Revolution with Respect to Disaster Planning and Crisis Managing." Working Paper 358, University of Delaware Disaster Research Center. Accessed May 29, 2009. http://dspace.udel.edu:8080/dspace/bitstream/19716/3055/1/PP%20358.pdf.

Sullivan, B. 2006. "Why cell phone outage reports are secret." *MSNBC The Red Tape Chronicles,* December 15. http://redtape.msnbc.com/2006/12/why_cell_phone_.html.

United States Government Accounting Office (US GAO). 2007. *Natural Hazard Mitigation* August. http://www.gao.gov/new.items/d07403.pdf.

Untied States Army Corps of Engineers (USACE). 1998. "Ice storms in New England and New York."

Victory, N. 2006. "Report and Recommendations of the Independent Panel Reviewing the Impact of Hurricane Katrina on Communications Networks." Memo to the Federal Communications Commission (FCC), June 12. http://www.fcc.gov/pshs/docs/advisory/hkip/karrp.pdf.

Sources of Information

http://www.dps.state.ny.us/mission.html

http://www.govtech.com/gt/635218?id=635218&full=1&story_pg=1

http://www.oft.state.ny.us/News/FinalNYS2008GoalsandStrategies.pdf

http://redtape.msnbc.com/2006/12/why_cell_phone_.html

Case 09-M-0527 brought before the NYS PSC re the Universal Service Fund http://documents.dps.state.ny.us/public/MatterManagement/CaseMaster.aspx?MatterSeq=31654

http://www3.dps.state.ny.us/pscweb/WebFileRoom.nsf/web/B3C502B29ECB84FD85256DF1007 56D51/$File/doc4618.pdf?OpenElement

Variations in Broadband Availability; NYS Broadband Council. http://www.nysbroadband.ny.gov/assets/documents/Final_Broadband_Strategy_June2009.pdf

http://www.nielsenmobile.com/documents/WirelessSubstitution.pdf

http://www.cdc.gov/nchs/data/nhis/earlyrelease/wireless200905.htm

http://www.ntia.doc.gov/broadbandgrants/BTOPAward_IONHoldCoLLC_121709.pdf

http://en.wikipedia.org/wiki/December_2008_Northeast_ice_storm

http://www.fema.gov/news/newsrelease.fema?id=48163

http://www.associatedcontent.com/article/1428697/kentucky_storms_weather_cause_phone.html and http://www.kentucky.com/news/state/story/682579.html

Kentucky power outages 1/28/09: http://vielmetti.typepad.com/.a/6a00d8341c4f1a53ef010536ff9773970c-800wi]

http://www.aimclearblog.com/2008/04/11/massive-spring-blizzard-takes-out-duluth-internet-services-electricity/

http://www.fema.gov/news/newsrelease.fema?id=3538

http://raincoaster.com/2006/06/08/the-ice-storm-quebec-1998/

http://www.nytimes.com/1998/01/11/nyregion/us-declares-five-counties-disaster-area.html

http://www.greenspun.com/bboard/q-and-a-fetch msg.tcl?msg_id=001HBW

http://www.stanford.edu/~rjohari/roundtable/sewg.pdf

Bell South/Katrina: https://netfiles.uiuc.edu/akwasins/www/Intelec06_Katrina.pdf

http://news.vzw.com/news/2008/09/pr2008-09-16s.html

NYS Public Workshop on Utility Preparation, Response, and Recovery from the December 2006 Wind Storm (Docket No. U-070067). http://www.governor.wa.gov/news/2007-03-09_storm_workshop_summary.pdf

Annual frequency of outages vs. customers affected for US 1984 to 1997
https://reports.energy.gov/B-F-Web-Part3.pdf.
Open File Report on Black Out 2003: http://www3.dps.state.ny.us/pscweb/WebFileRoom.nsf/Web/5FA2EC9B01FE415885256E69004D4C9E/$File/doc14463.pdf?
http://www.beyondpesticides.org/wood/pubs/poisonpoles/tables/table2.html
http://www.pcworld.com/article/159630/universal_chargers_to_finally_become_a_reality.html and http://reviews.cnet.com/8301-13970_7-10165603-78.html
http://www.arrl.org/
http://tsp.ncs.gov
http://www.iec.org/online/tutorials/ss7/index.asp

Appendix A. Stakeholder Interactions

The first ClimAID project stakeholder meeting for the Telecommunications sector was held in conjunction with the Transportation sector stakeholders on February 12, 2009. Following this initial meeting, a questionnaire was developed and sent to the stakeholders. The questionnaire highlighted information that would allow an assessment of the most important challenges posed by climate change.

ClimAID telecommunications infrastructure stakeholders were invited to comment on a chapter draft dated January 8, 2010. We acknowledge the thorough reviews by several stakeholders.

Stakeholder Questionnaire

NYS ClimAID: Telecommunications Survey for Information Covering the Entire State of New York (4/07/2009)

A. Commercial Power

1) How many a) office facilities (central offices, head-ends, mobile switch centers) and b) outside plant facilities (cell towers, controlled environmental vaults, fiber nodes, etc.) have back-up power generation? (Give both percentage and actual number for both a. and b.)
2) What portion of facilities with back-up power generation is provided by a) battery and b) generator, or c) some other type of back-up generation?
3) How long can facilities operate on back-up generation types identified in question 2?
4) What arrangements are in place to replenish backup generation fuel and supplies for extended commercial power outages?

B. Wireless Networks

5) How many transmitters/repeaters are a) singularly located on towers, and b) co-located on towers with other service providers? (Give both percentage and actual number for both a. and b.)
6) Do you expect the arrangements in question 5 to change significantly over the next 5 years? 10 years?
7) What portion of the backbone network interconnecting transmitters/repeaters to the mobile switching offices are comprised of the following facilities: a) wireless, b) telephone company, c) cable company, d) other service provider?
8) What portions of cable facilities are a) aerial and b) underground?

C. Wireline (cable TV, telephone) **Networks**

9) How much of the outside cable plant is a) aerial cable, and b) underground cable?
10) How much of the outside cable plant is a) copper cable, and b) fiber optic cable? (Give both percentage and actual miles for both 9. and 10.)

D. Climate Hazard Thresholds

11) Do outside plant facilities (towers, antennas, aerial cables) meet or exceed industry recommended standards for surviving maximum wind velocities (mph) and ice loading? What are these maximum limits?
12) How many a) office facilities (central offices, head-ends, mobile switch centers) and b) outside plant facilities (cell towers, controlled environmental vaults, fiber nodes, etc.) are located in FEMA-designated flood zones (according to FIRM maps)?
13) What restoration/contingency plans are in place to prevent or mitigate service interruptions if these facilities become inundated? Note: FIRM maps are web accessible by state/county from: http://msc.fema.gov/

Stakeholder Participants

Industry representatives:

- AT&T
- Cablevision Systems Corp.
- Frontier Communications
- Sprint Nextel
- T-Mobile
- Time-Warner Cable
- Verizon & Verizon Wireless
- The Cable Telecommunications Association of New York, Inc. (CTANY)
- National Grid

Government representatives:

- Department of Homeland Security (DHS)
- New York City Mayor's Office of Long Term Planning and Sustainability
- New York City Office of Emergency Management (NYCOEM)
- New York State Department of Environmental Conservation (NYSDEC)
- New York State Emergency Management Office (NYSEMO)
- New York State Energy Research and Development Authority (NYSERDA)
- New York State Public Service Commission (PSC)

[1] Based on http://www.bea.gov/regional/gsp/action.cfm and using the 2007 data for NYS's telecommunications and broadcasting industry; they yield for 2007 a 4 percent GSP contribution to the then $1.1 trillion gross state product.

[2] For updates see: http://www.broadband.gov/maps/availability.htm

[3] http://www.dps.state.ny.us/mission.html

[4] http://www.govtech.com/gt/635218?id=635218&full=1&story_pg=1

[5] http://www.oft.state.ny.us/News/FinalNYS2008GoalsandStrategies.pdf

[6] The 20-year recurrence period is inferred from the linear log-log relationship between annual frequency F of outage occurrence (for the entire United States) and number of affected customers N, i.e., $\log F = 4.4 - 0.77 \log N$.

[7] NYSDPS 2002 became the foundation for the Commission's proceeding of Case 03-C-0992 to improve telecommunications network reliability throughout the state, creating among other things requirements for geographic route diversity of critical interoffice traffic and stand-alone capability for remote switching facilities.

[8] MIMO is the use of multiple antennas at both the transmitter and receiver end to improve communication performance. It is one of several forms of smart antenna technology.

[9] These issues are addressed in the PSC's State Universal Service Proceeding (09-M-0527). A whitepaper on wired, cable, and wireless coverage in NY ("white-spots") was produced (Staff Report, issued 12/23/09 available from http://documents.dps.state.ny.us/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=09-M-0527).

[10] See Case 09-M-0527 brought before the NYSPSC re the Universal Service Fund to address related issues: see Staff Report of 12/23/2009, document 49 downloadable from: http://documents.dps.state.ny.us/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=09-M-0527 ; or from http://documents.dps.state.ny.us/public/MatterManagement/CaseMaster.aspx?MatterSeq=31654.

[11] http://www.beyondpesticides.org/wood/pubs/poisonpoles/tables/table2.html