Renewable Energy on Campus

An Overview of Renewable Energy Projects and Technologies Currently Operating or Under Construction on U.S. College Campuses

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1) EXECUTIVE SUMMARY

REPORT PURPOSE:

The purpose of this report is to provide an overview of renewable energy projects currently installed or under construction on university campuses in the United States. The purpose of providing the overview is to present potential options for NYU to engage in as an alternative to the current purchase of Renewable Energy Credits (RECs).

REPORT SCOPE:

This report covers the most widely utilized renewable energy technologies on university campuses, including wind, solar (both photovoltaic and solar thermal) and biomass on large and small scales. It also includes technology still in the development phase that has or has not yet been utilized on campuses but may be appropriate for NYU's urban location. These include tidal power, micro-wind turbines and fuel cell technology. The cost of projects described varies greatly from $45,000 to $43 million, as do funding sources. Each type of renewable is broken up into characterization categories such as "the biggest," "the economical," and "the symbolic." As it is an overview of renewable energy in higher education on the whole, the report is not specifically tailored to the fact that NYU is a unique campus located in a dense urban environment. Many of the projects could not be replicated identically at NYU's campus, but elements may be transferable.

HIGHLIGHTED PROJECTS THAT POTENTIALLY RELATE TO NYU:

*Certain projects are noted in this report for their potential installation in New York City.

Wind Power:

The Symbolic: Wind Power at Middlebury – Cost: $45,060

The Innovative: Micro-wind turbines in cities– estimated cost: $6,500 installation per 1 KW

Solar Photovoltaic Panels:

The Biggest: Rooftop photovoltaic panels at Loyola Marymount – Cost: ~$4.4 million

The Economical: Harvard University photovoltaic array – Cost: $378,487

Solar Thermal:

The Biggest: Governor's State University at Illinois – Cost: $300,000

Solar Passive and Active Combined:

The Experimental: University of Oregon's solar awnings – Cost: $50,000

Biofuels:

The Symbolic: Haywood Community College – Cost: $135,000

Fuel Cell Technology:

Reliable Energy: Yale University – Cost: ~$1.2 million

Technologies that require additional New York City assessment:

Price and viability of geothermal exchange well in central Manhattan

Tidal Power in the East River

NOTE: Other projects described, including wind turbines and biomass plants, while not suited for an urban environment, may be viable options for NYU's Sterling Forest research facility.

REPORT SOURCES:

The information in this report was compiled from online resources such as the AASHE, the College Sustainability Report Card, college sustainability websites and press releases, newspaper articles, government press releases, conversations with staff at AASHE and Solar1 and more.

2) WIND POWER

a. The Biggest: A Wind Farm on college property: providing power for the community.

Whitman College: Location: Walla Walla, Washington. Private. Enrollment: 1,300. Environment: Rural/windy Columbia River Gorge

As part of a 300 MW wind farm project built along the Columbia River between Oregon and Washing by Florida Power and Light (FPL) Energy Company, the Stateline Wind Energy Center, which consists of 454 large wind turbines, Whitman College offered its farm property to be used for the installation of 65 turbines. The turbines are owned by FPL and the electricity is hooked into the grid purchased by PacifiCorp Power. The turbines generate enough electricity to cover twice the consumption of Whitman per year.

Total Power Output of Project: 37.7 MW
Project Hardware: 65 large 660 KW (peak) wind turbines designed by Vestas Wind Systems
Total Cost of Project: Approximately $43 million for Whitman portion, $300 million for entire project.
Cost to University: nothing, royalties paid to Whitman for land use.
Partners: FPL and PacifiCorp Power

More information:
Whitman Article: http://www.whitman.edu/magazine/december2001/Wind%20power.html
Description of Stateline Wind Energy Center: http://www.rnp.org/projects/stateline.html
Vestas Wind Systems: http://www.vestas.com/

b. The Economical: One wind turbine provides large percentage of university electricity demand.

A number of universities have installed medium to large wind turbines on their campuses, which provide enough electricity to cover a large percentage of university demand. While capital costs are high, the projects pay for themselves over time and ultimately save significant cost. Depending on set-up, electricity from the wind turbine is either hooked directly into campus electricity supply or is sold to the local grid.

Carleton College: Location: Northfield, Minnesota. Private. Enrollment: 1,986. Environment: Small town/rural

Beginning in 2004, Carleton College worked with the local government and school district to install a large wind turbine 1.5 miles off campus. The electricity generated from the turbine is hooked into the local grid and purchased from Carleton for 3.3 cents per KWh by Xcel Energy.

Total Power Output of Project: 1.65 MW, 4.8 million KWh per year
Project Hardware: One 1.65 MW 360 foot turbine. Purchased from N.E.G. Micon, now part of Vestas Wind Systems. Blades are 26 ft longer than standard machines to accommodate the slower winds of the region.

Total Cost of Project: $ 1.8 million
Cost to College: $1.65 million
Funding Breakdown: Carleton received a $150,000 Community Wind grant from the Chamber of Commerce.
Contact: Richard Strong, Director of Facilities at Carleton (507) 646-4271

More information:
Article: http://www.cleanenergyresourceteams.org/files/CS_CWind_Carleton2005.pdf
Article: http://apps.carleton.edu/campus/facilities/sustainability/wind_turbine/

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St. Olaf College: Location: Northfield, Minnesota. Private. Enrollment: 3,000. Environment: Rural/small town

In 2004 St. Olaf College received a $1.4 million grant from the Xcel Energy Renewable Energy Fund to install a 1.6 MW wind turbine on campus. The wind turbine became operational in 2006 and is hooked directly into the University's electricity supply loop, generating approximately one-third of campus electricity demand.

Total Power Output of Project: 1.6 MW
Project Hardware: 350 feet tall turbine designed by Vestas Wind Systems
Total Cost of Project: $1.8 million
Cost to College: $400,000
Funding Breakdown: $1.4 million supplied by Xcel Energy Renewable Energy Fund Grant, $400,000 by College
Partners: Xcel Energy, Vestas Wind Systems

More information:
St. Olaf Website on project: http://www.stolaf.edu/green/turbine/index.html

c. The Symbolic: Small wind turbines installed as symbol of sustainability.

Many universities/colleges have installed 10 kW wind turbines to provide partial energy to one building on campus. These projects are generally presented as symbols of sustainability, rather than as economical or major investments. As part of this, they are generally used not only for power but also as research stations, centerfolds in programs or classes, or offered to the local government and non-profit organization as locations for educational and training work-shops.

Middlebury College: Location: Middlebury, Vermont. Private. Enrollment: 2,350. Environment: Rural/small town
*PROJECT NOTED FOR RELEVANCE TO NYU

In 2005, a Middlebury professor and her environmental science class received a grant from the Energy Efficiency Division of the Vermont Department of Public Service to cover half of the costs of installing a small 10 KW Bergey Wind Turbine on campus. The turbine was constructed by the

recycling center and provides it with power. The primary purpose of the turbine is educational – it serves as both a research station testing wind conditions in the region, and as a tool to teach students about sustainability (as evidenced by the turbine's website).

Total Power Capacity of Project: 10 KW
Project Hardware: Bergey Excel-S 10 KW wind turbine installed on an 80 foot NRG Systems tilt-up tube tower.
Total Cost of Project: $45,060.00
Cost to College: $25,560
Cost Breakdown (from grant application, may have changed slightly):
Wind Turbine: $24,750.00 Electrical Modifications: $2,200 Installation Labor: 2,660.00, wind turbine freight: $650.00, Site Improvements: $3,000 Excavation and back-fill: $800.00 Data collection system: $3,000
Funding Breakdown: Half of the cost covered by grant, the other half covered by the college.

More information:
Middlebury Wind Turbine Website:
http://community.middlebury.edu/~cri/Wind/history_wind.htm - link to copy of grant on website
Bergey Wind Power: http://www.bergey.com/

Supplemental Information:

Many other schools and Universities have installed small wind turbines on their property.
Link to DOE website: "Wind Powering America":
http://www.windpoweringamerica.gov/schools_projects.asp#WA

d. The Innovative: Small Roof Top Wind Turbine Technology
*TECHNOLOGY NOTED FOR RELEVANCE TO NYU

There is a growing interest in small rooftop wind turbines located in cities. In summer, 2008, Mayor Bloomberg pushed for the growth of this technology in New York City, asking for developers to come forward and propose project installations in the City to test viability. Around the country, small turbines have been installed on rooftops. Turbines have been installed at New York's Brooklyn Yard, on the top of Chicago's Daley Center, and at the Logan International Airport in Boston. Boston's Museum of Science also has plans to line its roof with small turbines and Harvard University has plans to put a number of small turbines on the roof of its Holyoke Center.

Despite the growing interest, there remains much speculation about the widespread implementation of this technology, primarily because it appears that due to low wind speeds on roofs and interference from other buildings, these turbines may never be able to generate enough electricity to pay for themselves. Yet, due to the fact that the technology is in its early stages there is hope that continued testing will work out these problems. In the meantime, installation serves as a very visible urban symbol of sustainability.

If NYU were to become involved in this technology, it could be in the form of a visible partnership with the Mayor's Office to test its viability on tall buildings in the center of Manhattan.

Regarding the technology, generally, small wind turbines currently have a rated capacity of one kilowatt. The average cost for a turbine is $6,500 (this is the price for an AeroVironment turbine – the most popular).

More information:

Companies that develop architectural wind turbines (linked to websites):

Abundant Renewable Energy, Aerotecture, AeroViroment, Bergey, Cleanfield, Eoltec, Pacwind, Proven, Skystream, Swift, Turby, Windsave

New York Times articles on small wind turbines:

http://www.nytimes.com/2008/08/20/nyregion/20windmill.html
http://www.nytimes.com/2008/09/04/business/04wind.html?_r=1&pagewanted=2&partner=rssnyt&emc=rss&oref=slogin

3) SOLAR POWER- PHOTOVOLTAICS

a. The Biggest: Solar Farms on campus

East Los Angeles College: Los Angeles, California. Community College. Enrollment: 23,632. Environment: Urban (not dense), car culture, very sunny.

As part of the Los Angeles Community College District's goal of taking all of its college campuses "off the grid", in April, 2008, East Los Angeles College (ELAC) powered up a 1.2 MW photovoltaic solar farm to rest atop its seven car-ports of its Northwest Parking lot (covering three acres). The solar farm will generate approximately 45% of the college's daytime energy needs, has a life expectancy of 40 years, and will save the university $270,000 annually in energy costs.

Total Power Capacity of Solar Project: 1.2 MW, 1.9 million kwh of electricity per year.
Project Hardware: 5,952 Kyocera KC200 solar panels
Total Cost of Project: $9 million
Cost to College: The college does not own the project – it is owned and operated by MMA Renewable Energy Ventures. The college entered into a PPA (power purchase agreement) in which ELAC buys the solar power from MMA Renewable Ventures annually.
Funding Breakdown: $2.8 million financial incentive from Southern California Edison's "Self Generation Incentive Program." $6.8 million cost to MMA Renewable Energy Ventures.

More information:
Los Angeles Community College Website on project:
http://www.laccdbuildsgreen.org/pressroom_factsheet_article.php?factsheet_id=27
Article on opening ceremony:
http://www.laccd.edu/news/hundreds_of_students_faculty_and_community_members_joined_laccd.htm
MMA Renewable Energy Ventures invests in renewable energy projects nationwide:
http://mmarenew.com/

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Rutgers University: New Jersey. Enrollment: 50,000. Public. Environment: three suburban campuses located throughout the state.

Rutgers University is currently constructing a ~1.3 MW photovoltaic project on its Livingston Campus. The project will be a fixed ground mounted installation. The solar farm will generate approximately 10% of campus electricity and reduce 1,200 of carbon dioxide emissions annually. It is expected to be operational in 2009.

Total Power Capacity of Project: 1.3454 MW, 1,555 MWh annually.
Project Hardware: 7,488 Shuco 180W solar panels with Xantrex inverters designed and to be installed by SunDurance Energy of South Plainfield, N.J.
Total Cost of Project: $10 million
Cost to University: ~$5.1 million with an annual payback of up to $300,000. Rutgers will also take advantage of New Jersey's Solar REC program and will sell SRECs to electricity supplies to enable them to meet their renewable energy quota in their electricity mix, as specified by New Jersey law.
Funding Breakdown: $4.9 million funded by New Jersey Board of Public Utilities Rebate as part of its Clean Energy Program.

More information:
Rutgers article on system:
http://news.rutgers.edu/medrel/news-releases/2008/09/rutgers-university-b-20080923/?searchterm=Solar
SunDurance Energy: http://www.sunduranceenergy.com/

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Loyola Marymount University: West Los Angeles, California. Private. Enrollment: 8,972. Environment: Urban/suburban campus, very hot and sunny
*PROJECT NOTED FOR RELEVANCE TO NYU

Loyola Marymount University (LMU) currently owns and operates a 723 KW rooftop-only photovoltaic system, covering 81,000 square feet of roof on three of the University's largest buildings. It has 723 KWh peak power output, and provides enough power to cover approximately 26% of the University's daytime electricity needs. It saves the University approximately $150,000 a year. It was funded primarily through rebates from the Los Angeles Department of Water and Power, and an incentive from the Southern California Gas Company.

Total Power Capacity of Project: 723 KW
Project Hardware: 6513 solar electric tiles designed by PowerLight, which utilize its PowerGuard Technology, "a building integrated photovoltaic roofing assembly" (more information on technology in case study linked below). They cover 81,000 square feet of roof.
Total Cost of Project: ~$4.4 Million
Cost to University: $325,000

Funding Breakdown: $3.7 million from Los Angeles Department of Water and Power, $325,000 from the Southern California Gas Company and $325,000 from the University.

More information:
PowerLight Case Study on LMU:
http://www.powerlight.eu/success/pdf/PowerLight_Case-Study_LoyolaMarymount.pdf
LMU description of project:
http://aslmu.lmu.edu/Page49037.aspx
Article about project announcement:
http://www.lmu.edu/Page890.aspx

c. The Economical: Single building photovoltaic arrays
*PROJECT NOTED FOR RELEVANCE TO NYU

Small photovoltaic arrays are much more common that solar farms at college campuses. These projects consist of a handful of photovoltaic solar panels on rooftop buildings or small plots of land. Many universities around the country have projects like these, generally initiated by students or professors and awarded as grants by the university.

Harvard University: Boston, Massachusetts. Private. Enrollment: 20,000. Environment: Urban
*PROJECT NOTE FOR RELEVANCE TO NYU

Harvard has a 37 KW photovoltaic array on top of its Fitness Center Shad Hall. Two students, working with Harvard Business School facilities, applied for a grant from the Massachusetts Technology Collaborative (MTC) and were awarded $143,500. The remainder of the cost was covered by Harvard's Green Campus Loan Fund in the form of a no-interest loan. With annual savings of ~$11,169, the project's anticipated payback is 22 years.

Total Power Capacity of Project: 37 KW, ~45 MWh per year
Project Hardware: 192 photovoltaic panels designed and installed by Global Resource Options, Inc.
Total Cost of Project: $378,487
Cost to University: $248,527
Funding Breakdown: Students received grants from MTC for $129,960. The remainder came from Harvard's Green Campus Loan Fund in the form of a no-interest loan.

More information:
Harvard Business School's Press Release:
http://www.hbs.edu/news/releases/102103_solar_panels.html
Green Campus Load Fund Case Study on project:
http://www.greencampus.harvard.edu/gclf/documents/gclf_case_study_100-23_hbs-shad_pv.pdf
Global Resources Options:
http://www.globalresourceoptions.com/

4) SOLAR POWER-SOLAR THERMAL

Many universities around the country have installed different types of solar thermal projects of varying sizes that generally provide hot water for residential or academic building hot water use. These projects consist of glass panels that collect the heat of the sun and transfer it to water, which is passed through panels. These systems are generally relatively inexpensive and very efficient, capturing 60% of the sun's energy.

a. The Biggest: Solar thermal to heat Olympic-sized pool

Governors State University: Chicago, Illinois. Public. Enrollment: ~6,000. Environment: Suburban, very cold in winter
*PROJECT NOTED FOR RELEVANCE TO NYU

Governors State University of Illinois has a solar thermal project mounted on the roof of its gym that pre-heats all of the water for its Olympic-sized pool, the hot water for the gym locker room and hot water for many of the University's other buildings. The system consists of 64 solar thermal collectors. Heat is collected on tempered, non-reflective glass that covers collectors. Water is passed through these collectors, heated and passed through a series of heat exchanges and storage tanks until eventually used to provide the building's hot water. The project is very efficient, self-sustaining, requires no maintenance, and heats water even on cold days. It saves the university approximately $10,000 annually. When the project was originally proposed, it had an expected 12-year payback. With rising oil prices, this timeline continues to decrease.

Energy Output: The project heats 4,168 gallons of water to 180 degrees Fahrenheit per day. This is equivalent to the energy provided by 40 thermos of natural gas a day.
Project Hardware: 64 solar thermal collectors designed and installed by Solar Services, Inc of IL. Each panel circulates one gallon of water per minute. Installation covers 40 square feet on top of physical plant.
Total Cost of Project: $300,000
Cost to University: ~$85,000
Funding Breakdown: University received renewable energy grants of $150,000 from the
Illinois Department of Commerce and Economic Opportunity (DCEO) and $65,323 from the Illinois Clean Energy Community Foundation.

More information:
Article about project in "Chief Engineer" – an online magazine
http://www.chiefengineer.org/content/content_display.cfm/seqnumber_content/2564.htm
State press release announcing project:
http://www.illinois.gov/PressReleases/ShowPressRelease.cfm?RecNum=4796&SubjectID=98
University press release on project:
http://www.govst.edu/NewsEvents/t_NewsEvents_PressReleases.aspx?id=3767
Solar Services, Inc: http://www.solarservices.com/

Supplemental Information:

Many universities and colleges have installed smaller inexpensive solar thermal installations, which utilize the same technologies. Examples include:
- Tufts University - solar thermal system provides 40% of Green Dorm needs: http://www.tufts.edu/tie/SGH/solarhotwater.htm
- Guilford College – solar thermal systems provides 100% of Shore Hall (residence hall) hot water needs. The cost of the project was $30,000. http://guilford.edu/about_guilford/news_and_publications/releases/ShoreHallSolarDedication.html

5) SOLAR POWER – PASSIVE AND ACTIVE SOLAR COMBINED

a. **The Experimental**

University of Oregon: Eugene, Oregon. Public. Enrollment: 20,376. Environment: Small town/rural. Higher than average cloud cover and rainfall.
*PROJECT NOTED FOR RELEVANCE TO NYU

The University of Oregon is experimenting with innovative solar awnings to cover windows on the campus Onyx Bridge – a footbridge linking two campus buildings. These panels will each be equipped with one KW of photovoltaic panels, will shade windows that get a lot of sun (and heat) and will include light-shelves at the top to provide light in the hall next to the window. As part of the experiment, temperature and electricity use of the building will be monitored and compared to previous data to test viability of awnings. Three local companies were involved, one to provide the photovoltaic panels, one to do wiring, and one to build and install the project. If successful, it will be implemented university-wide.

Total Power Capacity of Project: 12 KW plus power reduction amounts to be determined
Project Hardware: 12 4' awnings designed by U of O architectural professor Ihab Elzeyadi and his students.
Total Cost of Project: $50,000, university funded

More information: http://pmr.uoregon.edu/uo-in-the-news/archive-uo-in-the-news/august-2008/uo-e-clips-aug-7/

NOTE: This project is very similar to an NYU Green Grant titled: "Green Light System" which was awarded to Natalie Jerimijenko, Assistant Professor in Art, Steinhardt in 2008.

6) BIOFUELS

a-1. The Biggest: Landfill methane piped to campus

University of New Hampshire, Durham: Durham, New Hampshire. Public. Enrollment: 14,071. Environment: Rural/small town.

The University of New Hampshire (UNH) currently has a cogeneration plant that runs off of natural gas. In 2009, the methane used to run the facility will come directly from the gas waste of a local landfill. UNH is currently constructing a 12.7-mile pipeline from the landfill in Rochester, NY (where the gas is extracted and purified) to hook in directly to the cogeneration plant, which will allow the University to supply 80-85% of its energy needs with a renewable source. This supply will replace current natural gas purchases.

Total Power Capacity of Project: equivalent of approximately ~960 million cubic feet of natural gas
Project Hardware: 2.7 Mile Pipeline fed into UNH cogeneration plant
Total Cost of Project: $45 million
Cost to University: $45 million with an expected 10-year payback, UNH currently spends $12.9 million on energy annually
Funding Breakdown: The $45 million is being supplied internally through loans, and is not coming from tuition
Partner in project: Waste Management's Turnkey Recycling and Environmental Enterprise

More information:
UNH materials on project:
Brochure: http://www.unh.edu/ecd/images/lfgbrochure.pdf
Webpage: http://www.sustainableunh.unh.edu/climate_ed/cogen_landfillgas.html
Article: http://www.unh.edu/news/cj_nr/2007/aug/kb14landfill.cfm

a-2. The Biggest: **Biomass Plants on campus**

The potential for biomass plants on university campuses that create synthetic gas that can be used in the place of natural gas and heating oil to generate electricity and heat buildings exists primarily in rural areas with an abundance of biomass resources available. Many universities are experimenting in this field, constructing biomass plants to provide power and to test the effect of a biomass economy on local agriculture.

University of Minnesota, Morris: Morris, Minnesota. Public. Enrollment: 1,700. Environment: Rural/agrarian

UMM constructed an on campus gasification reactor and facility that converts corn stover (the remaining part of corn crops) and prairie grass of the region into synthetic gas to be used for 80% of the University's heating and cooling needs, replacing natural gas and heating fuels. UMM plans to contract with multiple farmers/landowners in the region and will take in approximately 9,000 tons of corn stover per year. The will be used for research to test the viability of a large biomass economy in rural America.

Total Power Capacity of Project: At peak capacity, 3,000 pounds of biomass an hour will generate 19 million BTU of heat energy for campus. The gasifier will replace about $500,000 of natural gas purchased annually to heat campus buildings
Total Cost of Project: ~$9 million

Cost to University: ~ $1.1 million (NOTE: this may be higher than the cost to the University, this is the total cost subtracting the State and Federal government grants, not including any other small grants the University may have received)
Funding Breakdown: $6 million grant from State government to construct the facility, $1.89 million grant from the USDA and U.S. DOE to conduct additional research on feedstock and ash properties on campus.

More information:
UMM Website on Biomass plant: http://renewables.morris.umn.edu/biomass/
UMM Article: http://www.morris.umn.edu/greencampus/View.php?itemID=6547

Supplemental Information

Middlebury College is constructing a biomass plant to use local woodchips to create natural gas for the College's central plant.
Middlebury Website on project:
http://www.middlebury.edu/administration/enviro/initiatives/energy/biomass.htm

b. The Symbolic: Biodiesel from cafeteria and local restaurant waste oil

A number of universities purchase biodiesel to power their campus fleets. Some have installed small-scale refineries/reactor projects to convert used cooking oil into biodiesel for vehicles.

Haywood Community College: Clyde, North Carolina. Community College. Enrollment: ~2,200. Environment: Small town/rural.
*PROJECT NOTED FOR RELEVANCE TO NYU

Haywood Community College plans to install a small refinery/reactor on campus to convert the waste oil from its cafeterias and from local public school cafeterias into biodiesel for campus vehicles that run on diesel and some local government vehicles that run on diesel. The reactor will also be used for educational purposes; to train individuals in installing their own refining projects and to teach Haywood students about sustainability.

Total Cost of Project: $135,000
Cost to University: Nothing, grant funded
Funding Breakdown: $135,000 from the Biofuels Center of North Carolina
Partners: Haywood County Government; Southwestern NC Resource Conservation & Development Council; NC Cooperative Extension; and Land of Sky Regional Council

More information: http://www.haywood.edu/news/hcc_awarded_135000_for_biofuels_project

7) FUEL CELL TECHNOLOGY

Stationary fuel cells use a technology in which fuel and air are supplied separately to alternating layers of electrodes, producing DC electricity. There are no direct carbon emissions from these systems when powered with hydrogen, and minimal emissions when powered with natural gas. A

number of universities and other institutions have installed fuel cells that run on hydrogen or natural gas to provide power for part of a campus building, and to help test the viability of the emerging technology. In general, however, the technology remains too expensive to be implemented on a wide scale, with installation costs running at ~$4,500 per kilowatt, and their application has been limited and widely dependent on grant money.

a. Reliable Energy

Yale University: New Haven, Connecticut. Private. Enrollment: 11,358. Environment: Rural/small town.
*PROJECT NOTED FOR RELEVANCE TO NYU

In 2004, Yale installed a 250 KW fuel cell that runs on natural gas. The fuel cell is hooked up to the Environmental Science Center and supplies 40-50% of the electricity of the building. The fuel cell waste heat is captured and used to heat the building as well. In partnership with the Connecticut Clean Energy Fund (CCEF), which purchased the fuel cell, Yale was utilized as a testing site, and all maintenance costs have been covered by Yale. During the first two years, the cell presented some technical difficulties, which were since worked through and it continues to provide reliable energy.

Total Power Capacity of Project: 250 KW
Project Hardware: One Fuel Cell Energy, Inc 250 MW cell designed to run on pure hydrogen, but that currently operates on natural gas.
Total Cost of Project: $1.2 million installation costs
Cost to University: upkeep and maintenance
Funding Breakdown: fuel cell purchased by the Connecticut Clean Energy Fund to promote/test the emerging fuel cell technology.

More information:
Yale Fuel Cell Website: http://www.yale.edu/sustainability/fuelcell.htm
Article about funding:
http://www.conntact.com/archive_index/archive_pages/4740_Business_New_Haven.html

Supplemental Information:

In New York City, the Central Precinct in Central Park runs entirely off of a 200 kW phosphoric acid fuel cell powered on natural gas. It was manufactured by United Technologies Corporation (UTC). UTC Case Study on Central Precinct:
http://www.utcpower.com/fs/com/Attachments/project_profiles/PP0103_CentralPark.pdf

General Information about Fuel Cell Technology- DOE Fuel Cell Information Website:
http://www.fe.doe.gov/programs/powersystems/fuelcells/index.html

Plug Power, A New York Based Fuel Cell Company (recommended by Solar1 employee, Chris Neidl): http://www.plugpower.com/

8) OTHER RENEWABLE TECHNOLOGIES WORTH NOTING
*TECHNOLOGIES NOTED FOR RELEVANCE TO NYU

a. Geothermal Exchange

Multiple universities use geothermal exchange technologies – primarily involving drilling deep into the ground below buildings and using the water below to transfer the cool temperature of the earth in the summer, and the warm temperature of the earth in winter into the building's heating and cooling systems. Wells are generally very small in diameter but go deep, often up to 1,500 feet below the surface. They save significant amounts of energy: at Hamilton College, a geothermal system in a residence hall cut energy consumption by 250% per square foot.

Unlike the other renewable options presented in this report, geothermal exchange heating and cooling costs vary dramatically depending on where the drilling is occurring. Drilling in New York City, in the center of Manhattan, will be far more expensive than drilling at Hamilton in upstate New York, where 15 450-foot deep boreholes will cost approximately $100,000 to construct.

Some universities that have utilized these technologies are
Harvard: http://www.greencampus.harvard.edu/cre/geothermal_case_studies.php
Hamilton: https://my.hamilton.edu/news/more_news/display.cfm?ID=10233

In New York City: Solar1 plans to incorporate 14 geothermal wells into its new facility, Solar2.

Supplemental Information:
Link to NYSERDA page on geothermal exchange systems: describing technology at length with link to presentation including case studies:
http://www.nyserda.org/programs/geothermal/default.asp

b. Tidal Power

While tidal power technology has not been implemented at any U.S. universities, there is growing global interest in tidal power technology. In New York City, along the East River, six small tidal turbines manufactured by Verdant Power have been installed as part of a state funded demonstration called the RITE Project. This demonstration has been used to test the technology's viability and thus far the turbines have generated ~50 MWh of electricity since their installation in 2006 and 2007. The electricity is used to power a Gristedes Supermarket and the Roosevelt Operating Corporation (RIOC) Motorgate parking garage.

The technology used at this site is Verdant's FreeFlow turbine. These turbines have horizontal-axis rotor with three blades, operating similar to wind turbines. These turbines are designed to pivot with changing tides.

If the experiment is successful, hopes are to install 300 turbines in the East River, with a 10 MW capacity. If made commercially viable, the projected installation cost is $2,000 per KWh.

More Information:
Link to Verdant Power RITE Project: http://www.verdantpower.com/what-initiative
Link to Washington Post Article on Project: http://www.washingtonpost.com/wp-dyn/content/article/2008/09/19/AR2008091903729.html