The Contribution of CHP to Infrastructure Resiliency in New York State

Final Report
April 2009

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THE CONTRIBUTION OF CHP TO INFRASTRUCTURE RESILIENCY IN NEW YORK STATE

Final Report

Prepared for the

NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY

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NOTICE

ABSTRACT

This report is the final deliverable 3 of the *CHP and Critical Infrastructure* project conducted under NYSERDA Agreement Number 9931. The purpose of the project is to identify and recommend the most opportune uses for CHP as a way to address critical infrastructure resiliency in selected end-use sectors in New York State. The report presents both quantitative data and information regarding CHP technical potential, infrastructure resiliency factors, and end-use sector energy demand to identify the sectors with the best opportunities for CHP as a hedge against supply disruptions in either natural or man-made emergencies. The authors recommend specific actions for facility owners and managers of those sectors to take in learning about CHP and in developing strategies for using CHP in the future.

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EXECUTIVE SUMMARY

The U.S. electric power system is vast and complex, with thousands of miles of high-voltage cable that serve millions of customers around the clock, 365 days per year. Although normally this "instant" supply of electricity is taken for granted, terrorist attacks and natural disasters remind us how dependent we are on electricity and how fragile the grid can be. Water systems; oil and gas pipelines; communications systems; residential, commercial, industrial, and institutional buildings; transportation; health systems; emergency operations; and nearly every other category of critical infrastructure is in some way dependent on electricity. Electricity is a critical foundation for homeland security.

Prior to September 11, 2001, emergency management planning focused primarily on preparedness and response—that is, what happens at the moment of an emergency and in the minutes, hours, days, and weeks thereafter. In the years since 2001, however, the idea of infrastructure resilience in key assets, systems, and functions—that is, the ability to maintain operations despite a devastating event—has become a key principle in disaster preparedness. Combined heat and power (CHP), a highly efficient form of distributed generation (DG), offers the opportunity to improve critical infrastructure (CI) resiliency, mitigating the impacts of an emergency by keeping critical facilities running without any interruption in service.

This is possible because CHP systems, which typically run on gas but can also use biomass and other renewable fuels, where appropriate, are not dependent on external supplies of electricity to meet base load requirements of the facilities they serve. If the electricity grid is impaired, a properly configured CHP system can continue to operate, ensuring an uninterrupted supply of power and heat to the host facility. The installation of CHP systems at select CI facilities could increase the ability of these facilities to ride through a prolonged electrical grid outage; and the uninterrupted functioning of critical facilities would increase the resiliency of the entire community. The high fuel efficiency of CHP systems enables a reduction in fuel use and air emissions when compared to separate heat and power systems. CHP systems often replace grid-supported electricity with cleaner and more reliable, efficient, and cost effective systems, which supply both electricity and heat/cooling under emergency and normal operating conditions.[1]

Several CI facilities in New York already have CHP systems. For example, the Montifiore Medical System in the Bronx has a CHP system with total electrical capacity of 10 MW, which provides 100% of the electric and thermal needs of the medical center. During the 2003 Northeast blackout, Montefiore was reportedly the only hospital in New York City able to continue normal operations. A 850-kW CHP system at ElderWood Health Care at Oakwood provides both electricity and heat for the nursing home; the system is estimated to yield nearly $100,000 in annual energy savings, resulting in a financial payback of six years.

Although CHP has been adopted by numerous facilities across the state, its unrealized technical potential in New York remains quite large. The technical potential for CHP in New York State is defined as the total capacity potential from existing and planned facilities—across all end-use sectors—that have the appropriate electric and thermal (or cooling) load characteristics to support a CHP system. This includes sites that could appropriately use CHP systems but may

[1] It is important that CHP systems be installed at facilities where they can meet both thermal and electricity needs in order to maximize fuel efficiency and cost effectiveness.

not necessarily install them. Other factors, such as the cost-effectiveness of installing such a system; competing demands; available resources; and specific site requirements, will ultimately determine the actual number of sites and the amount of capacity that is installed.

A recent analysis of CHP technical potential in New York State finds 19,730 potential sites that could generate approximately 9,778 MW of electricity.[2]

From an emergency management/disaster preparedness perspective, it is important to preferentially employ CHP systems at critical infrastructure facilities, which play an important role in providing or enabling essential services during a crisis event. The *National Infrastructure Protection Plan (NIPP)* identifies 17 CI sectors[3], each consisting of multiple sub-sectors. The NIPP, however, does not specify which of these sectors and subsectors would be most critical to maintain during an emergency event that may disable the electric power grid in New York State, or which of these sectors represent the best technical candidates for CHP systems.

An assessment of the most critical end-use sectors that must be maintained in an emergency requires addressing four categories of consequences for the surrounding community, including:

- **Human impact** – fatalities or injuries that would result if the critical asset is degraded or incapacitated
- **Economic impact** – the direct and indirect effects on the economy that could result if the critical asset is degraded or incapacitated
- **Impact on public confidence or psychological consequences** – the effect on public morale and confidence in national economic and political institutions if the critical asset is degraded or incapacitated
- **Impact on government continuity** – the reduction in the ability of state and local governments to deliver minimum essential public services, ensure public health and safety, and carry out national security-related missions if the critical asset is degraded or incapacitated.

This report ranks specific end-use sectors in New York State according to their importance during an emergency by using the above criteria as well as their technical potential for CHP. Sectors that might serve as places of refuge during an emergency have also been identified, as this can add importance to some sectors that might not otherwise be highly ranked. The resulting **primary market sectors** include:

- Hospitals
- Water treatment and sanitary facilities
- Nursing homes
- Food processing and food sales facilities
- Prisons

[2] *CHP Potential in End Use Sectors in New York State,* Energy and Environmental Analysis, Inc. – An ICF International Company, April 2008.

[3] An 18th critical infrastructure sector, Critical Manufacturing, was added in 2008. However, because this sector is not yet well-defined, this report only addresses the 17 sectors originally identified in the *NIPP*, published in 2006.

These are considered ***high value sectors*** for CHP investment in New York State. In addition, a sixth primary market sector, Places of Refuge, has been identified as being critical to public health and safety; many, though not all, places of refuge will also offer good technical potential as CHP host facilities. These facilities, however, will have to be evaluated individually based on municipal emergency planning in each jurisdiction. This sector includes various sub-sectors, as follows:

- Places of Refuge
    - Schools, colleges, and universities
    - Armories
    - Government buildings
    - Hotels and convention centers
    - Sports arenas
    - Other facilities, as appropriate

A seventh primary sector, **Chemicals**, is also included due to the importance of its pharmaceuticals sub-sector.

In addition to the primary market sectors listed above, this report identifies **secondary market sectors**. These offer significant potential contributions to community resiliency but do not have strong technical potential for CHP. They include:

- Gas stations
- Mass transit
- Fire protection
- Police
- Telecommunications
- Banking and finance
- Refrigerated warehouses

Recommended actions that address CHP potential for infrastructure resiliency in the most highly-ranked end-use sectors include:

- Develop and present compelling presentations and other communications materials on CHP for infrastructure resiliency to be used at meetings of state emergency management officials
- Identify potential CHP projects at wastewater treatment facilities, hospitals, and health care facilities, and schools and universities that may serve as places of refuge with CHP information and ranking results from the analysis in this report
- Recommend CHP audits, financial resources, and opportunities for overcoming institutional, financial, and/or regulatory obstacles to facility owners and managers in these end-use sectors

- Track CHP projects developed in the next 1-3 years to determine if Stimulus Funding, educational and outreach efforts, and/or direct technical support is having an effect on the number of CHP installations in these end-use sectors in New York State

The following provides details on the high-priority sectors, including their estimated technical potential and total MW possible, both upstate and downstate;[4] National Infrastructure Protection Plan (NIPP) sector; explanatory information about their role in addressing resiliency; and their average CHP-CI score.

Critical Infrastructure Sector	Coverage & Reach	Total Potential Sites	Total Potential MW	Comments/Notes	Final Score (Average)
Agriculture and Food Production	Food processing – Upstate	223	394.6	It is necessary to maintain electricity in the food processing and food sales/ supermarkets subsectors in order to ensure a stable food and water supply. Even in a very short term outage where power would be restored to these subsectors in a matter of days, the appearance of a potential food shortage could lead to a significant loss in public confidence.	2.75
	Food Processing – Downstate	285	288.1		2.50
	Food Sales/Super-markets – Upstate	1076	193.8		3.00
	Food Sales/Super-Markets – Downstate	1258	166.7		3.25
Chemicals	Pharmaceuticals and other Chemicals – Upstate	164	491.6	The loss of electricity in the pharmaceuticals/ other chemicals subsector would restrict the production of certain drugs and potentially cause casualties. In order to determine the harmful effects of restricted production in other types of chemical facilities, it is necessary to examine site specific details.	3.00
	Pharmaceuticals and Other Chemicals – Downstate	308	792.9		3.00
Drinking Water and Water Treatment	Water Treatment and Sanitation – Upstate	113	102.4	It is necessary to maintain electricity in the	3.25

[4] Downstate market consists of Long Island Power Authority, Consolidated Edison, and Orange and Rockland service areas. Upstate is made up of the remainder of the state.

Critical Infrastructure Sector	Coverage & Reach	Total Potential Sites	Total Potential MW	Comments/Notes	Final Score (Average)
Systems	Water Treatment and Sanitation – Downstate	64	70.9	water treatment/ sanitation subsector in order to ensure a stable food and water supply. Even in a very short term outage where power would be restored to this subsector in a matter of days, the appearance of a potential water shortage could lead to a significant loss in public confidence.	3.75
Places of Refuge	Armories – Entire State	14	1.9	Government buildings, although essential to government function, will not have a high level of consequence associated with loss of power because such agencies typically have incident management programs in place for such an instance.	1.00
	Government Buildings, Including State Office Buildings and Courthouses – Entire State	500	187.0		1.25
	Schools (elementary, middle, high, and technical) – Upstate	2099	220.1	An additional element of public safety includes maintaining places of refuge for evacuated people during an incident. It is important to maintain electricity in hotels, schools, colleges, and universities since some of these units could serve as places of refuge during an incident.	2.00
	Schools (elementary, middle, high, and technical) – Downstate	2861	299.4		2.00
	Colleges/Universities – Upstate	220	886.4		1.50
	Colleges/Universities – Downstate	209	880.5		1.50
	Hotels – Upstate	754	267.4		1.75
	Hotels – Downstate	622	419.1		1.75
Prisons	Prisons – Upstate	64	301.3		3.50

Critical Infrastructure Sector	Coverage & Reach	Total Potential Sites	Total Potential MW	Comments/Notes	Final Score (Average)
	Prisons – Downstate	23	69.4	Ensuring the supply of electricity to prisons is critical to the health and safety of vulnerable staff and inmate populations. In the event of a prolonged power outage at a prison, should backup generators fail, the health and safety of residents in surrounding communities could also be at risk.	3.50
Public Health and Healthcare	Hospitals (medical and psychological) - Upstate	178	267.4	Hospitals represent a subsector that is necessary for public safety. It is imperative to ensure that hospitals function during an incident to provide essential emergency response functions.	4.00
	Hospitals – Downstate	232	384.8		4.00
	Nursing Homes – Upstate	412	309.6		3.25
	Nursing Homes – Downstate	383	482.0		3.25

1.0 INTRODUCTION

Hurricane Katrina made landfall in Plaquiemines Parish, Louisiana, at 6:10 a.m. on August 29, 2005, with 130-mile per hour winds. A storm surge ranging from four to 30 feet extended through Alabama, Tennessee, Florida, and Mississippi. The death toll reached over 1,800, approximately 450,000 families were left homeless, and damage estimates ran as high as $34.4 billion.[5] The devastation came as a shock to the nation. The human, economic, and psychological impacts were far beyond what anyone could have imagined. During the days and weeks following Katrina, which included the subsequent landfall of Hurricane Rita, it became clear that the emergency planning, response, and recovery systems in place were inadequate. The critical infrastructure in the affected states did not have the resiliency to bounce back from a catastrophic event.

Critical infrastructure collectively refers to those assets, systems, and networks that, if incapacitated, would have a substantial negative impact on national security, national economic

[5] "2005 Louisiana Hurricane Impact Atlas." May 2006. Louisiana Geographic Information Center. 23 Sept. 2008 <http://lagic.lsu.edu/lgisc/publications/2005/lgisc-pub-20051116-00_2005_hurricane_atlas.pdf>.

security, or national public health and safety.[6] The *National Infrastructure Protection Plan (NIPP) identifies* 17 critical infrastructure sectors, each consisting of multiple sub-sectors.[7] The importance of resiliency in these sectors and their sub-sectors is compounded by the interdependencies between them. For example, hospitals and nursing homes, which are significant components of the Public Health Sector, are dependent on the Chemical Sector for pharmaceuticals. The Chemical Sector is dependent on the Transportation Sector to move supplies and products. The Transportation Sector is dependent on the Energy Sector for gasoline, and each of the 17 sectors is in some way dependent on the Energy Sector for electricity. Many examples confirm these interdependencies among critical infrastructure sectors, which is why the resiliency of the assets, systems, and functions in these sectors is so important.

On September 13, 2008, the emergency planning, response, and recovery systems in the United States were again tested when Hurricane Ike hit Texas and Louisiana. Although lessons learned from Katrina helped improve many elements of the emergency planning process, the energy sector was again hit hard. According to the *Department of Energy Hurricane Ike Situation Reports,* over 950,000 customers in Texas and Louisiana were without electricity for at least one week and over two million customers were without electricity for at least two days. Customers without power included critical infrastructure sub-sectors such as gas stations, schools, grocery stores, nursing homes, banks, chemical manufacturers, and other vital businesses.[8] On September 15, 2008, the *National Public Radio* website described some of the effects of the prolonged power outages from Hurricane Ike on average citizens:

> Maxwell and her neighbor, Audrey Jefferson, said that in addition to dealing with the uprooted trees and flooded streets, it is difficult to find groceries. The stores are nearly empty, they are accepting only cash, and finding gasoline to get there is a challenge. 'The only place we could get paper towels and marshmallows and crackers yesterday was at Target,' Jefferson said. 'And it was wiped out. It was all gone.'[9]

Without electricity, traffic lights do not function, deliveries cannot be made, and daily functions, such as getting cash from an ATM, are impossible.

This report provides an assessment of how the installation of combined heat and power (CHP) systems at critical infrastructure facilities in New York State may strengthen the resiliency of the entire community, allowing it to better weather emergency incidents involving prolonged electric grid outages of up to one week in duration.[10] This report further identifies those critical

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[6] According to the Patriot Act of 2001 Section 1016 (e), critical infrastructure is defined as "systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters."

[7] There are now 18 critical infrastructure sectors, including the newly established Manufacturing Sector. However, this report does not address the Critical Manufacturing Sector, and will therefore only reference the 17 sectors originally identified in the *NIPP*, published in 2006.

[8] *Department of Energy Situation Reports* are available to the public at http://www.oe.netl.doe.gov/named event.aspx?ID=20

[9] Del Barco, Mandalit. "Hurricane Ike Victims Line Up For Ice, Water, Food." 15 Sept. 2008. National Public Radio. 23 Sept. 2008 <http://www.npr.org/templates/story/story.php?storyid=94661941>.

[10] One week was selected as being representative of the duration of a grid outage due to a significant natural disaster or terrorist attack. This does not imply an outside duration of function for CHP units, which would continue to function during a grid outage of any duration, so long as fuel remained available.

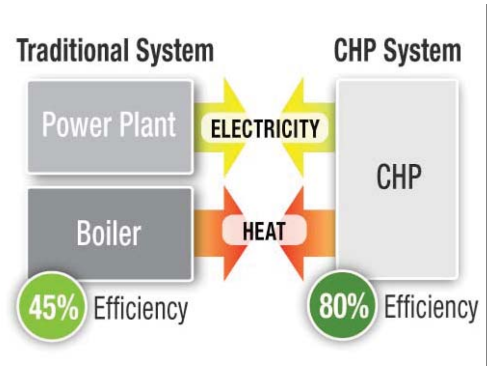
infrastructure sectors and sub-sectors in New York State that are both good technical candidates for CHP systems and whose uninterrupted functioning during a power grid failure is most critical. Finally, the report explains how these particular sectors were chosen, discusses the potential contribution of CHP in each of the selected sectors, and recommends directions for future activities.

2.0 WHAT IS CHP?

Combined heat and power (CHP) systems are a highly efficient form of distributed generation, typically designed to power a single large building, campus, or group of facilities. These systems comprise on-site electrical generators (primarily fueled with natural gas, but biomass-fed systems may be feasible in some locations) that achieve high efficiency by capturing heat, a byproduct of electricity production that would otherwise be wasted. The captured heat can be used to provide steam or hot water to the facility for space heating, cooling, and various industrial processes. Capturing and using the waste heat allows CHP systems to reach fuel efficiencies of up to 80%, compared with the average fuel efficiency of 45% achieved by conventional centralized electric power plants. This is both environmentally and economically advantageous. CHP systems can use the existing, centralized electricity grid as a backup source to meet peak electricity needs and provide power when the CHP system is down for maintenance or in an emergency outage. If the electricity grid is impaired, a properly configured CHP system will continue to operate, ensuring an uninterrupted supply of electricity and thermal services to the host facility.[11]

CHP technology can be deployed quickly, cost-effectively, and with few geographic limitations. It has been employed for many years, mostly in industrial, large commercial, and institutional applications. CHP may not be widely recognized outside these circles, but it has quietly been providing highly efficient electricity and process heat to some of the most vital industries, largest employers, urban centers, and campuses in the United States. Figure 1 shows a diagram of the CHP process flow.

Figure 1. CHP Process Flow Diagram



Critical infrastructure facilities are typically outfitted with backup generators to take over the supply of electricity in the case of a grid failure. CHP systems offer a number of advantages

[11] In order to provide uninterrupted electric service to the host facility during a grid failure, CHP systems must meet specific technical specifications, including black start capability, a generator capable of operating independent of the grid, ample carrying capacity, a parallel utility interconnection and switchgear controls (see Appendix C).

compared to traditional backup generators. In some sectors, such as hospitals, the presence of a CHP system may not override the necessity of having a backup generator, which is required by law. CHP systems, however, provide benefits to their host facilities all the time, rather than just during emergencies. Some advantages that CHP systems have over backup generators include:

- Backup generators are seldom used and are sometimes poorly maintained, so they can encounter problems during an actual emergency; whereas, CHP systems run daily and are typically highly reliable.
- Backup generators typically rely on a finite supply of fuel on site, often only enough for a few hours or days, after which more fuel must be delivered if the grid outage continues. CHP systems have a permanent source of fuel on demand.[12]
- Backup generators may take time to start up after grid failure, and this lag time, even though it may be quite brief, can result in the shutdown of critical systems. Also, in many cases, backup generators must be delivered to the sites where they are needed, leading to further delays in critical infrastructure recovery. CHP systems are the permanent and primary source of electricity for the site they serve, and if properly sized and configured, are not impacted by grid failure.[13]
- Backup generators typically rely on reciprocating engines burning diesel fuel, an inefficient and polluting method of generating electricity. CHP systems typically burn natural gas, a cleaner fuel, and achieve significantly greater efficiencies, lower fuel costs, and lower emissions by capturing waste heat.[14]
- Backup generators only supply electricity; whereas, CHP systems supply thermal loads as well as electricity to keep facilities operating as usual.

Compared to backup emergency generators, CHP systems are a more reliable, cleaner, efficient, and cost effective onsite power supply, which provides electricity and heating/cooling under both emergency and normal operating conditions.

3.0 WHO CAN USE CHP?

Facilities where CHP is appropriate include those that have access to a sufficient volume of natural gas or other fuel and where a significant heating or cooling, as well as electric, load exists. The heating/cooling load is important for CHP systems to function most economically and at highest efficiency. Other technical attributes may also be important when considering whether a CHP system is appropriate for a specific facility. For example, synchronous interconnection with the electrical grid, which is typical of CHP systems, is currently available in many—but not all—areas of New York City (see Appendix B).[15] CHP may be a very good fit for critical infrastructure sub-sectors such as hospitals, food sales and food processing facilities,

[12] The supply of natural gas is not, in general, dependent on electricity from the grid.

[13] A system that is connected in parallel with the grid can continue operation even when the grid goes down, however this type of interconnection arrangement can cost more than a standard interconnection that would not allow a CHP system to operate without grid power (see Appendix C).

[14] "Combined Heat and Power: Effective Energy Solutions for a Sustainable Future." Oak Ridge National Laboratory. December 2008.

[15] Those areas where CHP is not currently permitted are undergoing scheduled upgrades by Con Edison, and should be suitable for CHP systems within a few years' time.

nursing homes, prisons, and water treatment facilities. In some cases, CHP systems may also be appropriate for places of refuge and chemical and pharmaceutical facilities.

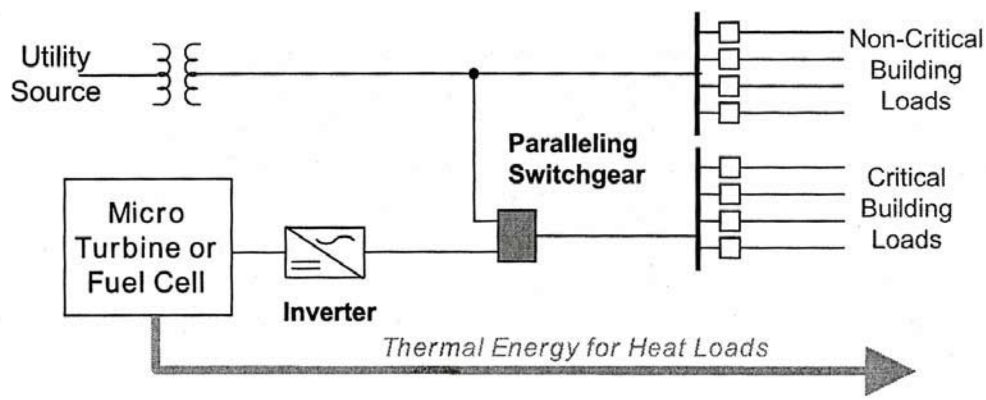
4.0 WHAT IS REQUIRED FOR A CHP SYSTEM TO DELIVER CRITICAL INFRASTRUCTURE POWER RELIABILITY?

The requirements for a CHP system to deliver power reliability, as in a CI facility, are fairly straightforward, but they may add some costs relative to CHP in a non-critical facility. In order to ensure uninterrupted operation during a utility system outage, the CHP system must have the following features:

1) ***Black start capability*** – The CHP system can use a battery powered starting device or another supplemental electricity supply system such as GenSet.
2) ***Generator capable of operating independently of the utility grid*** – The CHP electric generator must be able to continue operation without the grid power signal. High frequency generators (microturbines) or DC generators (fuel cells) need to have inverter technology that can operate the grid independently.
3) ***Ample carrying capacity*** – The facility must match the size of the critical loads to the CHP generator.
4) ***Parallel utility interconnection and switchgear controls*** – The CHP system must be able to properly disconnect itself from the utility grid and switch over to providing electricity to critical facility loads.

Figure 2 shows a diagram of a CHP system that is used for power reliability.

Figure 2. CHP System with Backup Responsibility for Critical Loads



Details of this type of system are discussed in Appendix C.

5.0 How Does CHP Fit into Current Disaster Preparedness Planning?

Following the terrorist attacks in 2001, the Northeast blackout in 2003, and natural disasters such as Hurricane Katrina in 2005 and Hurricane Ike in 2008, disaster preparedness planners have become increasingly aware of the need to protect critical infrastructure facilities and to better prepare for energy emergencies. Resilient critical infrastructures enable a faster response to disasters when they occur, mitigate the extent of damage and suffering that communities endure, and speed the recovery of critical functions. CHP can answer this need while making energy more cost- and fuel-efficient for the user, as well as more reliable and environmentally friendly for society at large. By installing properly sized and configured CHP systems, critical infrastructure facilities can effectively insulate themselves from a grid failure, providing continuity of critical services and freeing power restoration efforts to focus on other facilities. In many cases, the significant increase in fuel efficiency offered by CHP systems signifies that they are a sound financial investment, assuming the facility has a significant heating or cooling load that can be served by the CHP system.

The use of CHP systems for critical infrastructure facilities can also improve overall grid resiliency and performance by removing significant electrical load from key areas of the grid. This is possible when CHP is installed in areas where the local electricity distribution network is constrained or where load pockets exist. The use of CHP in these areas eases constraints and load pockets by reducing load on the grid. For this reason, CHP placement should be decided, not only based on the conditions and needs of the host facility, but also on the conditions and needs of the local grid system. Both facility- and grid-level assessments should be part of the cost/benefit analysis for any proposed CHP system.

To ensure continued progress towards addressing grid and critical infrastructure resiliency via technologies such as CHP, improved coordination between government emergency planners and the electricity sector must occur. One necessary tool, which this report seeks to provide, is an assessment of risk associated with electricity-dependent, critical infrastructure facilities that meet technical criteria for hosting CHP systems.

6.0 Assessing Risk

Safeguarding the nation's critical infrastructure is addressed in the *National Infrastructure Protection Plan (NIPP)*,[16] which provides the unifying structure for the integration of critical infrastructure and key resources (CIKR) protection into a single national program. The NIPP specifically addresses the need to prioritize sectors and sub-sectors through risk analysis in order to focus planning; foster coordination; and support effective resource allocation and incident management, response, and restoration decisions. Some sense of relative risk to assets both between and within the 17 CIKR sectors is necessary for the effective and efficient use of homeland security funding.

[16] *National Infrastructure Protection Plan* (2006), available at www.dhs.gov/nipp.

Assessing risk across sectors and sub-sectors, however, is difficult complete. The variety of asset, system, and function types, as well as the multitude of risk assessment methodologies in use across the 17 CIKR sectors, has made cross-sector comparisons of risk a primary challenge for homeland security policy makers. The Department of Homeland Security (DHS) is currently developing risk assessment tools to facilitate these comparisons, but full development, implementation, and data collection for these assessments remain incomplete.[17]

An earlier report (included as Appendix A to this report) compares and ranks CHP technical potential for end-use sectors in New York State, including each sector's importance to critical infrastructure resilience.[18] The focus is on identifying those critical infrastructure sub-sectors in New York State where an investment in electricity supply resilience will most significantly reduce the negative consequences of an emergency event that degrades or incapacitates the statewide electricity grid. This assessment is aligned with a previously completed technical analysis of the potential for CHP technologies in various sectors in New York State.[19] The resulting analytical framework provides a meaningful way to judge the critical infrastructure resilience benefits of investments in CHP sites, given the existing technical capacity for the implementation of CHP technologies.

7.0 CHP AND CRITICAL INFRASTRUCTURE RESILIENCE ASSESSMENT TOOLS

Two assessment tools are used to determine which critical infrastructure sub-sectors are the most likely candidates for CHP systems, with the ultimate aim of enhancing the resiliency of critical services during a worst reasonable case (one week) of electric grid failure.

The first assessment tool is a ranking of 17 CIKR sectors in New York[20], using multiple metrics, along a range from most to least critical. This ranking is intended to determine which services are most important to maintain during a natural disaster or a man-made attack. Stated another way, this ranking estimates the relative consequence associated with a disaster-related loss of electrical service in each sector. It draws from the Department of Homeland Security (DHS) *National Infrastructure Protection Plan (NIPP).*

In evaluating the most critical sub-sectors to maintain during an emergency, four categories of consequences for the community, aside from site-specific constraints, are considered:

- **Human Impact** is measured in terms of the fatalities or injuries that could result if the critical asset is degraded or incapacitated by the worst reasonable case power outage.

[17] See pages 16-17, 23-24, and 42-44 of the DHS *Office of Infrastructure Protection Strategic Plan: 2008–2013* (2007) for a description of current efforts to collect, analyze, and disseminate cross-sector risk-risk relevant information (available through the DHS Office of Infrastructure Protection).
[18] *DG/CHP and Critical Infrastructure Security, Task 2 Deliverable under NYSERDA Agreement No. 9931: Matrix of CHP Potential in End Use Sites in New York State with Importance to Critical Infrastructure Resilience, July 14, 2008*
[19] *DG/CHP and Critical Infrastructure Security, Task 1 Deliverable under NYSERDA Agreement No. 9931: CHP Technical Potential, Sector Descriptions, Site and MW Data in New York State, April 15, 2008*
[20] The assessments did not analyze the new Critical Manufacturing Sector.

- **Economic Impact** is measured in terms of the direct and indirect effects on the economy (e.g., cost to rebuild asset, cost to respond to and recover from attack, downstream costs resulting from disruption of product or service, long-term costs due to environmental damage) that could result if the critical asset is degraded or incapacitated by the worst reasonable case power outage.
- **Impact on Public Confidence** or **Psychological Consequences** are measured in terms of the effect on public morale and confidence in national economic and political institutions that could result if the critical asset is degraded or incapacitated by the worst reasonable case power outage.
- **Impact on Government Continuity** is measured in terms of the reduction in the ability of state and local governments to deliver minimum essential public services, ensure public health and safety, and carry out national security-related missions if the critical asset is degraded or incapacitated by the worst reasonable case power outage.

This risk assessment analytical framework and study method are described more fully in the Appendix A report.

The second assessment tool comprises a technical analysis of the potential for CHP system installations in each of the ranked sub-sectors. The technical potential for CHP has been defined as the total capacity potential from existing and new facilities that are likely to have the appropriate electric and thermal (or cooling) load characteristics to support a CHP system. The technical potential figures include all sites, both upstate and downstate, that could support a CHP system; however, they do not represent the amount of capacity that will *actually* enter the market. Other factors, such as the economic feasibility of installing a CHP system as well as specific site requirements and issues, will determine the number of sites and amount of capacity that is ultimately installed. This analysis of technical potential for CHP in New York State is described more fully in the Appendix A report on CHP potential in critical infrastructure facilities.

In this report, those sectors and subsectors that score highest in both critical importance and technical CHP potential are investigated further to identify sector-specific opportunities and barriers to the adoption of CHP technologies. Note that specific investment decisions will require facility- and community-specific assessments that examine the constraints, costs, and benefits associated with CHP installations at each individual location.

8.0 KEY SECTORS FOR USING CHP TO IMPROVE COMMUNITY RESILIENCE DURING EMERGENCY ELECTRICITY GRID OUTAGES IN NEW YORK STATE

8.1 Primary CHP-Resiliency Market Sub-Sectors

The following end-use sub-sectors show good technical potential for installing CHP and also play an important role in reducing the adverse consequences of emergency incidents that could disable the electricity grid. Therefore, these are considered ***high value sub-sectors*** for CHP investment:

- Hospitals
- Water Treatment/Sanitary Facilities
- Nursing Homes
- Prisons
- Food Processing and Food Sales Facilities
- Pharmaceuticals
- Places of Refuge

A summary of both the CHP technical potential and resiliency benefits for each of these six end-use sub-sectors is provided below. A seventh end-use sector, Chemicals, is also discussed, because of its relatively large technical CHP potential and the possible impact on the production of critical drugs by the Pharmaceuticals sub-sector in case of an emergency.

8.1.1 Hospitals

About 450 hospital facilities in New York State have the technical potential to be, or are currently, served by CHP systems. Hospitals are key players in the public health critical infrastructure sector.

Sustaining hospital operations is always a high priority, but it is perhaps one of the highest and most widely recognized priorities during emergency incidents. It is imperative to ensure that hospitals function during an incident to provide essential emergency response services. Accordingly, the consequences of a sustained power outage are rated as severe or high (4 or 5 on the five point scale) for all but the impact on government continuity. The potential impact of power interruptions at hospitals is provided below:

- Human impact rating: 5 (potential for fatalities and injuries with more than 1,000 deaths)
- Economic impact rating: 4 (direct or indirect impact of $1 million to $100 million)
- Public confidence impact rating: 5 (severe)

- Impact on government continuity rating: 2 (low)
- **Average Rating for Hospitals Sub-Sector: 4 (high)**

Sustaining hospitals during grid power supply interruptions is already a planning priority. The emergency power restoration plans of utilities place a priority on restoring power to hospital facilities. All hospitals now have backup energy supply systems, often diesel generators and boilers fueled with natural gas, oil, or propane. These emergency backup generators must be maintained for the infrequent occasions when grid power supplies are interrupted.

Hospitals are good candidates for the installation of CHP systems because hospital facilities require a steady supply of electricity and hot water. Furthermore, CHP installations in the healthcare industry are not a new and novel idea. Currently, 30 hospital/health care facilities in New York State that have installed CHP systems exist, providing about 121 MW of electricity generating capacity to serve these facilities (the average system size is 4,000 kW and the median size is 536 kW).

Another 410 hospital facilities, 232 in the downstate region and 178 upstate, with the potential to install another 652 MW of electricity generating capacity are located throughout New York. Almost all of these facilities would require relatively small CHP units, about 45 percent with capacity under 1 MW and almost all of the remaining 55 percent in the 1-5 MW range.

Guaranteeing the operation of services at hospitals is a vital component of emergency preparedness planning. Yet, the Northeast blackout of August 14, 2003 , highlighted several major shortcomings with existing emergency standby systems at hospitals. Approximately half of New York City's 58 hospitals experienced failures of their emergency backup generators, diminishing their capability to provide vital health services during this crisis.[21] In the midst of the August 2003 Northeast blackout, the comments of David P. Rosen, President of Jamaica Hospital in New York City, could be considered symptomatic of healthcare institutions throughout the region: "Everybody is blowing generators ... I'm shocked at what I'm seeing. And I'm troubled. For all the yelling and screaming that everybody did after 9/11, there is nothing forthcoming to help us shore up this infrastructure."[22]

By contrast, some hospitals in New York City with CHP systems were able to ride through the blackout with little or no discernable problems. Montifiore Medical System in the Bronx has a CHP system with total electrical capacity of 10 MW with two standby engines providing an additional 4 MW of capacity. The initial system was installed in 1994 and consists of three reciprocating engines; a gas turbine was added in 2002. During normal operations, the CHP system provides base-load power. The system provides 100% of the electric and thermal needs of the medical center while providing service to additional buildings on the block. The system provides 80% of the electric needs of the block (including the entire medical center) and 100% of the thermal needs of the block (including cooling). During the blackout, Montefiore was

[21] New York Times, August 16, 2003.

[22] Levy, C. and Zernike, K. The Blackout: Hospitals; Lessons Learned on 9/11 Help Hospitals Respond. New York Times, August 16, 2003.

reportedly the only hospital in New York City that continued to admit patients, perform surgeries, and continue normal operations.[23]

South Oaks Hospital on Long Island operates a 1.3 MW CHP system, consisting of two dual-fuel reciprocating engines, at its campus in Amityville. During the blackout in August 2003, South Oaks Hospital never lost power, while the area around the hospital lost power for 14 hours. Hospital employees were not immediately aware of the blackout because they saw no interruption in their service.[24]

A leading medical journal has published an article detailing the effects of the August 2003 New York City healthcare delivery system, suggesting several lessons for disaster preparedness planning. The authors cite a marked increase in EMS and hospital activity in the wake of the blackout. They report unexpected increases due in large measure to failures of respiratory equipment in the population of community-based patients. Their findings suggest that the capacity to respond to public health emergencies could be overwhelmed by widespread and/or prolonged power outages in New York. They conclude:

> Disaster preparedness planning would be greatly enhanced if fully operational, backup power systems were mandated, not only for acute care facilities, but also for community-based patients dependent on electrically powered lifesaving devices.[25]

CHP does not serve as a replacement for code mandated emergency power requirements in New York State. CHP, in addition to emergency generators, however, offers healthcare facilities an extra measure of redundancy and resiliency. The healthcare industry has seen a trend to install more and larger backup generators, extending backup power well beyond what is required to meet critical life-safety needs. CHP in many instances will be a more economical means of providing greater coverage of these functions at hospital/health care facilities. When capital cost decisions are evaluated, placing more circuits on a baseload CHP system and reserving a minimum amount of power needs to be met by emergency generators may well prove to be more economical than simply expanding the size and number of emergency generators at a site. It is difficult to measure the added security benefits of CHP, but evidence suggests that these benefits are real and substantive.

Despite the advantages of CHP systems for hospitals, institutional barriers have limited the installation of CHP systems to a relatively small number of large hospitals in New York. The most significant barriers are high priority competing demands on limited capital resources and the relatively higher cost per megawatt of CHP in the smaller size ranges. Certain fixed costs of CHP projects do not vary much, or at all, with system size. This makes smaller-scale projects more costly than larger projects on a $/MW basis. For example, a 2003 analysis prepared for the U.S. EPA indicated that a typical cost for a 5 MW gas turbine CHP system was $1,010 per kW.

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[23] Hedman, Bruce and Carlson, Anne. "Assessing the Benefits of On-Site Combined Heat and Power during the August 14, 2003 Blackout." Oak Ridge National Laboratory, 2004. www.eere.energy.gov/de/pdfs/chp_blackout_081403.pdf (December 12, 2008)
[24] ibid
[25] Prezant, David J. MD; Clair, John; Belyaev, Stanislav MD; Alleyne, Dawn MD; Banauch, Gisela I. MD, MSCR; Davitt, Michelle MD; Vandervoorts, Kathy; Kelly, Kerry J. MD; Currie, Brian MD, MPH; Kalkut, Gary MD, MPH. "Effects of the August 2003 blackout on the New York City healthcare delivery system: A lesson for disaster preparedness." Critical Care Medicine. 33(1) Supplement: 96-101, January 2005.

For a similar 1 MW system, installed cost was estimated at $1,780 – 76 % more than the per kW cost of the 5 MW system.[26]

A recently published guidebook, *Combined Heat & Power (CHP) Resource Guide for Hospital Applications,*[27] provides background and reference data and information for hospital managers who are considering CHP. Hospital administrators are faced with rising and volatile energy costs, a need for greater energy reliability, increasing environmental demands, and shrinking facility budgets. Evaluating realistic, alternative approaches to meeting the facilities' energy requirements in an economic, reliable, and environmentally sound manner is a constant need. The guide provides basic principles and rules-of-thumb regarding the evaluation and suitability of the use of CHP systems at hospital facilities. It provides an information toolkit tailored to the specific circumstances of New York State hospitals, as well as detailed information on state regulatory processes (certificate of need, state air permitting, and so forth). It also addresses perhaps the most critical issue facing CHP project development at hospitals—the problematic issue of financing.

8.1.2 Water Treatment/Sanitary Facilities

Water treatment systems include water supply, treatment, and distribution as well as wastewater collection, treatment, and disposal.[28] The U.S. Environmental Protection Agency (EPA) observes:

> Without a reliable drinking water source and the means to safely dispose of waste, hospitals will not be able to support a community in need, first responders will not be able to fight fires, hazardous materials workers cannot take decontamination measures, and response workers will not be able to stay onsite due to a lack of potable water. Ultimately, the economic stability of a city, town, or region may be jeopardized without water that is safe to use and drink.[29]

It is necessary to maintain electrical service in the water treatment/sanitation sub-sector in order to ensure a stable food and water supply. Even in a very short term outage where power would be restored to this sub-sector in a matter of days, the appearance of a potential water shortage or interruption in sanitation services could lead to a significant loss in public confidence. About 173 MW of CHP potential at water treatment and sanitation facilities in New York State exist.

The consequences of a sustained power outage impacting this sector are rated as moderate to high (3.25 to 3.75 on the five point scale). The potential impact of power interruptions at water treatment/sanitary facilities is shown below:

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[26] U.S. Environmental Protection Agency. "A Brief Characterization of Gas Turbines in Combined Heat and Power Applications." August 2003.
[27] Midwest CHP Application Center, Avalon Consulting, Inc., Energy and Environmental Analysis, and PEA, Inc. 2007. Combined Heat & Power (CHP) Resource Guide for Hospital Applications. www.chpcentermw.org/pdfs/USHospitalGuidebook_111907.pdf (January 5, 2009)
[28] *Critical Infrastructure and Key Resources Support Annex*. January 2008. Federal Emergency Management Agency, Page 31. Available on the Internet at www.fema.gov/pdf/emergency/nrf/nrf-support-cikr.pdf
[29] U.S. Environmental Protection Agency. "Water Sector-Specific Plan Fact Sheet." December 2007. Available on the Internet at www.epa.gov/safewater/watersecurity/pubs/plan_security_watersectorspecificplan_brochure.pdf

- Human impact rating: 3-4 (potential for human fatalities and injuries with up to 1,000 deaths)
- Economic impact rating: 3 (direct or indirect impact of $100 thousand to $1 million)
- Public confidence impact rating: 4-5 (high to severe)
- Impact on government continuity rating: 3 (moderate)
- **Average Rating for Water Treatment Facilities Sub-Sector: 3.25-3.75 (moderate to high)**

Seven waste water treatment facilities in New York State have installed CHP systems, with a total capacity of 14.1 MW. Estimated technical potential for CHP is 173 MW at 177 water treatment and sanitation facilities across New York. Almost 80% of this capacity is at 55 facilities that have a technical capacity in the 1-5 MW range, with the balance in the 100 kW to 1 MW range.

Large waste water treatment facilities offer the added opportunity of using the solid waste or methane generated onsite as a biofuel feedstock for a CHP system.[30]

8.1.3 Nursing Homes

About 840 nursing homes in New York State are or could be served by CHP systems with an estimated technical potential of about 792 MW. Nursing homes are components of the broader public health critical infrastructure sector, providing life supporting services to the elderly and infirm who require nursing care on an extended basis. Installing CHP systems at nursing homes reduces the risk of electric power outages at facilities that require a steady supply of heat and electricity to maintain their very vulnerable patient population. This population is sensitive to cold and extreme heat and requires food and oftentimes critical health services that rely on electricity.

The consequences of extended power outages at nursing home facilities is high (4 on the five point scale) for all but their impact on government continuity. The potential impact of power interruptions at nursing homes is as follows:

- Human impact rating: 4 (potential for fatalities and injuries with 100 to 1,000 deaths)
- Economic impact rating: 4 (direct or indirect impact of $1 million to $100 million)
- Public confidence impact rating: 4 (high)
- Impact on government continuity rating: 1 (none)
- **Average Rating For Nursing Home Sub-Sector: 3.25 (moderate)**

A large number of nursing homes could be equipped with CHP systems because these facilities require a steady supply of electricity and hot water, but the relatively small total energy requirements of these facilities will make installations expensive. Currently, 42 nursing homes in New York State have installed CHP systems, providing a total of about 9.2 MW of electricity

[30] U.S. Environmental Protection Agency Combined Heat and Power Partnership. “Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities.” 2006. www.epa.gov/chp/documents/chp_wwtf_opportunities.pdf (December 12, 2008).

generating capacity to serve these facilities (average capacity = 210 kW each). Another 795 nursing home facilities, 383 in the downstate region and 412 upstate, with the potential to install another 792 MW of electricity generating capacity exist in New York. Almost all of these facilities would need relatively small CHP units; about three-quarters of them would be sized at less than 1 MW capacity and the remaining quarter would be in the 1-5 MW range.

According to a recent article in *Distributed Generation*,[31] the New York City metropolitan area is currently experiencing particularly favorable conditions for CHP installations in nursing homes. The article lists a number of indicators of project viability that are aligned in the New York City nursing home market. These include:

- A favorable spark-spread (i.e., the difference between what it costs to buy power from the utility versus generating it onsite);
- Significant heat load (demand for hot water or steam);
- Seasonal heating and heat-fired cooling;
- A mandatory need for power redundancy;
- Multiple incentives programs;
- Availability of innovative technologies;
- Availability of vendors and skilled contractors;
- A supportive public policy;
- Good, inexpensive equipment that matches the niche parameters; and
- Relatively low utility company barriers.

The article indicates that a number of CHP installers in the New York City metro area are using modified compact natural gas-powered reciprocating engines made by Cummins and GM, which are easily adapted from their primary use in transportation fleets. These engines are affordable, rugged, pre-qualified by air-quality regulators, and ideally sized for the average residence of about 200-250 beds.

NYSERDA has long recognized the benefits of situating CHP systems at nursing homes. As early as 2002, NYSERDA helped fund the installation of two natural gas engines and one diesel engine at ElderWood Health Care at Oakwood. The 850-kW system channeled recovered heat to the existing boiler system and domestic hot water tanks. When ice storms left more than 45,000 Western New Yorkers without power, ElderWood's electricity and heat supplies were unaffected. The system was estimated to save the facility nearly $100,000 in annual energy costs, which would pay off the costs of installation in just six years.[32]

8.1.4 Prisons

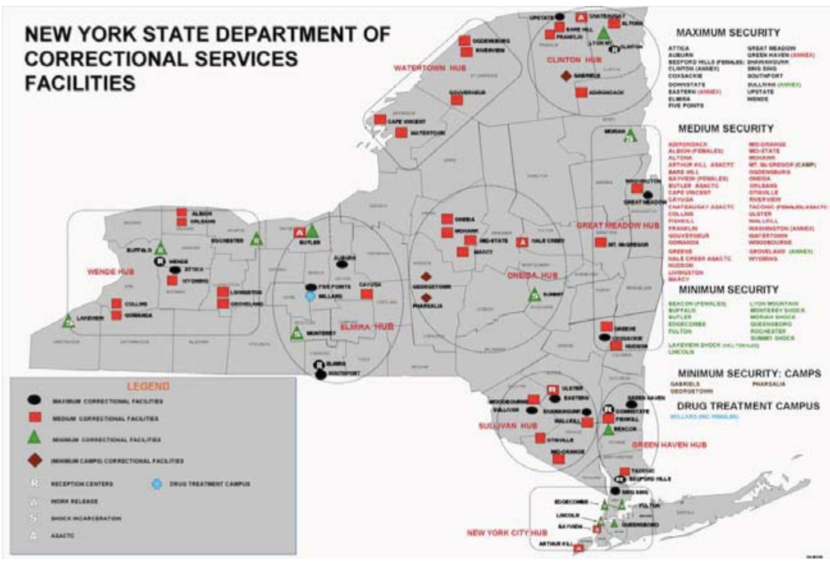
This report includes prisons as institutions that represent "critical infrastructure," even though they are not listed in the NIPP, because it is in the interest of the state and its citizens to keep uninterrupted electric power on at all correctional facilities during an emergency event. New

[31] Engle, D. 2008. A 'Mature' Market. Distributed Generation, V. 6, N. 5.

[32] NYSERDA, 2002. State Provides $425,000 to Help Senior Care Center Produce Its Own Power. Press release. www.nyserda.org/Press_Releases/press_archives/2002/06_24_02.asp (December 12, 2008).

York State maintains 70 prisons, which house 62,599 inmates under custody as of January 1, 2008.[33] Each facility also accommodates a considerable number of staff. These facilities typically have large heating and electric loads, making them good candidates for CHP systems. Altogether, prisons in New York State represent 370 MW of electric load—49 of these are in the 1-5 MW range, with 19 in the 5-20 MW range and another 19 at less than 1 MW. Prisons are widespread in communities across the state, as shown in Figure 3.

Figure 3. Correctional Facilities in the State of New York



Although prisons may not be "critical" in the sense of providing a place of refuge or emergency services to the general public, ensuring the supply of electricity to prisons is critical to the health and safety of vulnerable staff and inmate populations. In the event of a prolonged power outage at a prison, should backup generators fail, the health and safety of residents in surrounding communities could also be at risk because the loss of essential services to prisoners or the breakdown of security measures could result in inmate riots and/or escapes. Such a scenario would carry significant risks to human life, interrupt important government services, impact public confidence, and could result in severe economic consequences. Thus, prisons score high on all four categories of consequences for critical infrastructure, as shown below:

- Human impact rating: 3 (medium) (potential for fatalities and injuries with less than 100 deaths)
- Economic impact rating: 3 (medium) (direct or indirect impact of $100,000 to $1 million)
- Public confidence impact rating: 5 (severe)
- Impact on government continuity rating: 3 (medium)
- **Average Rating For Prisons: 3.5 (high)**

The potential extent of prison system disruption and threat to prisoner health and safety that can result from power outages during a disaster was demonstrated during Hurricane Katrina. Some

[33] There are also many county jails; however, most of these would likely be too small to make good host sites for CHP systems.

6,500 prisoners housed at Orleans Parish Prison were left to weather the storm without electricity, food, water, or sanitation as the rest of the city's population fled under a mandatory evacuation order and floodwaters rose above eight feet. Evacuation of the prison took another four days; after evacuation, prisoners spent days in scorching heat on the interstate overpass until they could be transported to other facilities around the state. The overload of the state's criminal justice and correctional systems caused extreme systemic dysfunction. Criminal trials did not resume in New Orleans until 10 months after the hurricane. A year after the storm, the displaced prisoners—most of whom were being held on minor municipal charges, such as unpaid fines or public drunkenness—had still not been formally charged, much less tried.[34] According to Human Rights Watch, the plight of the New Orleans prisoners at the Templeman facility after the prison generators failed and the prison staff fled was among the worst disasters to result from Hurricane Katrina.[35]

Although all New York State prisons have backup generators and all used them during the blackout of 2003, CHP systems would provide a much more reliable and uninterruptible power source. Additionally, the state has an interest in decreasing the cost of maintaining inmate populations, which could be achieved through the higher fuel efficiency of CHP. Although no New York State prisons currently have CHP systems, the NYC Mayor's Office has expressed interest in installing a CHP system at Riker's Island Correctional Facility.

8.1.5 Food Processing & Sales Facilities

Food processing and sales facilities are components of the agriculture and food production critical sector, which includes the chain of food production processes from farm to consumer.[36] Food processing and sales facilities are the final links in this chain.

Maintenance of electrical service in the sub-sectors of food processing, food sales/supermarkets, and refrigerated warehouses is critical for a stable food and water supply. Even in a very short term outage where power would be restored to these sub-sectors in a matter of days, the appearance of a potential food shortage could lead to a significant loss in public confidence. Together the food processing and retail food sales sub-sectors offer a technical potential of more than 1,000 additional MW of CHP in New York.

The overall consequences of extended power outages on food processing and sales and supermarket facilities is rated in the medium range (in a range of 2.5 to 3.25 on the five point scale), but the risk associated with threats to public confidence is high to severe (4 to 5).

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[34] McIlwain, Amber. 2006. "Abandoned behind bars — Hurricane Katrina's prisoners." The Business Times Online, http://business.timesonline.co.uk/tol/business/law/article600447.ece

[35] Human Rights Watch, 2005. "New Orleans: Prisoners Abandoned to Floodwaters." http://www.hrw.org/en/news/2005/09/21/new-orleans-prisoners-abandoned-floodwaters

[36] "The National Strategy defines the Food and Agriculture Sector CIKR as the supply chains for feed, animals, and animal products; crop production and the supply chains of seed, fertilizer, and other necessary related materials; and the post-harvesting components of the food supply chain, from processing, production, and packaging through storage and distribution to retail sales, institutional food services, and restaurant or home consumption. In general terms, the Food and Agriculture Sector comprises the Nation's agricultural production and food systems from farm to table." page 12. U.S. Department of Homeland Security. *Agriculture and Food: Critical Infrastructure and Key Resources Sector Specific Plan.* May 2007. Available on the Internet at: http://www.usda.gov/documents/nipp-ssp-ag-food.pdf

Ratings of the potential impact of power interruptions at food processing and food sales/supermarket facilities are as follows:

- Human impact rating

    Food Processing: 2 (no human fatalities, potential for human injuries)

    Food Sales/Supermarkets: 2 (no human fatalities, potential for human injuries)

- Economic impact rating

    Food processing: 2 to 3 (direct or indirect impact of less than $100,000 to $1 million)

    Food Sales/supermarkets: 3 to 4 (direct or indirect impact of $100 thousand to $100 million)

- Public confidence impact rating

    Food Processing: 4 (high)

    Food Sales/Supermarkets: 5 (severe)

- Impact on government continuity rating

    Food Processing: 2 (low)

    Food Sales/Supermarkets: 2 (low)

- **Average ratings**

    Food Processing Sub-Sector: 2.5-2.75 (low to medium)

    Food Sales/Supermarkets Sub-Sector: 3.0 downstate and 3.25 upstate (medium)

Although the critical infrastructure rating is low to medium, the food processing sub-sector may offer significant technical potential for using CHP to provide on-site power. Food processing facilities have 683 MW of CHP potential, half of which is at large installations (greater than 5 MW capacity) that provide much higher returns on investment than do small facilities (i.e., 225 MW of CHP in the range of 5-20 MW and 150 MW of CHP at facilities with a capacity greater than 20 MW). Large food processing facilities also have the potential to use food waste as a biomass feedstock in the CHP system.

Food sales/supermarkets also offer relatively large total potential capacity (about 360 MW), but these facilities would be much smaller in size, all smaller than 5 MW and most in the 100 kW to 1 MW range.

NYSERDA and the U.S. Department of Energy have sponsored research, development, and deployment of CHP at both food processing and food sales sites in New York and around the country. One supermarket, the A&P Fresh Market in Mt. Kisco, New York, has been outfitted with four microturbines and a double-effect absorption chiller. The system is sized to meet approximately 50% of the store's load, providing 150 refrigeration tons (RT) of cooling, 950,000 BTU (950 MBH) of thermal, and 230 kW at 59°F. Other CHP technologies are viable in this sub-sector as well. The Whole Foods supermarket chain has installed a 200-kW hydrogen fuel cell CHP system in one of its Connecticut stores; the fuel cell generates 50% of the store's electricity and nearly 100% of its hot water. The high efficiency of the fuel cell is consistent with the store's environmentally progressive image. The fuel cell manufacturer, UTC Power, has recently introduced a new 400 kW fuel cell that would supply 100% of the store's electricity needs.

This is a large sub-sector with significant potential for CHP. Additionally some retail supermarket chains have great potential for a standardized system design that could help lower up-front costs for installation, a fact that NYSERDA has recognized by initiating a new financial assistance program for chain CHP installations.

8.1.6 Pharmaceuticals Sub-Sector of the Chemicals Sector

The chemicals sector offers significant technical potential for CHP installations. Because this sector includes a diverse group of sub-sectors, some of which may offer very high resiliency benefits, it is worth including in the list of critical infrastructure opportunities. For example, the pharmaceuticals sub-sector provides some critical products for human health. A reduction in the ability of the pharmaceuticals sub-sector to produce or deliver certain drugs could potentially result in casualties.

The availability of some chemical supplies may also impact the ability of other critical sectors to function in extended emergencies, e.g., the water treatment sector may be dependent on deliveries of chemicals required to sustain safe water supply systems.

The sector offers 1,284 MW of CHP technical potential. At many sites, CHP facilities would be larger than 5 MW; this is significant because large CHP systems provide higher economic returns to the owner than smaller ones do. New York State has 35 such facilities with a technical potential for CHP larger than 5 MW each, which altogether offer a total technical CHP potential of 875 MW.

Ratings of the potential impact of power interruptions in the pharmaceuticals sub-sector of the chemical sector are as follows:

- Human impact rating – 3 (potential for fatalities and injuries with less than 100 deaths)
- Economic impact rating – 3 (direct or indirect impact of $100,000 and $1 million)
- Public confidence rating – 4 (high)
- Impact on government continuity rating – 2 (low)
- **Average Rating for Pharmaceuticals Sub-Sector of the Chemicals Sector – 3 (medium)**

8.1.7 Places of Refuge

A variety of facilities from several different sectors may be identified as potential places of refuge. Although this report does not rank emergency shelters for their contribution as critical facilities under the four categories of consequences for a community during power outages, these facilities can play a crucial role in supporting public health and safety. In the Northeast U.S., power outages during the winter can be life threatening to a large percentage of the population who rely on electricity to operate their home heating systems.

This includes not only those homes using electric heat but also those heating with gas or oil systems that require electricity for heating ignition systems or heat distribution equipment (water and air circulators). Such scenarios have resulted in many people leaving their homes during winter power outages to seek heated temporary shelters. Emergency electric power planners in New York have placed a high priority on restoring power to emergency shelters, which are viewed as being on par with hospitals in terms of their critical importance.[37]

To a lesser degree, electric grid outages during the summer have also resulted in many people leaving their homes to seek cooling centers. Because of the nearly universal reliance of residential heating and cooling systems on electricity, power outages during severe weather events can displace large numbers of people, requiring the provision of public shelter for extended periods of time.

Facilities that may serve as places of refuge include schools, colleges, and universities; armories; government buildings; hotels and convention centers; and sports arenas. These facilities possess attributes that suit them for a role as places of refuge. They can provide accommodations for large numbers of people, are widely distributed in communities, and typically possess kitchens and sanitary facilities, which are required to sustain people dislocated during a crisis.
Many of these facilities also have a combination of thermal and electric load that qualifies them for the installation of CHP systems (e.g., schools that are used year-round, have air conditioning loads, and/or have a heated pool). For example, 430 college/university sites have been identified in New York State where CHP facilities may be technically feasible, with 67 in the 5-20 MW range and another 23 with a potential capacity exceeding 20 MW. In total, schools, colleges, and universities in New York offer almost 2,300 MW of CHP potential.[38]

Not all facilities identified as emergency shelters, however, are good candidates for CHP. Some may be too small or lack the combination of thermal and electricity loads necessary to justify an investment in a CHP system.

This report does not examine how many facilities targeted for use as emergency shelters are good candidates for CHP systems. This will require the active participation of emergency management planners in communities across New York who are familiar with local facilities that are considered good candidates to serve as places of refuge.

8.2 Secondary CHP-Resiliency Market Sectors or Sub-Sectors

These market sectors or sub-sectors offer significant potential contributions to community resiliency but do not have sufficient potential for CHP to justify identifying them as appropriate

[37] Interview statements by Michael Worden, Chief, Distribution Systems and Generation, New York State Department of Public of Service. July 2008.
[38] It is worth noting that 46 NYS colleges and universities are currently signatories to the *American College & University Presidents Climate Commitment,* meaning they are committed to reducing greenhouse gas emissions from their campuses and incorporating sustainability into their curricula. This commitment may provide further justification at these institutions for investing in CHP installations, especially if such installations provide an opportunity for student involvement and learning. Colleges and universities also typically have the ability to raise the money necessary to make the initial investment in a CHP system.

for installation of CHP. Individual cases of facilities within these sectors or sub-sectors may prove that installation of CHP will offer great value, but the CHP technical potential assessment indicates the general potential for such applications will be limited. The seven sectors or sub-sectors in this group together account for only about 270 MW of estimated CHP technical potential, which is typically spread over a large number of small, scattered facilities. The following sectors or sub-sectors are included in this second group:

- Gas Stations
- Mass Transit
- Fire Protection
- Police
- Telecommunications
- Banking and Finance
- Refrigerated Warehouses

Gas Stations play an important role in dispensing fuel supplies for transportation as well as small emergency generators that many homes keep for emergency situations. The subsector analysis of emergency risk assigns gas stations a moderate to high rating (3.5) but includes only 48 sites with appropriate technical potential for CHP. These sites, all under a 1 MW capacity, offer a total capacity of 3.1 MW. Few gas stations have a significant thermal load to be served by CHP systems.

Mass Transit plays an important role in keeping communities functioning well and recovering from critical emergencies. The subsector analysis of emergency risks assigns Mass Transit a high rating (4) but includes only nine sites with appropriate technical potential for CHP. These sites offer a total capacity of 4.8 MW.[39] The relatively small amount of CHP potential in this subsector makes mass transit a low priority for searching for CHP opportunities to strengthen community resiliency.

Police Stations and Fire Protection facilities are necessary for public safety. It is imperative to ensure that they function during an incident in order to provide essential emergency response operations (resiliency rating = 4). They have limited technical potential for CHP, however—a total of 183 police station sites have a collective 52 MW of CHP potential and 236 fire protection facilities have a collective 25 MW of CHP potential.

Communications Facilities (including the Telecommunications Sub-Sector) are critical to community responsiveness during a natural or man-made disaster. Disruption of communications services has the potential to cause negative cascading economic disturbances in the New York State economy (resiliency rating = 4), but the sub-sector includes 296 facilities with a total collective CHP potential of only 59 MW.

[39] The MTA has initiated a pilot CHP project at one of its bus depots, and is interested in expanding this to other bus depots if the pilot is successful. Subway operations, however, are not considered practical for CHP because too much electricity is required to power the trains, though the stations themselves don't have a high electric or heating load.

Banking and Finance disruption has the potential to cause negative cascading economic disturbances. A power outage in a large financial institution is also likely to greatly reduce public confidence in the economy, thereby increasing the cascading effects. It is common practice for banking and finance institutions to invest in emergency power supplies to sustain operations (resiliency rating = 4); however, only 80 MW of technical CHP potential exists, spread over some 330 facilities statewide.

Refrigerated Warehouses receive a low to moderate resiliency rating (2.5 to 3) but are part of the important agriculture and food production sector. Only about 46 MW of capacity spread over 92 sites statewide, however, exist in the refrigerated warehouse subsector.

9.0 SUMMARY AND RECOMMENDATIONS

Seven end-use sectors in New York State have the potential to use CHP systems to strengthen the state's capacity to sustain critical operations during prolonged power system outages (up to one week). In terms of their technical potential for additional CHP and their importance of maintaining operations during emergencies, these sectors provide vital resiliency to the economy and public safety of the New York. The seven sectors of primary interest include:

- Hospitals
- Water treatment/sanitary facilities
- Nursing Homes
- Prisons
- Food processing and food sales facilities
- Places of refuge
- Select chemical/pharmaceutical facilities

Each of these seven sectors/sub-sectors offers significant technical potential for installing CHP to meet energy needs, and each plays an important role in maintaining essential services during a natural disaster or homeland security event. In particular, the role that places of refuge play is a critical one in terms of combined heat and power. Where CHP can be installed at critical sector facilities prior to the occurrence of a disaster, the impact of the disaster on the health and security of large numbers of citizens of New York will be lessened.

Institutional and financial constraints continue to stymie combined heat and power projects. In the hospital sector, for example, institutional barriers have limited the installation of CHP systems to a relatively small number of large hospitals in New York. The most significant barriers are high priority competing demands on limited capital resources and the relatively higher cost per megawatt of CHP in the smaller size ranges. Similarly, a large number of nursing homes could be equipped with CHP systems because these facilities require a steady supply of electricity and hot water, but the relatively small total energy requirements of these facilities make installations expensive. In the food processing and sales facilities sector, the potential for CHP is significant. Some retail supermarket chains have great potential for a standardized system design that could help lower up-front costs for installation, a fact that NYSERDA has recognized by initiating a new financial assistance program for chain CHP installations. This program addresses the institutional and financial barriers inherent in "custom" CHP design and installation.

Other sectors in the "top-seven" offer technical and resiliency potential for CHP, including water treatment and sanitary facilities, nursing homes, prisons, pharmaceuticals, and places of refuge. All have both CHP potential and could contribute to infrastructure resiliency in New York State. Successful application of CHP in these sectors will depend on bringing the design and construction costs down, overcoming institutional barriers related to siting, permitting, and utility requirements, and engaging the support of decision-makers who build, manage, and operate these facilities. Emergency management professionals are an additional key group that must be engaged in the effort, for they provide a gateway to their stakeholders who play an important role, at the local level, in developing emergency response plans and taking action when needed. These professionals are interested in becoming better educated about CHP and distributed energy opportunities as a way to address power emergencies.

Recommended activities include:

- Develop and present compelling presentations and other communications materials on CHP for infrastructure resiliency to be used at meetings of state emergency management officials
- Identify potential CHP projects at wastewater treatment facilities, hospitals, and health care facilities, and schools and universities that may serve as places of refuge with CHP information and ranking results from the analysis in this report
- Recommend CHP audits, financial resources, and opportunities for overcoming institutional, financial, and/or regulatory obstacles to facility owners and managers in these end-use sectors
- Track CHP projects developed in the next 1-3 years to determine if Stimulus Funding, educational and outreach efforts, and/or direct technical support is having an effect on the number of CHP installations in these end-use sectors in New York State

APPENDICES

APPENDIX A: MATRIX OF CHP POTENTIAL IN END-USE SITES IN NEW YORK STATE WITH IMPORTANCE TO CRITICAL INFRASTRUCTURE RESILIENCE

DG/CHP and Critical Infrastructure Security

Task 2 Deliverable:
Matrix of CHP Potential in End Use Sites in New York State with Importance to Critical Infrastructure Resilience

Submitted to:

New York Energy Research and Development Authority
Under NYSERDA Agreement Number 9931

Submitted by:

Energetics Incorporated
Energy and Environmental Analysis – An ICF Company
Pace University Energy Project

July 14, 2008

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1.0 Introduction

Assessing risk across sectors is difficult to do. The variation of asset, system, and function types integral to the Nation's system of critical infrastructure, as well as the multitude of risk assessment methodologies currently in use across 17 critical infrastructure and key resources (CIKR) sectors, has made cross-sector comparisons of risk a primary challenge for homeland security policy makers. The Department of Homeland Security (DHS) is currently developing risk assessment tools to facilitate these comparisons, but full development, implementation, and data collection for these assessments remains incomplete.[1]

Until a single method of cross-sector risk analysis is developed and implemented, homeland security analysts use a variety of methods to do the necessary work of making homeland security investments across the 17 CIKR sectors, as well as among the various assets, systems, and functions within sectors. This analysis provides a comparison of risk across sectors, and the primary asset types within the sectors, to determine the most efficient way to invest in electricity grid resilience through the application of combined heat and power (CHP) technologies. The focus is on identifying points in the system of critical infrastructure in New York where an investment in electricity supply resilience will most reduce the human, economic, psychological, and continuity of government consequences of a homeland security event that degrades or incapacitates the electricity grid in New York. Once this assessment is made, the results are compared with the technical analysis of the potential for CHP technologies described in the Task 1 deliverable of this project (see *Appendix*) to determine where CHP investments can have the most beneficial impact on critical infrastructure resilience in New York.

Grid resiliency reflects recovery time in case of a disruption, possibility for 'islanding' from the grid, and a number of other characteristics that are dependent in large part on the location and power situation at buildings and facilities included in this report. Sectors and sub-sectors that are potentially good CHP candidates, as well as important in terms of infrastructure resiliency, will be analyzed for grid resiliency on a case by case basis in the Task 3 Report.

2.0 Notes on Method

Safeguarding the Nation's critical infrastructure is a government priority addressed in the DHS's National Infrastructure Protection Plan (NIPP).[2] The NIPP provides the unifying structure for the integration of CIKR protection into a single National program. The NIPP specifically addresses the need to prioritize sectors through risk analysis in order to focus planning, foster coordination, and support effective resource allocation and incident management, response, and restoration decisions. Some sense of relative risk to assets both between and within the 17 CIKR sectors is necessary for the effective and efficient use of scarce homeland security funding.

The NIPP defines risk as a function of threat, vulnerability, and consequence,

R = f (T,V,C), where threat is the likelihood of an incident occurring; vulnerability is the likelihood that characteristics of the asset, system, or function will render it susceptible to incapacitation; and consequences are the physical, economic, psychological, or government continuity effects

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[1] See pages 16-17, 23-24, and 42-44 of the DHS *Office of Infrastructure Protection Strategic Plan: 2008 – 2013* (2007) for a description of current efforts to collect, analyze, and disseminate cross-sector risk-risk relevant information (available through the DHS Office of Infrastructure Protection).

[2] *National Infrastructure Protection Plan* (2006), available at www.dhs.gov/nipp.

of a successful attack or event on the region or Nation.[3] In this analysis, we factor in the threat to a sector by basing the analysis on a hypothetical worst reasonable case scenario power outage of one week. In other words, the threat is assessed as a constant by presuming that a homeland security event of a given magnitude has already taken place (in the more formal notation, **T=1**).

To factor in vulnerability, we look only at those sectors with a significant dependence on electricity. While nearly all sectors and subsectors are to an extent dependent on electricity, some sectors and subsectors will be more thoroughly incapacitated than others by a disruption in the supply of electricity. In order to focus our analysis on the most important sectors, we use a threshold analysis and eschew a more granular ranking. That is, sectors and subsectors that do not rank highly in terms of vulnerability to a power outage are excluded from further analysis, while those that we include are regarded as equal in their vulnerability characteristics (more formally, **V=1**). This allows us to focus on the most important sectors from a grid resilience standpoint, without the methodological complications of a detailed ranking of sectors and subsectors.

Finally, we judge **consequences** for the remaining of sectors and subsectors by ranking from one to five the human, economic, psychological, and government continuity consequences of a worst reasonable case power outage of one week.[4]

Human Impact is measured in terms of the fatalities or injuries that could result if the critical asset is degraded or incapacitated by the worst reasonable case power outage:

1 = No human fatalities or injuries
2 = No human fatalities, potential for human injuries
3 = Potential for human fatalities and injuries with less than 100 deaths
4 = Potential for human fatalities and injuries with 100 to 1000 deaths
5 = Potential for fatalities and injuries with more than 1000 deaths

Economic Impact is measured in terms of the direct and indirect effects on the economy (e.g., cost to rebuild asset, cost to respond to and recover from attack, downstream costs resulting from disruption of product or service, long-term costs due to environmental damage) that could result if the critical asset is degraded or incapacitated by the worst reasonable case power outage:

1 = Little or no economic impact
2 = Direct or indirect impact of $100,000 or less
3 = Direct or indirect impact $100,000 and $1 million
4 = Direct or indirect impact of $1 million to $100 million
5 = Direct or indirect impact of more than $100 million

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[3] NIPP, page 35.
[4] The NIPP defines consequence as, "the negative effects on public health and safety, the economy, public confidence in institutions, and the functioning of government, both direct and indirect, that can be expected if an asset, system, or network is damaged, destroyed, or disrupted by a terrorist attack, natural disaster, or other incident" (page 35).

Psychological consequences are measured in terms of the effect on public morale and confidence in national economic and political institutions that could result if the critical asset is degraded or incapacitated by the worst reasonable case power outage, or Impact on Public Confidence:

1 = None
2 = Low
3 = Medium
4 = High
5 = Severe

Finally**, impact on government continuity** is measured in terms of the reduction in the ability of State and local government to deliver minimum essential public services, ensure public health and safety, and carry out national security-related missions if the critical asset is degraded or incapacitated by the worst reasonable case power outage, or Impact on Government Capability:

1 = None
2 = Low
3 = Medium
4 = High
5 = Severe

The result of this analysis will yield a risk measure that will indicate those critical infrastructure sectors or subsectors where critical infrastructure resilience investments can have a significant impact by reducing the human, economic, psychological, and government continuity consequences of a worst reasonable case scenario event in the most vulnerable sectors. In more formal terms, given a worst reasonable case scenario of a one week power outage, infrastructure resilience investments should be made in the selected sectors where **R=*f*(C)** is highest.

It is important to note that while every effort has been made to be consistent and rigorous in the analysis, judgments of human, economic, psychological, and government continuity impacts are necessarily approximate (as are judgments on 'worst reasonable case scenario' and the vulnerability of various sectors). While the methodology and rankings here provide solid and informed guidance for investments in critical infrastructure resilience, different judgments on particular values (or different definitions of the key variables) may change the precise investments deemed most beneficial. Regardless, the framework in the following chart - ***Matrix of CHP Potential in End Use Sites in New York State with Importance to Critical Infrastructure Resilience*** - provides a meaningful way to judge the critical infrastructure resilience benefits of investments in CHP sites, given the technical capacity for the implementation of CHP technologies.

3.0 Matrix of CHP Potential in End Use Sites in New York State with Importance to Critical Infrastructure Resilience

Human Impact

1 = No human fatalities or injuries
2 = No human fatalities, potential for human injuries
3 = Potential for human fatalities and injuries with less than 100 deaths
4 = Potential for human fatalities and injuries with 100 to 1000 deaths
5 = Potential for fatalities and injuries with more than 1000 deaths

Economic Impact

1 = Little or no economic impact
2 = Direct or indirect impact of $100,000 or less
3 = Direct or indirect impact $100,000 and $1 million
4 = Direct or indirect impact of $1 million to $100 million
5 = Direct or indirect impact of more than $100 million

Impact on Public Confidence

1 = None
2 = Low
3 = Medium
4 = High
5 = Severe

Impact on Government Capability

1 = None
2 = Low
3 = Medium
4 = High
5 = Severe

Critical Infrastructure Sector	Coverage & Reach	Total Potential Sites[5]	Total Pot-ential MW	Human Impact Score	Economic Impact Score	Impact on Public Confidence Score	Impact on Govt. Capability Score	Potential Place of Refuge?	Comments/ Notes	Final Score (Average)
Agriculture and Food Production	Food processing - Upstate	223	394.6	2	3	4	2		It is necessary to maintain electricity in the food processing,	2.75
	Food Processing - Downstate	285	288.1	2	2	4	2			2.50

[5] The methodology used to determine the Total Potential Sites and Total Potential MW data was provided in the Task 1 Deliverable. See Appendix of this document for details.

Critical Infrastructure Sector	Coverage & Reach	Total Potential Sites[5]	Total Pot-ential MW	Human Impact Score	Economic Impact Score	Impact on Public Confidence Score	Impact on Govt. Capability Score	Potential Place of Refuge?	Comments/ Notes	Final Score (Average)
F	ood Sales/Super-markets - Upstate	1076	193.8	2	3	5	2		food sales/ supermarkets, and refrigerated warehouses subsectors in order to ensure a stable food and water supply. Even in a very short term outage where power would be restored to these subsectors in a matter of days, the appearance of a potential food shortage could lead to a significant loss in public confidence.	3.00
F	ood Sales/Super-Markets - Downstate	1258	166.7	2	4	5	2			3.25
Refrig	erated Warehouses – Upstate	47	27.3	2	4	4	2			3.00
Refrig	erated Warehouses - Downstate	45	18.7	2	3	3	2			2.50
	Digesters – No data available									N/A

Critical Infrastructure Sector	Coverage & Reach	Total Potential Sites[5]	Total Pot-ential MW	Human Impact Score	Economic Impact Score	Impact on Public Confidence Score	Impact on Govt. Capability Score	Potential Place of Refuge?	Comments/ Notes	Final Score (Average)
Banking and Finance	Entire State Included	330	80.4	1	5	5	5	T	he banking/financial institution subsector is vital to the day to day processes of the United States economy. Any disruption has the potential to cause negative cascading economic disturbances. A power outage in a large financial institution is also likely to greatly reduce public confidence in the economy, thereby increasing the effects of a cascading economy.	4.00
Chemicals Pharmac	euticals and other Chemicals – Upstate	164	491.6	3	3	4	2		The loss of electricity in the pharmaceuticals/	3.00

Critical Infrastructure Sector	Coverage & Reach	Total Potential Sites[5]	Total Pot-ential MW	Human Impact Score	Economic Impact Score	Impact on Public Confidence Score	Impact on Govt. Capability Score	Potential Place of Refuge?	Comments/ Notes	Final Score (Average)
Pharmac	euticals and Other Chemicals – Downstate	308	792.9	3	3	4	2	other	chemicals subsector would restrict the production of certain drugs and potentially cause casualties. In order to determine the harmful effects of restricted production in other types of chemical facilities, it is necessary to examine site specific details.	3.00
Commercial Facilities	Schools (elementary, middle, high, and technical) - Upstate	2099	220.1	2	2	2	2	Yes	An additional element of public safety includes maintaining places of refuge for evacuated people during an incident. It is important to maintain electricity in hotels, schools, colleges, and universities since some of these units could serve as places of refuge during an incident.	2.00
	Schools (elementary, middle, high, and technical) - Downstate	2861	299.4	2	2	2	2	Yes		2.00
Coll	eges/Universities – Upstate	220	886.4	1	2	2	1	Yes		1.50
Coll	eges/Universities - Downstate	209	880.5	1	2	2	1	Yes		1.50
	Hotels - Upstate	754	267.4	1	3	2	1	Yes		1.75
	Hotels – Downstate	622	419.1	1	3	2	1	Yes		1.75

Critical Infrastructure Sector	Coverage & Reach	Total Potential Sites[5]	Total Pot-ential MW	Human Impact Score	Economic Impact Score	Impact on Public Confidence Score	Impact on Govt. Capability Score	Potential Place of Refuge?	Comments/ Notes	Final Score (Average)
	Office Buildings – Upstate	2,109	721.0	1	4	2	2			2.25
	Office Buildings – Downstate	4,420	1,675.0	1	5	2	2			2.50
Communications T	elecommunications, including Data Centers - Entire State	296	58.9	3	5	4	4	T	he tele-communications subsector is vital to the day to day processes of the United States economy. Any disruption in these processes has the potential to cause negative cascading economic disturbances.	4.00
Dams Not	included									N/A
Defense Industrial Base	Not included									N/A
Drinking Water and Water	Water Treatment and Sanitation - Upstate	113	102.4	3	3	4	3		It is necessary to maintain	3.25

Critical Infrastructure Sector	Coverage & Reach	Total Potential Sites[5]	Total Pot-ential MW	Human Impact Score	Economic Impact Score	Impact on Public Confidence Score	Impact on Govt. Capability Score	Potential Place of Refuge?	Comments/ Notes	Final Score (Average)
Treatment Systems	Water Treatment and Sanitation - Downstate	64	70.9	4	3	5	3		electricity in the water treatment/sanitation subsector in order to ensure a stable food and water supply. Even in a very short term outage where power would be restored to this subsector in a matter of days, the appearance of a potential water shortage could lead to a significant loss in public confidence.	3.75
Emergency Services	Fire Protection – Entire State	236	25.1	4	3	5	4	Polic	e stations and fire protection are subsectors that are necessary for public safety. It is imperative to ensure they function during an incident to provide essential emergency response functions.	4.00
	Police – Entire State	183	52.1	4	3	5	4			4.00

Critical Infrastructure Sector	Coverage & Reach	Total Potential Sites[5]	Total Pot-ential MW	Human Impact Score	Economic Impact Score	Impact on Public Confidence Score	Impact on Govt. Capability Score	Potential Place of Refuge?	Comments/ Notes	Final Score (Average)
Energy	No data available for oil and natural gas facilities, or electricity substations									N/A
	Gas Stations – Entire State	48	3.1	3	4	4	4			3.75
Government Facilities	Armories	14	1.9	1	1	1	1	Yes	Government buildings, although essential to government function, will not have a high level of consequence associated with loss of power because such agencies typically have incident management programs in place for such an instance.	1.00
Government	Buildings, Including State Office Buildings and Courthouses – Entire State	500	187.0	1	1	2	1			1.25
Information Technology	Not included									N/A
National Monuments and Icons	Not included									N/A
Nuclear Reactors, Materials and Waste	Not included									N/A
Postal and Shipping	Not included									N/A
Public Health and Healthcare	Hospitals (medical and psychological) - Upstate	178	267.4	5	4	5	2	Yes	Hospitals represent a subsector that is	4.00

Critical Infrastructure Sector	Coverage & Reach	Total Potential Sites[5]	Total Pot-ential MW	Human Impact Score	Economic Impact Score	Impact on Public Confidence Score	Impact on Govt. Capability Score	Potential Place of Refuge?	Comments/ Notes	Final Score (Average)
Hospit	als – Downstate	232	384.8	5	4	5	2	Yes	necessary for public safety. It is imperative to ensure that hospitals function during an incident to provide essential emergency response functions.	4.00
	Nursing Homes – Upstate	412	309.6	4	4	4	1			3.25
	Nursing Homes – Downstate	383	482.0	4	4	4	1			3.25
Transportation Systems	Mass Transit – Entire State	9	4.8	2	5	5	4		The mass transit subsector includes multiple-occupancy vehicles such as transit buses,	4.00
	Maritime, trucking, and rail – no data available									N/A
	Airports – Upstate	9	1.4	1	1	1	1			1.00

Critical Infrastructure Sector	Coverage & Reach	Total Potential Sites[5]	Total Pot-ential MW	Human Impact Score	Economic Impact Score	Impact on Public Confidence Score	Impact on Govt. Capability Score	Potential Place of Refuge?	Comments/ Notes	Final Score (Average)
	Airports – Downstate	23	4.1	1	3	2	3	ferr	yboats, subway, light rail, and cable cars. Mass transportation systems–particularly downstate–rely heavily on electricity. The impact of a disruption on the economic vitality, human suffering, public confidence, and government affairs could be significant. A power outage in an airport would cause negative economic effects due to employers not being able to commute/travel, loss of capital by airlines, and a loss of capital to the tourism industry. These effects would cause a slight loss of public confidence.	2.25
TOTAL		**19,730**	**9,778 MW**	N/A	N/A	N/A	N/A		N/A	N/A

Appendix

DG/CHP and Critical Infrastructure Security

Task 1 Report
CHP Potential in End Use Sectors In New York State

Submitted to:

New York Energy Research and Development Authority
Under NYSERDA Agreement Number 9931

Submitted by:

Energetics Incorporated
Energy and Environmental Analysis – An ICF Company
Pace University Energy Project

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Exhibit 3. Existing CHP in New York (Critical Infrastructure Applications) A-1-5

Exhibit 4. CHP Technical Potential in Critical Infrastructure Sectors A-1-6

1.0 Executive Summary

Combined heat and power (CHP) has great potential value to critical infrastructure applications that are dependent upon electricity. Critical infrastructure assets across market sectors can be insulated from disruption to the grid through the use of CHP and other forms of distributed energy.

The National Infrastructure Protection Plan (NIPP) identifies seventeen (17) critical infrastructure sectors that are of concern to national security. Each of these sectors includes organizations and institutions that need to be protected from specific threats or incident situations. Each of these sectors uses energy, specifically electricity. Opportunities for using CHP vary in each sector and depend on the size and nature of their thermal loads. While the potential for using CHP as part of smart infrastructure resilience is good in many critical sectors, its actual use has been slowly adopted, in large part a symptom of lack of awareness and understanding by end users. To emphasize the resiliency benefits of CHP, one of the goals of this task was to pinpoint the critical infrastructure sectors in New York State that have both technical and institutional potential for using CHP. Twenty sub-sectors of the NIPP critical infrastructure sectors have been identified as having significant CHP opportunity. These sub-sectors include:

- Food Processing
- Food Sales/Supermarkets
- Refrigerated Warehouses
- Banking and Financial Institutions
- Pharmaceuticals/Other Chemicals
- Schools
- College/Universities
- Hotels
- Office Buildings
- Telecommunications
- Water Treatment/Sanitation
- Fire Protection
- Police Stations
- Gas Stations
- Armories
- Government Buildings
- Hospitals
- Nursing Homes
- Mass Transit
- Airports

A number of these sub-sectors are those which have traditionally been excellent candidates for CHP in numerous locales across the country. In fact, CHP has been installed in many of these types of facilities throughout New York State, as is described in more detail in Section 2.0 of this report. Exhibit 1 illustrates the total technical potential - in terms of total sites and total MWs – for CHP in the state, by critical infrastructure sector, and sub-sector, including both upstate and downstate locations.

Exhibit 1. DG/CHP and Critical Infrastructure Security CHP Technical Potential Sector Descriptions, Site and MW Data

Critical Infrastructure Sector	Coverage & Reach	Total Sites	Total MW
Agriculture and Food Production	Food processing - Upstate	223	394.6
	Food Processing - Downstate	285	288.1
	Food Sales/Super- markets - Upstate	1076	193.8
F	ood Sales/Super- Markets - Downstate	1258	166.7
Refrig	erated Warehouses – Upstate	47	27.3
	Refrigerated Warehouses - Downstate	45	18.7
	Digesters – No data available		
Banking and Finance	Entire State Included	330	80.4
Chemicals	Pharmaceuticals and other Chemicals – Upstate	164	491.6
	Pharmaceuticals and Other Chemicals – Downstate	308	792.9
Commercial Facilities	Schools (elementary, middle, high, and technical) - Upstate	2099	220.1
	Schools (elementary, middle, high, and technical) - Downstate	2861	299.4
	Colleges/Universities – Upstate	220	886.4
	Colleges/Universities - Downstate	209	880.5
	Hotels - Upstate	754	267.4
	Hotels – Downstate	622	419.1
	Office Buildings – Upstate	2,109	721.0
	Office Buildings – Downstate	4,420	1,675.0
Communications	Telecommunications, including Data Centers - Entire State	296	58.9
Dams Not	included		
Defense Industrial Base	Not included		
Drinking Water and Water Treatment Systems	Water Treatment and Sanitation - Upstate	113	102.4
	Water Treatment and Sanitation - Downstate	64	70.9
Emergency Services	Fire Protection – Entire State	236	25.1
	Police – Entire State	183	52.1
Energy	No data available for oil and natural gas facilities, or electricity substations		
	Gas Stations – Entire State	48	3.1
Government Facilities	Armories	14	1.9
Government	Buildings, Including State Office Buildings and Courthouses – Entire State	500	187.0
Information Technology	Not included		
National Monuments and Icons	Not included		
Nuclear Reactors, Materials and Waste	Not included		
Postal and Shipping	Not included		

Critical Infrastructure Sector	Coverage & Reach	Total Sites	Total MW
Public Health and Healthcare	Hospitals (medical and psychological) - Upstate	178	267.4
	Hospitals – Downstate	232	384.8
	Nursing Homes – Upstate	412	309.6
	Nursing Homes – Downstate	383	482.0
Transportation Systems	Mass Transit – Entire State Maritime, trucking, and rail – no data available	9 4.8	
	Airports – Upstate	9	1.4
	Airports – Downstate	23	4.1
TOTAL		**19,730**	**9,778 MW**

2.0 Existing CHP Capacity in New York State

To effectively utilize CHP, a commercial building or industrial facility must have at least a portion of its electric and thermal load coincide with the thermal and electric energy available from CHP systems. For best economic performance, this coincident thermal and electric load should be fairly steady for as many hours per year as possible. A continuous process industry with a nearly constant steam demand and electric load is an excellent target; a hospital with steady electric and hot water demands is a very good target. Facilities with intermittent electric and thermal loads are progressively less attractive as the number of hours of coincident load diminishes.

New York has traditionally been a leading state in terms of CHP installations, due to its focus on promoting energy efficiency. However, there are still many barriers to installing CHP; previous studies indicate that only 9 to 25 percent of technical potential capacity will enter the market. There are currently 387 sites in New York State with CHP systems, representing 5,795 MW of capacity (Exhibit 2). The majority of this **capacity** is in the industrial sector, including food processing, paper production, chemicals, and primary metals. However, the majority of the **installations** are in smaller commercial applications including schools, hospitals, nursing homes, and multi-family buildings.

Exhibit 2. Existing CHP in New York State
(All Applications)

Application	# Sites	Capacity (MW)
SIC 01: Agriculture	2 56.1	
SIC 02: Livestock	7 2.6	
SIC 13: Crude Oil	1 0.5	
SIC 20: Food	21 170.3	
SIC 22: Textile Products	1 0.3	
SIC 24: Wood Products	5 5.5	
SIC 25: Furniture	1 0.7	
SIC 26: Paper	16 937.2	
SIC 27: Publishing	2 3.8	

Application	# Sites	Capacity (MW)
SIC 28: Chemicals	17	578.0
SIC 30: Rubber	4	348.7
SIC 32: Stone, Clay, Glass	3	32.1
SIC 33: Primary Metals	2	1,121.0
SIC 34: Fabricated Metals	2	56.5
SIC 35: Machinery	2	7.7
SIC 37: Transportation Equip	3	241.1
SIC 38: Technical Instruments	1	55.0
SIC 39: Misc. Manufacturing	2	143.0
SIC 4000: Ground Transportation	1	0.2
SIC 4500: Air Transportation	4	110.8
SIC 4800: Communications	2	4.7
SIC 4939: Utilities	7	517.3
SIC 4952: Wastewater Treatment	7	14.1
SIC 4953: Solid Waste Facilities	6	124.7
SIC 4961: District Energy	3	391.0
SIC 5000: Wholesale/Retail	7	14.4
SIC 5411: Food Stores	7	1.9
SIC 5812: Restaurants	1	0.3
SIC 6512: Comm. Building	8	10.7
SIC 6513: Apartments	40	96.9
SIC 7011: Hotels	10	14.8
SIC 7200: Laundries	3	1.4
SIC 7542: Carwashes	6	1.6
SIC 7990: Amusement/ Rec.	13	2.5
SIC 8051: Nursing Homes	42	9.4
SIC 8060: Hospital/Healthcare	30	120.8
SIC 8211: Schools	60	21.2
SIC 8220: Colleges/Univ.	17	195.0
SIC 8300: Comm. Services	2	0.1
SIC 8400: Zoos/Museums	2	3.8
SIC 8900: Services NEC	4	0.6
SIC 9100: Government Buildings	5	1.2
SIC 9700: Military	5	374.2
SIC 9900: Unknown	3	1.6
Total	**387**	**5,795.0**

A table summarizing existing CHP installations in the critical infrastructure sectors identified above is provided as Exhibit 3. It shows that CHP systems are installed at 254 critical infrastructure sites totaling over 2,200 MW of capacity.

Exhibit 3. Existing CHP in New York
(Critical Infrastructure Applications)

Application	# Sites	Capacity (MW)
SIC 01: Agriculture	2	56.1
SIC 02: Livestock	7	2.6
SIC 20: Food	21	170.3
SIC 28: Chemicals	17	578.0
SIC 4000: Ground Transportation	1	0.2
SIC 4500: Air Transportation	4	110.8
SIC 4800: Communications	2	4.7
SIC 4939: Utilities	7	517.3
SIC 4952: Wastewater Treatment	7	14.1
SIC 5411: Food Stores	7	1.9
SIC 6512: Comm. Building	8	10.7
SIC 7011: Hotels	10	14.8
SIC 8051: Nursing Homes	42	9.4
SIC 8060: Hospital/Healthcare	30	120.8
SIC 8211: Schools	60	21.2
SIC 8220: Colleges/Univ.	17	195.0
SIC 8300: Comm. Services	2	0.1
SIC 9100: Government Buildings	5	1.2
SIC 9700: Military	5	374.2
Total	**254**	**2,203.4**

3.0 Technical CHP Potential in New York State

Using previous research results from CHP assessments in New York, and updating these assessments with new information for sectors not included in past studies, Energy and Environmental Analysis (EEA) has prepared estimates of the technical potential for CHP installations in each of the 20 critical infrastructure sub-sectors. The total technical potential in each sector and sub-sector is shown in Exhibit 4. A more detailed table provided in Appendix A breaks down CHP potential into the number of sites and MW capacity in each of five size ranges. The results indicate that there is technical potential for CHP at more than 19,000 critical infrastructure sites representing 9,778 MW of capacity.

The technical potential for CHP is defined as the total capacity potential from existing and new facilities that are likely to have the appropriate physical electric and thermal load characteristics to support a CHP system with high levels of thermal utilization. The technical potential figures include all sites that would be able to support a CHP system; however, they do not represent the amount of capacity that will actually enter the market. Other factors such as the economic feasibility of installing a CHP system and specific site requirements and issues affect the number of sites and amount of capacity that is ultimately installed. The methodology used to develop the technical potential estimates is described in Section 4.0.

Exhibit 4. CHP Technical Potential in Critical Infrastructure Sectors

St	Region	Application	100 kW -1 MW Sites	100 kW - 1MW (MW)	1-5 MW Sites	1-5 MW (MW)	5-20 MW Sites	5-20 MW (MW)	>20 MW Sites	>20 MW (MW)	Total Sites	Total MW
NY	Upstate	Colleges/Universities	136	71.4	41	102.5	29	362.5	14	350	220	886.4
NY	Downstate	Colleges/Universities	117	68.0	45	112.5	38	475.0	9	225	209	880.5
NY	Upstate	Food Processing	173	44.6	40	100.0	8	100.0	2	150	223	394.6
NY	Downstate	Food Processing	242	68.1	38	95.0	4	50.0	1	75	285	288.1
NY	Upstate	Food Sales	1,014	116.3	62	77.5	0	0.0	0	0	1,076	193.8
NY	Downstate	Food Sales	1,237	140.5	21	26.3	0	0.0	0	0	1,258	166.7
NY	Upstate	Hospitals	84	32.4	94	235.0	0	0.0	0	0	178	267.4
NY	Downstate	Hospitals	99	32.3	131	327.5	2	25.0	0	0	232	384.8
NY	Downstate	Hotels	517	124.8	92	172.5	13	121.9	0	0	622	419.1
NY	Upstate	Hotels	706	147.4	44	82.5	4	37.5	0	0	754	267.4
NY	Upstate	Nursing Homes	351	157.1	61	152.5	0	0.0	0	0	412	309.6
NY	Downstate	Nursing Homes	233	107.0	150	375.0	0	0.0	0	0	383	482.0
NY	Upstate	Schools	1,999	150.1	97	60.6	3	9.4	0	0	2,099	220.1
NY	Downstate	Schools	2,756	221.3	100	62.5	5	15.6	0	0	2,861	299.4
NY	Upstate	Refrig Warehouses	43	17.3	4	10.0	0	0.0	0	0	47	27.3
NY	Downstate	Refrig Warehouses	44	16.2	1	2.5	0	0.0	0	0	45	18.7
NY	Upstate	Water Treatment/Sanitary	81	22.4	32	80	0	0	0	0	113	102.4
NY	Downstate	Water Treatment/Sanitary	41	13.4	23	57.5	0	0	0	0	64	70.9
NY	Upstate	Chemicals	99	34.1	48	120.0	15	187.5	2	150.0	164	491.6
NY	Downstate	Chemicals	219	77.9	71	177.5	13	162.5	5	375.0	308	792.9
NY	Upstate	Office Buildings	1,796	329.7	313	391.3	0	0.0	0	0.0	2,109	721.0
NY	Downstate	Office Buildings	3,654	717.5	766	957.5	0	0.0	0	0.0	4,420	1,675.0
NY	Upstate	Airports	9	1.4	0	0.0	0	0.0	0	0.0	9	1.4
NY	Downstate	Airports	23	4.1	0	0.0	0	0.0	0	0.0	23	4.1
NY S	Entire State	Armories	14	1.9	0	0.0	0	0.0	0	0	14	1.9
NY	Entire State	Banking and Finance	316	45.3	12	22.5	2	12.6	0	0	330	80.4
NY	Entire State	Fire Protection	236	25.1	0	0.0	0	0.0	0	0	236	25.1
NY	Entire State	Mass Transit	8	1.9	1	2.9	0	0.0	0	0	9	4.8
NY	Entire State	Police	178	38.0	5	14.1	0	0.0	0	0	183	52.1
NY	Entire State	Telecommunications	288	39.7	8	19.2	0	0.0	0	0	296	58.9
NY	Entire State	Gas Stations	48	3.1	0	0.0	0	0.0	0	0	48	3.1
NY	Entire State	Government Buildings	451	100.4	49	86.6	0	0.0	0	0	500	187.0
		Total	**17,212**	**2,969.9**	**2,349**	**3,923.4**	**136**	**1,559.5**	**33**	**1,325.0**	**19,730**	**9,777.8**

4.0 Methodology

The basic approach to developing the technical potential is described in this section.

4.1 Identify Existing CHP in the State

The analysis of CHP potential starts with the identification of existing CHP. In New York, there are 387 operating CHP plants totaling 5,795 MW of capacity. This existing CHP capacity is deducted from any identified technical potential.

4.2 Identify Applications Where CHP Provides A Reasonable Fit to the Electric and Thermal Needs of the User

Target applications were identified based on reviewing the electric and thermal energy (heating and cooling) consumption data for various building types and industrial facilities. Data sources include the DOE EIA *Commercial Buildings Energy Consumption Survey (CBECS),* the DOE *Manufacturing Energy Consumption Survey (MECS)* and various market summaries developed by DOE, Gas Technology Institute (GTI), and the American Gas Association. Existing CHP installations in the commercial/institutional and industrial sectors were also reviewed to understand the required profile for CHP applications and to identify target applications.

4.3 Quantify the Number and Size Distribution of Target Applications

Once applications that could technically support CHP were identified, the iMarket, Inc. *MarketPlace Database* and the *Major Industrial Plant Database* (MIPD) from IHS Inc. were utilized to identify potential CHP sites by SIC code or application, and location. The *MarketPlace Database* is based on the Dun and Bradstreet financial listings and includes information on economic activity (8 digit SIC), location (metropolitan area, county, electric utility service area, state) and size (employees) for commercial, institutional and industrial facilities. In addition, for select SICs, limited energy consumption information (electric and gas consumption, electric and gas expenditures) is provided based on data from Wharton Econometric Forecasting (WEFA). MIPD has detailed energy and process data for 16,000 of the largest energy consuming industrial plants in the United States. The *MarketPlace Database* and MIPD were used to identify the number of facilities in target CHP applications and to group them into size categories based on average electric demand in kilowatts.

For applications that EEA had not previously identified as target CHP applications (armories, banking, fire protection, mass transit, police, telecommunications, gas stations, and government buildings), the *MarketPlace Database* and U.S. Census figures for energy use per employee were used to quantify the number of sites for each application. The *MarketPlace* data provided the number of sites along with the average number of employees for each application. This data was combined with Census figures for average electric use in kilowatt-hours per employee, to calculate the total capacity at the sites in each application.

4.4 Estimate CHP Potential in Terms of MW Capacity

Total CHP potential was then derived for each target application based on the number of facilities in each size category. It was assumed that the CHP system would be sized to meet the average site electric demand for the target applications unless thermal loads (heating and cooling) limited electric capacity. The market is divided into two distinct applications and two levels of annual load, resulting in four market segments in all. In traditional CHP, the thermal energy is recovered and used for heating, process steam, or hot water. In cooling CHP, the system provides both heating and cooling needs for the facility. High load factor applications operate at 80% load factor and above; low load factor applications operate at an assumed average of 4500 hours per year (51%) load factor.

5.0 Next Steps – Task 2 Analysis and Report

The Project Team will identify high-priority CHP market segments from Task 1 that are most important in terms of critical infrastructure resilience. Criteria will be developed and applied to the segments, so as to provide deeper insight into those with most importance in terms of recovery time; grid resiliency; ability to "island" from the grid; economic benefits; environmental impact; and so forth. Additional criteria, such as each segment's cultural values, social or political importance, community importance, etc., will be overlaid. The Team will deliver a report which will include a matrix of end-use sectors that can utilize CHP **and** serve to enhance infrastructure resiliency.

Appendix A: CHP Potential in New York State – All Applications

St	Region	SICs	Application	100 kW -1 MW Sites	100 kW - 1MW (MW)	1-5 MW Sites	1-5 MW (MW)	5-20 MW Sites	5-20 MW (MW)	>20 MW Sites	>20 MW (MW)	Total Sites	Total MW	Thermal Ratio	Hours of Use	CHP Type	Market Type
NY	Upsta te	8221, 8222	Colleges/Universities	136	71.4	41	102.5	29	362.5	14	350	220	886.4	1	7500	Traditional	Existing
NY	Dow nstate	8221, 8222	Colleges/Universities	117	68.0	45	112.5	38	475.0	9	225	209	880.5	1	7500	Traditional	Existing
NY	Upsta te	20	Food Processing	173	44.6	40	100.0	8	100.0	2	150	223	394.6	1	7500	Traditional	Existing
NY	Dow nstate	20	Food Processing	242	68.1	38	95.0	4	50.0	1	75	285	288.1	1	7500	Traditional	Existing
NY	Upstate	5411, 5421, 5451, 5461, 5499	Food Sales	1,014	116.3	62	77.5	0 0.0	0		0	1,076	193.8	0.5	5000	Cooling	Existing
NY	Downstate	5411, 5421, 5451, 5461, 5499	Food Sales	1,237	140.5	21	26.3	0 0.0	0		0	1,258	166.7	0.5	5000	Cooling	Existing
NY	Upstate	8062, 8063, 8069	Hospitals	84	32.4	94	235.0	0 0.0	0		0	178	267.4	1	7500	Traditional	Existing
NY	Downstate	8062, 8063, 8069	Hospitals	99	32.3	131	327.5	2	25.0	0	0	232	384.8	1	7500	Traditional	Existing
NY	Dow nstate	7011, 7041	Hotels	517	124.8	92	172.5	13	121.9	0	0	622	419.1	0.75	7500	Traditional	Existing
NY	Upsta te	7011, 7041	Hotels	706	147.4	44	82.5	4	37.5 0		0	754	267.4	0.75	7500	Traditional	Existing
NY	Upstate	8051, 8052, 8059	Nursing Homes	351	157.1	61	152.5	0 0.0	0		0	412	309.6	1	7500	Traditional	Existing
NY	Downstate	8051, 8052, 8059	Nursing Homes	233	107.0	150	375.0	0 0.0	0		0	383	482.0	1	7500	Traditional	Existing
NY	Upstate	8211, 8243, 8249, 8299	Schools	1,999	150.1	97	60.6	3 9.4	0		0	2,099	220.1	0.25	5000	Traditional	Existing
NY	Downstate	8211, 8243, 8249, 8299	Schools	2,756	221.3	100	62.5	5	15.6 0		0	2,861	299.4	0.25	5000	Traditional	Existing
NY	Upsta te	4222, 5142	Refrig Warehouses	43	17.3	4	10.0	0 0.0	0		0	47	27.3	1	7500	Traditional	Existing
NY	Dow nstate	4222, 5142	Refrig Warehouses	44	16.2	1	2.5	0 0.0	0		0	45	18.7	1	7500	Traditional	Existing
NY	Upsta te	4941, 4952	Water Treatment/Sanitary	81	22.4	32	80	0	0 0 0			113	102.4	1	7500	Traditional	Existing
NY	Dow nstate	4941, 4952	Water Treatment/Sanitary	41	13.4	23	57.5	0	0 0 0			64	70.9	1	7500	Traditional	Existing
NY	Upsta te	28	Chemicals	99	34.1	48	120.0	15	187.5	2	150.0	164	491.6	1	7500	Traditional	Existing
NY	Dow nstate	28	Chemicals	219	77.9	71	177.5	13	162.5	5	375.0	308	792.9	1	7500	Traditional	Existing
NY	Upsta te	6512	Office Buildings	1,796	329.7	313	391.3	0 0.0	0		0.0	2,109	721.0	0.5	4500	Traditional	Existing
NY	Dow nstate	6512	Office Buildings	3,654	717.5	766	957.5	0	0.0	0	0.0	4,420	1,675.0	0.5	4500	Traditional	Existing
NY	Upsta te	4581	Airports	9	1.4	0	0.0	0	0.0	0	0.0	9	1.4	1	5000	Cooling	Existing
NY	Dow nstate	4581	Airports	23	4.1	0	0.0	0	0.0 0		0.0	23	4.1	1	5000	Cooling	Existing
NY	Entire State	9711	Armories	14	1.9	0	0.0	0 0.0	0		0	14	1.9				
NY	Entire State	60	Banking and Finance	316	45.3	12	22.5	2	12.6	0	0	330	80.4				
NY	Entire State	9224	Fire Protection	236	25.1	0	0.0	0 0.0	0		0	236	25.1				
NY	Entire State	4111	Mass Transit	8	1.9	1	2.9	0 0.0	0		0	9	4.8				
NY	Entire State	9221	Police	178	38.0	5	14.1	0 0.0	0		0	183	52.1				
NY	Entire State	48	Telecommunications	288	39.7	8	19.2	0 0.0	0		0	296	58.9				
NY	Entire State	5541	Gas Stations	48	3.1	0	0.0	0 0.0	0		0	48	3.1				
NY	Entire State	9100	Government Buildings	451	100.4	49	86.6	0 0.0	0		0	500	187.0				
			Total	**17,212**	**2,969.9**	**2,349**	**3,923.4**	**136**	**1,559.5**	**33**	**1,325.0**	**19,730**	**9,777.8**				

APPENDIX B: NEW YORK METROPOLITAN AREA DISTRIBUTED GENERATION INTERCONNECT MAPS

*All applications are queued when determined to be complete by Con Edison in accordance with its procedures. Each evaluation of synchronous generation will include all prior fault current contributors on the queue. Customer DG's may require fault mitigation if the resulting fault current exceeds the capacity of the DG's associated load area.

Synchronous generation is prohibited at the grid network (120/208 volt) level.

DC Generation with inverters (Fuel Cells, Photovoltaic, Microturbines) or induction generation may be installed at all locations.

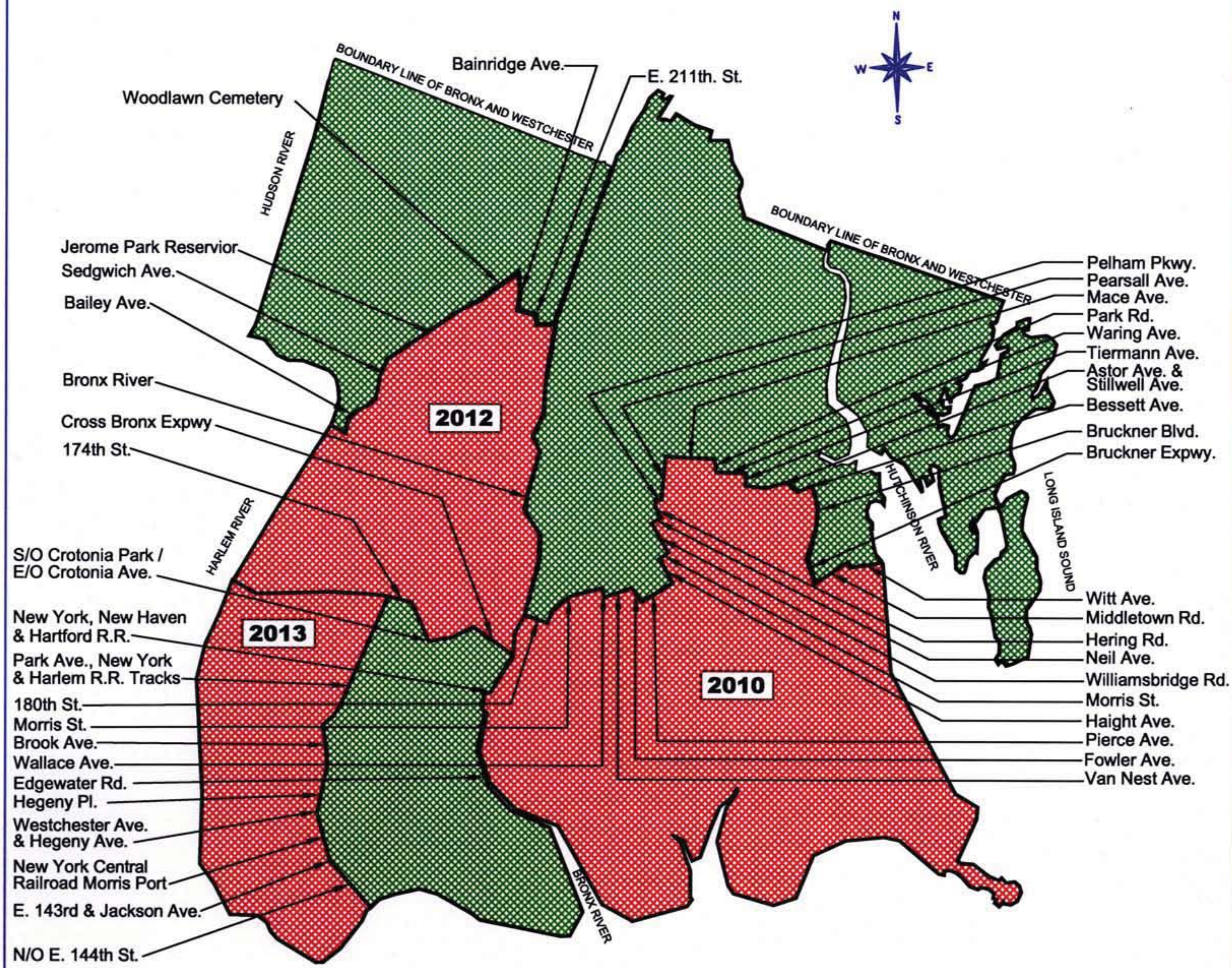
Notwithstanding the available margin or type of generation, each proposed location and installation must be evaluated for eligibility.

Bronx Key

Potential areas for synchronous generation without fault current mitigation*.

2010 — Synchronous Generation requires fault mitigation. The number indicates the planned year for upgrade completion.

All boundaries are approximate.
Contact your CPM for exact boundary details.
Upgrade years and boundaries are subject to change without notice.
Breaker replacement at substations is an ongoing process, requiring several years to complete a substation.



Status as of: June 1, 2008
Next Update: December 1, 2008

Synchronous generation is prohibited at the grid network (120/208 volt) level.

DC Generation with inverters (Fuel Cells, Photovoltaic, Microturbines) or induction generation may be installed at all locations.

Notwithstanding the available margin or type of generation, each proposed location and installation must be evaluated for eligibility.

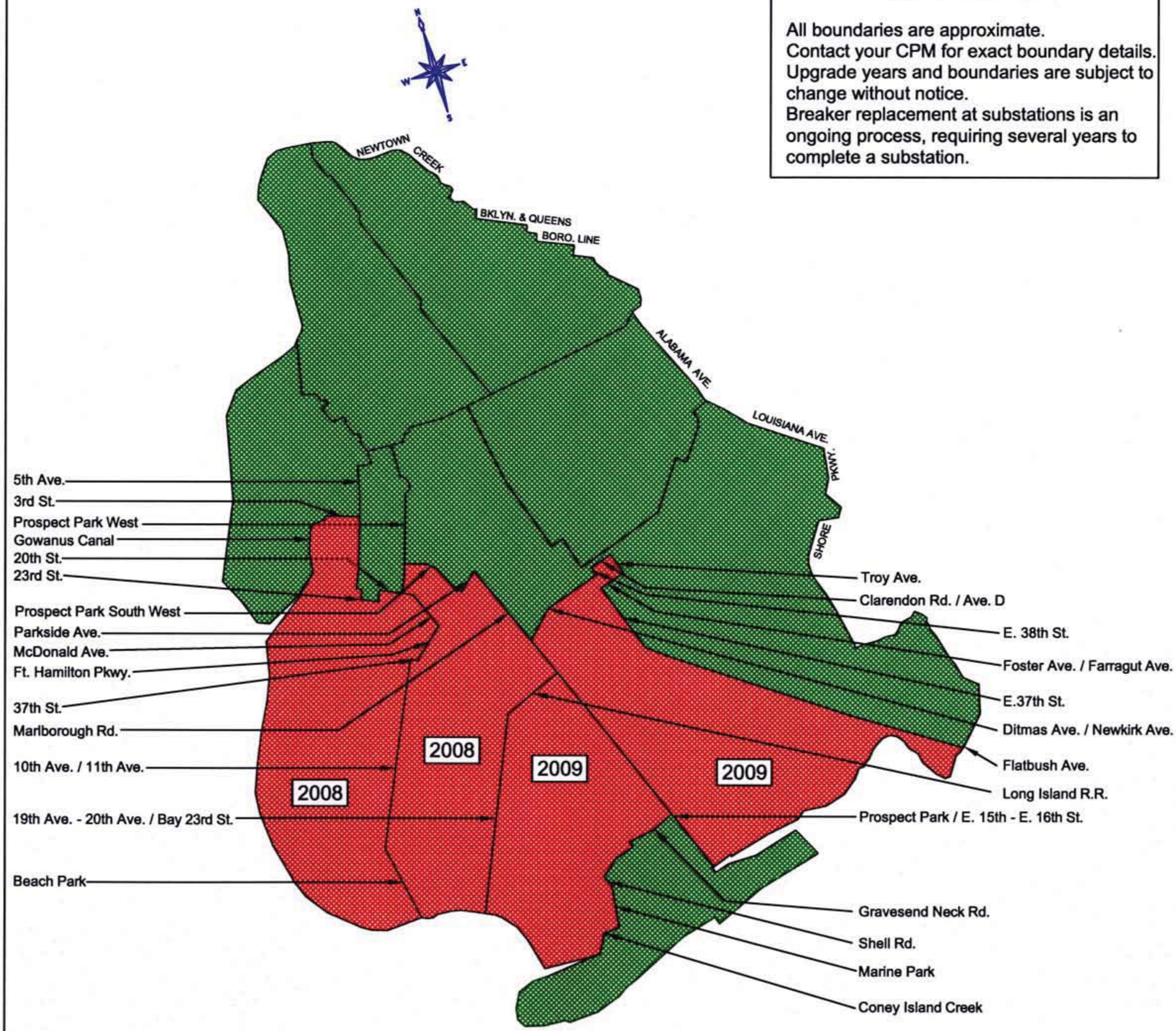
* All applications are queued when determined to be complete by Con Edison in accordance with its procedures. Each evaluation of synchronous generation will include all prior fault current contributors on the queue. Customer DG's may require fault mitigation if the resulting fault current exceeds the capacity of the DG's associated load area.

Brooklyn Key

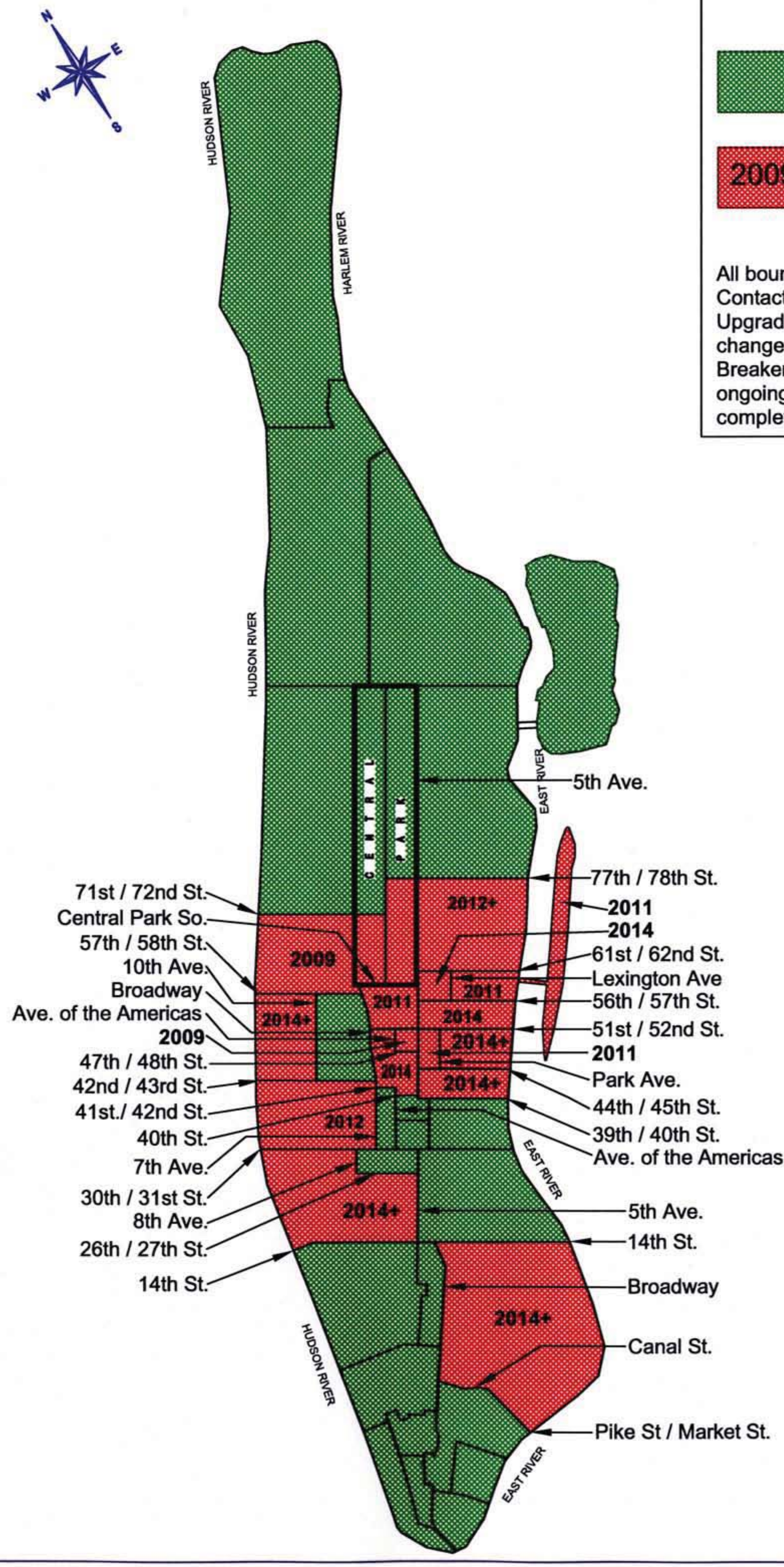
Potential areas for synchronous generation without fault current mitigation*

2009 — Synchronous Generation requires fault mitigation. The number indicates the planned year for upgrade completion

All boundaries are approximate.
Contact your CPM for exact boundary details.
Upgrade years and boundaries are subject to change without notice.
Breaker replacement at substations is an ongoing process, requiring several years to complete a substation.



Status as of: June 1, 2008
Next Update: December 1, 2008



Manhattan Key

Potential areas for synchronous generation without fault current mitigation*

2009 — Synchronous Generation requires fault mitigation. The number indicates the planned year for upgrade completion.

All boundaries are approximate.
Contact your CPM for exact boundary details
Upgrade years and boundaries are subject to change without notice.
Breaker replacement at substations is an ongoing process, requiring several years to complete a substation.

*All applications are queued when determined to be complete by Con Edison in accordance with its procedures. Each evaluation of synchronous generation will include all prior fault current contributors on the queue. Customer DG's may require fault mitigation if the resulting fault current exceeds the capacity of the DG's associated load area.

Synchronous generation is prohibited at the grid network (120/208 volt) level.

DC Generation with inverters (Fuel Cells, Photovoltaic, Microturbines) or induction generation may be installed at all locations.

Notwithstanding the available margin or type of generation, each proposed location and installation must be evaluated for eligibility.

Status as of: June 1, 2008
Next Update: December 1, 2008

Synchronous generation is prohibited at the grid network (120/208 volt) level.

DC generation with inverters (Fuel Cells, Photovoltaic, Microturbines) or induction generation may be installed at all locations.

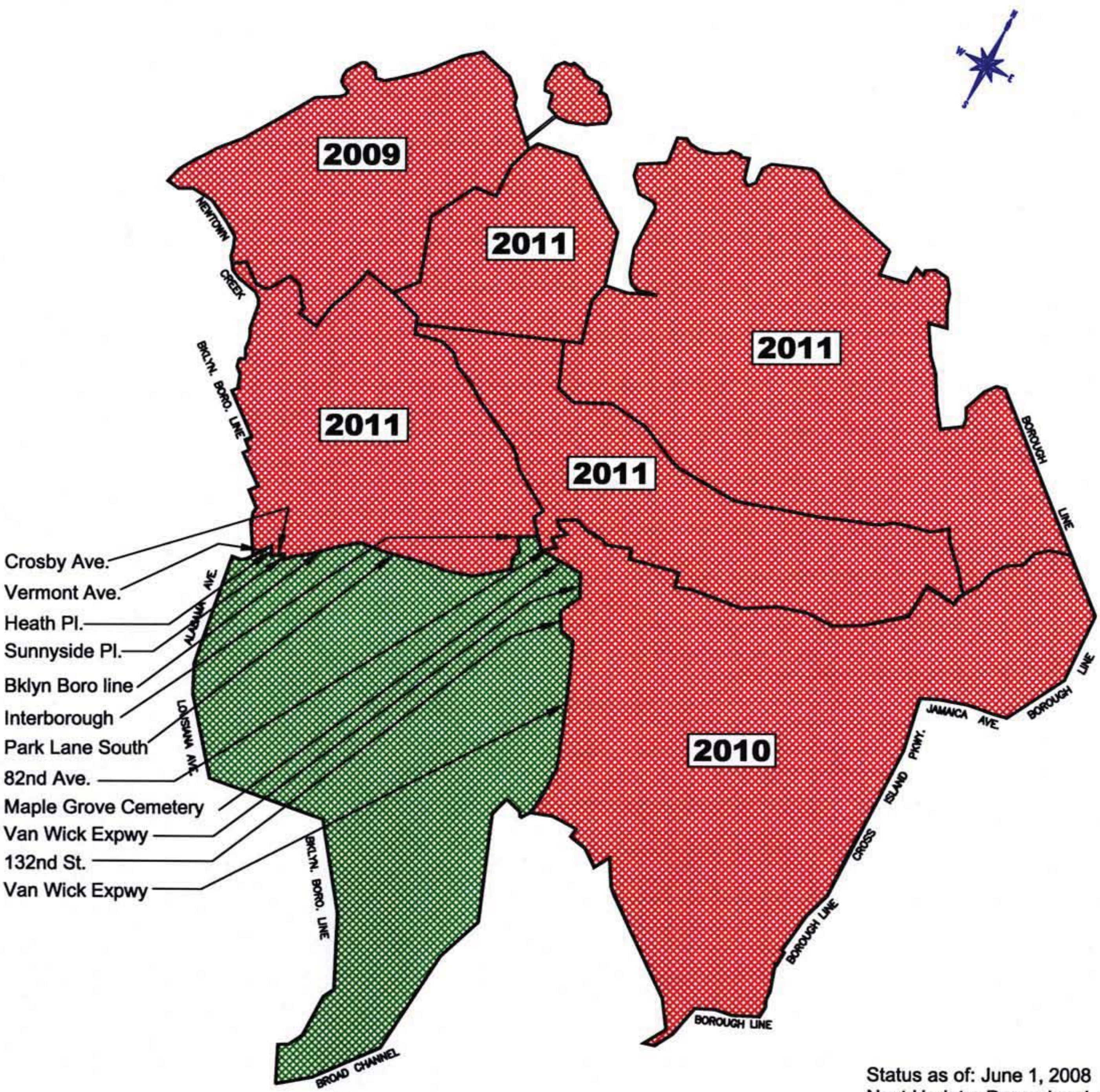
Notwithstanding the available margin or type of generation, each proposed location and installation must be evaluated for eligibility.

*All applications are queued when determined to be complete by Con Edison in accordance with its procedures. Each evaluation of synchronous generation will include all prior fault current contributors on the queue. Customer DG's may require fault mitigation if the resulting fault current exceeds the capacity of the DG's associated load area.

Queens Key

(green)	Potential areas for synchronous generation without fault current mitigation*.
2011	Synchronous Generation requires fault mitigation. The number indicates the planned year for upgrade completion.

All boundaries are approximate.
Contact your CPM for exact boundary details.
Upgrade years and boundaries are subject to change without notice.
Breaker replacement at substations is an ongoing process, requiring several years to complete a substation.



Status as of: June 1, 2008
Next Update: December 1, 2008

* All applications are queued when determined to be complete by Con Edison in accordance with its procedures. Each evaluation of synchronous generation will include all prior fault current contributors on the queue. Customers DG's may require fault mitigation if the resulting fault current exceeds the capacity of the DG's associated load area.

Synchronous generation is prohibited at the grid network (120/208 volt) level.

DC Generation with inverters (Fuel Cells,Photovoltaic, Microturbines) or induction generation may be installed at all locations.

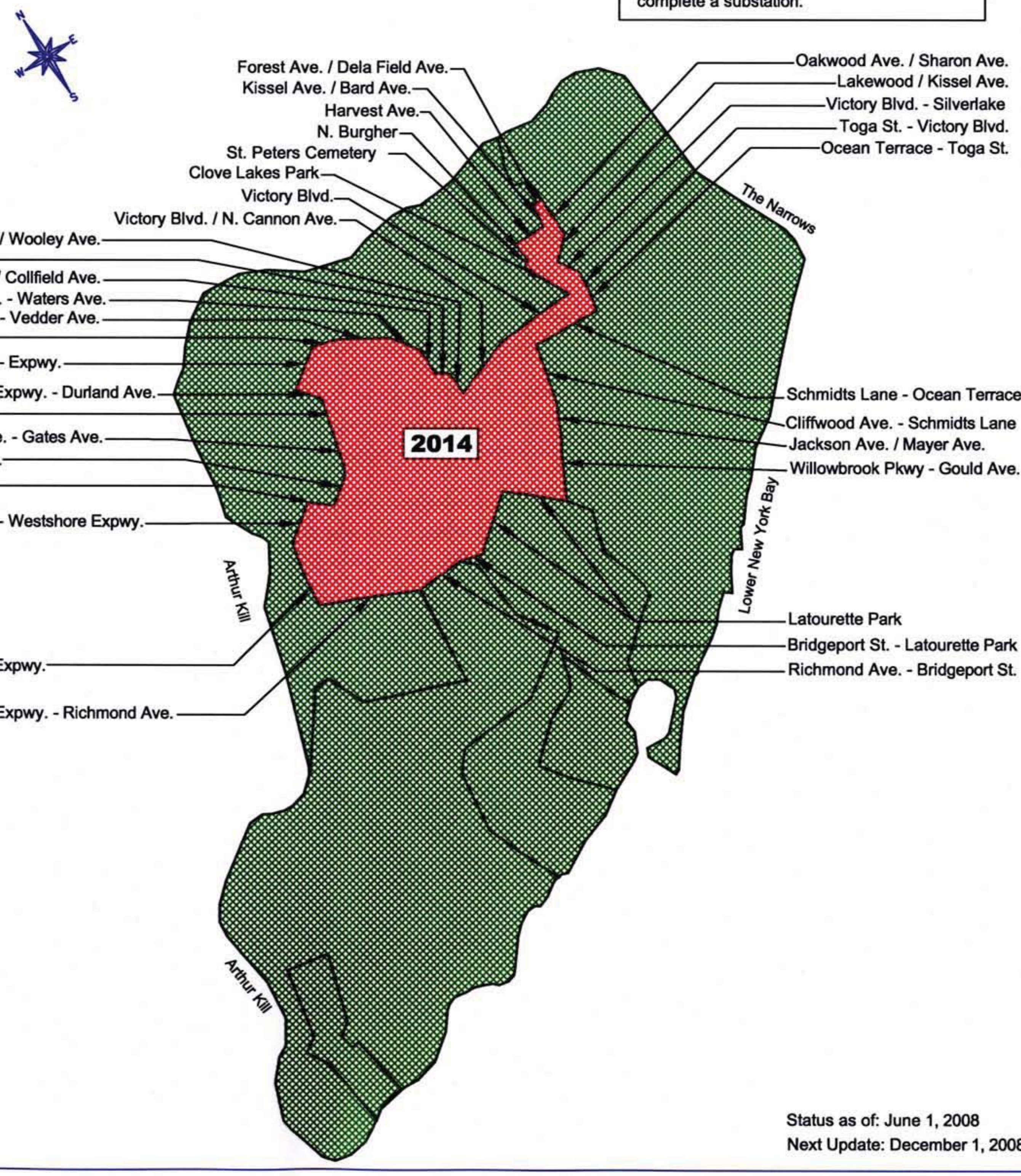
Notwithstanding the available margin or type of generation, each proposed location and installation must be evaluated for eligibility.

Staten Island Key

Potential areas for synchronous generation without fault current mitigation*

2014 Synchronous Generation requires fault mitigation. The number indicates the planned year for upgrade completion

All boundaries are approximate.
Contact your CPM for exact boundary details.
Upgrade years and boundaries are subject to change without notice.
Breaker replacement at substations is an ongoing process, requiring several years to complete a substation.

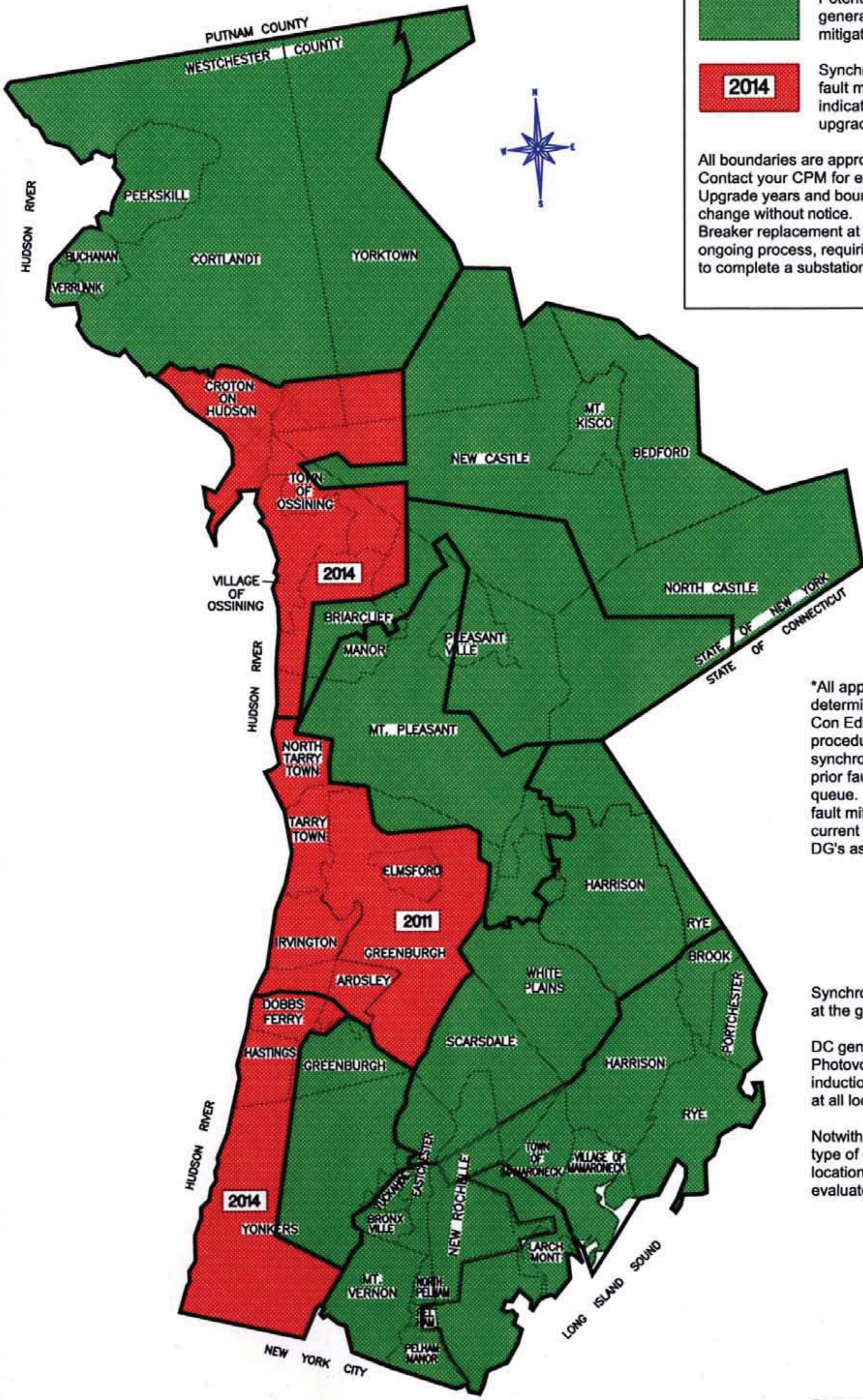


Status as of: June 1, 2008
Next Update: December 1, 2008

Westchester Key

(green)	Potential areas for synchronous generation without fault current mitigation*
2014 (red)	Synchronous Generation requires fault mitigation. The number indicated the planned year for upgrade completion

All boundaries are approximate.
Contact your CPM for exact boundary details.
Upgrade years and boundaries are subject to change without notice.
Breaker replacement at substations is an ongoing process, requiring several years to complete a substation.



*All applications are queued when determined to be complete by Con Edison in accordance with its procedures. Each evaluation of synchronous generation will include all prior fault current contributors on the queue. Customer DG's may require fault mitigation if the resulting fault current exceeds the capacity of the DG's asscociated load area.

Synchronous generation is prohibited at the grid network (120/208 volt) level.

DC generation with inverters (Fuel Cells, Photovoltaic, Microturbines) or induction generation may be installed at all locations.

Notwithstanding the available margin or type of generation, each proposed location and installation must be evaluated for eligibility.

Status as of: June 1, 2008
Next Update: December 1, 2008

APPENDIX C: CHP FOR POWER RELIABILITY – SYSTEM REQUIREMENTS

Black Start Capability

Electric generation equipment cannot be started without an electrical signal. In most cases, when starting a CHP system after a shutdown, the electric grid can be used as the source of this electrical signal. If both the grid and the CHP system are down and not supplying power at the same time, however, then the CHP system will need to be outfitted with "black start capability" so that it can begin operation. Similar to the way a car battery is used to start the engine of a car, a CHP system needs an electrical signal from a battery located on-site to allow it to start operation when the grid is experiencing an outage.

Generator Capable of Operating Independently of the Utility Grid

CHP systems that utilize reciprocating engines, gas turbines, or steam turbines as their prime mover technologies convert the mechanical shaft power to electricity through the use of an electric generator. Two types of generators are used in CHP systems: synchronous and induction.

Synchronous generators are internally (self) excited generators that do not need the external power grid to provide the source of excitation. They are preferred by CHP owners because the CHP system has the potential to continue to produce power through grid brownouts and blackouts. It is more complex and costly to safely interconnect this type of generator to the grid, as the facility must ensure that when the grid is de-energized, the CHP system can not export power to the "downed" grid, which could injure utility personnel or repair equipment.

Induction generators require an external source of power to operate (i.e. they need the external power grid to provide the source of excitation). Induction generators are preferred by utilities because the CHP system cannot operate if the grid is de-energized. This ensures that no power can be fed into a "downed" grid, ensuring the safety and integrity of the grid and utility service personnel. The downside to the customer is that this configuration does not enhance electrical power reliability to the customer because if the grid is de-energized, the CHP system shuts down. The advantage is that it is simpler and less costly to safely connect to the grid.

Ample Carrying Capacity

The traditional optimal sizing strategy for CHP is to meet as much as possible of the 24/7 electric loads without having to cycle or export power and without delivering more thermal energy than is needed to meet the building cooling loads. Typically, CHP does not replace the grid-supplied power entirely but rather reduces the amount of purchased power by making electricity on-site. The thermal energy recovered from CHP may be used for space heating or cooling, process heating, or dehumidification. The goal for CHP is to install the correct size generator to meet both thermal needs and electric power requirements, providing the highest CHP system efficiency. Power from the local power supplier is usually needed to supplement the CHP system during those times when heating or cooling needs are reduced and the CHP system is generating less electrical power.

Rather than install a diesel backup generator to provide outage protection, a facility can design that capability into a CHP system that provides electric and thermal energy to the site on a continual basis, resulting in daily operating cost savings. In this type of configuration, the CHP system would be sized to meet the base load thermal and electricity needs of the facility. Supplemental power from the grid would serve the facility's peak power needs on a normal basis and would provide the entire facility's power when the CHP system is down for planned or unplanned maintenance. The CHP system, however, would also need to be sized large enough to maintain critical facility loads in the event of an extended grid outage.

During the design phase of a CHP system, the proper amount of electrical capacity would need to be determined based on the day-to-day electrical needs of the site and the importance of having the system provide for all the power needs of a facility during a grid outage. Using traditional system sizing methods, most commercial CHP applications that are highlighted in this report would have CHP systems that provide for most, but not all, of the electrical requirements of the site. The decision must be made during the design phase of the project whether to a) size the system for optimal energy and economic efficiency, as well as designate critical loads to be supplied during a grid outage; or b) size the system for all of the site electrical requirements and try to export power to the grid or operate at partial load on typical days.

Parallel Utility Interconnection and Switchgear Controls

During normal CHP operation, both the traditional electric grid and the CHP system supply electricity directly to the facility, and typically no service interruptions occur when switching from one source to the other. This operation mode is referred to as operating in "parallel" with the utility. When connecting an on-site generator to a utility grid, the major concerns include the safety of the customers, line workers, and general public; integrity of the power grid; protection of connected equipment; and the ability of the utility to retain system control. Proper interconnection equipment and design is critical to address these concerns. An on-site generator is not allowed to feed power back onto a de-energized grid, so utilities require interconnect designs that ensure CHP systems are disconnected from their grid automatically when they sense a grid outage. In addition, most utilities require that a separate external disconnect switch be installed that is accessible by utility personnel to disconnect and lock out the CHP system from the grid. Any CHP installation must be reviewed with the local utility to ensure that the utility's ability to manage grid operations is not compromised.

After a CHP system disconnects from the utility grid due to an outage, appropriate switchgear and controls are required to isolate and serve critical loads without overloading the generator capacity. These critical loads must be isolated from the rest of the facility's non-critical loads, which must be shut down during a system outage through the installed switchgear and control logic. The switching capability can be designed for manual transfer (providing emergency power within several minutes), automatic transfer (providing emergency power in a few cycles to a few seconds), or a static transfer system (which provides seamless transfer from the grid to the CHP system in a stand-alone mode).

CHP systems running parallel to the grid can operate in either export or non-export mode.

As the name implies, “export” mode allows the host facility flexibility to sell excess power to the grid or purchase supplemental power when needed. This mode allows for more flexibility in CHP sizing, but full advantage of the increased reliability of the electric system will not be captured, since the CHP system is likely to stop generating and supplying power to the load if the grid is de-energized during blackouts and brownouts.

In “non-export” mode, a CHP system is configured with reverse current relays that prohibit it from exporting power to the grid at any time (whether the grid is operating or de-energized). In this situation, the CHP system and grid still simultaneously feed the loads—the CHP system feeds the building load and the grid provides whatever power is beyond the capacity of the CHP system. This mode requires the CHP system to operate in the electric load following mode or to size the system to never produce more than the required electric load. Also, should the CHP system generate more power than the load requires, the CHP system will be automatically shut down; if the grid is de-energized, the CHP system can continue to supply power to the load, (uninterrupted and paralleled to the grid) providing the capacity of the CHP system is capable of handling the entire load and the CHP system includes a synchronous generator. Overall system reliability is increased because the CHP system backs up the grid (should the grid go down) and the grid backs up the CHP system (should the CHP system go down).

Costs

Typically, the switchgear and circuiting costs are roughly comparable to what the facility would install for a diesel standby system meeting a portion of the facility load; therefore, the incremental cost for the CHP system for switchgear, control, and circuiting is included in the estimate of the installed diesel gen-set cost. A facility considering CHP that would not otherwise install back-up generation, however, might want to include that function by investing in the appropriate switchgear and controls. Typically, such a customer (i.e., one with low to moderate outage costs below the threshold of investment for backup), would require only a basic system.

The additional costs for switchgear and controls for a CHP system depend on the level of control and the speed with which the facility needs to have the CHP system pick up the critical loads in the case of a utility power outage. Table C-1 describes three levels of protection—manual, automatic, and seamless—and site-specific costs for reconfiguring the site wiring and control panels to isolate and serve the critical load. The level of back-up capability and control chosen for a CHP system will be directly tied to the value of reliability and risk of outages for the customer.

Table C-1. Control Costs for Generator Backup Capability[40]

Control Level	Time to Pick Up Load	Equipment Required	Capital Cost
Manual	Up to an hour	■ Engine start ■ Manual transfer switch ■ Distribution switchgear	\$20–\$60 per kW
Automatic	5 to 10 cycles when running	■ Engine start ■ Open transition automatic transfer switch ■ Distribution switchgear	\$25–\$105 per kW
Seamless	$^1/_4$ to $^1/_2$ cycle when running	■ Engine start ■ Closed transition automatic transfer switch with bypass isolation ■ Distribution switchgear	\$45–\$170 per kW
Reconfiguring for Load Shedding	Not applicable	As needed by the site: ■ Design ■ Engineering ■ Rewiring ■ Added electrical panels, breakers, controls	\$100–\$500 per kW

Note: Cost range figures represent estimates for a 500 kW CHP system at the high end and a 3,000 kW CHP system at the low end. Cost estimates do not include recircuiting costs, which depend on site needs.

Manual control requires an operator to isolate the generator to the emergency circuits using manual transfer switches. An *automatic* transfer switch eliminates the need for operator intervention. The generator is switched to the emergency circuit automatically, a process in which the circuit is open for only a fraction of a second (5-10 cycles). *Seamless* transfer—most often integrated with a full UPS—utilizes a more costly, closed transition, automatic transfer switch with bypass isolation. This switch is a "make-before-break" design that momentarily parallels the two circuits before switching. An isolation bypass switch allows removal of the automatic switching mechanism in the case of failure with the ability to then manually switch the load.

[40] Adapted from: K. Darrow and M. Koplow, *Dual Fuel Retrofit Market Assessment*, Onsite Energy Corporation for Gas Research Institute, 1998. (Costs escalated at 3% per year for equipment and 6% per year for labor.)

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