Microgrids & District Energy: Pathways to Sustainable Urban Development

Supplemental Material: Case Studies

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Note that all case studies in this document are district heating systems; utilizing combined heat and power (CHP); can island from the electricity grid; and possess black start capability. Black start capability means that the CHP system is able to start independently from the grid by using power from a backup source.

Princeton University, Princeton, New Jersey

Market Sector: University **CHP / Photovoltaic Capacity (MW):** 14.6/5 = 19.6 Total

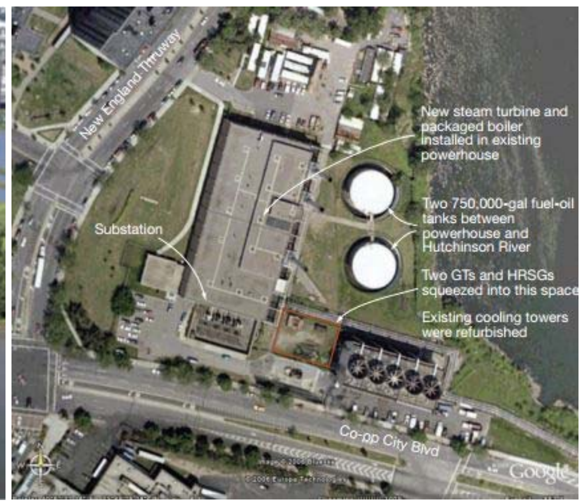
Princeton University's microgrid is noted worldwide for its resilience and sophistication. The Princeton University campus energy facility more than proved its worth when Superstorm Sandy lashed the eastern United States in October 2012. Over eight million electric customers lost their power. But the University was able to continue to power its essential buildings and operations and was able to keep the students dorms, library, all critical research centers, emergency response center, infirmary, and refrigeration powered up.

During the storm, the University was a beacon of light because of its microgrid – and the strategic vigilance of those who operate it. Seeing trouble coming as the storm bore down on New Jersey, the energy facility islanded, or disconnected, from the local utility, Public Service Gas & Electric.

The Princeton university system has four main components: steam boilers, water chillers, an electric generator, and a large Thermal Energy Storage (TES) system which stores 2.6 million gallons of chilled water that is produced during times when grid power is cheap and stored for use as needed. The Combined Heat and Power (CHP) plant and District Energy system provides a campus of 150 buildings, 9.5 million square feet and nearly 8,000 students with efficient heating, cooling and electricity. When New Jersey moved to real-time pricing in the electric market in 2003, Princeton upgraded its cooling systems and installed a cutting-edge monitoring and dispatch system in the campus energy plant. Depending on market prices, the Princeton system changes plant production strategies for electricity, steam and chilled water. During peak demand periods, Princeton reduces its electric load on the grid, which reduces stress on the grid and lowers demand costs. The campus further increases efficiency by using Thermal Energy Storage. In 2012, a 5.3-megawatt solar collector field was installed on 27 acres which Princeton owns in West Windsor Township. The system is comprised of 16,500 photovoltaic panels and reflects an extension of the Microgrid

The microgrid provides Princeton the flexibility to get out of the way and self-generate in an island mode during emergencies when the central grid is in trouble. In normal mode the university, benefits both operationally and financially. The facility can rely on the grid for back-up power should its own equipment fail. It can also hedge its power purchases based on real-time prices in the PJM Interconnection's wholesale market. When wholesale prices are low, Princeton buys grid power; when power prices are high, it generates more power onsite. The onsite resources help ease pressure on the grid when power is in high demand. Using real-time power purchase management Princeton limits the amount of power it buys during the hours of the year when demand is highest in PJM.

Coop City, Bronx, New York



Market Sector: Large Urban Residential Co-operative **CHP Capacity (MW):** 40

Co-op City, sited next to the Hutchinson River in the Baychester section of the Bronx (New York City), is the largest single residential development in the United States. The 340-acre complex is home to about 60,000 people who occupy 15,372 residential units in 35 high-rise buildings and seven townhouse clusters as well as retail, houses of worship, day-care centers, and other amenities.

The reconstruction of its central district energy plant from 2004-2007 resulted in a robust, tri-generation facility with a combined heat and power microgrid connected to ConEdison and the facility produces annual revenues of $15-25 million from the sale of excess electricity to the utility. The investment for this microgrid was paid back after just five years, aided by the sale of surplus power back to the grid.

During Super Storm Sandy, the microgrid continued to provide electricity, heat, hot water and air conditioning for all residents, while neighboring areas sat in darkness.

Markham District Energy, Markham, Ontario, Canada


Market Sector: Downtown **CHP Capacity (MW):** 15.7

Markham District Energy (MDE) is a thermal energy utility owned by the City of Markham. It is the only district energy utility in Canada operating two thermal grid systems – Markham Center & Cornell Center within the same municipality. The systems are served from four Energy centers – Warden, Clegg, Birchmount and Bur Oak.

In the late 1990s, the deregulation of the Ontario power industry, the infamous 1998 Quebec ice storm, and IBM Canada's interest in locating a major facility in Markham Centre created a unique opportunity for Markham to develop a community energy system in step with its new downtown core known as Markham Centre, a community of over 30 million square feet of residential, commercial and institutional buildings.

Markham District Energy completed construction of the Warden Energy Centre in 2000 and commenced operations to its first customer, IBM Canada. Since 2000, nearly 6 million square feet of building space has been connected to the Markham Centre district energy system, reducing the City's carbon footprint and increasing customers' comfort compared to traditional electric resistance heating. This model of sustainability solution will serve all 41,000 residents and 39,000 employees.

During a blackout in 2003 which swept the eastern seaboard of North America, leaving nearly 10 million people in Ontario without electricity, Markham District Energy continued to function. Markham's investment in a cogeneration facility allowed the Town to continue providing heating and cooling to high-tech companies, such as IBM and Motorola.

MDE is committed to expanding its combined heat and power (CHP) fleet to match the growing thermal load in the City's district heating systems. MDE's first CHP unit (3.5 MW) was commissioned in 2001 at its Warden Energy Centre. MDE then won one of seven contracts awarded by the Province for CHP capacity resulting in the installation of the second CHP plant (5.2 MW) in 2008. In 2013 MDE's added CHP totaling 7.0 MW bringing its total capacity to 15.7MW.

CHP	Rating	Plant/System Location	Prime Mover	In-Service Date
G1	3.5 MW	Warden Energy Centre (Markham Centre)	Caterpillar G3616	2001
G2 + G3	5.2 MW	Warden Energy Centre (Markham Centre)	2 x Caterpillar G3612	2008
G4	3.0 MW	Birchmount Energy Centre (Markham Centre)	Caterpillar GC260-12	2013
G5	4.0 MW	Bur Oak Energy Centre (Cornell Centre)	Caterpillar GC260-16	2013
Total	**15.7 MW**			

Although Canadian municipalities are able to issue bonds, the actual application of municipal bonds is limited because of the challenges associated with obtaining the necessary provincial backing. Municipalities can, however, form private corporations which allow them to carry debt. For example, Markham District Energy is a private corporation whose sole shareholder is the city of Markham. Operating as a private business with municipal oversight has financial and management advantages.

As a private company, MDE can take advantage of tax advantages available to the private sector for the construction and operation of plants, such as a recently created accelerated write-off provision for certain types of equipment used to produce energy in a more efficient way. At the same time, as a wholly owned municipal entity, MDE can leverage sources of capital provided only to Canadian municipalities, such as the Green Municipal Fund.

University of Massachusetts Medical Center, Worcester, Massachusetts

Market Sector: University **CHP Capacity (MW):** 17.5

Hospitals and medical facilities are required to provide reliable, consistent care for their patients 24 hours a day, 365 days a year. This means that heating and cooling, hot and chilled water and electricity, also need to be reliable and accessible at all times. Unfortunately, storms, overloads and security breaches pose significant threats to the traditional electric grid and can result in grid failures and utility outages, putting medical facilities and their patients at high-risk. Microgrids with interconnected on-site power generation and district energy eliminate that risk.

While almost every hospital and medical facility has an emergency backup generator, CHP provides reliable energy independence from the electric grid and can seamlessly transition from on-grid to off-grid power. Using grid power and then switching to an emergency backup generator can cause patient care to stall, diagnostics to be delayed and losses in vital research due to temperature fluctuations. When off-grid power sources like CHP or district energy are used, these risks can be avoided. Backup generators often produce less electricity, less efficiently compared to CHP and district energy systems.

The University of Massachusetts Medical Center in Worcester is a 60-acre campus comprising a medical trauma center, school, and medical research center. It operates a 17.5 MW combined heat and power system. The Medical Center Microgrid utilizes a district energy loop which connects approximately 3 million square feet and provides electricity, steam, and chilled water to all buildings.

Completed in 2013, the new central plant expansion included the installation of a 7.5 megawatt, gas-fired combustion turbine and associated heat recovery system, which replaced the UMass Medical School's oil-fired steam boilers and added to the 10MW of existing CHP capacity. The new system produces 60,000 pounds of high-pressure steam per hour which is used to drive two of the plant's existing electric generators and feed the campus' steam distribution network to heat buildings and drive compressors that make chilled water for the campus' cooling systems. The expansion increased electricity, steam, and water-chilling capacity but actually reduced overall greenhouse gas emissions because the turbine is more efficient than the previous boiler system; this is despite the added energy load from the new buildings. The system operates at 80% efficiency and the thermally driven plant provides 58,000 MWh of annual electricity savings, or $6.2 million, creating a payback period of less than 3 years. National Grid granted UMass Medical School a $5.6 million incentive in support of the project.

The system was financed as part of a $450 million campus capital campaign, a result of integrating the system into the hospital's long-term master plan years prior to construction.

New York University, New York, New York

Market Sector: University **CHP Capacity (MW):** 13.4

Microgrids took a front seat during Superstorm Sandy in October 2012, proving their critical value in supporting resiliency and ensuring reliable power and heat supply.

The storm left over 8 million customers in the tristate area without power, and many communities lost power for weeks. Throughout Manhattan, over 250 large buildings were also without power for several weeks, and in many cases months, due to severe flooding that knocked out a power station in the East Village. But on the nearby campus of New York University (NYU), home to 38,000 students, the lights stayed on and buildings had heating, hot water, and cooling, thanks to a self-sufficient microgrid system designed to distribute electricity independently of Consolidated Edison's main grid network. The campus provided New York residents a safe and warm haven during the storm and emergency personnel were able to set up a command post to better assist with storm response.

The Microgrid is anchored by a 13.4 MW CHP plant housed below Mercer Street. The system upgrade in 2011 resulted in a doubling of capacity with two 5.5 MW gas turbines and one 2.4 MW steam turbine. The steam capacity is 90,000 lbs. per hour.

The electrical and district heating and cooling systems supply electricity to 22 buildings and 100% of the heating, cooling, and water heating to 37 campus buildings. The CHP plant has an operating efficiency of 75 percent and prevents an estimated 43,400 tons per year of CO_2 emissions. By reducing demands on existing transmission and distribution infrastructure, the CHP system also helps support grid stability. NYU is also able to sell excess electricity to the utility when campus demand is low, resulting in additional revenue.

The upgrade of the plant has presented impressive results both economically and environmentally and has proven its benefits. NYU has evaluated savings on total energy costs to be $5 to $8 million per year.

The upfront capital cost of the upgrade was $125 million. However, tax-exempt bonds arranged through the Dormitory Authority of the State of New York and through NYU tuition and fees helped to provide low-cost financing sources.

District Energy St. Paul, St. Paul, Minnesota

Market Sector: Downtown **CHP Capacity (MW):** 25

District Energy St. Paul, one of several combined heat and power (CHP) plants in Minnesota, runs North America's largest hot water district heating system, in addition to distributing chilled water, and is fueled in part by wood waste. In March 2011 they added North America's largest solar thermal production to the system.

The system provides hot water service to 29 million ft^2 representing 90% of the downtown market. The District Cooling system serves over 17 million ft^2 and is supported by a thermal energy storage tank with a 6 million gallon capacity. An additional benefit of this thermal storage is the reduction of peak-electric demand by as much as 9 MW.

The CHP plant has a capacity of 25 MW (electric) and 65 MW (thermal equivalent) operates at double the efficiency of conventional power plants, and has been able to keep prices stable for customers.

Renewable clean urban wood waste is the primary fuel, but the system is fuel flexible and can also use natural gas, coal, and oil. Purchases of the municipal wood recirculate over $12 million in the local economy. The biomass wood waste displaces 275,000 tons coal per year and cuts land fill use while reducing CO_2 emissions by 280,000 tons per year. Connecting to the central plant has enabled the elimination of over 150 smokestacks at buildings and reduced sulfur dioxide and particulate emissions by more than 60 percent.

District Energy St. Paul’s for-profit consulting, operation, and management firm is Ever-Green Energy.

Marine Corps Air Ground Combat Center, Twentynine Palms, California

Market Sector: Military **CHP / Photovoltaic Capacity (MW):** 8/5 = 13 Total

Twentynine Palms, located in the Mojave Desert, is home to the Marine Corps Air Ground Combat Center, which is one of the largest military training areas in the nation. The base has a population of about 28,000 people – including military, civilian and families – and over 8 million square feet of facilities.

In late 2014, over half of all microgrids under development in the United States were on military bases. Utilizing a third party ESCO strategy, Twentynine Palms was able to integrate CHP and renewables into a software optimized microgrid in order to deliver highly reliable energy for mission critical operations.

Reliability and resiliency originally became a worry for the military base during the California energy crisis 15 years ago, which triggered many blackouts across the region. At that time, diesel generators were the only source of backup power on the base and they were unable to function and sustain operations for a prolonged period of time. Today, the CHP and microgrid system in place at Twentynine Palms allows the facility to island from the grid and sustain power independently.

On a military base, the functionality provided by a microgrid is crucial. Energy independence is seen as a national security priority, and the microgrid ensures mission readiness 24 hours a day while helping to cut costs, approximately $10 million dollars a year, from an already shrinking military budget.

Veolia Energy North America, Boston-Cambridge, Massachusetts

Market Sector: Downtown **CHP Capacity (MW):** 256

Veolia's district energy networks serve the critical energy requirements of approximately 250 commercial, healthcare, government, institutional and hospitality customers occupying 45 million square feet of building space within the central business district of Boston and the Longwood Medical Area as well as the biotechnology corridor of Cambridge. In Cambridge, Veolia operates the Kendall Station combined heat and power (CHP) plant as well as a cogeneration plant on behalf of a major biotechnology company. In the Longwood Medical Area of Boston, Veolia operates the Medical Area Total Energy Plant (MATEP) facility supplying heat, cooling, and electrical power to the hospitals in that section of the city.

Located beneath the streets and bridges of Boston and Cambridge, invisible to the cities above, is a network of district energy steam pipes delivering environmentally friendly thermal energy or "Green Steam" throughout the Boston-Cambridge system. "Green Steam" is an innovative environmental solution that recaptures and reuses thermal energy previously lost to the environment, utilizing advanced cogeneration technology. Following the completion of a 7,000-foot steam pipeline extension in 2013 and a planned reconfiguration of the recently acquired Kendall Station, up to 75% of Veolia's district energy heat supply will consist of recycled "Green Steam." This innovative $112 million investment generates significant benefits for Cambridge and Boston, including:

- Reducing greenhouse gas emissions by 475,000 tons annually - the equivalent of removing 80,000 cars from the roads
- A 6% reduction of non-transportation carbon emissions for both cities
- Minimizing thermal pollution from the Charles River ecosystem

- Improving air quality, reducing NOx and SO2 emissions by approximately 36% and 61%, respectively
- 147,500 man hours invested to support the construction of the "Green Steam" project;
- Increasing capacity, reliability and overall system efficiency
- Supporting the Greenovate Boston goal of reducing Boston's greenhouse gas emissions 25% by 2020 and 80% by 2050
- Supporting sustainable development in both Boston and Cambridge
- Increasing the region's energy reliability

Hamilton Community Energy, Hamilton, Ontario, Canada

Market Sector: Downtown **CHP Capacity (MW):** 3.5

Hamilton Community Energy's (HCE) Combined Heat and Power and District Energy System located on the grounds of a Hamilton public school, is a natural gas–fired facility that supplies electricity and hot-water heating to customers through combined heat and power. HCE produces 3,500 kilowatts of electricity through a reciprocating engine connected to a generator. The power is either sold directly to the grid or provides backup electricity to 2 million sq. ft. of commercial, institutional and multifamily properties in downtown Hamilton.

Hamilton is a port city of approximately 500,000 residents located in a densely populated region at the west end of Lake Ontario. The HCE Cogeneration Unit played a vital role in keeping City of Hamilton operations functioning during the 2003 blackout.

Hamilton Community Energy (HCE) is a division of Hamilton Hydro Services, Inc., which is a subsidiary of Hamilton Utilities Corporation, a private corporation wholly owned by the city of Hamilton.

In 2010, HCE formed a strategic partnership with McMaster Innovation Park in Hamilton, completing an on-site satellite operation to become one of the first in Ontario to combine conventional DES with renewable technology; connecting and interfacing district heating and cooling equipment with a geo exchange system of eighty-one 500 ft. geo wells.

This district energy system sits on a former brownfield site in Hamilton. Designed, built and operated by Hamilton Community Energy and opened in 2011, the district energy system provides heating and cooling services to three large buildings: the McMaster Innovation Park Atrium, the CANMET Materials Technology Laboratory, and the McMaster Automotive Resource Centre. The core of the system is an underground geo-exchange field; the stable temperature beneath the surface raises the water temperature in the pipes in winter and lowers the water temperature in summer. Used in combination with electrically powered heat pumps that further raise or lower the water temperature as needed, the geo-exchange system provides extremely high efficiency heating and cooling. Used in heating mode, the geo-exchange system is expected to deliver more than three units of output energy for each unit of input.

Helen Ltd. (Helsingin Energia), Helsinki, Finland

Market Sector: Municipal Scheme **CHP Capacity (MW):** 630

Helen Ltd, formerly Helsingen Energia, is the utility provider for the city of Helsinki and the surrounding area. It is a for-profit company owned by the city of Helsinki, which supplies electric energy to nearly 400,000 customers in Finland and covers over 90% of the heat demand of the capital city with district heating. In 2011, the connected heat load in the district heating system was 3,262 MW while the cooling load for the district cooling system was 120 MW. District cooling is provided by utilizing cold sea water, heat from sewage waste water, and the surplus heat from CHP. Eighty percent of the cooling energy leverages sources that would otherwise remain unused. Sites connecting to district cooling include data centers, shopping centers, office building and residential spaces.

Summer afternoons in Helsinki only reach an average of 70°F and for half the year daytime temperatures are less than 50°F. Heating the buildings, therefore, is close to a year-round activity. This makes the city, like the rest of the country, an ideal location for CHP.

The smart city solution combines four CHP plants, district heating and district cooling in the most energy-efficient way. The system is supported and diversified by harnessing waste heat accumulated along the energy chain. The power grid connection is self-healing and provides enhanced reliability and uptime through active feeds from two substations.