THE EARTH INSTITUTE
COLUMBIA UNIVERSITY

<u>**Professor Vijay Modi**</u>

Professor, Mechanical Engineering
Member, Earth Institute Faculty
Director, Sustainable Engineering Lab
Columbia University

Vijay Modi is a Professor and past-Chair of Mechanical Engineering in the School of Engineering and Applied Science and a faculty member at the Earth Institute, Columbia University. Between October 2011 and 2012, he was a member of the U.N. Secretary General's high-level task force on "Sustainable Energy for All" and he currently leads the U.N. Sustainable Development Solutions Network working group on Energy Access for All.

He received his Ph.D. from Cornell University in 1984 and worked as a post-doc at MIT from 1984 to 1986 before joining the faculty at Columbia University. Prof. Modi's areas of expertise are energy resources and energy conversion technologies. His laboratory, the Sustainable Engineering Lab (SEL), has been responsible for technologies such as "SharedSolar" and widely used tools such as "Network Planner" and a free open-source app called FormHub, used over a million times.

While his early work was on computational fluid dynamics and micro-electro-mechanical systems, his recent work has been on energy infrastructure design & planning; solar energy; energy efficiency in agriculture, and data analytics spanning from urban settings to remote rural settings.

He is currently working closely with city and national agencies/utilities to understand how energy services can be more accessible, more efficient and cleaner. His recent project on minigrids is providing a unique understanding of consumer behavior, demand for energy, and business models for deploying energy solutions and energy efficiency.

Bio for John (Jack) P. DiEnna Jr.

Mr. DiEnna, the Executive Director & Founder of the Geothermal National & International Initiative (GEO-NII) is a business development and marketing professional with over forty years combined experience in the electric utility industry and the renewable energy industry. He is a nationally recognized authority on all aspects of renewable technology and specifically geothermal heat pumps (GHP), including marketing, creative financing, and the resulting positive economic and environmental impact that can be derived from the use of geothermal heat pump systems and other renewable technologies.. His expertise is internationally acknowledged as a valued resource by not only the renewable & geothermal heat pump industry but also by government officials, both national and international, trade allies, and all major market segment associations in the promotion of geothermal heat pump technology.

Mr. DiEnna has been the Marketing Chairman for the International Ground Source Heat Pump Association (IGSHPA) for over 25 years and was the driving force in the creation and development of the Certified GeoExchange Designer (CGD) certification, a training program for design professionals in GHP Technology. In 2013, he was asked to become a member of the American/Canadian Bi National GHP Standards Committee and he is also a founding member of the New York Geo Association.

Mr. DiEnna, is the originator of the "Road to 30%", a program designed to increase the GHP industry to a 30% share of the HVAC market. Mr. DiEnna is involved in approximately 30% of all commercial geothermal heat pump projects in the North America and consults to numerous companies and trade associations. His vision is to eliminate the "first cost" barrier, of GHP technology, through participation by Utilities and other third party owners of the ground loop heat exchanger.

BIO FOR:

John Rhyner, PG, LEED AP
P.W. Grosser Consulting
630 Johnson Avenue, Suite 7
Bohemia, NY
Phone: (631) 589-6353
Cell: (516) 250-9765
johnr@pwgrosser.com
www.pwgrosser.com

John Rhyner is a licensed Professional Geologist, LEED-certified professional, and Director of the Sustainable Energy Group with P.W. Grosser Consulting (PWGC) in Bohemia, Long Island, New York. John has nearly 30 years of diverse consulting experience, with the past 15 years working on geothermal projects in New York City, Long Island, and throughout New England. John co-authored the recent update to the city's *Geothermal Heat Pump Manual* for the New York City Department of Design and Construction, and has collaborated with NYC City Council and several other city agencies on the feasibility of geothermal heat pump technology in the five boroughs.

John has assessed the use of geothermal at over 250 commercial, institutional, residential, and educational facility project sites and manages geothermal projects through initial feasibility analysis, field testing, design, permitting, construction support and start-up. John has consulted on geothermal projects in the city of all types—standing column wells, open loop, and vertical closed loop systems—projects include St. Patrick's Cathedral, Brooklyn Navy Yard's historic Building 92 Renovation, the Brooklyn Botanic Gardens Visitor's Center, the Weeksville Heritage Center in Brooklyn, Columbia's historic Knox Hall renovation, and the Staten Island Museum at Snug Harbor Cultural Center.

Most recently, John managed a site investigation and preliminary design for an innovative vertical closed loop borefield to serve the first building of Cornell University's planned new Technology Campus being constructed on Roosevelt Island.

John is a founding board member of the Long Island Geothermal Energy Organization and serves as Chairman of the Standards and Codes Committee. John received his BA in Geology from Dartmouth College and has completed course work for his MS in Hydrogeology from SUNY-Stony Brook, New York.

10A FRI 2.27.15 hearing testimony Denise Katzman * EnviroHancement
Site-Sourced and Stored Renewable Energy Conference

I thank the Committee for holding this vitally urgent hearing.

Every problem is a Solution in disguise. The Environment & Economy are mutually inclusive, representing the cross roads of life. Clean energy Solutions are the right trajectory. Rewind July 2010 NTL GEO The 21st CENTURY GRID * NYC is tied to fossil fuels, with less than 1% of its electricity coming from wind or solar. Fast-forward late 8.2014: Richard Kauffman NYS' energy & finance guru told FORTUNE mag that NYS remains more of a 20th century energy dinosaur. 2.23.15 Kauffman joined a CT panel: Relationship between utilities, government needs to change, experts say It's always a relationship thing. Utilities are still wrapped up in a barbaric energy blanket. Utilities can and must promote evolutionary innovation to protect human, enviro & economic health. NYC, not solely the PSC, has the authority to enforce utilities to be good actors.

This hearing will *Flip the Switch* from unsustainable energy to resilient clean energy. Transforming NYC into a vibrant energy democracy via local jobs and value capture that supports a clean energy economy.

The Fossil fuel & Nuclear industries refuse to perform Cradle to Grave analytics. Instead they prefer EcoCide. These industries produce GHGs that absorb infrared radiation, triggering rising temps aka Greenhouse Effect 2.25.15 Greenhouse Effect Is Witnessed...and Getting Worse, while denying that Stranded Assets are devaluing their chokehold. These industries also violate mortgages, insurance & equity loans. NYS' Penal Law, section on Radiation, is also violated. industry: Depleting Risk of Loss insurance is totally obvious in these industries Annual Reports and 10Ks. Cyber Security is MIA. US gov't issues cybersecurity guidance to help energy sector protect critical infrastructure - FierceHomelandSecurity 1.8.15 the FED issued these new guidelines coupled with voluntary platforms that defeat necessary action. All combustible fuel infrastructure, along with NUC, are Cyber terrorism targets.

Insurance & Bonds: 2015 World Economic Forum Global Risks report, over 900 experts declaring Climate Crisis as the 2nd largest threat to global stability The Global Risks report 2015 | World Economic Forum - The Global Risks report 2015 2.23.15 Insurers show strong interest in green bonds : Insurance Asset Risk Ceres event: World Bank, Swiss Re Americas CEO J. Eric Smith "The costs of another Sandy will grow form $19 billion to $90 billion", Lisa Carnoy head of Global Capital markets Bank of America Merrill Lynch exhorted her colleagues to "fund clean energy until every blue chip company in the S&P and every investment manager has a green energy bond". Zurich Insurance, Germany CIO Michael Leinwand, "Practically, this means investing for the next generation. What better way could we find than working with the World Bank on a customised solution to both outperform our liabilities and tackle climate change?" Donovan Richards is a true Enviro leader, therefore; EP must take the lead to institute LEG pertaining to CAT Bonds aka Catastrophe Bonds 1.20.15 **Scope for re/insurance, cat bonds & ILS to tackle key business risks | Artemis.bm** The bonds will protect us from Climate Crisis via NYC financing with Mike Bloomberg 1.21.15
Bloomberg gives $48M to help states meet Obama's climate rule | TheHill
and the Green Bank's GAP financing.

NYC Panel on Climate Change, as NY Magazine 2.18.15 New Climate-Change Report Reminds Us, NYC Will Eventually Become a Sweltering Swampland. Leaving the City for good is still probably your best bet: 2 of the many salient points: 6 heat waves per year compared with the current 2 annual heat waves by the 2080s (defined as 3 or more consecutive days over 90 degrees) and by the 2080s the 100-year flood – meaning, a flood that has a 1% chance of occurring – will become a 1 in every 8 year occurrence. 1.6.15 The Atlas of Drowned Cities is based on 100' Sea Level Rise: The NY Seas. Based on the melting of the world's Ice Sheet via Jeffery Linn and his GIS (Geographic Info Science) Spatialities I Cities, streets, plans, maps

The good stuff. In the 37 years that we lost, since Dr. Alan Hoffman commenced the Clean Energy revolution via the Carter administration The Growth Of US Renewables During 2014 As A Vindication - The ECOReport Dr. Hoffman is still enthusiastic "When you look at the numbers, both from the Energy Information Administration (EIA) of the Department of Energy and the Federal Energy Regularity Commission (FERC) you can see that the transition is beginning to take place. The new capacity that is coming online is largely renewables." The President's DOE FY 2016 Energy Efficiency and Renewable Energy budget includes a 44 percent increase in funding for the Solar Energy program to nearly $336 million, an over 9 percent increase for the Bioenergy Technologies program ($246 million), a 36 percent increase in funding for the Wind Energy program ($145 million), a 6 percent increase in funding for the Hydrogen and Fuel Cell Technologies program ($103 million), a 75 percent increase in funding for the Geothermal Technologies program ($96 million), and a nearly 10 percent increase in funding for the Water Power program ($67 million).

1.12.15 City of Palo Alto Utilities Offers New Green-e Climate Certified Natural Gas Offset Program to Residential and Commercial Customers | 3BL Media
The City of Palo Alto Utilities (CPAU) has launched PaloAltoGreen Gas, a gas offset program that pairs Green-e Climate certified carbon offsets with customers' natural gas use. PaloAltoGreen Gas is the first Green-e Climate certified gas offset program offered by a municipal-level utility, and the first-ever certified gas offset program offered to residential customers.

2014 Solar jobs were upward 22% – onward Baby. 2.10.15 Apple commits $848M to California solar - FierceEnergy. 2.18.15 Citi unveils $100B program to fight climate change | TheHill Apple and Citibank are in NYC. EP can hook up with both. 2.25.15 Every 150 seconds a brand new solar project is happen' in the U.S.By the Time You Read This, They've Slapped a Solar Panel on Your Roof - Bloomberg Business We must use best practices regarding NY – Sun Initiative Get Solar Overview - The NY -Sun Initiative This can be accomplished via CCA (Community Choice Aggregation). NJ utilizes CCA – I don't think NYC wants to be in NJ's shadow.

MicroGrids are a CCA component. Siemens is all over MGrids from financing to construction.11.2014 http://servicecenter.fiercemarkets.com/files/leadgen/siemens no2 custom final.pdf Microgrids have the potential to play a significant and positive role in promoting a cleaner, more resilient energy infrastructure. HOMER Energy ain't as well known but it knows it's stuff http://homerenergy.com/index.html

Kinetic Energy aka People Power uplifts conventional power to a brand new sustainable plateau that is constantly evolving nPower? nPower PEG (Personal Energy Generator) for mobile devices : nPower PEG You can power all sorts of gadgets by walking & running. Stationary bikes can power a concert & a conventional bike can be *Macgyver-ed* to power your blender. The Macgyver series is being recast as a woman, to inspire young women towards the really cool domains science and engineering.

We are cognizant that we are the stewards of a healthy resilient planet, now and for future generations. Have a great weekend!

DANIEL KARPEN
PROFESSIONAL ENGINEER & CONSULTANT, P.C.
3 HARBOR HILL DRIVE
HUNTINGTON, NEW YORK 11743

(631) 427-0723
www.danielkarpen.com

August 28, 2013

Jane Blair, P. E.
Executive Secretary
Engineering Board
NYS Department of Education
Education Building
2nd floor mezzanine, east wing
89 Washington Avenue
Albany, N. Y. 12234

Dear Jane:

This letter is too important to be put in an e-mail.

There are a number of firms who are advertising and making proposals for energy audits and energy efficiency reports to be prepared under NYC Local Law 87. A copy of the law, the regulations, and the energy efficiency report format to be submitted to the NYC Building Department are enclosed with this letter.

The law requires that these reports be prepared by a registered professional, either an architect or an engineer. In reality, very few architects have the training to prepare these reports.

Approximately 2,000 to 2,200 of these reports are due to the NYC Dep't of Buildings by December 31, 2013, and a like number every year thereafter.

The energy efficiency form requires that the name of the engineer and firm be placed on the form prior to submittal.

Question:

1. Is the preparation of an energy audit and/or energy efficiency report signed by a registered professional considered "engineering services"?
2. If so, can a firm not registered as an engineering firm by your department offer these services?

If the answer to question 2 is "NO", then there are a number of companies purporting to be offering these services in violation of the law.

If so, I am prepared to provide to you a list of those firms known to me that purport to offer these services so that your office can be begin an immediate investigation and issue "seize and desist" letters to these companies.

You may call me at the above number.

Yours truly,

Daniel Karpen

ENGINBD - Energy Audits

From: ENGINBD
To: dkarpen@danielkarpen.com
Date: 10/10/2013 10:26 AM
Subject: Energy Audits

Dear Mr. Karpen:

Thank you for contacting the New York State Board for Engineering and Land Surveying.

In response to your inquiry regarding Energy Audits - services that fall within the scope of practice as defined in Education Law section 7201 would of course be considered the practice of engineering. In NYS all firms providing such professional services must be appropriately authorized.

If an individual or firm is engaged in practice without a license or is holding themselves out as being licensed or authorized, they may be subject to disciplinary action. When any action of misconduct is are reported to the Department, our Office of Professional Discipline will perform an investigation and take the appropriate action. For an investigation to initiated a complaint needs to be filed with our Office of Professional Discipline.

Information on how to file a complaint may be accessed from our website at http://www.op.nysed.gov/opd/ .

We hope this information is helpful.

Sincerely,
Jane W. Blair, PE
Executive Secretary

NYS Board for Engineering & Land Surveying
89 Washington Ave.
2nd Floor Mezzanine, East Wing
Albany, NY 12234-1000
enginbd@mail.nysed.gov
http://www.op.nysed.gov/pe.htm
(518) 474-3817 ext 140
(518) 473-6282 (fax)

LOCAL LAWS
OF
THE CITY OF NEW YORK
FOR THE YEAR 2009

No. 87

Introduced by Council Member Gennaro, the Speaker (Council Member Quinn), Brewer, Comrie, Dickens, Garodnick, Gioia, James, Koppell, Lappin, Mitchell, Palma, Recchia Jr., Reyna, Rivera, Stewart, Liu, Yassky, Sears, White Jr., Mendez, de Blasio, Mark-Viverito, Vann, Avella, Vacca, Gerson, Jackson, Gonzalez, Ferreras, Vallone Jr., Barron, Arroyo, Crowley and Mealy

A LOCAL LAW

To amend the New York city charter and the administrative code of the city of New York, in relation to requiring energy audits and retro-commissioning of base building systems of certain buildings and retro-fitting of certain city-owned buildings.

Be it enacted by the Council as follows:

Section 1. Chapter 3 of title 28 of the administrative code of the city of New York is amended by adding a new article 308 to read as follows:

ARTICLE 308
ENERGY AUDITS AND RETRO-COMMISSIONING OF BASE BUILDING SYSTEMS

§28-308.1 ***Definitions.*** *As used in this article, the following terms shall have the following meanings:*

BASE BUILDING SYSTEMS. *The systems or subsystems of a building that use energy and/or impact energy consumption including:*

1. *The building envelope.*
2. *The HVAC (heating ventilating and air conditioning) systems.*
3. *Conveying systems.*

Purpose: The purpose of this Local Law is to reduce energy use and energy cost for the owners of the buildings covered by this article *determined by the department of cultural affairs.*

COVERED BUILDING. *As it appears in the records of the department of finance: (i) a building that exceeds 50,000 gross square feet (4645 m^2), (ii) two or more buildings on the same tax lot that together exceed 100,000 gross square feet (9290 m^2), or (iii) two or more buildings held in the condominium form of ownership that are governed by the same board of managers and that together exceed 100,000 gross square feet (9290 m^2).*

Exception: *The term "covered building" shall not include real property classified as class one pursuant to subdivision one of section 1802 of the real property tax law of the state of New York.*

CURRENT FACILITY REQUIREMENTS. *The owner's current operational needs and requirements for a building, including temperature and humidity set points, operating hours, filtration, and any integrated requirements such as controls, warranty review, and service contract review.*

ENERGY AUDIT OR AUDIT. *A systematic process of identifying and developing modifications and improvements of the base building systems, including but not limited to alterations of such systems and the installation of new equipment, insulation or other generally recognized energy efficiency technologies to optimize energy performance of the building and achieve energy savings, provided that such process shall not be less stringent than the Level II Energy Survey and Engineering Analysis of the 2004 edition of Procedures for Commercial Building Energy Audits published by the American Society of Heating, Refrigerating and Air-conditioning Engineers Inc. (ASHRAE).*

ENERGY AUDITOR. *An approved agency authorized by the department ~~to perform~~ energy audits and ~~to certify~~ audit reports required by this article. Until such time as there*

new definition

DESIGN PROFESSIONAL: A New York State registered professional engineer, or registered architect employed by an engineering firm or architectural firm with a certificate of authorization

OUT

issued by the Education Department of New York State *the department of finance's annual New York city tax lien sale list; or*

4. *Has an active or effective commitment letter from a governmental agency that provides for the financing of the rehabilitation, within a period of 5 years or less, of such building by such government agency for the purposes of affordable housing for low or moderate income families.*

OUT

OWNER. *The owner of record of a covered building, except that in the case of a net lease of an entire building for a term of 49 years or more, inclusive of renewal options, the term owner shall refer to the net lessee and in the case of a covered building held in cooperative or condominium form of ownership, the term owner shall refer to the board of managers in the case of a condominium and the board of directors in the case of a cooperative apartment corporation.*

RETRO-COMMISSIONING. *A systematic process for optimizing the energy efficiency of existing base building systems through the identification and correction of deficiencies in such systems, including but not limited to repairs of defects, capital improvements, cleaning, adjustments of valves, sensors, controls or programmed settings, and/or changes in operational practices.*

RETRO-COMMISSIONING AGENT. *An individual, who shall not be a certified refrigerating system operating engineer or a licensed high pressure boiler operating engineer on the staff of the building being retro-commissioned, ~~authorized by the department to certify retro-commissioning reports required by this article.~~ ~~Until such time as there is a national standard establishing qualifications for persons who perform retro-commissioning and such standard has been adopted by the department,~~ A retro-commissioning agent shall be a New York State registered design professional, a certified refrigerating* *system operating engineer, or a licensed high pressure boiler operating engineer, with such other qualification or certification as determined by the department. ~~After the establishment of such a national standard, the department may adopt the qualifications of the national standard with such modifications as the department deems to be appropriate.~~* OUT

SIMPLE BUILDING. *A covered building with neither a central chilled water system nor a central cooling system that covers more than 10% of the building's gross area.*

SIMPLE PAYBACK. *The number of years for the projected annual energy savings to equal the amount invested in the energy conservation measure, as determined by dividing the investment by the annual energy* cost *savings.*

SPACE. *An area within a building enclosed by floor to ceiling walls, partitions, windows and doors*, including parking garages.

SYSTEM OR SUBSYSTEM. *Shall have the same definition as set forth in section 202 of the New York city energy conservation code.*

§28-308.2 Energy audits required. *The owner shall ensure that an energy audit is performed on the base building systems of a covered building prior to filing an energy efficiency report as required by this article. Except as otherwise provided in section 28-308.7, an energy audit shall be performed by or under the supervision of* a registered design professional *~~an energy auditor~~ and shall be performed in accordance with rules promulgated by the department. The audit process shall cover the base building systems and shall identify at a minimum:*

1. ~~2.~~ *All reasonable measures, including capital improvements, that would, if implemented, reduce energy use and/or the cost of operating the building;*

3\. *For each measure, the associated annual energy savings, the cost to implement,*

~~A descri~~ A narrative description of the base building systems including the building envelope, the HVAC (heating, ventilation, and air conditioning systems), conveying systems, domestic hot water systems, and electrical and lighting systems.

For steam heated buildings a description of type of steam system (one pipe or two pipe) and the boiler auxiliaries;

and the simple payback, calculated by a method determined by the department;

3. The building's benchmarking output consistent with the United States Environmental Protection Administration (EPA) Portfolio Manager tool or as otherwise established by the department. A monthly billing analysis for electric and natural gas for the previous 12 months. For fuel oil deliveries, a printout for the previous 12 month prior to the date of the audit, including the daily average fuel oil ~~delivery~~ ~~between~~ usage between fuel oil deliveries. Most recent cost per unit data shall be used to complete energy cost savings for the energy conservation measures.

4. A break-down of energy usage by system and predicted energy savings and cost by system after implementation of the proposed measures; and

5. A general assessment of how the major energy consuming equipment and systems used within tenant spaces impact the energy consumption of the base building systems based on a representative sample of spaces.

7. A comparison between the average fuel usage between billing periods or fuel oil deliveries with ~~the average fuel usage~~ ~~report~~ BTU input to the boiler in the building.

OUT

Exceptions:

1. *No energy audit is required if the building complies with one of the following as certified by a registered design professional:*

   1.1. *The covered building has received an EPA Energy Star label for at least two of the three years preceding the filing of the building's energy efficiency report.*

   1.2. *There is no EPA Energy Star rating for the building type and a registered design professional submits documentation, as specified in the rules of the department, that the building's energy performance is 25 or more points better than the performance of an average building of its type over a two-year period within the three-year period prior to the filing of an energy efficiency report consistent with the methodology of the Leadership in Energy and Environmental Design (LEED) 2009 rating system for Existing*

Buildings published by the United States Green Building Council (USGBC) or other rating system or methodology for existing buildings, as determined by the department.

1.3. *The covered building has received certification under the LEED 2009 rating system for Existing Buildings published by the USGBC or other rating system for existing buildings, as determined by the department, within four years prior to the filing of the building's energy efficiency report.*

OUT

2. *An energy audit shall not be required for the first energy efficiency report of a simple building that is in compliance with six out of seven of the following items as certified by a registered design professional:*

OUT

2.1. *Individual heating controls. (i) Each dwelling unit in the building has one or more thermostatic controls controlling all the heating units within the dwelling unit and any heated space not within a dwelling unit has one or more thermostatic controls controlling all the heating units within the space, or (ii) the building has a central heating system controlled by an energy management system or a building management system that incorporates temperature sensors located in at least 10 percent of the dwelling units and 10 percent of the heated spaces, except that the total number of sensors required within the building shall not be less than 10 nor more than 30.*

2.2. *Common area and exterior lighting. Common area (lighting outside of tenant spaces) and exterior lighting, at a minimum, are in* *compliance with the provisions of the New York city energy conservation code as in effect for new systems installed on or after July 1, 2010.*

2.3. *Low flow faucets and shower heads. All faucets and shower heads within the building, at a minimum, meet the standards of table 604.4 of the New York city plumbing code as in effect for new systems installed on or after July 1, 2010.*

2.4. *Pipe insulation. All exposed pipes that are used to convey heat or hot water are insulated, at a minimum, in accordance with the standards of the New York city energy conservation code as in effect for new systems installed on or after July 1, 2010.*

2.5. *Domestic hot water. All domestic hot water tanks that do not have built-in insulation are insulated with a minimum insulation value of R-8.*

2.6. *Washing machines. All common area clothes washing machines are front loading.*

2.7. *Cool roof. The roof complies with section 1504.8 of the New York city building code as in effect for new buildings constructed on or after July 1, 2010.*

OUT

§28-308.2.1 Contents of audit report. *The energy auditor shall prepare and certify a report of the energy audit. Except as otherwise provided in section 28-308.7, the audit report shall include such information relating to the audit as shall be specified in the rules of the department, including but not limited to (i) the date that the audit* *was completed, and (ii) the information specified in section 28-308.2.*

§28-308.2.1.1 Compliance with landmarks laws. *The cost estimates for covered buildings that are regulated by any city, state or federal law regulating landmarks and historic buildings shall include all additional costs necessary for the proposed work to comply with such law.*

§28-308.2.2 Timing of energy audit. *Except as otherwise provided in section 28-308.7, the energy audit shall be completed no earlier than four years prior to the date on which a covered building's energy efficiency report is filed with the department pursuant to this article.*

§28-308.3 Retro-commissioning required. *The owner shall ensure that retro-commissioning is performed on the base building systems of a covered building prior to filing an energy efficiency report as required by this article. Except as otherwise provided in section 28-308.7, retro-commissioning shall be performed by or under the supervision of a retro-commissioning agent in accordance with rules promulgated by the department. Such rules, at a minimum, shall ensure that sufficient analysis, corrections and testing have been done so that the base building systems meet the following criteria demonstrating efficient operation:*

1. Operating protocols, calibration, and sequencing:

- *1.1. HVAC temperature and humidity set points and setbacks are appropriate and operating schedules reflect major space occupancy patterns and the current facility requirements.*
- *1.2. HVAC sensors are properly calibrated.*
- *1.3. HVAC controls are functioning and control sequences are appropriate*

for the current facility requirements.

1.4. *Loads are distributed equally across equipment when appropriate (i.e. fans, boilers, pumps, etc. that run in parallel).*

1.5. *Ventilation rates are appropriate for the current facility requirements.*

1.6. *System automatic reset functions are functioning appropriately, if applicable.*

1.7. *Adjustments have been made to compensate for oversized or undersized equipment so that it is functioning as efficiently as possible.*

1.8. *Simultaneous heating and cooling does not occur unless intended.*

1.9. *HVAC system economizer controls are properly functioning, if applicable.*

1.10. *The HVAC distribution systems, both air and water side, are balanced.*

1.11. *Light levels are appropriate to the task.*

1.12. *Lighting sensors and controls are functioning properly according to occupancy, schedule, and/or available daylight, where applicable.*

1.13. *Domestic hot water systems have been checked to ensure proper temperature settings.*

1.14. *Water pumps are functioning as designed.*

1.15. *System water leaks have been identified and repaired.*

2. *Cleaning and repair:*

2.1. *HVAC equipment (vents, ducts, coils, valves, soot bin, etc.) is clean.*

The proper type of air

2.2. *Filters are clean and protocols are in place to replace, as appropriate.*

2.3. *Light fixtures are clean.*

2.4. *Motors, fans, and pumps, including components such as belts, pulleys, and bearings, are in good operating condition.*

2.5. *Steam traps have been replaced as required to maintain efficient operation, if applicable.* Radiator airvents and main steam line airvents have been replaced or reinstalled to optimize steam system operation

2.6. *Manual overrides on existing equipment have been remediated.*

2.7. *Boilers have been tuned for optimal efficiency, if applicable.*

2.8. *Exposed hot and chilled water, condensate lines and steam pipes ~~three (3)~~ 3/4" inches or greater in diameter with associated control valves are insulated in accordance with the standards of the New York ~~city~~ city energy conservation code as in effect for new systems installed on or after ~~July 1, 2010~~ January 1, 2015.*

2.9 *In all easily accessible locations, sealants and weather stripping are installed where appropriate and are in good condition.*

2.10 Steam pipe knocking and banging problems have been identified and corrected

3. *Training and documentation:*

3.1. *Permits for all HVAC, electrical and plumbing equipment are in order.*

3.2. *Critical operations and maintenance staff have received appropriate training, which may include labor/management training, on all major equipment and systems and general energy conservation techniques.*

3.3. *Operational and maintenance record keeping procedures (log books, computer maintenance records, etc.) have been implemented.*

3.4. *The following documentation is on site and accessible to the operators: the operations and maintenance manuals, if such manuals are still available from the manufacturer; the maintenance contracts, and the most recent retro-commissioning report.*

2.11 Steam pressure settings are set as low as possible to provide for even steam distribution throughout the building.

2.12 Excessive outside air entering boiler rooms has been corrected by the installation of a solenoid activated outside air damper.

2.13 Overheated [illegible] have been removed or replaced with smaller radiators to eliminate overheating problems.

~~2.14~~ Steam pipe risers insulated to eliminate overheating problems.

Exception: *No retro-commissioning is required if the covered building has received certification under the LEED 2009 rating system for Existing Buildings published by the USGBC or other rating system for existing buildings, as determined by the department, within two years prior to the filing of the building's energy efficiency report and earned the LEED point for Existing Building Commissioning investigation and analysis and the LEED point for Existing Building Commissioning implementation.*

§28-308.3.1 Contents of retro-commissioning report. *The retro-commissioning agent shall prepare and certify a retro-commissioning report. The retro-commissioning report shall include such information relating to the retro-commissioning as shall be set forth in the rules of the department including, at a minimum:*

1. Project and team information:

1.1 Building address.

1.2 Experience and certification of person performing retro-commissioning and any staff involved in the project.

1.3 Name, affiliation, and contact information for persons performing retro-commissioning and members of the retro-commissioning team, owner of building, and facility manager of building.

2. Building information:

2.1. List of all HVAC, domestic hot water, electrical equipment, lighting, and conveyance equipment types in the base building systems.

2.2. Benchmarking output.

3. Testing protocol:

3.1. List of all equipment types tested.

3.2. For each equipment type tested, a list of the sample rates (percent of each type of equipment tested), the testing methodology, including any diagnostic equipment used, and the test results.

3.3. List of integrated system testing performed.

4. Master list of findings, including for each, the name of the retro-commissioning measure and its assigned number, a brief description of the measure, recommended corrections, the benefits attained, estimated annual savings (energy and cost), the estimated implementation cost, and the simple payback.

5. Deficiencies corrected:

5.1. List of repairs completed during investigation.

5.2. List of deficiencies corrected, including, for each deficiency, the date corrected, by whom the correction was made, the actual cost, and projected savings.

§28-308.3.2 Timing of retro-commissioning. *Except as otherwise provided in section 28-308.7, the retro-commissioning shall be completed no earlier than four years prior to the date on which a covered building's energy efficiency report is filed with the department pursuant to this article.*

§28-308.3.3 Documentation of retro-commissioning. *A copy of the latest up-to-date equipment manuals and the most recent retro-commissioning report shall be* *maintained at every covered building and shall be made available upon request for inspection by the department.*

§28-308.4 Energy efficiency report required. *Except as otherwise provided in section 28-308.7, the owner of a covered building shall file an energy efficiency report for such building between January first and December thirty-first of the calendar year in which such report is due pursuant to this section and between January first and December thirty-first of every tenth calendar year thereafter.*

Exceptions:

1. *An owner may apply for an extension of time to file an energy efficiency report if despite such owner's good faith efforts, to be documented in such application, the owner is unable to complete the required energy audit and retro-commissioning prior to the scheduled due date for such report. The commissioner may grant no more than two such extensions of no more than one year each. Extensions granted pursuant to this provision shall not extend the scheduled due dates for subsequent energy efficiency reports.*

out

2. ~~*An owner may receive annual extensions of time to file an energy efficiency report based on financial hardship of the building.*~~

§28-308.4.1 Due dates. *The first energy efficiency reports for covered buildings in existence on the effective date of this article and for new buildings shall be due, beginning with calendar year 2013, in the calendar year with a final digit that is the same as the last digit of the building's tax block number, as illustrated in the following chart:*

Last digit of tax block number	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Year first EER is due	*2020*	*2021*	*2022*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*

Owners of covered buildings (i) that are less than 10 years old at the commencement of their first assigned calendar year or (ii) that have undergone substantial rehabilitation, as certified by a registered design professional, within the 10 year period prior to any calendar year in which an energy efficiency report is due, such that at the commencement of such calendar year all of the base building systems of such building are in compliance with the New York city energy conservation code as in effect for new buildings constructed on and after July 1, 2010, or as in effect on the date of such substantial rehabilitation, whichever is later, may defer submitting an energy efficiency report for such building until the tenth calendar year after such assigned calendar year.

***Exception:** The first due dates for city buildings shall be in accordance with a staggered schedule, commencing with calendar year 2013 and ending with calendar year 2022 for buildings in existence on the effective date of this article, to be submitted by the department of citywide administrative services to the department on or prior to December 31, 2011. A city building constructed after the effective date of this article shall be added to such schedule within 10 years after the issuance of the first certificate of occupancy for such building. Copies of energy efficiency reports submitted to the department with respect to city buildings that are not submitted by the department of citywide administrative services shall also be submitted to the department of citywide administrative* *services.*

§28-308.4.2 Combined audit and retro-commissioning. *Nothing in this article shall prevent an owner from performing the audit and the retro-commissioning in a combined process, provided that all the requirements of sections 28-308.2 and 28-308.3 are met.*

§28-308.5 Content of energy efficiency report. *Except as otherwise provided in section 28-308.7, the energy efficiency report shall include, in a format prescribed by the department, (i) the energy audit report or documentation substantiating that an exception as set forth in section 28-308.2 applies to such building, and (ii) the retro-commissioning report or documentation substantiating that an exception as set forth in section 28-308.3 applies to such building.*

§28-308.6 Notification by the department of finance. *The department of finance shall notify the owner of the requirements of this article three years prior to the calendar year in which the covered building's energy efficiency report is due and in the calendar year prior to the calendar year in which such report is due.*

§28-308.7 Early compliance. *Notwithstanding any other provision of this article, an owner may submit an energy efficiency report, including both an energy audit report pursuant to section 28-308.7.1 and a retro-commissioning report pursuant to section 28-308.7.2, in the calendar year commencing January 1, 2013 and ending December 31, 2013 in order to achieve early compliance with this section. An energy efficiency report submitted for early compliance shall be deemed to satisfy the first required energy efficiency report for the building as assigned pursuant to section 28-308.4.1. The next required energy efficiency report for such building shall be due in the tenth calendar year* *after the first assigned due date for such report.*

§28-308.7.1 Early compliance energy audit report. *An energy audit report for a covered building shall be acceptable for early compliance if it is completed after January 1, 2006 and it includes:*

1. *The address of the building, completion date of the audit, signature and credentials of the person performing or supervising the performance of the audit and of the audit team; and*
2. *The information required in items 1 through 5 of section 28-308.2.*

§28-308.7.1.1 Early compliance audit completed after January 1, 2006 and prior to the effective date of this article. *An early compliance audit completed after January 1, 2006 and prior to the effective date of this article shall have met the following additional criteria:*

1. *The audit shall have met the requirements of the Level II Energy Survey and Analysis of the 2004 edition of Procedures for Commercial Building Energy Audits published by ASHRAE; or*
2. *The audit shall have been performed under a New York Power Authority or New York State Energy Research and Development Authority (NYSERDA) contract or by a NYSERDA Flex Tech contractor; and*
3. *The audit report shall be submitted along with certification by a registered design professional that the audit satisfies the criteria of this section.*
4. *A partial audit completed after January 1, 2006 and prior to the effective date of this article shall qualify for early compliance only if the base building systems that were not subject to such audit are audited, after the*

effective date of this article, in the manner set forth in section 28-308.7.1.2.

§28-308.7.1.2 Early compliance audit completed after the effective date of this article. *An early compliance audit completed after the effective date of this article shall meet the following additional criteria:*

1. *The audit shall be performed by or under the supervision of a registered design professional and shall meet the requirements of the Level II Energy Survey and Analysis of the 2004 edition of Procedures for Commercial Building Energy Audits published by ASHRAE;*
2. *The auditing team shall include an individual who is one of the following:*
   - 2.1. *A NYSERDA-approved Flex Tech contractor;*
   - 2.2. *A Certified Energy Manager (CEM) or Certified Energy Auditor (CEA), certified by the Association of Energy Engineers (AEE);*
   - 2.3. *A High-Performance Building Design Professional (HPBD) certified by ASHRAE; or*
   - 2.4. *For audits of multifamily residential buildings only, a Multi-family Building Analyst (MFBA), certified by the Building Performance Institute (BPI), or have such other qualification or certification as determined by the department;*

out

3. *An individual with at least three years of professional experience performing energy audits on buildings larger than 50,000 gross square feet (4645 m^2) shall be a member of the auditing team;*
4. *The building's operations and maintenance staff shall be consulted at the*

start of and during the audit process; and

5. *The registered design professional performing or supervising the audit shall certify that the audit satisfies the criteria of this section.*

*§28-308.7.2 **Early compliance retro-commissioning.** a. Retro-commissioning shall be acceptable for early compliance if it is completed after the effective date of this article and meets the following criteria:*

1. *The retro-commissioning shall be performed under a NYSERDA contract for base building retro-commissioning or certified by an individual who is not on the staff of the building and is (i) a registered design professional, (ii) a certified Refrigerating System Operating Engineer, or (iii) a licensed High Pressure Boiler Operating Engineer;*
2. *The retro-commissioning team shall include an individual who is a Certified Commissioning Professional (CCP) certified by the Building Commissioning Association (BCA), a Certified Building Commissioning Professional (CBCP) certified by the AEE, a Commissioning Process Management Professional (CPMP) certified by ASHRAE, or an Accredited Commissioning Process Authority Professional (ACPAP) approved by the University of Wisconsin, or has such other certification as determined by the department;*
3. *The retro-commissioning team shall include an individual with at least one year of professional experience performing retro-commissioning on the mechanical systems of buildings larger than 50,000 gross square feet (4645 m^2);*
4. *The building's operations and maintenance staff shall be consulted at the start*

of and during the retro-commissioning process; and

5. *The retro-commissioning report shall contain a certification that sufficient analysis and testing has been done and corrections have been performed so that the base building systems meet the criteria of section 28-308.3 and shall include the information specified in section 28-308.3.1.*

b. Nothing in this section shall be construed to determine which individuals may perform the work to correct deficiencies identified during the retro-commissioning process, except as otherwise provided by applicable law.

§28-308.8 Optional compliance for energy efficiency reports due in the calendar year commencing January 1, 2013. *Notwithstanding any other provision of this article, audits and retro-commissioning for energy efficiency reports scheduled to be due in the calendar year commencing January 1, 2013 shall be performed, at the option of the owner, in accordance with the provisions for early compliance as set forth in section 28-308.7 or in accordance with procedures set forth in the rules of the department, if such procedures are promulgated within one year prior to the due date of such report. If such procedures are not promulgated within one year prior to the due date of such report, audit and retro-commissioning for energy efficiency reports due in the calendar year commencing January 1, 2013 shall comply with the audit and retro-commissioning procedures for early compliance.*

§28-308.9 Rules. *The department shall promulgate such rules as are necessary to carry out the provisions of this article in a timely manner, which may include separate fees for filing and review of applications and reports filed pursuant to this article.*

§2. Chapter 9 of the New York city charter is amended by adding a new section

224.2 to read as follows:

§224.2 Required energy conservation projects in city buildings. a. Definitions. For the purposes of this section, the terms 'base building systems", "city building", "energy audit", "energy efficiency report", and "simple payback" shall have the same meanings as defined in section 28-308.1 of the administrative code.

b. No later than one year after the submission, in accordance with article three hundred eight of chapter three of title twenty-eight of the administrative code, of an energy efficiency report for a city building, reasonable capital improvements to the building's base building systems that are recommended in the building's energy audit shall be completed, including, at a minimum, all those improvements of the base building systems having a simple payback of not more than seven years or capital improvements that, when combined, would equal or exceed the overall reduction in energy consumption of such recommended capital improvements having a simple payback of not more than seven years.

c. The mayor shall promulgate rules as may be necessary to carry out the provisions of this section.

§3. Report on capital improvements of base building systems. The department of citywide administrative services shall submit annual reports to the mayor and the speaker of the city council on capital improvements of base building systems completed pursuant to section 224.2 of the charter, as added by section 2 of this local law, for each city fiscal year commencing with the fiscal year beginning July 1, 2013. The first such report for the fiscal year commencing July 1, 2013 shall be submitted by December 31, 2014. Subsequent reports shall be due six months after the close of the fiscal year covered by the report. Each report shall include at a minimum:

a. The latest energy efficiency reports (including energy audit and retro-commissioning) submitted pursuant to article three hundred eight of chapter three of title twenty-eight of the administrative code for each building covered by the applicable report of the department of citywide administrative services.

b. An analysis of the most commonly recommended capital improvements of base building systems recommended in the energy audits of such buildings.

c. An analysis of the accuracy of such energy audits in predicting costs of the recommended capital improvements.

d. An analysis after one year of operation of the accuracy with which such audits predicted the actual saving achieved by the capital improvements.

e. Recommendations as to appropriate legislative or administrative actions or a statement as to why no legislative or administrative actions are needed.

§4. Severability. If any section, subsection, sentence, clause, phrase or other portion of this local law is for any reason declared unconstitutional or invalid, in whole or in part, by any court of competent jurisdiction, such portion shall be deemed severable, and such unconstitutionality or invalidity shall not affect the validity of the remaining portions of this local law, which remaining portions shall continue in full force and effect.

§5. This local law shall take effect immediately.

THE CITY OF NEW YORK, OFFICE OF THE CITY CLERK, s.s:

I hereby certify that the foregoing is a true copy of a local law of The City of New York, passed by the Council on ......December 9, 2009.................... and approved by the Mayor on ......December 28, 2009....................................

MICHAEL M. McSWEENEY, City Clerk Clerk of the Council.

CERTIFICATION PURSUANT TO MUNICIPAL HOME RULE §27

Pursuant to the provisions of Municipal Home Rule Law §27, I hereby certify that the enclosed Local Law (Local Law 87 of 2009, Council Int. No. 967-A) contains the correct text and was passed by the New York City Council on December 9, 2009, approved by the Mayor on December 28, 2009 and returned to the City Clerk on December 28, 2009.

JEFFREY D. FRIEDLANDER, Acting Corporation Counsel.

Energy Auditing Your Building

How Good is Your Local Law 87 Report?

By Daniel Karpen, P.E.

There are a number of consultants out there that are "pretending" that they can prepare the energy audit and energy efficiency reports required by Local Law 87.

Local Law 87 of New York City's Greener, Greater Buildings Plan requires all buildings over 50,000 square feet to file an Energy Efficiency Report (EER) with the New York City Department of Buildings. The EER consists of an ASHRAE Level II energy audit and retro-commissioning study of base building systems.

Energy Efficiency Reports are due once every ten years. The first reports must be filed by 2013, and are due in a staggered schedule based on the last digit of the building's tax block number. Both the energy audit and retro-commissioning study must be completed within four years before the EER is filed.

I had the recent unfortunate opportunity to review an energy efficiency report that was poorly prepared and of almost no use to the client.

Be Prepared

Needless to say, you cannot wait until December 1, 2013 to start preparing a report due on December 31, 2013. It may take your consultant several months to prepare the energy audit report, and in some cases, it might take 6 to 18 months to fully implement the recommendations.

The energy audit report is supposed to tell you what operations and maintenance work, and capital improvements, are needed in the building to reduce energy use. Once you get the energy audit report, you are required by Local Law 87 to complete the retro-commissioning work.

Some of the work may be minor, for example, a boiler cleaning. Other work may be major, for example, replacement of an oversized boiler—in which case, it might take an engineer several months to select a smaller boiler. It can take from 6 to 18 months from start to finish to complete a major job such as this.

What can go wrong? As Murphy's Law tells you, almost everything. Let's start with some basics:

The energy audit report should have a page summarizing energy usage and costs for the past one or two years for fuel oil, natural gas and electricity. It should also provide a baseline cost of each of the units of energy to be used in the report's calculations.

For the cost of oil, the question is whether to use the present cost of the last delivery or the average cost over the past year. I recommend to use the most recent cost, as it is difficult to predict the future cost of oil. If the last delivery was several months ago, I prefer to call up the supplier and use the present cost.

For natural gas, your consultant should not use an average cost per therm from the last bill, but rather should look at the incremental cost of the last therm of gas, plus any applicable taxes and surcharges.

For electricity, if you are billed for energy and demand charges, your consultant should break down these charges. There may be distortions in the energy cost savings calculations for certain energy conservation measures. For example, an energy conservation measure involving lighting that is on 24 hours a day, 7 days a week may distort the cost savings if an average cost per kWh is used in the calculations.

Each energy conservation measure should be on a separate page. It should begin by describing the present condition. It should describe the recommended energy conservation measure. Energy saving calculations must be based on sound science. It should provide a verifiable calculation showing how much energy will be saved by the measure. A cost estimate needs to be provided for the energy conservation measure, and a basis for the cost. A simple payback period needs to be provided.

Energy conservation measures should not engage in double accounting of energy savings. For example, tuning up a boiler may raise its steady state efficiency from 75 to 80 percent. A calculation for the energy savings to insulate a steam line should be based on the 80 percent efficiency rate, not the 75 percent efficiency.

Is Your Heating System Oversized?

The report that I saw had a calculation for replacing a 5-ton lobby air conditioning system with a more efficient system. There was no load calculation to determine if the 5-ton A/C system was oversized. And in this case, a smaller system may have been more efficient and cheaper to install.

Also, the basis for the energy savings

continued on page 40

ENERGY AUDITING...

continued from page 31

calculation was based on a guess of the number of hours the system was running; it was not based on any actual measurements. It was assumed that the system was running continuously; A/C systems do cycle. The fan may run continuously, but the compressor may cycle. Also, the cost of the installation was too low, making the potential payback period appear shorter than reality. Additionally, no mention was made of a need to clean the ductwork.

Another factor is that the heating description was incomplete. The report mentioned the make and model of the steam boiler, but did not tell whether it was a one-pipe or two-pipe steam system. No mention was made of whether the boiler had adequate insulation. There was also no inventory of the uninsulated steam lines; I have yet to see a building in New York City which has adequate steam pipe insulation. If your boiler room is over 65 degrees, your boiler or your steam lines, or both, do not have adequate insulation. No mention was made if the outside air to supply the boiler room had a solenoid-activated damper in series with the boiler controls to keep cold air out of the boiler room when the boiler is off.

It was also not clear if the boiler was oversized for the building. No inventory was made of the attached steam radiators to determine the total BTUs necessary to get steam to all of the radiators at the same time. One must compare the attached radiation load against the firing rate of the boiler. It was not clear if the radiators were oversized; once you put double-glazed windows in a building, your radiators become immediately oversized which leads to overheating situations. In this case, you need to put smaller radiators in the building. Thermostatic radiator valves can be great, but sometimes putting in smaller radiators is actually much cheaper.

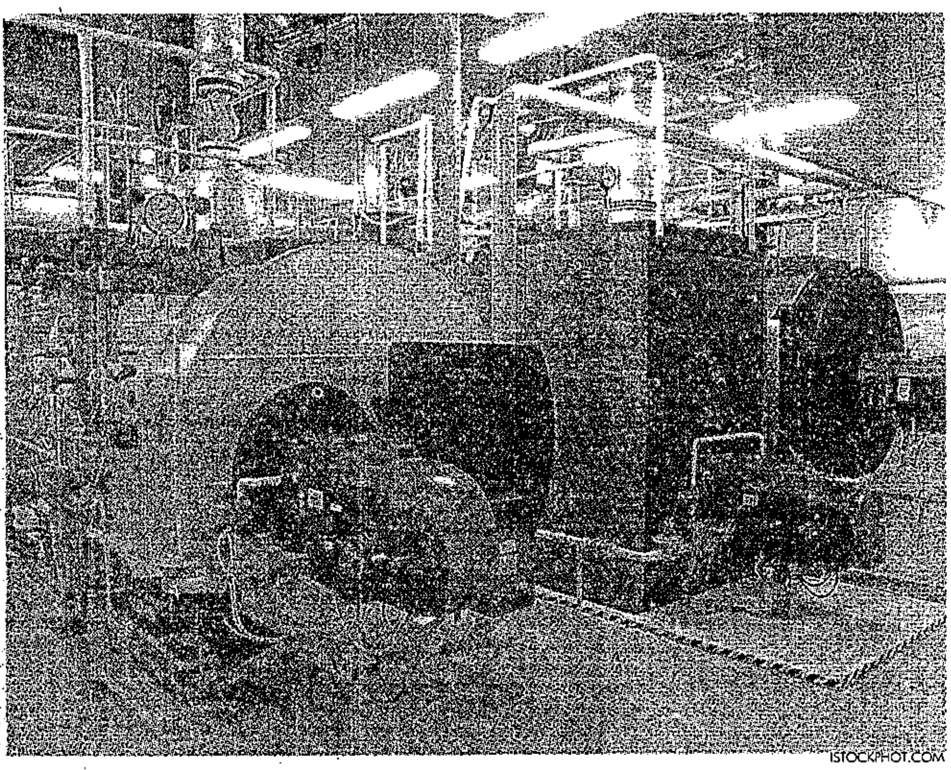
Any calculation that is based on a "percentage" must be treated as suspect. Any consultant that relies on manufacturer's literature rather than sound engineering principles can be prone to inaccuracies in their reports. My advice is to question everything. Use best practices and practical engineering rather than guesswork to avoid any problems down the line. ■

Daniel Karpen is a Long Island-based professional engineer and consultant.

Is Your Building Wasting Energy?

Improving the Efficiency of Steam Heating Systems

BY DANIEL KARPEN, P.E.



ISTOCKPHOTO.COM

Steam heating using both single- and two-pipe steam radiators will continue to dominate the heating of a majority of buildings in New York City well into the present century. But how do we determine if an apartment building is energy efficient?

One way is to sum up the amount of oil consumed on an annual basis in the building. An energy efficient apartment building should be using the equivalent of 250 gallons of fuel oil per unit per year, or its natural gas equivalent, to provide heat and hot water to the building. For natural gas, 1.387 therms of gas is equivalent in input heat to one gallon of No. 2 fuel oil.

If you are using more than the above amount on an annual basis to provide heat and hot water to your building, you are wasting a considerable amount of energy. I still see buildings in New York City that are using 375 to 550 gallons of fuel oil per year to provide heat and hot water—these buildings are energy guzzlers.

By May 1, 2011, private buildings over 50,000 square feet in area must provide annual water and energy benchmarking. Thus, they must determine on an annual basis how much energy is being used in their building.

Things to Consider

There are many reasons why your building may be consuming too much energy. Here are some common problem areas:

The steam pressure is set at the wrong pressure. In many buildings, the steam pressure is set too high. Do you know what the steam pressure is set to in your building? Is it at 2 psi or it is at 5 psi? Can you answer this question? Why is the steam pressure set where it is?

There can be a considerable amount of wasted energy if the steam pressure is set at the wrong pressure. I have seen buildings where resetting the steam pressure to a level it is supposed to be, based on the initial design of the steam heating system, reduced fuel consumption by 10 percent. A great deal of overheating in buildings is due to the wrong steam pressures. Radiators waste energy if the building steam pressure is set at the wrong level.

What happens is that steam enters the condensate return system, where it does not belong. In this case, the condensate lines act as steam lines instead of condensate lines, resulting in a great deal of energy waste. Because the condensate lines are now hot,

continued on page 61

IS YOUR BUILDING...

continued from page 49

along with the stream radiators, the apartment vastly overheats.

Damaged Steam Traps

Another problem is blown steam traps in two pipe steam systems. Steam traps generally last only 3 to 5 years, yet in many buildings, the steam traps have not been replaced in 50 years. Because the steam traps don't work, building supers keep the steam pressure at the wrong level. Stream traps that fail in an open position allow steam to fill up the condensate lines, which again results in overheating.

To prevent this, the functioning of steam traps needs to be checked on a regular basis with a thermal scanner that reads the temperature of the returning condensate on the condensate return lines. If the temperature of the condensate is above 135 degrees F, you most likely have blown traps in your building. I have seen buildings where most of the steam traps had failed in an open position. The simple act of replacing steam traps can cut fuel consumption in a building by 5 to 10 percent.

Another big problem in many buildings is inadequate insulation on the boiler and on the steam and condensate lines in the basement or cellar. Energy that is lost in the boiler room does not get to the occupants of the apartments upstairs, where it belongs. The temperature of a boiler room with properly insulated steam and condensate lines, and a well insulated boiler, should be about about 70 degrees F. If your boiler room is above 70 degrees, it is wasting energy.

In the summer, an excessively hot boiler room causes occupants in the space above the boiler room to run the air conditioning more than necessary. A properly insulated boiler and boiler room piping can cut fuel consumption in a building by five percent or more. Boiler replacement may be necessary if a boiler is defective and can not be repaired satisfactorily.

Keep in mind that most boilers are vastly oversized for the building they are heating. An oversized boiler can waste as much as 40 percent of the annual fuel consumption. Before a boiler is to be replaced, an engineering analysis is necessary to size a new boiler. A new boiler can be sized on the basis of the present fuel oil usage rate. For example, I once saw a boiler that was sized to burn 1,200 gallons of fuel oil per day, but the actual amount of heat necessary to heat the building was the energy equivalent of 200 gallons of fuel oil per day.

Some of the more efficient boilers have three inches of insulation in the jacket of the boiler, which can keep the boiler room much cooler. The in-

continued on page 62

IS YOUR BUILDING...

continued from page 61

sulation is on all four sides and on the top of the boiler.

It is recommended that owners should install a boiler capable of burning 10 gallons of fuel oil per hour. A properly sized new boiler not only saves owners the cost of operation, but a smaller boiler is often much less expensive. ■

Daniel Karpen is a professional engineer based in Huntington, New York.

Maintenance

Fixing a Noisy Steam Pipe

Throwing Down the Hammer

By Daniel Karpen, P.E.

No, your steam lines are not supposed to be noisy. The Beatles are considered to be among the best musicians of all time. But the cacophony you get from noisy steam lines is far from considered music at all.

So what is causing the noise within my steam system? It can be any number of factors.

Often, it is a litany of factors largely related to poor operation, maintenance, and the design of your steam heating system.

Let's look at some of the reasons you can have steam hammer and pipe banging:

1. The pipes are not pitched properly. Condensate is supposed to go downhill by gravity to return to the steam boiler. I have seen cases where a pipe hanger has broken, resulting in a sag in the steam line where the condensate has collected; the steam comes down the steam line, and bangs the condensate to the end of the line where is makes a thud against the hard stubborn steel.

2. The steam pressure is set too high. If you set the steam pressure above about 2 psi, the condensate can back up in the return line, and if the return line is just several feet above the water line in the boiler, one can have water hammer in that return line. If the steam pressure is too high, set it much lower. The lower the steam pressure, the less the pipes will knock. You will also save energy by lowering the steam pressure.

3. The condensate lines are clogged and are preventing condensate from returning to the boiler. A friend of mine told me about this problem. One side of the building was not getting heat due to blocked condensate return lines. Once he opened up the condensate lines and cleaned the 75 years of accumulated rust from the line, the pipe knocking problem went away.

4. The steam traps have failed in the two pipe steam heating system. Since the traps are now open, steam is flowing into the condensate return lines, causing the condensate to be pushed along into waves down the pipe.

Unfortunately, steam is not emotional. It follows the laws of physics. You need to replace all of the thermostatic traps at the end of each radiator. You cannot pray that this problem will do away on its own. You must spend money from your co-op or condo budget to fix the problem.

5. You have dirty boiler water. Because the water chemistry of the water is poor, condensate is being thrown up the steam lines along with the steam. You will need to dump the boiler water and clean the internals of the boiler using boiler water cleaning compounds. You will need to institute a program of treating the water in the boiler to keep the pH between 8.0 and 11.0 to prevent condensate from being lifted out of the boiler into the steam lines.

6. You have uninsulated steam lines. Steam is condensing along the line, and the condensate is causing the steam hammer. In order to solve the problem, you need to insulate the stream lines. For the proper amount of insulation, refer to the 2010 New York State Energy Conservation Construction Code.

7. One pipe radiators that are partially open. If the valve is not fully open, the condensate is getting in the way of the steam trying to get into the radiator. This problem is usually restricted to individual radiators.

8. If you replace a boiler, make sure that the water line is in at the proper height. If you change the level of a water line, a dry return line can turn into a wet line that will knock depending on the boiler stream pressure.

9. A long nipple at the Hartford Loop connection. I once saw this problem. The long nipple gives the returning condensate a "runway" to smash into the equalizer as the steam bubbles rising up the equalizer condense. It took me a long time to explain to the owner of the building why this problem was causing the pipe knocking.

10. Someone used concentric reducers instead of eccentric reducers where the main steam lines changes size. I see this problem in about 5 percent of the steam systems that I inspect for owners. The only way to solve this problem is to replace the reducers on the steam lines, which can be expensive.

Every steam heating system is different. Your system could have one of the above causes for the water hammer problem, or several causes.

If you want your residents to stop complaining about the water hammer problem, you need to identify the exact causes, and get them taken care of.

Water hammer is not normal. I have seen steam heating systems that are as quiet as a mouse. ■

Daniel Karpen is a licensed professional engineer specializing in energy conservation and environmental consulting. He is based in Huntington, New York

Phasing Out No. 6 Fuel Oil

A Case Study for Conversion

By Daniel Karpen, P.E.

New York City law will phase out the burning of Number 6 fuel oil in the near future.

Should you wait until the last minute until making the switch to cleaner fuel oil in your own building? Does it make sense to do it now, or do it later?

The fact is that the sooner you phase out Number 6 fuel oil, the more money you will save. There are several ways of phasing out Number 6 fuel oil. An easy way is to tell your fuel oil company that you want to burn the Number 6 fuel oil that you have in the tank until it is almost empty, pump out the remaining Number 6 fuel oil, clean the tank, and fill it up with Number 2 fuel oil. You would then disconnect the heater for the Number 6 fuel oil, set up the fuel pump to run only when the burner is running, and change the burner nozzle and replace the fuel filter. You could also do any other work that your service technician recommends at the time.

While Number 6 fuel oil has more BTU per gallon than Number 2 fuel oil, 145,000 BTU per gallon compare with 138,700 BTU per gallon for Number 2 fuel oil, the reduction in the

parasitic losses from handling the Number 6 fuel oil by preheating it and running the fuel pump continuously would make up some of the difference in net operating costs.

Also, Number 2 fuel oil burns cleaner than Number 6 fuel oil, so at the time of conversion, you would need to clean the boiler tubes to remove the soot on the fireside of the fire tubes.

One Building's Story

Two years ago, I prepared an engineering study for a 116-unit apartment building on the East Side of Manhattan near the United Nations. The building was burning Number 6 fuel oil. For the 2008 calendar year, the boilers burned approximately 47,942 gallons of Number 6 fuel oil; thus the fuel oil usage was 413 gallons per unit per year.

The boilers were original to the building which was built about 1965. There were two Federal firetube firebox-type boilers each rated at 134 boiler horsepower. Each boiler was fired by a 50-gallon per hour Johnson rotary burner.

As part of my engineering study, I performed a combustion efficiency test on the boiler in use at the time. The stack temperature was 450 degrees F, and there was 4 percent carbon dioxide in the flue gas. The steady state efficiency of the boilers was 66 percent.

The super told me that prior to the installation of low-E windows in the building, maximum fuel oil consumption on a cold winter day was approximately 450 gallons.

A review of recent consumption records noted a maximum daily consumption of about 300 gallons per day, a reduction of about one third.

At a firing rate of 50 gallons per day, each boiler in the building can burn 1,200 gallons of Number 6 fuel oil per day. Of the 300 gallons of fuel oil burned each day in the coldest weather, 100 gallons is lost in stack losses. Thus, only 200 gallons equivalent of BTU in the oil is necessary to heat the building.

It is illegal in New York City to install a new burner that can fire Number 6 fuel oil at less than 20 gallons per hour. Thus, the only alternatives that made sense in this case were natural gas or Number 2 fuel oil. According to Con Ed a large uptick in natural gas usage would have necessitated the digging up of the street back to First Avenue to install new gas mains, as the present mains could not support additional service.

In light of all this, my recommendation to the owner was to install two new high efficiency boilers rated at 10 gallons of Number 2 fuel oil per hour. If we divided 200 gallons by 24 hours per day, the building only needs the equivalent of 8.3 gallons equivalent per hour to heat the building. Assuming a boiler efficiency of 83 percent, one could heat the building with a new boiler with a firing rate of 10 gallons per hour. I also recommended that all the steam traps be changed at the time of installation of the new boilers and that changes be made to the condensate return system so that a gravity return system take the place of a condensate receiver tank.

Energy and Cost Savings

The cost of conversion for the East Side building was projected at $100,000. This cost included removal of the old boilers, installation of new boilers,and commissioning the new boilers to run on Number 2 fuel oil.

Energy savings from combustion efficiency savings were estimated at 11,744 gallons of Number 2 fuel oil per year. Off-cycle savings, when the burners were not firing, were estimated at 10,194 gallons of Number 2 fuel oil per year. Total energy savings were estimated at 21,938 gallons of Number 2 fuel oil per year. Usage of

continued on page 44

PHASING OUT NO.6...

continued from page 32

Number 2 fuel oil was projected to be 28,688 gallons per year, or just 247 gallons of fuel oil per unit per year.

Even with a cost differential of $.3575 per gallon between Number 2 and Number 6 oil, the fuel oil cost savings were projected at $9,827 per year. An additional $3,000 per year savings per year was projected from a reduction of electrical usage.

Total cost savings was projected at $12,827 per year at the time of the study. The simple payback period was 7.8 years. With today's fuel oil costs, the payback period would be between 4 and 5 years. So even though the initial cost and work might have seemed daunting, over the expected life of the boiler, it certainly pays to replace sooner rather than later.

Daniel Karpen is a professional engineer based in Huntington, New York.

Maintenance

Maintaining Steam Traps

Fixing Water Condensate Problems

By Daniel Karpen

If you want to catch mice the simple solution is to use a mouse trap. If the mouse trap does not work, and often they don't, then you have to find an alternate solution. One good solution is to get a natural predator of the mouse to assist. The house cat is about as effective a mouse eradication tool known to man and they will accomplish the job. A simple solution for a simple problem.

Don't Get Steamed

The same goes if you're going to try to trap steam, you find the most effective way to accomplish this, and what is the tool to use? It's known as a steam trap. Now you may be asking, what does a steam trap do? To answer that question, we have to examine what are the different types of steam heating systems? There are two general types of low pressure steam heating systems—there are one pipe systems and two pipe systems. In a one pipe steam system, steam and condensate share the same pipe to the radiator. In a two pipe steam system, the steam enters the radiator through one pipe and condensate leaves through another pipe at the opposite end of the radiator. That is what we mean by the term—two pipe steam heating.

The problem then is the following: How do you prevent steam from leaving the radiator so it does not get into the condensate return system? There are various ways of solving this problem. The most commonly used technique is to put a "steam trap" at the end of the radiator.

A steam trap is a mechanical device that has to do two things: It has to allow the condensate to leave a radiator while at the same time preventing steam from getting into the condensate return lines. The type of trap used for this purpose is a thermostatic trap. There are also float and thermostatic traps on the ends of the main steam lines. These traps are designed to handle the larger amounts of condensate which forms in the main steam lines in basements and cellars of residential buildings.

Two pipe steam systems revolutionized the heating of buildings. You had much better control than a one pipe steam system. You could modulate steam flow at a radiator manually through a throttling valve. Because you had better control, you could heat much larger buildings. Typically, smaller apartment buildings had one pipe steam systems.

Two Pipes are Better Than One

Two pipe steam systems were also more expensive to install than one pipe steam systems because you needed two sets of pipes, one set for the steam lines and one set for the condensate return lines. Some of the extra expense was offset by the use of smaller lines for the steam supply lines to the radiators because there was very little condensate in the supply lines compared with the steam lines necessary for a one pipe steam system. Two pipe steam systems were also installed in single-family homes where the owner was willing to pay for it.

The thermostatic trap also functions as an air vent. So the first thing that happens is that the air is vented out of the system's steam trap. If the steam trap fails in a closed position, the air is trapped in the radiator and it stays cold. This problem is rare, but it can occur.

Every thermostatic radiator trap has a bellows that is filled with an alcohol-water mixture. The manufacturer sets the mixture to boiler at 180 degrees Fahrenheit. As steam approaches the trap, the alcohol-water mixture flashes off and expands. That expansive force drives the bellows out, pushing the pin into the seat and closing the trap. As the steam gives up its latent heat and condenses, the alcohol mixture inside the bellows senses the drop in temperature and opens to let the condensate flow back to the boiler.

How Long Do Thermostatic Traps Last?

As you can surmise, the traps are constantly opening and closing all through the heating season. In a typical New York City building, the steam may be live in the steam lines about 900 hours per season. This trap may be opening and closing about three times per minute. Thus in a single heating season, the trap may be opening and closing about 162,000 times. After six years, the trap may be opening and closing more than one million times.

That is a lot of wear and tear on the

continued on page 43

MAINTAINING...

continued from page 43

steam traps in your building? If you don't know, they are ready for replacement. Bad traps can be the major cause of water hammer problems, and steam in the condensate lines can cause overheating in your building. Supers often increase the steam pressure to make up for the losses in system pressurization from having bad steam traps. Increased steam pressure can be the cause of pipe knocking in the system. Also, bad traps lead to losses in the vent pipe at your condensate receiver, if you have one.

Local Law 87 and its Impact on Steam Traps

If you have more than 50,000 square feet in your building and you have a two pipe steam system with thermostatic traps, Local Law 87 forces you to test your traps. In my view, testing the traps is a waste of time. They are bad if you don't remember when you last changed all of them. For better or for worse, you are going to have to replace your steam traps.

I was in a church that had bad steam pipe knocking problems. I told them that the traps needed replacement. The building was more than 100 years old. The traps did not have wrench marks on them indicating that nobody ever changed them or the inserts.

Believe it or not, most of the traps were original to the building. (More than 100 years old) Some of them had more than ten layers of paint on them. Also, believe it or not, the church was convinced to replace all the traps in the building. Voila, pipe knocking problem solved.

For once, someone actually listened to me! ■

Daniel Karpen is a professional engineer and consultant based in Huntington, New York.

Testimony for **Hearing on Site-Sourced and Stored Renewable Energy** by Ken Gale
Thank you for holding this hearing and for giving us the opportunity to speak.

I'm Ken Gale, and since 2002, the host and producer of the environmental radio show Eco-Logic on WBAI-FM here in New York City and also the founder of the New York City Safe Energy Coalition, NYCSEC. I'm also on the advisory board of New York City Friends of Clearwater, a member of the Environment TV team and a founding member of the New York Climate Action Group, which was instrumental in getting the commercial net metering law passed in 2008. I keep busy.

I was hoping for this hearing when I learned that the City Council had passed by a 47 to zero vote Int # 378 to lower greenhouse gas emissions. Renewable energy is one of the many ways to reach that goal.

When people save money on energy, they tend to spend the money they save locally, so the benefits to the local economy are greater than merely what we save on energy. Clean energy is healthier, that cuts down on healthcare costs and increases worker and student productivity. Don't underestimate that.

These days, there are a lot of studies on how to provide for New York City's electricity needs without fossil fuel or nuclear power. The Jacobson study is a good start, but I prefer CUNY's solar roofs and Solar City studies and especially SUNY-Albany's solar research headed by Dr. Richard Perez. We can get 50% of our electricity from solar. More in the summer, when prices are highest, less in the winter.

Last Oct. 8, at a New York Solar Energy Society Solar Salon, someone from Con Ed said there are over 2,000 solar voltaic installations in the City giving us 40 megawatts, with almost that many MW from 1,000 more in queue. It wasn't that long ago that there were only 75 installations, so we've gotten better and the City's new streamlined solar permitting is a big reason for that. However, with a million buildings in the City, 3,000 is a poor showing. 3/10 of a percent. That needs to accelerate.

In doing my radio show and talking to local solar installers, one of the big complaints they have is financing. Many banks don't or won't. My friends from Occupy Wall St. say that's because of interlocking boards of directors of banks with oil companies and utilities. I hope it's only ignorance on their part, but it was about <u>ten</u> years ago that *Home Improvement* magazine had an article on how much solar panels increase a home's value and re-sale speed, so the banks should know better by now. There have been more recent articles in other magazines saying that sometimes solar panels increase the value of a house by more than the cost of the panels. With lower monthly energy bills, the borrower will find it easier paying for efficiency and solar loans than probably any other type of home improvement.

On Long Island and upstate, there is on-bill financing, where homeowners can pay for energy efficiency and solar and tie the cost to their utility bill. Con Ed does not participate in that and I think they should. The Green Bank only helps large installations and it's time they also helped homeowners find solar-friendly banks and credit unions.

One caveat: solar LEASING and Power Purchase Agreements, despite their zero upfront costs and lowering of electricity bills, often lower property values for people who don't want to be tied into someone else's lease or contract. Buying the solar panels is best.

One form of solar power that gets very little discussion is **solar thermal**, which directly replaces fossil fuel used for heat and hot water. Until recently, Richard Klein of Quixotic Systems in the West Village was the only solar thermal installer in New York City. Now there are a handful. Bronx and Kingsborough Community Colleges had courses to certify solar thermal installers that didn't take long and were inexpensive. A representative from Bronx Community College told me they were discontinued due to lack of interest, but they would re-offer them if the interest is there. Solar thermal pre-incentive costs are 1/8 to 1/10 as much as photo voltaic - electricity - and a rooftop solar thermal array can supply all the heat and hot water for a five-story building, but the same size pv array can only supply enough electricity for one story (I got that info from tours of Quixotic Systems' installations). Solar thermal directly replaces methane and with less methane being used, there is less chance of another gas explosion like what happened in East Harlem in March, 2014. Larger buildings have multiple boilers, which operate depending on tenant demand. The first boiler can be connected to a solar thermal array and subsequent ones use other fuels.

I assume most of the testimony today will be about sources of energy, but new sources alone will not get us to a point where 100% of our energy is from renewable sources. We waste a lot of the energy that we buy. Goes right through the window. Using less energy means we won't burn as much fossil fuel or irradiate anyone.

Passive House techniques have been around since the '70s, originally developed in Illinois as the "lo-cal house" and homes were heated in an Illinois winter with the people and appliances within the building. They have been perfected to use less than 1/10 the energy of what is usually called a conventional building. There are claims of using only 5% of the energy for buildings currently being built in Germany. New York City architect Chris Benedict has shown that they don't have to cost one cent more to build, either.

At the Passive House conference in NYC this past June 17th, I discovered that there are four different organizations certifying buildings as passive house. That would explain the low numbers of passive house buildings Councilman Levin mentioned at the Oct. 23rd hearing on lowering greenhouse gas emissions. There are many architects and architectural firms building and retrofitting passive houses in New York City and vicinity. There are regular passive house tours organized through meetup.com.

Buildings are built to code and no better, so our **building codes** must take energy use into account. Just as many people buy cars with the mileage in mind, choosing energy efficient cars, so too should buildings be made and bought with their efficiency in mind.

Most of our buildings were not built with efficiency in mind, so they must be retrofitted. It will pay for itself in a few years, much less time than the life of the building. This benefits landlords, tenants AND homeowners. I suggest loans, not grants. With the great financial benefits to using less energy, there should be no cost at all to New York City. And again, there are many architects and architectural firms retrofitting buildings in New York City and vicinity. The Northeast Sustainable Energy Association, NESEA.org is a good way to find some.

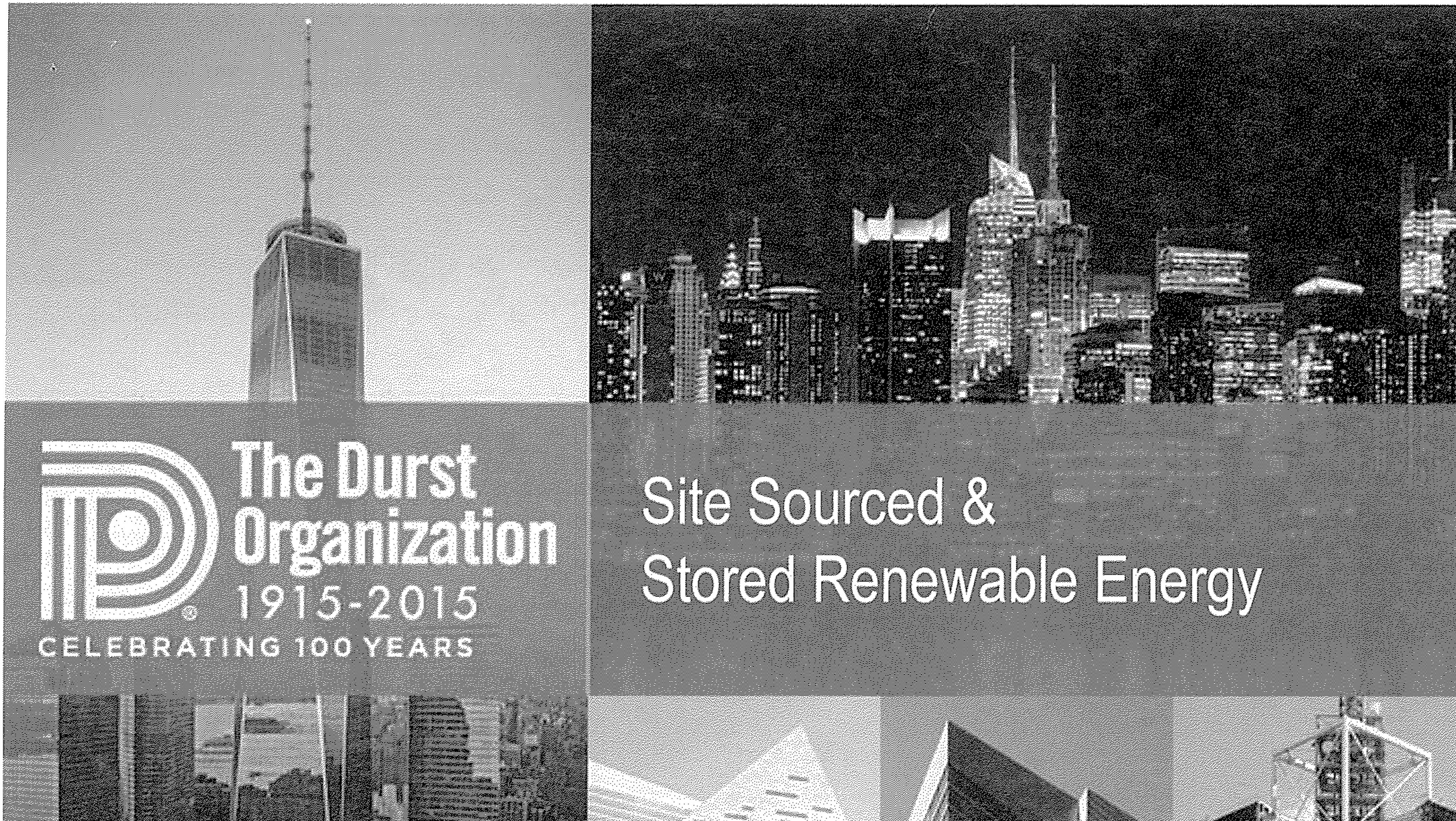
Andy Padian from Steve Winter Associates, one of New York City's foremost energy experts, made a presentation at a recent NYC Safe Energy Coalition meeting. The number of simple and cheap improvements that can be done to lower energy costs and our carbon footprint is more than I had realized, even with decades of energy activism. Most boilers are old and inefficient. We use more hot water than we need to, and thus waste more energy heating it. Most of our toilets are old and inefficient, increasing energy costs to pump replacement water and increasing wastewater treatment costs. Andy's biggest easy energy saving is from cable boxes. They use the same amount of energy, 20 watts, when they're off as when they're on. In California, the same company that supplies our cable boxes supplies theirs, and they only use two watts when off, a 90% savings. Every cable box that is replaced should be replaced with an efficient one. If the cable companies won't do it voluntarily, perhaps legislation is needed.

Environmental activists like myself may know how much more economical and green energy star appliances are, but I think the average person does not. More education is needed.

Solar panels, insulation and better windows cannot be installed from overseas. They mean local jobs. Let's stop burning our money or sending it to Texas and the mid-east. Let's spend it at home.

When the air or water are clean, thank an environmentalist. If not, become one. 'Nuff Said!

Thank you.
Ken Gale
nuffsaid@riseup.net


The Durst Organization
1915-2015
CELEBRATING 100 YEARS
Site Sourced &
Stored Renewable Energy

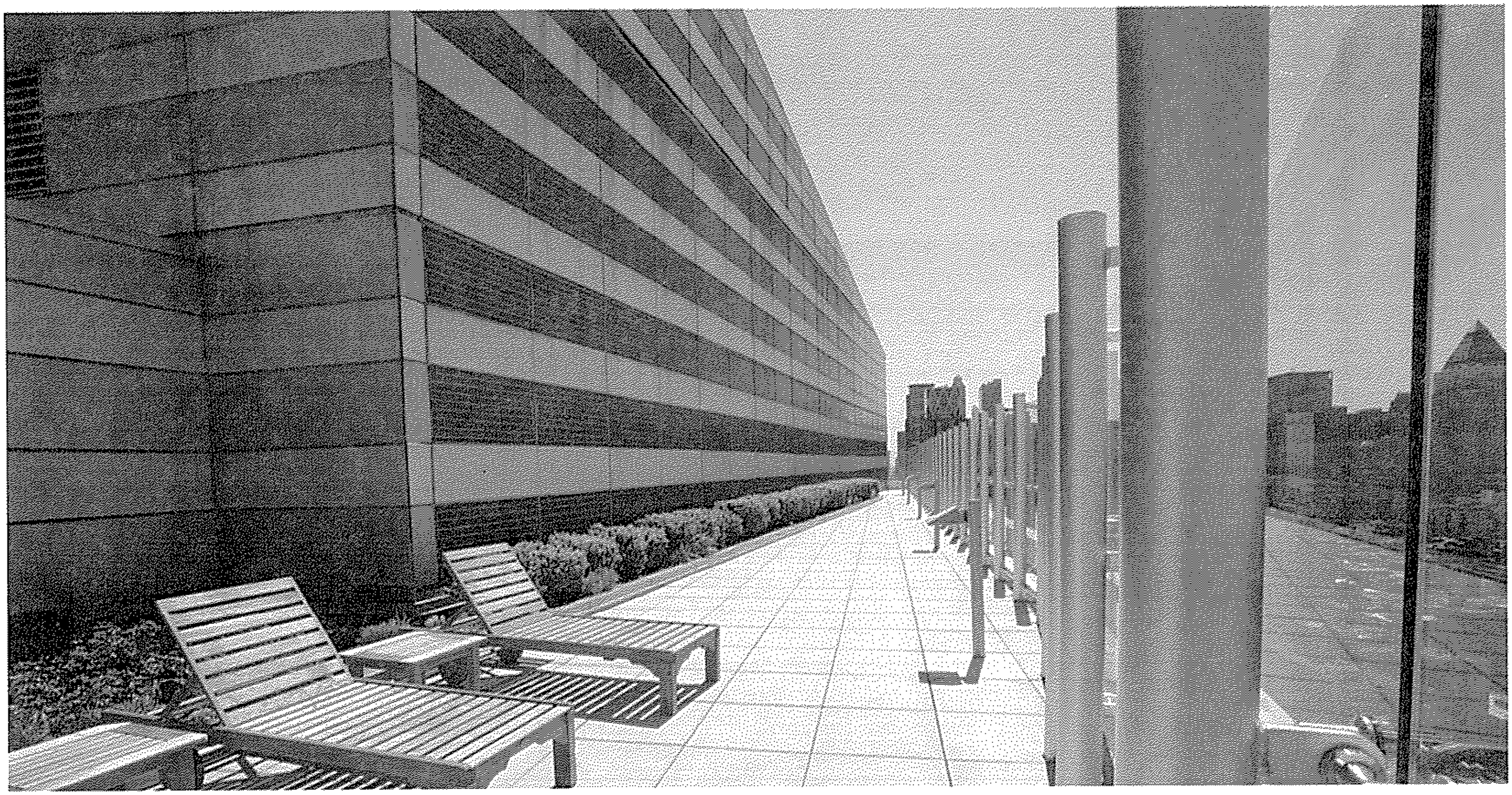
The Durst Organization
1915-2015
CELEBRATING 100 YEARS

Solar Energy

4 Times Square

- Installed Capacity – 5kW
- Installed Cost - $80,000
- Annual Power Generated – 3,600 kWh
- Payback - >100 years
- Issues with manufacturer longevity and location on a vertical wall

The Helena



- Installed Capacity – 27 kW
- Installed Cost – $270,000
- Incentives – $100,000
- Annual Power Generated – 25,000 kWh
- Payback – 35 years

The Durst Organization
1915-2015
CELEBRATING 100 YEARS

Wind Energy

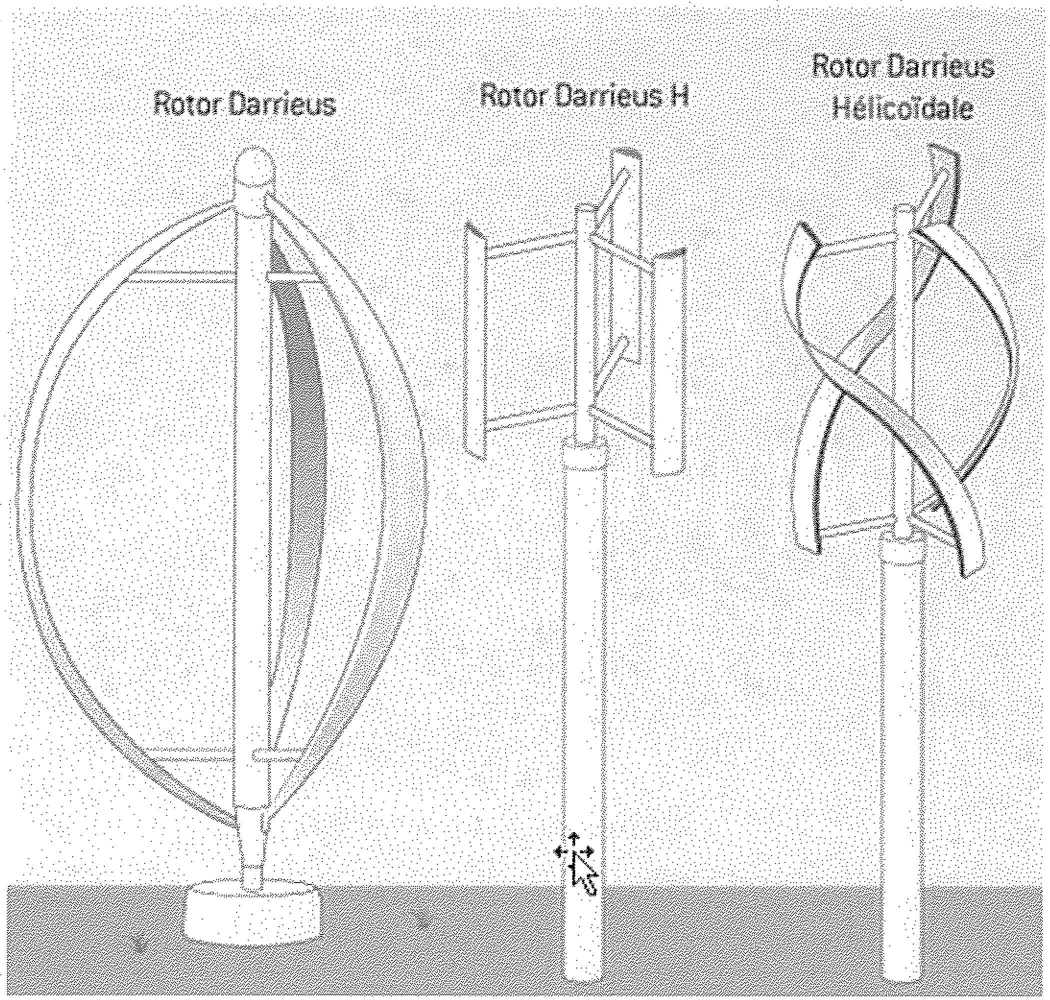
Portfolio Power Purchase

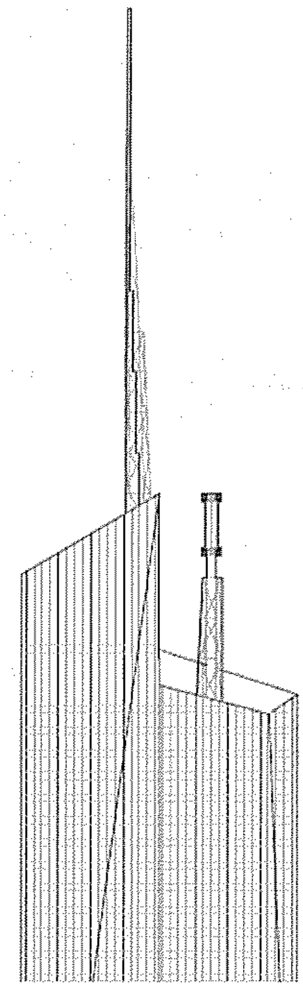
conEdison Solutions

Energy. Efficiency. Expertise.

- Through Con Ed Solutions, receive a $.002 / kWh discount off the mandatory hourly pricing that is then used to purchase NE regional wind at $.020 / kWh which equates to 10% NE regional wind
- Total Annual Wind Power Purchased – 11,434,710 kWh

One Bryant Park Wind Turbine Study





- Results – Not economically feasible
- Turbine cut-in speed too high
- NYC wind not consistent enough

The Durst Organization
1915-2015
CELEBRATING 100 YEARS

Geo-Thermal Heat Pumps

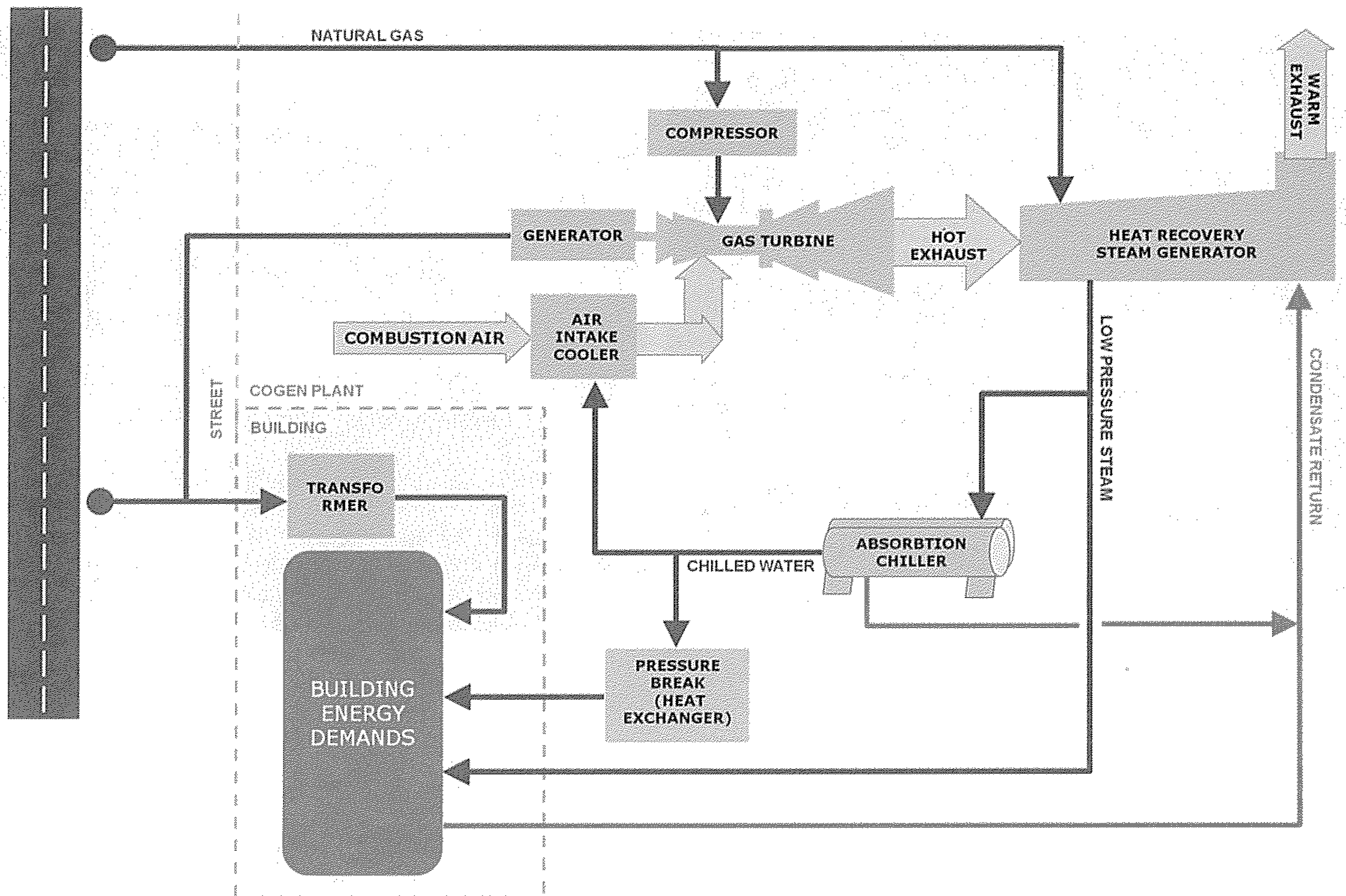
Historic Front Street

- Did not work
- Brackish ground water caused corrosion of stainless steel piping
- Open loop to apartment heat pumps cause condenser coils to corrode and leak
- Well pump failures due to low water table – slug/air bound problems
- Replace system with VRF (Variable Refrigerant Flow) Heat Pump System after Super Storm Sandy

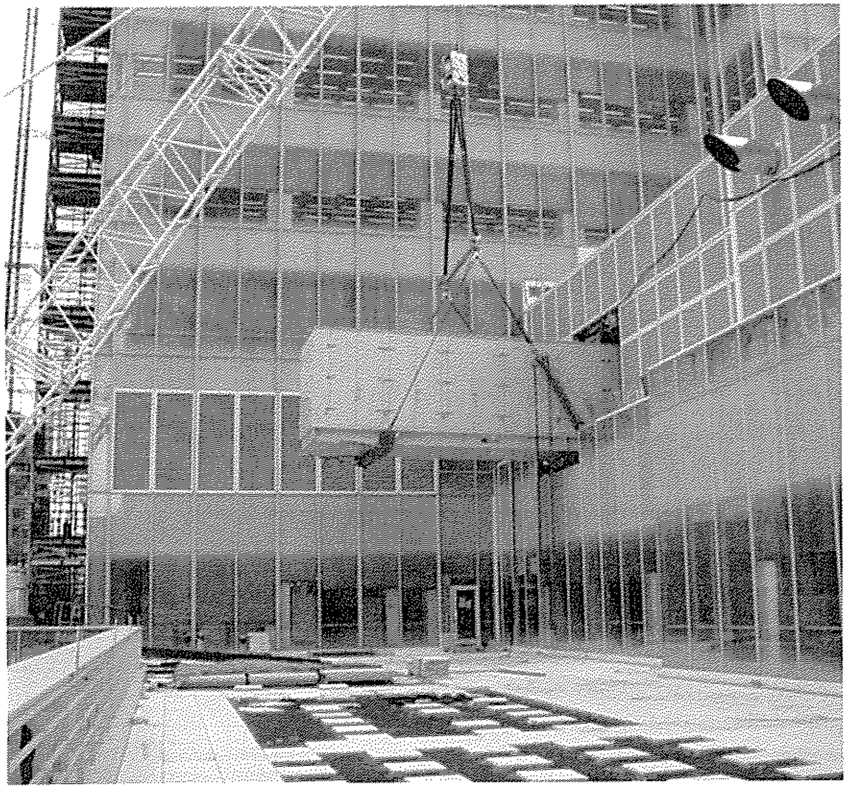
The Durst Organization
1915-2015
CELEBRATING 100 YEARS

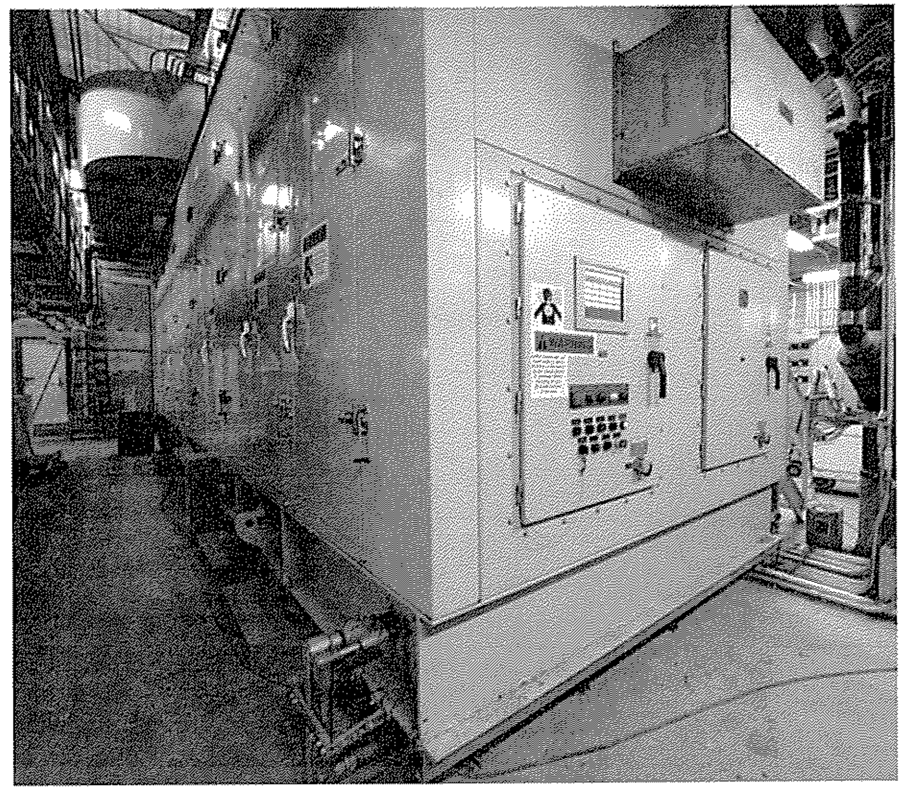
Cogen

One Bryant Park



One Bryant Park

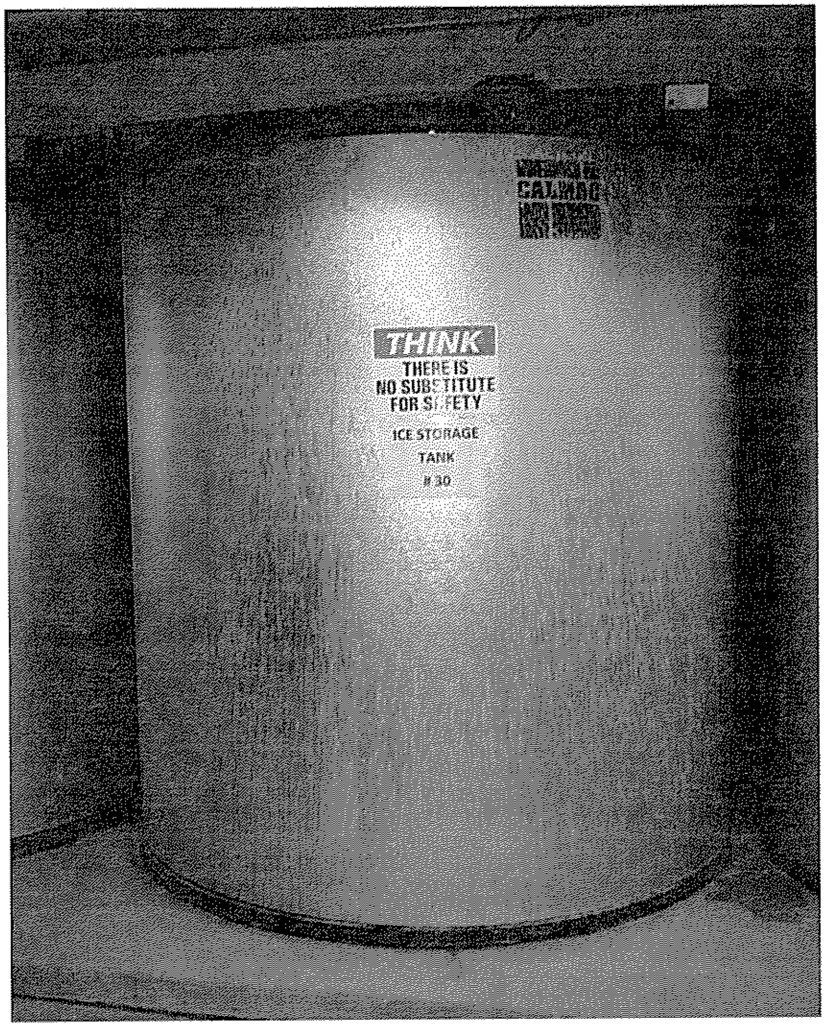


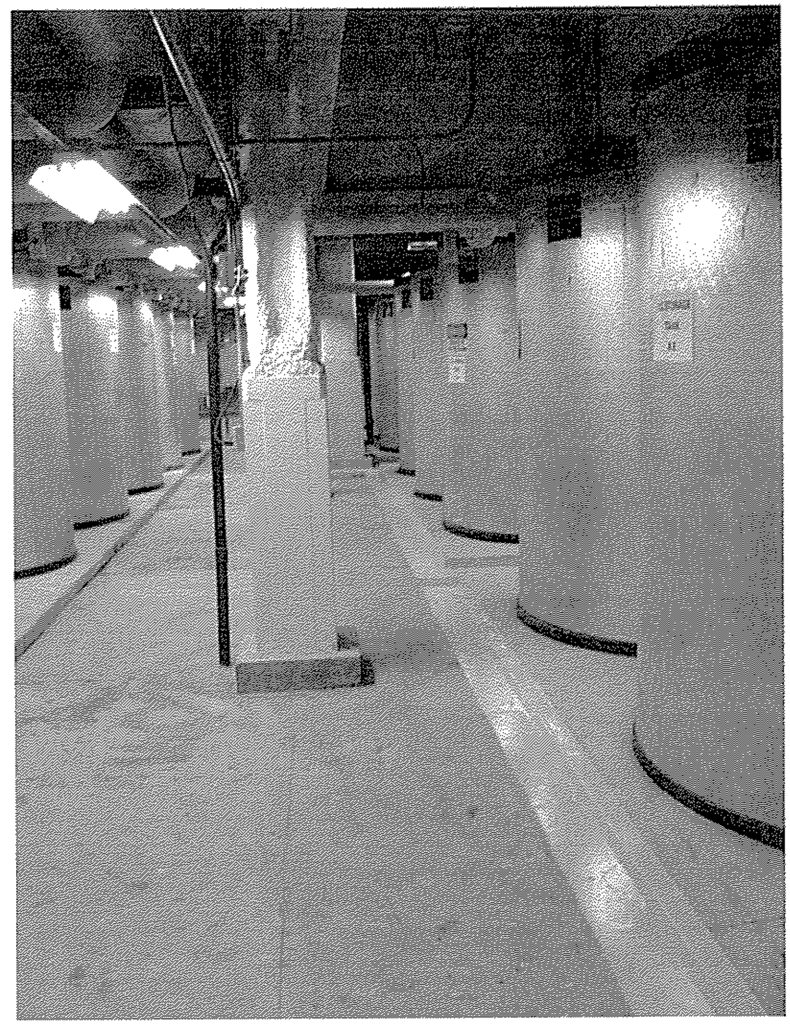


The Durst Organization
1915-2015
CELEBRATING 100 YEARS

Energy Storage

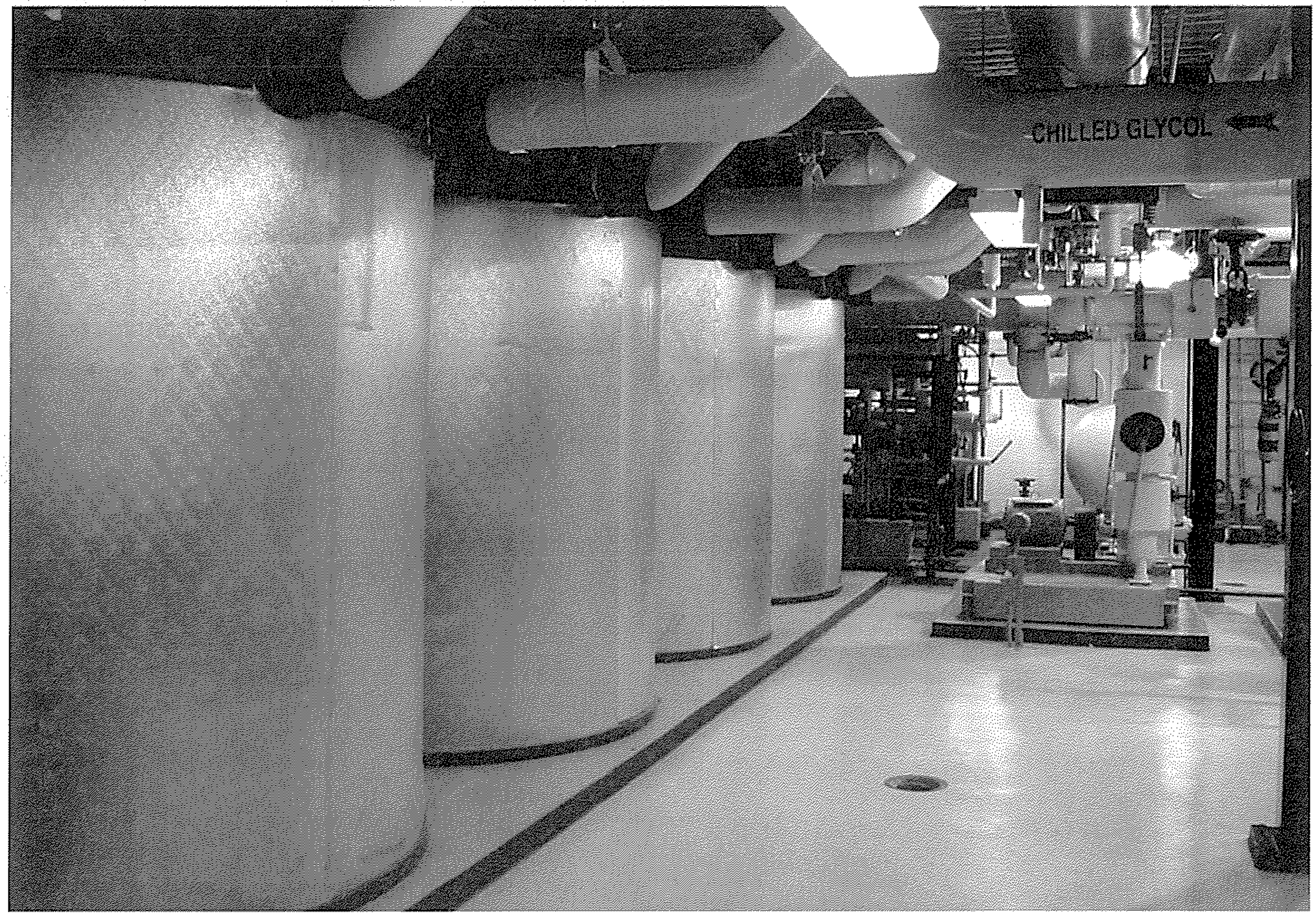
One Bryant Park





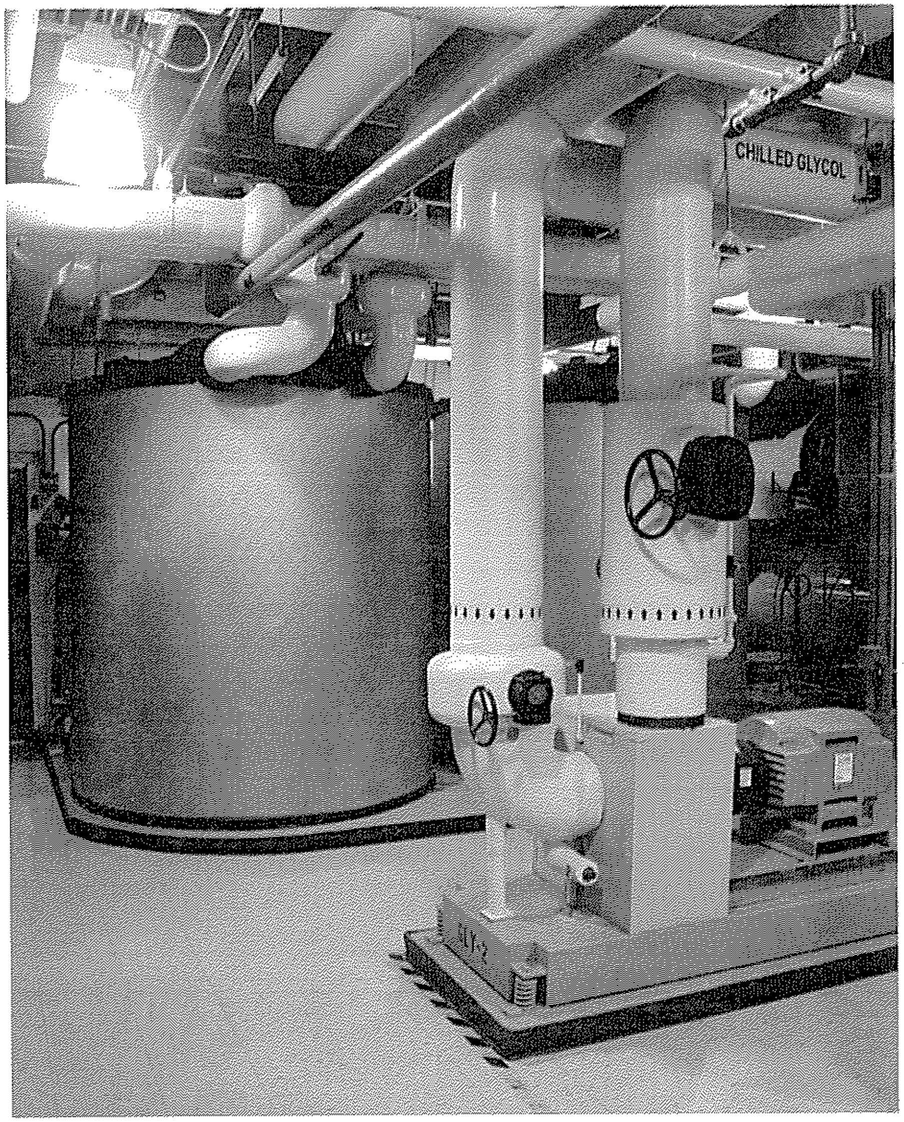
- Ice Storage Tanks – Installed Capacity – 7500 Ton-Hrs
- Equates to a 500kW demand reduction over 10hrs

1155 Avenue of the Americas



- Ice Storage Tanks – Installed Capacity – 3200 Ton-Hrs
- Equates to a 200kW demand reduction over 10hrs

Ice Storage



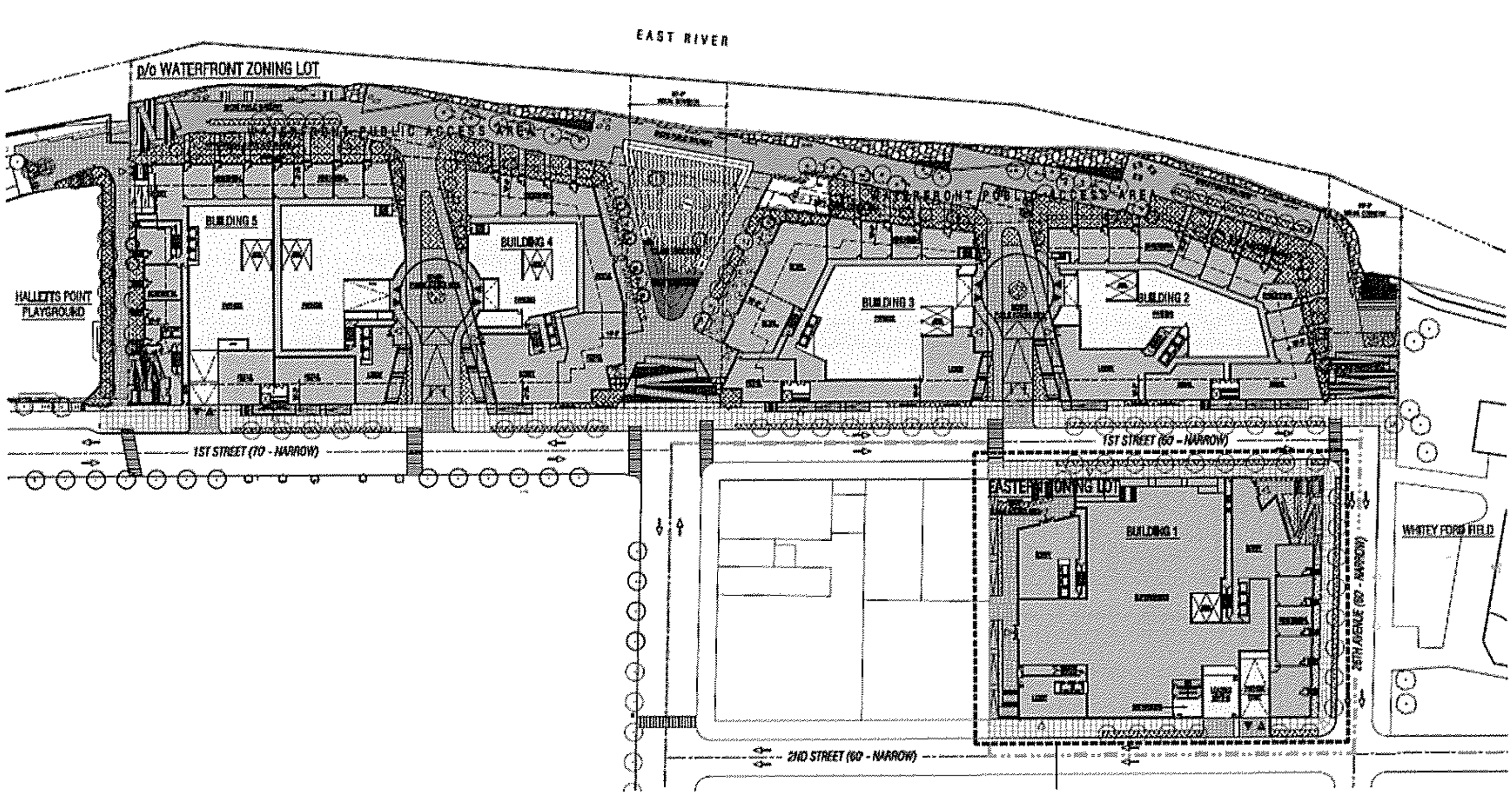
PROS
- Offsets peak energy load to off-peak
- Save marginal peak carbon
- Economically feasible

CONS
- Large footprint
- Requires 24hr watch operating engineer

The Durst Organization
1915-2015
CELEBRATING 100 YEARS

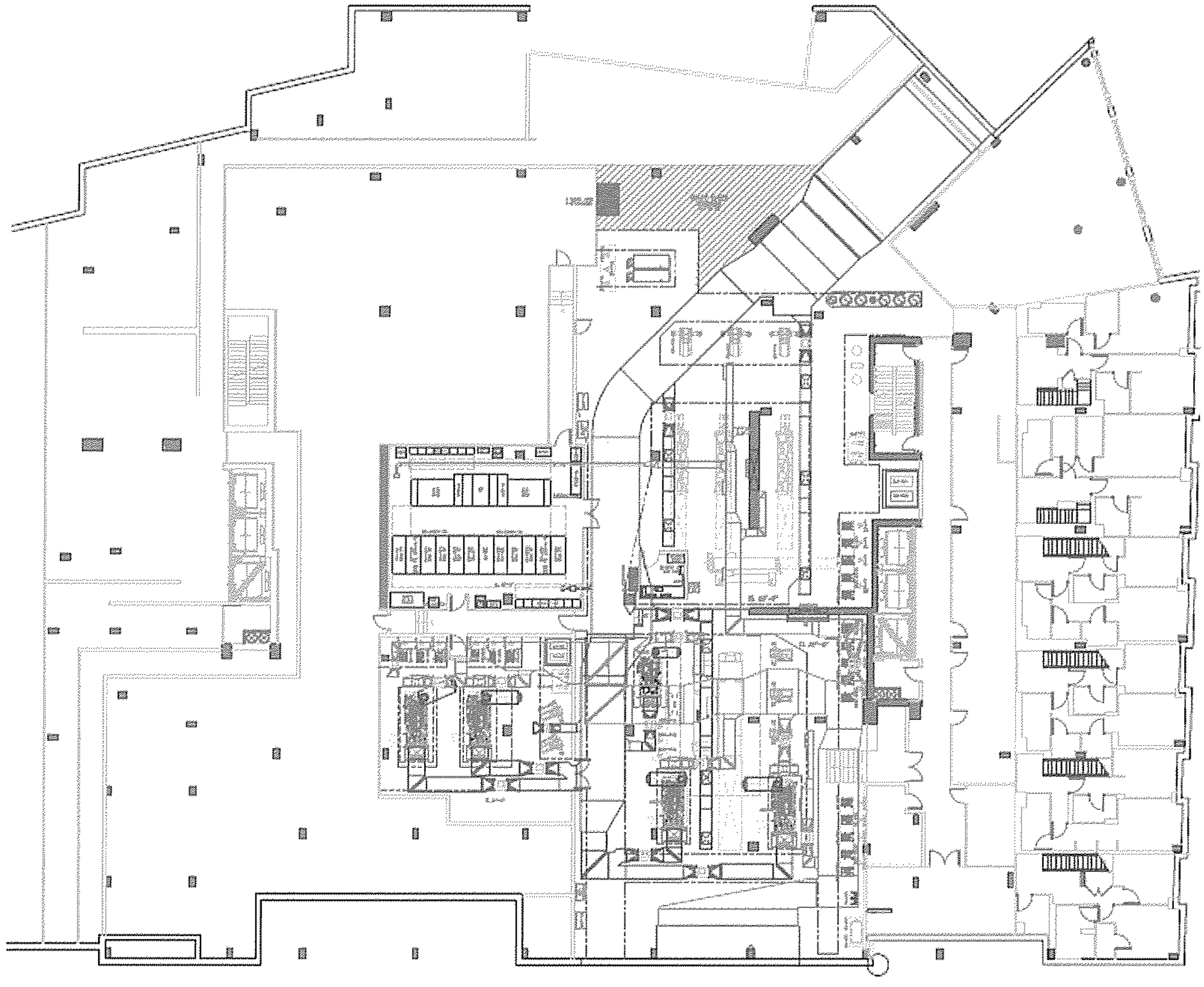
Projects Under Development

Halletts Point – Distributed Micro Grid

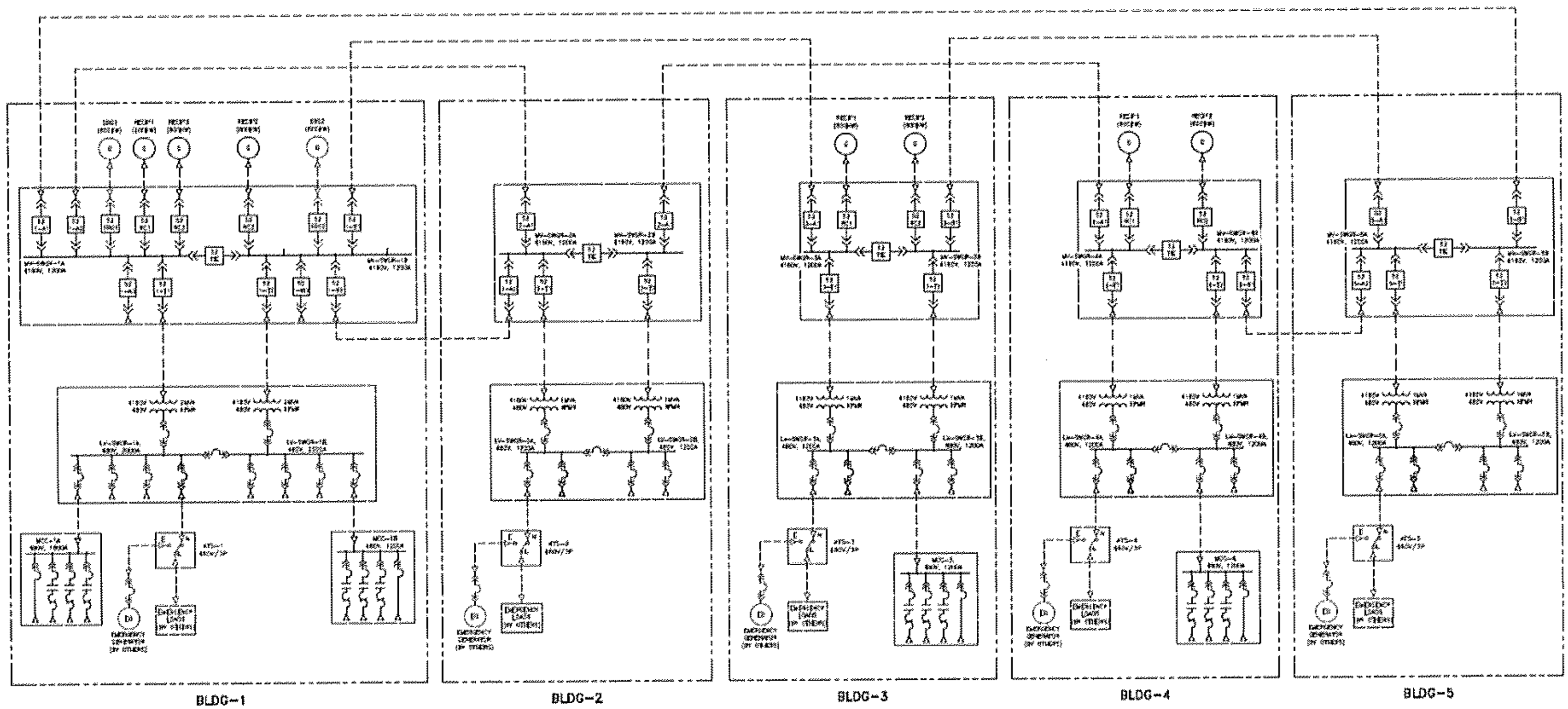


- 3 CHP Plants to Supply 5 Buildings (2.1M Sq.Ft., 1800 Apartments)
- 6.8MW total installed capacity
- N+2 Redundancy – Capacity (Similar to Con Ed)
- 2N Redundancy – Distribution Between Buildings
- Provide Electricity for the entire facility
- Provides Hot Water & Chilled Water to apartment FCU's
- Residents charged for chilled water at discounted rate
- $0.06 worth of gas to make $0.30 worth of electric
- $23M increase in Capital Cost
- 9 Year Payback

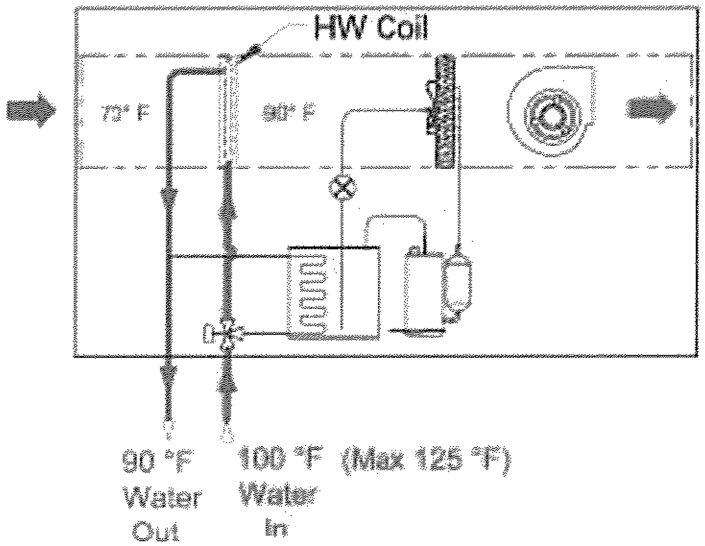
Halletts Point – Building 1 Plant Layout



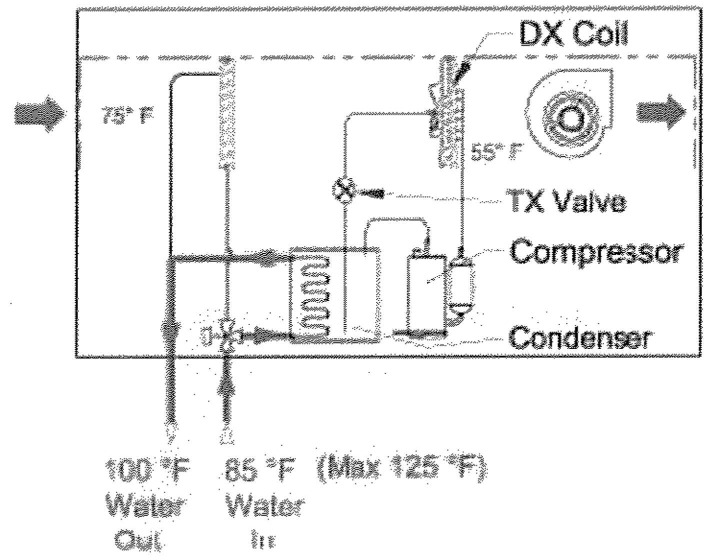
Halletts Point – Electrical Diagram



855 Avenue of the Americas & 625 West 57th Street



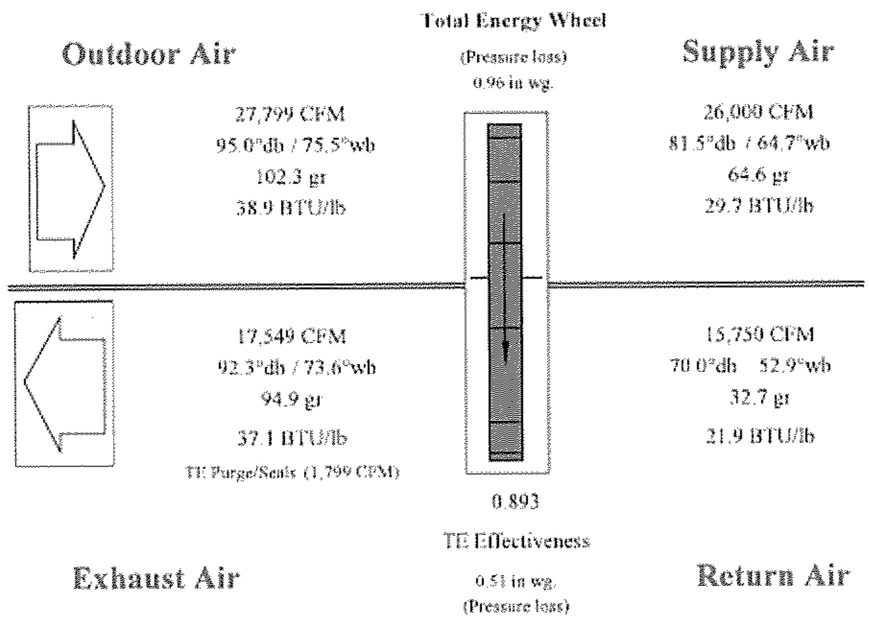
Fan Coil in Heating Mode

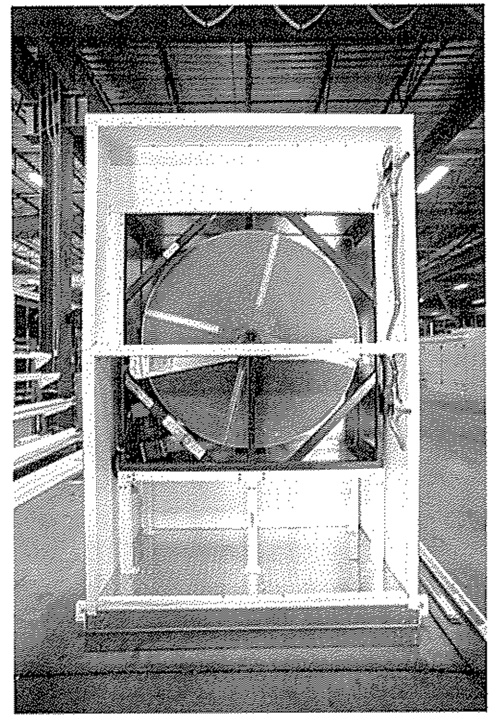


Water-Cooled AC in Cooling Mode

- Use of hybrid heat pumps with condensing boilers
- Summer Operation - Water-Cooled AC Unit
- Winter Operation – Hot Water Fan Coil Unit
    - Low Temp Hot Water w/Lower Tem Return Water
    - Provides best efficiency when used with Natural Gas-fired Condensing Boilers

Energy Recovery
855 Avenue of the Americas & 625 West 57th Street





- Energy Recovery Units with Energy Wheels used to transfer heat from the spill air to temper outside air without mixing air-streams.
- Winter Operation – Heat rejected from the office space DX units is transferred to the residential apartment hybrid heat pumps in lieu of rejecting the heat out of the building via the cooling towers. Saves gas by not having to fire the boilers to make up that heat to the apartments.

The Durst Organization

Thank you.

The Place for Small Scale Solar Generators in our plans for a renewable future

Chris Mejia

Consolidated Solar

chris@consolidatedsolar.net

consolidatedsolar.net

717-884-2204

Consolidated Solar is a small business that provides mobile solar generators for a variety of customers including fairs, festivals, construction sites, agricultural uses, and telecom. Our generators can power a small house, they operate day and night, they require no fuel, they are completely silent, and they produce zero emissions. The units are small solar microgrids mounted on a trailer. The panels produce power from the sun, the energy is stored in a battery, and we can plug into the outlets to provide power for any number of uses. Mobile solar generators can replace gas and diesel generators in many applications and we hope to see greater adoption of this technology as time goes on.

In the aftermath of Superstorm Sandy we had the privilege of working with DC Solar Solutions, SolarCity, and SolarOne.org to deploy small solar generators to some of the hardest hit areas. As you know these areas were without power for weeks. Some families were lucky enough to have small portable gas generators, these were very noisy, smelly, prone to theft, and required gasoline to operate, which was difficult to find.

The solar generators that we provided required no fuel and made no noise. They simply produced clean electricity from sunlight and stored it in batteries for people to use around the clock, whenever they needed it. Families were able to charge their cell phones, charge laptops, use hot plates to prepare meals, operate lighting, and watch movies. A strategy that contributed to the success of the Solar Sandy Project was a decision made early on to place the generators in communal areas like parks, shelters, food banks, and other areas where people were congregating. This allowed us to share this resource with a great number of people, many whom only needed a small amount of power to charge their phone or laptop.

Cell phone charging is something we take for granted today. For so many people cell phones are so much more than a simple phone, they are a lifeline to the world, to friends and family, to business concerns, and a source of news and entertainment. The most popular use of our solar generators across the board was cell phone charging, and it drove this point home for us.

We believe that on-site power production and storage is an important goal as we look to the future of energy management, and the ability for a building to disconnect from the grid in an outage situation has many well documented benefits. However we mustn't minimize the benefit of small autonomous power sources for minimal loads, and we encourage the development of small off grid solar solutions for cellphone and laptop charging. Small solutions can be placed next to bus stops, in parks, in front of municipal buildings, police stations, fire houses, etc.

We look forward to being part of the transition of our energy future, one that will see more distributed generation and storage, and one that will be less prone to failures and outages.

These are exciting times.

Thank you

Factors for Evaluating Heating Alternatives in New York State –DRAFT Work In Progress–

Bob Wyman
bob@wyman.us

February 26, 2015

Summary

On December 28, 2012, New York State Governor Andrew M. Cuomo issued Executive Order 88 which mandates a 20 percent improvement in the energy efficiency of State government buildings by April 2020. (20x20)[?] The New York State Energy Plan[?] calls first for a 50% reduction of energy sector CO_2 emissions by 2030 (50x30) and then an all-sector reduction in emissions of 80% by 2050 (80x50). Additionally, both the Mayor of New York City and its City Council have accepted the goal of reducing that City's carbon emissions 80% by 2050 (80x50).[?]

Reductions in the direct, point-of-use combustion of fossil fuels will be essential in meeting these goals as fossil fuel combustion is responsible for the bulk of both energy production and carbon emissions in this State. Today, direct, point-of-use combustion of fossil fuels is generally more expensive than using electrically powered alternatives. The cost advantage of fossil-free alternatives will only increase as our easily accessed reserves of fossil fuels are exhausted. Fossil fueled systems also use energy less efficiently than grid-powered systems, such as heat pumps, which harvest readily available site-sourced renewable energy. When combined, the fact that fossil fuels are more expensive, dirtier, and less efficient than the alternatives means that it is inevitable that we will eventually eliminate virtually all direct combustion of fossil fuels in buildings as well as in other sectors, such as transportation. It isn't a question of "if" we will replace fossil fuels, it a question of "when."

In order to rationally plan the achievement of the stated goals, it is necessary to use a variety of factors that characterize the efficiency and impacts of heating alternatives. This paper presents a number of such factors and attempts to provide some commentary to explain their utility and implications. These factors should be used together. No single factor is suitable for addressing the wide range of emissions, efficiency, and economic goals.

Many of the factors discussed in this document are summarized on page 2. That table contains factors for estimating:

- **Total Source Energy Consumption**: A measure of the amount of energy required to produce and deliver a unit of thermal energy to a site.
- **Fossil Source Energy Consumption**: A measure of the amount of fossil sourced energy which is consumed in the process of satisfying a site's need for thermal energy. In New York State, fossil fuel is used for less than 50% of electricity generation.
- **Renewable Energy Consumption**: A measure of the amount of energy, derived from renewable resources, which is consumed in the process of satisfying a site's need for thermal energy.
- **CO_2 Emissions**: A measure of the CO_2 emissions which will be produced per unit of useful heat in each of three eGrid sub-regions in the State.[?]
- **Social Cost of Carbon**: The estimated net present value of damages that will result from incremental carbon emissions. (Using Federal government standards)
- **Marginal Cost** (fuel costs): The marginal cost, primarily fuel costs, associated with operating the various heating systems (Not including cost associated with capital financing or maintenance).

Even a quick scan of the computed factors shows that ground source heat pumps (GSHP) are the most efficient and cleanest alternatives in most areas of the state. In some contexts, GSHP may be impractical, however, it is clear that they should always be considered and should often be the preferred alternative.

Table 1: Summary of Factors for Evaluating Alternative Heating Systems in New York State

Heating Equipment Type	Energy Consumed per Unit of Useful Heat			CO_2 Emissions (lbs/kWh) in eGrid Sub-Region			Cents/kWh$_t$ Useful Heat NYS Avg	Cents/kWh$_t$ Social Cost of CO_2 NYS Avg
	Source Energy	Fossil Energy	Renewable Energy	NYC[1]	Upstate	Long Island		
Grid Delivered Electricity[2]				0.66	0.58	1.42		1.12
Energy Star Tier 3 GSHP								
Closed Loop Water-to-Air	0.93	0.46	0.56	0.18	0.16	0.39	5.5	0.31
Open Loop Water-to-Air	0.81	0.41	0.59	0.16	0.14	0.35	4.8	0.27
Closed Loop Water-to-Water	1.08	0.54	0.52	0.21	0.19	0.46	6.3	0.36
Open Loop Water-to-Water	0.95	0.48	0.55	0.19	0.17	0.41	5.6	0.32
DGX[3]	0.93	0.46	0.58	0.18	0.16	0.39	5.4	0.31
Energy Star ASHP								
Split Systems	1.39	0.70	0.45	0.28	0.24	0.59	8.2	0.47
Single Unit	1.43	0.71	0.44	0.28	0.25	0.61	8.4	0.48
Energy Star Furnace								
Oil Furnace	1.19	1.19	0	0.65	0.65	0.65	15.9	1.16
Gas Furnace (North)	1.10	1.10	0	0.42	0.42	0.42	5.4	0.74
Installed Alternatives								
All Heat Pumps (Avg)	1.39	0.70	0.45	0.28	0.24	0.59	8.2	0.47
Electric	3.34	1.67	0.22	0.66	0.58	1.42	19.6	1.12
Oil Furnace	1.29	1.29	0	0.71	0.71	0.71	17.3	1.26
Propane Furnace	1.29	1.29	0	0.61	0.61	0.61	16.4	1.07
Gas Furnace	1.28	1.28	0	0.49	0.49	0.49	6.2	0.86

Note: The values shown in this table are discussed at length in later sections of this document.

[1] New York City shares an eGrid sub-region with Westchester County.

[2] The values for Grid Delivered Electricity measure only the emissions produced in generating the electricity and delivering it to the "meter" at the ultimate site of use.

[3] "Direct GeoExchange," alternatively known as "Direct Exchange" or DX.

Contents

List of Tables

List of Figures

1 Summary

New York State has the second lowest per-capita energy consumption of any US State and the lowest per-capita spending on energy.[?] Yet, we waste well over half of all the source energy resources that we consume.[1] Even though over half of New York's electricity is generated using "clean" or renewable resources, we lead the nation in consumption of oil for home heating and we rank fifth in the nation for total consumption of both natural gas and petroleum. Because we burn so much fossil fuel in this state, we rank ninth for production of the CO_2 emissions that drive Climate Change.

We can, and must, do better. Doing better will mean doing things differently than we have in the past. In particular, it is essential that we dramatically reduce, if not eliminate, our reliance on fossil fuels as the means used to deliver energy to end-use applications. We must transition to an energy system in which energy is delivered, not as fossil fuel, but as electricity, generated using clean, renewable resources.

Electricity is not the problem Today, only about one-third of New York's energy demand[2] is satisfied by electricity. The bulk of our end-use energy needs, two-thirds of the total, is satisfied by fossil fuels – mostly natural gas and petroleum. That fuel is burned, at point-of-use, primarily to serve our needs for transportation and heating and is the source of most of our CO_2 and greenhouse gas emissions.[3] The burning of that fuel is also the primary source for many of the other pollutants, such as PM2.5 and heavy metals, whose impact on our health and environment are much more immediate than Climate Change.

While much attention is given to the problem of reducing emissions from the electrical sector, it is clear that there is much greater potential for emission reductions in the transportation and heating sectors.

Even if our entire electrical sector were converted to clean, renewable resources, that would only eliminate 23% of our State's current CO_2 emissions. If we then used that clean electricity to power our transportation sector, the result would be a further reduction of emissions by an amount equal to 40% of today's total emissions. Using clean power to replace fossil fuels for heating in residential and commercial applications would reduce emissions by 31% of today's emissions. Clearly, the greatest opportunities to reduce emissions are found in the transportation and heating applications. Supplying more and cleaner electricity is necessary, but it is not sufficient unless we also switch the bulk of end-use demand from fossil fuels to electricity.

Electric vehicles and heat pumps are inevitable Fortunately, there is nothing about fossil fuels that uniquely suits them to addressing our needs for transportation and heating.

We know how to produce practical electric vehicles that are more efficient and generate fewer emissions than fossil fueled vehicles. When the full cost of ownership is considered, there are already electric vehicles that are cheaper to own and operate than comparable conventional vehicles.[4] As the electric vehicle industry matures and grows, this will become commonplace and the cost advantage of internal combustion vehicles will be lost forever.

We also have decades of experience with electrically powered heat pumps which are more efficient than fossil fueled alternatives and, in many parts of the country, including New York State, are often much cheaper to own and operate than fossil fueled systems.

As the price of fossil fuels inevitably increases, the cost advantage of electrically powered alternatives will only grow. As the environmental and health damage from fossil fuel combustion accumulates and grows more evident, we will become increasingly unwilling to accept the continued use of fossil fuels. The result is inevitable. We will eventually insist that fossil free technologies replace our existing vehicles and furnaces.

[1] In Figure ??, which shows data for 2008, wasted energy is shown on the right side as "Rejected Energy." Usefully consumed energy is shown as "Energy Services."

[2] "Energy Services" in Figure ??

[3] See Figure ??

[4] "As a result of federal subsidies and falling battery prices, some models, such as the Mitsubishi iMiEV and the Nissan Leaf SE, have an upfront price lower than comparable conventional vehicles. Even more vehicles are cost competitive when considering the total cost of ownership because they offer considerable fuel and maintenance savings. " See Figure 3.5 in [?].

The transition will take time The transition from fossil fuels to cleaner alternatives will take time. Awareness of the problems caused by fuel combustion is growing slowly and the cost advantage of the more efficient and cleaner alternates is not yet widely understood. In any case, because vehicles and heating equipment are expensive, we can't expect existing equipment to be replaced more rapidly than the natural replacement rate unless there are significant fossil fuel price shocks or new mandates.

In New York State, a building's heating equipment has a normal life of about 20 years. Thus, we can expect that about 5% of buildings will normally overhaul their heating/cooling systems in any one year. For the auto industry, the replacement rate is about 17% per year. We expect cars to be replaced every five or six years. These rates establish the maximum expected rates at which systems that consume fossil fuels might be eliminated, however, the actual rates will be much lower unless government acts to encourage higher rates of replacement.

The Second Great Electrification The First Great Electrification of our nation focused on lighting, communications, and appliances. It created the industry that now provides a bit less than one-third of the energy consumed in end-use applications. The Second Great Electrification will focus on our transportation and heating requirements – the remaining two-thirds of our energy demand. When we're done with this second phase of electrification, larger than the first, we will have built a society that runs almost entirely on clean, renewable energy generated with low marginal costs.

Revenue will flow from fossil fuels to electricity The economic impact of the Second Great Electrification will be tremendous and overwhelmingly positive for most of society, but one of the most significant impacts will be a massive transfer of revenue from the fossil fuel industry to the electric industry.

As noted earlier, two-thirds of the energy purchased for end-use in New York State is delivered in the form of fossil fuels. The same pattern holds across most of the country. As a result, the fossil fuel producers top the world's lists of high revenue businesses and the countries that host large fossil fuel reserves, even though they often have highly repressive regimes and few other products of value, are among the richest. Those producers will still have markets for their products even after a complete transition of the energy sector to fossil fuel free systems, but their sales and revenues will be greatly reduced. They will still provide much of the feedstock for the massive chemicals and plastics industries, but most of their energy revenue will have been transferred to others who will provide cleaner energy more cheaply, more sustainably and in a more distributed fashion.

The transfer of revenue away from the fossil fuel producers may be one of the most significant economic shifts that we'll experience during our lifetimes. While much of the money will flow to the large electrical utilities and their suppliers, much of it will also flow, at least in the form of savings, to the millions of individuals and businesses who will invest in solar, wind, geothermal or other forms of site-sourced energy generation.

Later in this paper, it is shown that a conversion from fossil fueled heating to heat pump systems in just those single-family homes that do not currently heat with natural gas has the potential to increase New York State electric utility revenues by up to $2 billion per year[5] while also reducing individual's annual energy bills by up to $4 billion per year.[6] Most of that increased revenue and savings would come as a result decreased fossil fuel industry revenue.

From pay-as-you-go to pay-for-capacity In a world which relies primarily on fossil fuels, consumers are able to purchase energy and have it delivered as they need it. They buy energy "Just in Time" or close to it. Thus, the costs of any fossil fueled system are spread across its lifetime. There is an up-front cost to purchase the combustion equipment, but that cost is typically quite low compared to the accumulated marginal cost of fuel purchases over the equipment's lifetime. For many, this spreading of costs over time provides a real advantage because it allows deferring the cost of energy investment to a time closer to the need for energy consumption.

[5] See: Table ??
[6] See: Table ??

A key attribute of the fossil-free energy systems is that they have extremely low marginal costs but high up-front capital costs. The sun's light, the wind, geothermal energy and tidal power are all essentially "free" fuels. The expense of producing clean, renewable energy comes primarily from the up-front cost of building and installing the equipment needed to "harvest" the bounty of free energy resources. This is true whether you are building a large, utility-scale wind farm, a roof-top solar panel, or a home's heat pump system. With these renewable systems, most of the expensive comes up-front and the marginal costs are either zero or very low when compared to the marginal costs of fossil fuels.

In a fossil-free world which relies on renewable energy, you, or someone else, will need to pay up-front for the energy that you will consume over the lifetime of your equipment. These costs will be lower than those for fossil fueled systems, but they will be timed less conveniently. Since few individuals or businesses can afford to pay in advance for decades of energy consumption, what we'll see is that the financial and leasing industries, who deploy long term capital, will become much more important than they traditionally have been in the energy business.

As we move from pay-as-you-go to pay-for-capacity, the economics of the end-use energy market will begin to look much more like that of the real estate and vehicle markets. When you choose to buy a house rather than rent, you are choosing to assume the cost of many years of housing rather than paying for housing a month at a time. If you can afford to buy the house, you might do so. Otherwise, you might finance the purchase and pay the up-front costs over time. Similar decisions are made when you choose between hiring a taxi, leasing a vehicle or buying one. In the future, it is likely that the more wealthy among us will purchase their fossil-free energy systems while the rest of us will seek to lease or finance them. While this will be a change from today's custom, it will result in reduced long-term expenses for all of us.

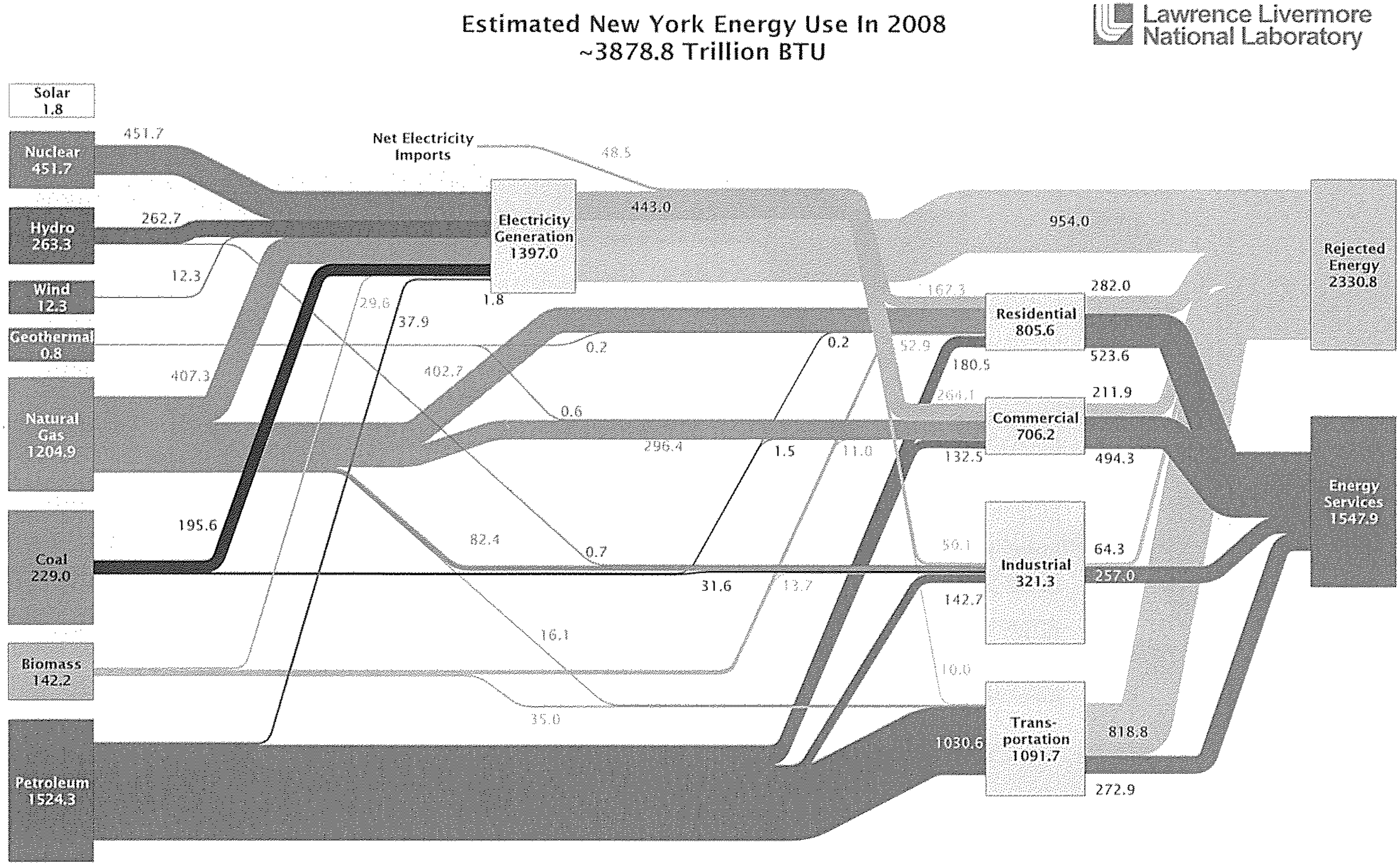
1.1 Plan for this document

While reducing fossil fuel use for both transpiration and heating is important, the focus of this paper is on those factors that should be considered when comparing heating systems that rely on direct, on-site combustion of fossil fuels to those that do not. The combustion-free systems considered here are primarily those that rely on heat pumps.

This draft of the paper is incomplete. Later versions will expand on and improve the discussion here. The latest version of the document will be found at: `http://goo.gl/ziZojH`

1.2 Commenting on this document

Comments on this, or any other draft are welcome if sent to bob@wyman.us. Please include the date of the paper in any correspondence.



Source: LLNL 2010. Data is based on DOE/EIA-0214(2008), June 2010. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for non-thermal resources (i.e., hydro, wind and solar) in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. Interstate and international electricity trade are lumped into net imports or exports and are calculated using a system-wide generation efficiency. End use efficiency is estimated as 65% for the residential, 70% for the commercial, 80% for the industrial sector, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Figure 1: Estimated New York Energy Use in 2008

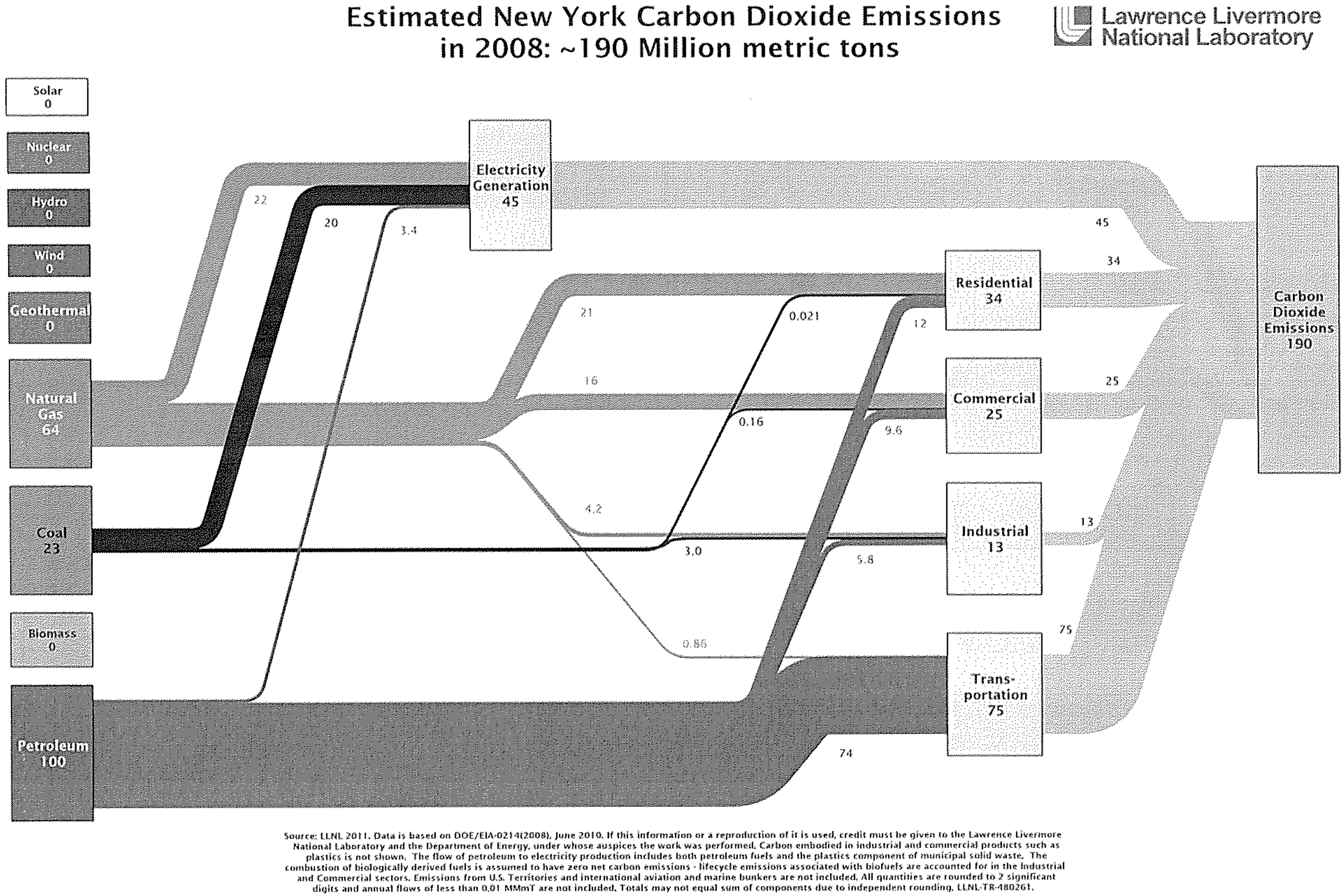


Figure 2: Estimated New York Carbon Emissions in 2008

2 Heating Alternatives

A broad range of methods can be used to improve the efficiency of buildings or reduce the emissions that are associated with their operation. For instance, improvements to building envelopes, more efficient lighting or the installation of intelligent building energy management systems can all have dramatic impacts on both a building's efficiency and its emissions. But, while increased efficiency will reduce buildings' energy requirements and thus their need to consume fossil fuels, they do not eliminate that need. In order to eliminate fossil fuel combustion, we must transition to fossil-free alternatives. Thus, the focus of this paper is to assess the costs and benefits associated with both fossil fueled and fossil-free heating alternatives.

It will be shown that while there might once have been a time when fossil-fueled heating alternatives were considered to be the only practical method of heating our buildings, that is no longer the case. Today, systems that rely on electrically powered heat pumps can satisfy our heating needs with minimal or no harmful emissions and lower costs compared to fossil fueled systems – even when those heat pumps are powered by electricity delivered by the electric grid and generated, at least in part, by burning fossil fuels. Heat pump systems that are powered by site-sourced or grid-supplied renewable energy are, essentially, emission-free.

The four general classes of heating equipment alternatives considered in this paper are:

- New Ground Source Heat Pumps (GSHP) also known as "Geothermal Heat Pumps."
- New Air Source Heat Pumps (ASHP)
- New Oil and Natural Gas Furnaces
- Installed Systems (Heat Pumps and Oil, Propane, or Gas Furnaces)

In later sections, these classes of equipment will be characterized in terms of their performance, emissions, and cost factors and will be compared to show which among them are likely to produce the fewest emissions, the lowest operating costs, etc. Ground Source Heat Pumps will be shown to excel in all of the various comparisons considered in this document.

Metrics for Comparison A confusing variety of metrics are commonly used to describe the performance of heating equipment or to measure the consumption of energy. The energy inputs and outputs of fuel-based heating systems are usually measured in units of BTU (British Thermal Units), while those of electrical systems will typically be measured in kWh (kilowatt-hours). The efficiency of heating systems may be described using "SEER", "HSPF", "EER", or "COP." However, in order to make comparisons easier and more understandable, this paper converts all measures of energy to kWh[7] and all efficiency metrics to a common "Coefficient of Performance (COP)."

What is meant by COP and the implications of its definition are discussed in the next section.

2.1 Coefficient of Performance (COP)

"COP" or "Coefficient of Performance" is used throughout this paper to describe the efficiency of heating systems. The COP of a heating or cooling system is a ratio of the heating or cooling provided to the energy consumed in doing so. COP values are normally shown as decimal numbers (e.g. 3.1, 0.95, etc.). Higher COPs indicate higher efficiency. The COPs of fossil fuel systems can never rise above 1 (i.e. 100% efficiency) while the COPs of heat pump systems are normally significantly greater than 1. In fact, they commonly rise as high as 5 or even 6.

Moving heat, not making it Some confusion arises because COP values for heat pump systems are normally greater than 1.0 and so may appear to imply a clearly impossible system efficiency higher than 100%. The confusion is resolved by understanding that heat pumps are used to move energy from one place to another rather than, as with a combustion system, simply used to convert from one form of energy

[7] 1 kilowatt hour = 3,412.14163 BTU

to another (e.g. Combustion of fossil fuels converts chemical energy to thermal energy). Although the input electrical energy will be converted to heat and thus add to the output energy, when a heat pump is operating with a COP greater than 1.0, the bulk of the energy moved is harvested from the environment, not the input energy. When using a heat pump to heat, the energy harvested from the environment should be considered "renewable energy." The portion of renewable energy harvested by a heat pump system with a COP greater than 1 is calculated as $\frac{COP-1}{COP}$. (e.g. If the COP is 3, then $\frac{2}{3}$ or 66% of the thermal energy output came from renewable sources. If the COP is 4, then $\frac{3}{4}$ or 75% of the output came from renewable sources.)

Alternatives to COP COP is not universally used to characterize heating and cooling equipment. A variety of other measures are commonly used. These include:

- AFUE (Annual Fuel Utilization Efficiency): $(Average(Btu_{out}/Btu_{in}))$ Commonly used to describe systems that burn fossil fuels such as oil, propane or gas furnaces. AFUE is the average thermal efficiency of the combustion equipment over a year. Given the constraints of the laws of physics, an AFUE value will always be less than 100%.
- EER (Energy Efficiency Rating): (Btu_{out}/Wh_{in}) Commonly used to describe air source heat pumps and air conditioners, the EER is the ratio of output cooling or heating energy (in BTU) to input electrical energy (in watt-hours) under specific conditions.
- SEER (Seasonal Energy Efficiency Rating): $(Average(Btu_{out}/Wh_{in}))$ SEER is the average EER over a cooling season. It is the ratio of cooling energy (in BTU) during a typical cooling-season divided by the total electric energy input (in watt-hours) during the same period. In New York, the cooling season extends from April through September.
- HSPF (Heating Season Performance Factor): $(Average(Btu_{out}/Wh_{in}))$ Similar to the SEER, HSPF is the ratio of heat energy output (in BTU) over the heating season to the total electric energy (in watt-hours) consumed. In the New York, the heating season extends from October through March.

Fortunately, all of these measures can be converted to COP values. AFUE is converted to COP simply by converting the percentage value to a decimal value. Thus, an AFUE of 95% is converted to a COP of 0.95. Any of EER, SEER, or HSPF are converted to COP by dividing the value by 3.41214. Thus, an EER, SEER or HSPF of 8.2 would be converted to a COP, or average COP, of 2.4.

It should be noted that AFUE, SEER, and HSPF measure average performance over a period of time while EER and COP are instantaneous values that measure the performance of a system under specific conditions. Thus, while EER and COP are easily compared, it is somewhat problematic to compare either ERR or COP to any of the averages. Comparisons become particularly difficult when comparing air source heat pumps, which are typically characterized by HSPF or SEER, with ground source heat pumps, which are typically characterized by COP. During a typical heating season, the outside temperature varies significantly. While the performance of a ground source heat pump will be relatively constant throughout the heating season, the performance of an air source heat pump at any particular moment is correlated with the outside air temperature at that moment.

The impact of climate on SEER and HSPF It is entirely possible for an air source heat pump to run with a very high EER during milder periods but a very low EER during the coldest periods of the heating season. Air source heat pumps become proportionately less efficient as the outside temperature drops. Thus, the average EER (the HSPF) for the air source heat pump might be relatively high if the coldest periods of the heating season are relatively short or mild. The same variability of performance will be experienced during the cooling season.

As the outside air temperature increases above the desired inside temperature, the efficiency of an air source heat pump will drop. An air source heat pump's cooling efficiency will be lowest at precisely the time when the outside temperature, and load on the electrical grid, is at its peak. Similarly, an air source heat pump's heating efficiency will be lowest when the outside air temperature is at its lowest point.

Consider two identical buildings with identical air source heat pump systems. One is located in New York City and the other is located in Binghamton, NY. Assuming that both buildings maintain the same indoor temperature, for any given outdoor temperature, the two ASHP systems would operate at precisely the same EER or COP. However, we would expect that the New York City ASHP system would record a lower SEER and a higher HSPF than the ASHP in Binghamton.

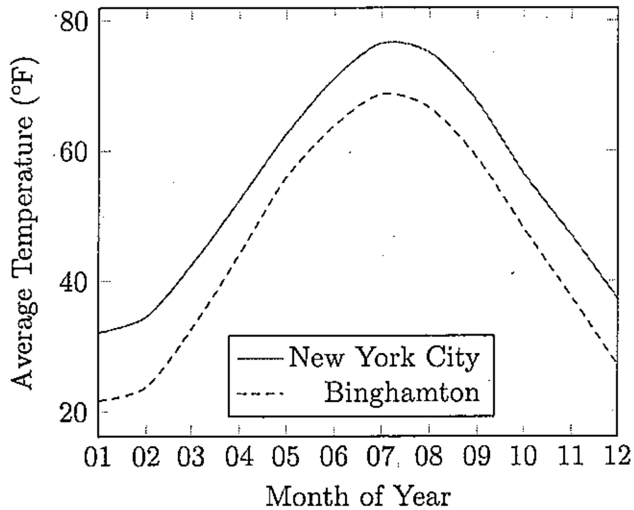


Figure 3: Average Temperatures In New York City and Binghamton, NY

Figure ?? plots the average temperature in each city throughout a typical year. Summers are hotter in New York City than in Binghamton, thus, an ASHP in that city will spend more time cooling during periods with higher outside temperatures and thus lower EERs than an ASHP in Binghamton. Also, the winters are warmer in New York City, thus, ASHP units in the New York City will spend more of the heating season running at higher EERs than would ASHP units in Binghamton. The difference in SEER and HSPF will be entirely attributable to the difference in the climates of the two cities, not to any differences in the installed equipment.

Formal definitions COP is defined formally using Equation ?? where Q is the amount of thermal energy (heat) moved to or from some reservoir and W is the "work" or energy consumed by the heat pump in moving the amount of heat represented by Q.

$$COP = \frac{Q}{W} \tag{1}$$

Clearly, if Q is greater than W (i.e. more energy was moved than was consumed in the process of moving that energy), then the COP will be greater than 1.0.

Maximum Theoretically Possible COP Given T_{hot}, the temperature in degrees Kelvin of a heat source, and T_{cold}, the temperature of a heat sink, we can use Equation ?? to compute the maximum theoretical COP for a perfectly efficient heat pump in heating mode as it moves heat from a heat source to a heat sink.[8]

$$COP_{heating} = \frac{T_{hot}}{T_{hot} - T_{cold}} \tag{2}$$

Similarly, the maximum theoretically possible COP in cooling mode can be found using Equation ??:

$$COP_{cooling} = \frac{T_{cold}}{T_{hot} - T_{cold}} \tag{3}$$

What these equations imply is that the COP of a heat pump system will vary as a function of the difference in temperature between the heat source and the heat sink. COP will be highest when there is no difference between the source and sink temperatures. COP will decrease as the difference in temperature increases.

Using the Equation ??, we can see that the maximum theoretically possible COP for a ground source heat pump in heating mode would be 33.2 (see Equation ??) if the ground temperature was 56°F (286.5°K)

[8] Check any physics book for the appropriate derivations.

and a building's desired temperature or set point was 72°F (295.4°K). An air source heat pump would have the same maximum theoretically possible COP if the outside air temperature were also 56°F.

$$COP_{heating} = \frac{T_{hot}}{T_{hot} - T_{cold}} = \frac{295.4}{295.4 - 286.5} = 33.2 \quad (4)$$

If the outside air temperature were 32°F (273.2°K), the ground source heat pump would still operate at a COP of 33.2 but the air source heat pump's COP would be reduced to 12.3.

It should be noted that actual heat pumps operate at COPs that are much lower than those which are theoretically possible for perfect systems. Commonly measured COPs for heat pump systems usually vary between 1 and 5. Nonetheless, understanding the behavior of these systems in theory allows us to better appreciate how they operate in the real world.

Comparing GSHP and ASHP COPs To further illustrate the theoretical difference between air-coupled systems and ground-coupled systems, consider Figure ?? which plots the maximum theoretical COP for both air source and ground source heat pumps when the building's set point is at 72°F.

The COP of an air source heat pump varies greatly as the outside temperature moves above or below the set point while the COP of a ground source heat pump is stable since it is coupled to the ground, whose temperature is relatively constant whatever the air temperature may be at any point in time. Given the plotted conditions, a ground source heat pump will, in theory, operate at a higher COP than an air source heat pump whenever the outside air temperature is higher than about 90°F or lower than 56°F.

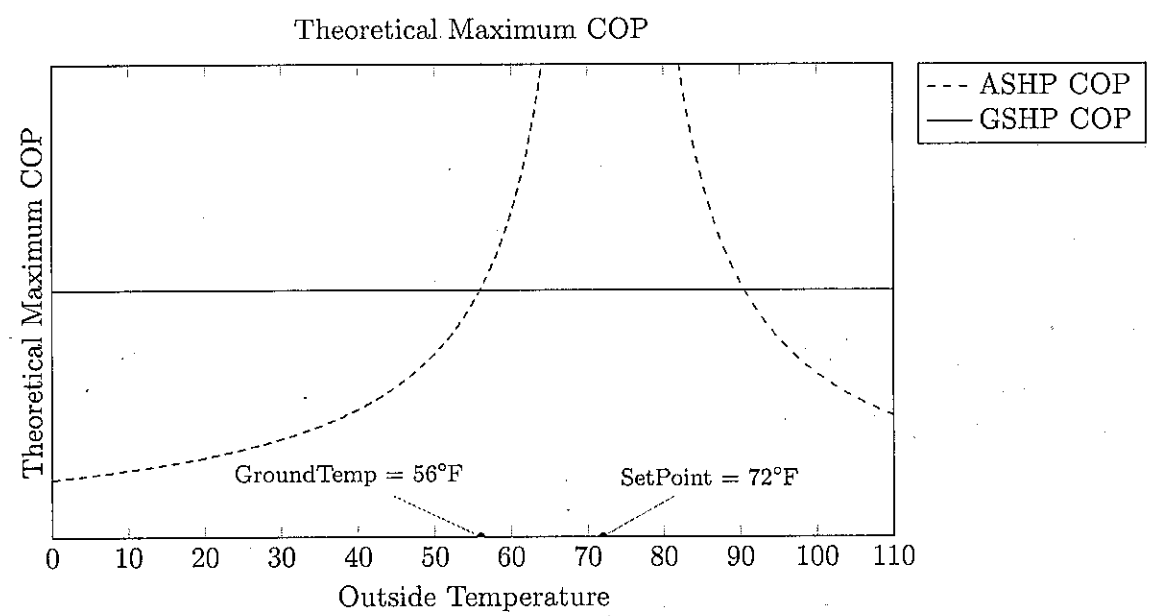


Figure 4: Maximum Theoretically Achievable COP for Heat Pump Systems

Impact of Ground Temperature on GSHP Performance While ASHP performance is dependent on outside air temperature, the performance of a GSHP unit is dependent on the ground temperature. A GSHP system, when cooling a building, is pumping heat from that building into the ground. Over time, this warms the ground. A GSHP system, when heating a building, pumps heat from the ground into the building. This cools the ground. As the ground temperature temperature gets closer to the building's set point, the GSHP COP will increase. it will decrease as the ground temperature moves away from the set point.

Figure ?? attempts to illustrate these relationships. The top red line repeats the average temperature plot for New York City as shown previously in Figure ??. During the April to September cooling season, the GSHP system will be heating the ground. During the October to March heating season, the GSHP system will be cooling the ground. The second, blue line shows the plot of ground temperature over time for one possible building. The bottom line shows the maximum theoretically possible average monthly COP for the GSHP system given the average ground temperature during that month.

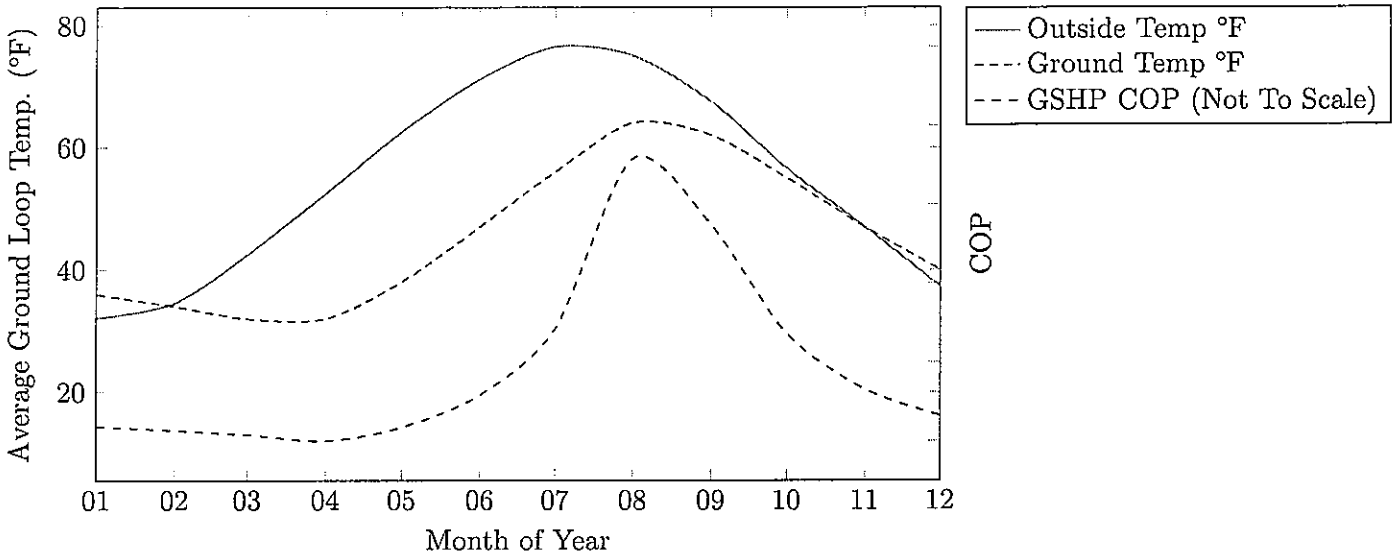


Figure 5: NYC Ground Temperature and COP Over Time

A properly designed and installed GSHP system will ensure that the ground temperature achieves a constant average from year to year. If the system's cooling load doesn't balance its heating load, the ground will tend to get warmer from year to year, driving up the average ground temperature and reducing performance. A similar effect will result if the system's heating load exceeds the cooling load. The ground will become progressively cooler and performance will diminish.

2.2 Energy Star Minimum Criteria

The EPA Energy Star program defines minimum performance criteria for Ground Source Heat Pumps[?], Air-Source Heat Pumps[?] and for both oil and gas furnaces[?]. These criteria are summarized in Table ??.

Table 2: Energy Star Minimum Criteria Heating Equipment

Energy Star Minimum Criteria for Heating Equipment					
Equipment Type	AFUE	HSPF	SEER	EER	COP
Energy Star Tier 3 GSHP					
Closed Loop Water-to-Air				17.1	3.6
Open Loop Water-to-Air				21.1	4.1
Closed Loop Water-to-Water				16.1	3.1
Open Loop Water-to-Water				20.1	3.5
DGX (Direct GeoExchange)				16.0	3.6
Energy Star ASHP					
Split Systems		8.2	14.5	12.0	2.4[1]
Single Package & gas/electric package units		8.0	14.0	11.0	2.34[1]
Energy Star Furnaces					
Oil Furnace	85%				0.85[1]
Gas Furnace (North)	95%				0.95[1]
Gas Furnace (South)	90%				0.90[1]

[1] Not specified by Energy Star. Calculated either by converting AFUE to a decimal or by dividing HSPF by 3.41214.

EPA Energy Star minimum criteria are either required by law or are required to qualify for benefits such as tax incentives. Since it is unlikely that less efficient systems will be installed in the future, these criteria are a reasonable approximation for the minimum efficiency of new systems. Note: Energy Star criteria apply only to residential equipment, not commercial or industrial equipment.

Energy Star defines minimum, not normal, values Heat pump and furnace installers typically install equipment that is more efficient than required by Energy Star. For instance, it is common today to find Ground Source Heat Pump systems with a COP greater than 4 and even reaching to 5 or 6. However, the EPA Energy Star Tier 3 minimum COP values relied upon in this document only range from 3.1 to 4.1. In a conservative analysis such as this one, it is best to rely on Energy Star minimum requirements to ensure validity for all applications.

Adjusting HSPF values for New York's Climate The HSPF values defined by Energy Star should not be used, without adjustment, to predict air-source heat pump system performance in New York State.[9] This is because they are calculated assuming climate conditions that are not typical of New York State. As shown earlier, HSPF and SEER values are dependent on local climate conditions.

The EIA publishes a "Heating Fuel Comparison Calculator" that can be used to adjust standard HSPF ratings to those expected given local conditions in three New York cities.[?] The adjusted values are shown in Table ??.

Table 3: Energy Star ASHP COP Values Converted for use in New York

	8.0 HSPF		8.2 HSPF	
Location	Adjusted	COP	Adjusted	COP
Albany	5.3	1.6	5.4	1.6
Buffalo	5.8	1.7	5.9	1.7
New York (JFK)	6.6	1.9	6.8	2.0

The HSPF values for systems installed in New York City require less adjustment than those for systems installed elsewhere in the State. This is because New York City, along with Westchester County and Long Island, falls within "Climate Zone 4." The climate conditions used in computing standard HSPF values are most like those that would be expected to occur in parts of Climate Zone 4. But, even within a single Climate Zone, there is significant variability of conditions.

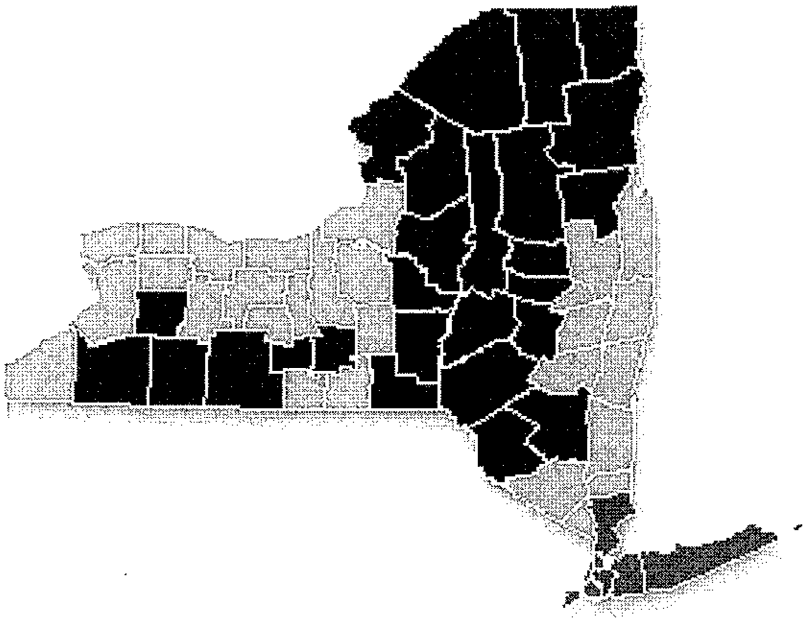
Most of New York State falls within either Climate Zone 5 or Climate Zone 6. The division of the State's counties into their Climate Zones is shown in Figure ?? on page ??.

To Do: The rest of this paper uses the standard, unadjusted HSPF values for ASHP performance. Thus, the performance of ASHP systems in New York State is overstated. The emissions and marginal costs of AHSP systems are understated. Future drafts of this paper will attempt to select more appropriate adjusted values for ASHP performance. However, it is expected that doing so will not significantly change the relative ranking of the alternatives considered here.

Note to Policymakers: The need to adjust published HSPF and SEER values to local conditions can make it difficult to prepare regulations describing state-wide performance targets based on published equipment ratings. One method for eliminating this difficulty would be to require that installed systems include monitoring and verification equipment that measures both input and output energy. From this

[9] [?] states: "The rated/nameplate HSPF from ARI 210/240 is based on the temperature in Climate Region IV (2000-2500 heating load hours) and the minimum Design Heating Requirement (DHR) that is a function of machine heating capacity. ... Although published HSPFs are linked to this climate, and specifically to 2080 heating load hours, **it was never envisioned that this single value could be used to generically predict performance for all climate locations.**"

Figure 6: New York Climate Zones



Note: The green areas, including Long Island, New York City and Westchester County, are in Climate Zone 4. The Light Blue areas are in Climate Zone 5 and the Dark Blue areas are in Climate Zone 6. These classifications conform to the International Energy Conservation Code (IECC) Climate Regions scheme. If the Building America scheme is used, then the Climate Zone 4 counties would be classified as "Mixed-Humid" while counties in Zones 5 and 6 would be classified as "Cold."[?]

data, actual building-specific HSPF or SEER values would be derived. Then, laws and regulations could be written tying rebates, credits, incentives, etc. to the actual system performance rather than to the theoretical system capabilities.

If policy makers were to determine that an actual HSPF of 10.6 (average COP of 3.1) was sufficient to justify incentives, they could simply require that those incentives be conditional on the availability of verifiable system log data demonstrating actual performance.

Alternatively, the incentives could be scaled to increase from a minimum level to some maximum as system performance increases. The Energy Tax Reform Proposal submitted by US Sen. Baucus might serve as a model for such scaled incentives.[10] In that proposal, systems which were at least 25% or more superior to average installed systems would be eligible for some incentive. The amount of incentive would then rise to a maximum in proportion to how much the installed system exceeded the minimum target.

Tying incentives to actual performance would encourage building owners to install the most efficient, affordable system rather than tending to prefer the least expensive system that qualifies for incentives. Also, such a scheme would encourage the use of monitoring equipment and thus facilitate better maintenance and operation of equipment.

2.3 Installed System Performance – Historical Data

Table 4: Old Equipment COPs

Equipment Type	COP
Electric Resistance	1.0
Oil Furnace	0.78
Propane Furnace	0.78
Gas Furnace	0.82

The performance values which are used in this document to characterize existing installed systems are taken from EIA reports of average values for equipment that has been historically installed and is still in operation.

Because the efficiency of all equipment is improving, the Installed System metrics will always be "worse" than those of new Energy Star

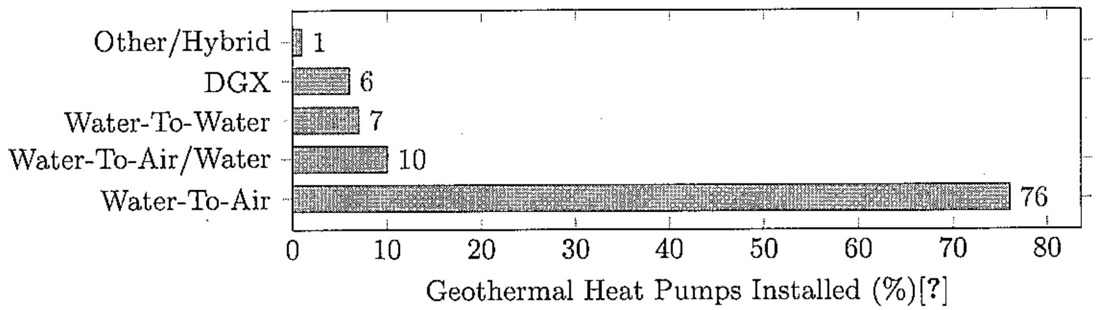
[10] http://www.finance.senate.gov/newsroom/chairman/release/?id=3a90679c-f8d0-4cb6-b775-ca559f91ebb4

Compliant systems. Some installed systems are more efficient than average and others are less efficient.

One should recognize that these average values may not be representative of the metrics that apply to any specific installed system. Manufacturer's specifications and operating histories should be consulted.

Distribution of Installed GSHP Units by Type: A recently completed survey sponsored by the U.S. DOE indicates that the most commonly installed GSHP systems are of the most efficient type: Water-To-Air.[?] However, this was a national survey and may not reflect actual patterns in New York State.

Figure 7: Distribution of Installed GSHP Units by Type



2.4 Alternatives Not Analyzed in this document

Not all alternatives are discussed at length in this document although some may, in fact, be appropriate given the special circumstances of specific buildings. Some of the excluded alternatives are listed below:

- Wood and other biomass: While biomass may be appropriate in a small number of niche applications, the social costs associated with large scale reliance on such fuel would prove to be unacceptable. In order to be "carbon neutral," biomass may only be consumed at a rate at or below the rate at which new biomass is created. Thus, its use simply can't be scaled up enough to replace the tremendous amount of fossil fuels currently used in our state. In any case, the burning of wood and biomass produces a variety of pollutants other than carbon.
- Passive House Design:[?] While the principles for Passive House design should be more widely followed, most practical Passive House systems will require some form of powered heating and cooling system at least to provide supplemental HVAC or space/water heating during exceptional conditions. Thus, while Passive House dramatically reduces the need for HVAC energy, it does not eliminate it. Those building Passive House compliant buildings should still consider the fossil free alternatives discussed here.
- Solar Thermal: Electrically powered solar thermal systems can provide substantial amounts of renewable thermal energy for use in HVAC and water heating systems. However, such systems are typically insufficient to address the full requirements of most buildings. Thus, they are expected to be used primarily as supplemental source of thermal energy, often in combination with GSHP systems.
- New Electric Resistance: Electric Resistance systems are discussed here only as an existing technology that should be replaced in all but niche applications or when used to provide supplemental or emergency heat.
- Combined Heat and Power (CHP): CHP systems increase the efficiency of fuel combustion by exploiting the waste heat produced while generating electricity. Such systems, particularly when their electricity is used to power Ground Source Heat Pumps, can be very efficient. However, they appear to be suitable for only a minority of buildings or in district heating systems.

- District Heating and Thermal Mini-Grids: District Heating and Cooling systems, such as the New York City steam network[?] or the many systems relied upon in Europe, have existed for more than 700 years, with the first commercially successful modern district heating system deployed in Lockport, New York in 1877 by Birdsall Holly's *Holly Steam Combination Company.*[11] While there is a great potential for such systems, the focus of this paper is on site-specific HVAC alternatives.

3 Energy Consumption

New York energy consumption is briefly described in the following subsection. In later subsections, a number of "Energy Consumption Factors" are described and computed in order to allow comparison of various equipment choices based on the amount of Source, Fossil and Renewable energy that they consume for each unit of useful heat produced.

3.1 Total Energy Consumption

Residential Market The EIA Residential Energy Consumption Survey for 2009 found 7.2 million residential households in New York State. Their total energy consumption is summarized in Table ??.

Table 5: New York State Residential Space Heating Fuel Consumption (w/2009 Consumption Rates)

	Electricity	Oil	Propane	Natural Gas	All
Total Energy Consumption (QuadBtu)	0.007	0.138	0.006	0.256	0.407
Total Energy Consumption (GWh)	2,051	40,443	1,758	75,026	119,279
Average Energy Consumption (kWh/HH[1])	1,368	18,384	17,584	17,863	14,910
Price per kWh (2013 $)	0.19	0.13	0.13	0.05	0.081
Total Cost (2013 $ billions)	0.389	5.257	0.228	3.751	9.627
Average Expenditures (2013 $/HH)		2,390	2,286	893	1,203
Households (HH) using fuel (millions)	1.5	2.2	0.1	4.2	8[2]
As Primary fuel	0.5	2.1		4.1	6.7
As Secondary fuel	1	NA[3]		0.3	1.3
Total CO_2 Emissions (million metric tons)	0.825	13.025	0.486	16.675	31.012

[1] HH = Household
[2] There were only 7.2 million households found during the 2009 RECS. However, since some households use more than one fuel, there is some over-counting.
[3] Because electric heat is primarily used as a secondary heat source, it doesn't make sense to compute an average expenditure.

Commercial and Industrial Good numbers for the commercial and industrial markets don't seem to exist. The most recent published EIA Commercial Buildings Energy Consumption Survey (CBECS)[12] covers 2003. Results for 2012 CBECS are currently scheduled to be published prior to Fall/Winter 2015.

3.2 Source Energy Consumption

It takes energy to generate and deliver energy to an end-use site. For every unit of energy delivered, some additional energy must been consumed in the process of extracting that energy, converting it to the form in which it is delivered, transmitting or shipping it, etc. Because of this, any measure of the amount of energy consumed at a particular site is a very poor measure of the total amount of energy that was consumed in order to make that on-site consumption possible.

[11] `http://www.districtenergy.org/in-our-second-century-of-service`
[12] `http://www.eia.gov/consumption/commercial/index.cfm`

If energy is delivered as electricity and is generated by burning fossil or nuclear fuel in order to drive steam generators, the low efficiency of the steam generators will result in two units of energy being converted to waste heat for every one unit of electricity that is made available for delivery. Steam turbines in use today typically run with about 33% efficiency. Thus, for every one unit of energy delivered as electricity, fuel containing three units of "source energy" will be consumed if that electricity is generated using steam turbines. On the other hand, if electricity is generated using hydro, solar or wind generators, that electricity is made immediately available for transmission over the electric grid. As a result, these non-steam generators are able to deliver close to one unit of electricity for every unit of "source energy" they produce. Whatever the means for generating the source electricity, there will be some loss of energy as a result of transmitting that electricity through the electric grid.

When energy is delivered as fossil fuel for combustion at point-of-use, in order to estimate the amount of "source energy" consumed, we must adjust the delivered quantity to include the fuel used in delivering that fuel. For instance, the fuel used in the trucks that delivered the fuel or the energy used to pump the fuel through pipelines. We should also add in the energy costs of extracting and refining the fuel.

3.2.1 Source Energy Factors

For each type of fuel, or means of delivering energy to an end-use site, we can use "Site to Source Conversion Factors" or Source Energy Factors to estimate the amount of Source Energy consumed in the process of delivering each unit of delivered energy. Thus, grid-supplied electricity, oil, gas, etc. will all have their own Source Energy Factors.

A variety of estimates for Source Energy Factors or Source-To-Site Ratios are in common use. The most well-known are probably those used by the EPA's Portfolio Manager system.[?] However, in New York State, *Executive Order 88 Guidelines*[?] dictates in its Appendix D different factor values to be used when measuring energy savings in New York State owned buildings.[13]

A number of Source Energy Factor estimates are shown in Table ??. The Executive Order 88 Source Energy Factors are used in this document since they appear to reflect state policy, if not reality.

Table 6: Source Energy Factors (aka: Source-Site Ratios)

	Source Energy Factors		
Delivered Fuel Type	EO 88	EPA-PM[1]	NREL-2007[2]
Electricity (grid purchase)	3.34	3.14	3.011[3]
Electricity (on-site Solar or Wind)	1.0	1.0	1
Fuel Oil (#2, #4, or #6)	1.01	1.01	1.158
Propane and Liquid Propane	1.01	1.01	1.151
Natural Gas	1.047	1.05	1.092

[1] National average values used in EPA Energy Star Portfolio Manager.[?]
[2] Based on NREL study, Revised 2007 [?]
[3] New York specific estimate for 2004 from Table B-9 in [?]

3.2.2 Source Energy Consumption Factors

Given these Source Energy Factors and estimates, such as those provided by Energy Star or EIA ratings, for the efficiency of heating equipment, we can compute Source Energy Consumption Factors for a variety of heating alternatives. These factors will allow us to compare alternatives according to the amount of Source Energy that they will consume for every unit of useful heat provided to the building – after considering all production, transmission, distribution and on-site energy losses. If one is attempting to increase the

[13] It should be noted that the EO 88 Source Energy Factor for electricity appears to be rather high for a state like New York that has such a low percentage of electricity generated by steam turbines. It is likely that the actual Source Energy Factor for New York's electricity is much lower than required by EO 88. The use of such a high value diminishes the estimated value of grid-powered solutions while improving the apparent benefits of fossil fueled alternatives.

efficiency of a building, one should prefer solutions that have lower Source Energy Consumption Factors, whatever the Source Energy Factor may be for the energy used to power the alternative.

Source Energy Consumption Factors are calculated using Equation ??.

$$SourceEnergyConsumptionFactor = \frac{SourceEnergyFactor}{SystemCOP} \tag{5}$$

For instance, using Equation ??, we can see that the Source Energy Consumption Factor for an existing Fuel Oil system, which has a Source Energy Factor of 1.01 and a COP of 0.78 in existing installations, would be $\frac{1.01}{.78}$ or 1.3. On the other hand, a new heat pump system would have a much higher Source Energy Factor, 3.34 rather than 1.01, but also a higher COP, perhaps 4.1 rather than 0.78. Given these numbers, the Source Energy Consumption Factor for the heat pump would be lower than that for the Fuel Oil system. It would be: $\frac{3.34}{4.1}$ or 0.81. The heat pump system would consume about 37% less source energy when compared to the oil furnace.

Figure ?? plots the Source Energy Consumption Factor for the various alternatives. All grid-powered heating alternatives, including ASHP, GHSP, solar thermal, and electric resistance systems, will fall on the curve plotted in that figure. A subset of the data in tabular form in Table ?? on page ??.

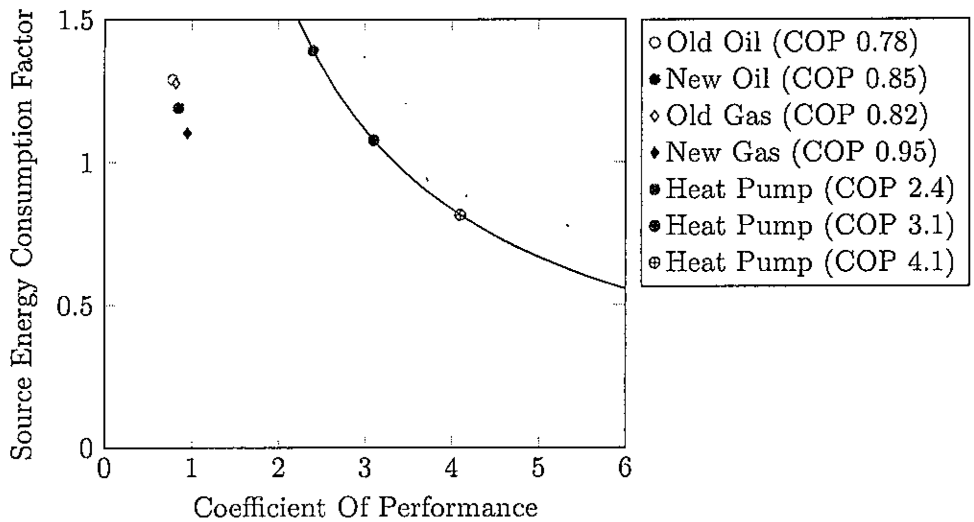


Figure 8: Source Energy Consumption Per Unit of Useful Heat Output

3.2.3 Relative Source Energy Consumption

The lowest expected Source Energy Consumption will come from installing new Energy Star compliant, ground source heat pumps. Second best would be to install Energy Star compliant fossil fueled systems. Air Source Heat Pumps that meet only the minimum Energy Star criteria would not be useful unless the alternatives were infeasible or if the current heating source was Electric Resistance.

Even though ASHP units appear to be less desirable when only Source Energy consumption is considered, one should be aware that ASHP units are available that have higher efficiency than the Energy Star minimums. Such units might suit a building's needs and allow Source Energy Consumption to be reduced. On the other hand, ASHP will often require Electric Resistance heat backup to compensate for ASHP's reduced efficiency at low temperatures. The use of this backup will increase source energy consumption during periods of exceptional heating demand. Even so, when factors discussed later in this document, such as emissions and fossil fuel consumption are considered, ASHP units will be shown to be generally superior alternatives to systems that rely on direct combustion of fossil fuels even though they will be ranked lower than GSHP units on all measures other than up-front cost.

For those designing measures to achieve specific minimum reductions, such as the 20% source energy reduction required by Executive Order 88, it may be more useful to show the percentage reductions in Source Energy consumed for each of the possible replacement alternatives.

Table 7: Source Energy Consumption Factors and Ranks for New York State

New Heating Equipment Type	Site Energy Efficiency (COP)	Total Source Energy: Source Energy Factor	Consumed Per Unit Heat	Consumed Energy Rank[1]
Energy Star Tier 3 GSHP				
Closed Loop Water-to-Air	3.6	3.34	0.93	2
Open Loop Water-to-Air	4.1	3.34	0.81	1
Closed Loop Water-to-Water	3.1	3.34	1.08	5
Open Loop Water-to-Water	3.5	3.34	0.95	4
DGX	3.6	3.34	0.93	2
Energy Star ASHP				
Split Systems	2.4	3.34	1.39	11
Single Unit	2.34	3.34	1.43	13
Energy Star Furnace				
Oil Furnace	0.85	1.01	1.19	7
Gas Furnace (North)	0.95	1.047	1.10	6
Installed Alternatives				
All Heat Pumps (Avg)[2]	2.4	3.34	1.39	12
Electric	1	3.34	3.34	14
Oil Furnace	0.78	1.01	1.29	9
Propane Furnace	0.78	1.01	1.29	9
Gas Furnace	0.82	1.047	1.28	8

[1] Rank among the alternatives with "1" indicating the lowest consumption.
[2] This "average" COP for heat pumps historically installed in New York State is taken from the NYSERDA study entitled *Energy Efficiency and Renewable Energy Potential Study of New York State, Volume 2: Energy Efficiency Methodology and Detailed Results*. The source of the estimate is not obvious from reading that paper.[?]

A relative Source Energy Consumption measure can be computed using Equation ??.

$$RelativeSourceEnergyConsumption_{alt-1} = \frac{SourceEnergyConsumptionFactor_{alt-1}}{SourceEnergyConsumptionFactor_{alt-2}} \tag{6}$$

As shown in Table ??, replacing fossil fueled systems with ground source heat pumps provides significant reductions in Source Energy Consumption. However, if Electric Resistance Heat is currently installed, then even a conversion to oil or gas heat (if gas service is available) can provide substantial reductions in Source Energy Consumption even though other impacts would be negative. (e.g. Fossil Source Energy Consumption would increase and the use of renewable energy would decrease.)

3.2.4 Source Energy Consumption Break Even COP

Given the Source Energy Consumption Factor (SECF) for one alternative and the Source Energy Factor (SEF) for second, we can compute the COP at which the second alternative will consume the same amount of Source Energy as the first; when the Source Energy Consumption Factor for the two alternatives will be the same. This COP value is known as the "Source Energy Consumption Break Even COP" and can be calculated using Equation ??.

$$SECF_2 = SECF_1 \text{ when } COP_2 = \frac{SEF_2}{SECF_1} \tag{7}$$

Using Equation ??, we can see that the Source Energy Consumption Break Even COP will be 2.578 when we are comparing an electrically powered heating system (having Source Energy Factor 3.34) to an

Table 8: Total Source Energy Reductions By Replacing Old Equipment

New Heating Equipment Type	Total Source Energy Reduction By Replacing Old Equipment				
	Old Heat Pumps	Electric	Oil Furnace	Propane Furnace	Gas Furnace
Energy Star Tier 3 GSHP					
Closed Loop Water-to-Air	33%	72%	28%	28%	27%
Open Loop Water-to-Air	41%	78%	37%	37%	36%
Closed Loop Water-to-Water	23%	68%	17%	17%	16%
Open Loop Water-to-Water	31%	71%	26%	26%	25%
DGX	33%	72%	28%	28%	27%
Energy Star ASHP					
Split Systems	0%	58%	-7%	-7%	-9%
Single Unit	-2%	57%	-10%	-10%	-12%
Energy Star Furnace					
Oil Furnace	15%	64%	8%	8%	7%
Gas Furnace (North)	21%	67%	15%	15%	14%

old oil furnace with COP of 0.78. Any electrically powered heating system with a COP greater than 2.578 will consume less Source Energy than an old oil furnace with a COP of 0.78.

A number of Source Energy Consumption Break Even COP values are computed in Table ??.

Table 9: Source Energy Consumption BreakEven COPs (Assuming 3.34 SEF for Electricity)

	Oil		Natural Gas	
	Old	New	Old	New
BE/COP for Grid-Powered System	2.578	2.809	2.616	3.031

3.3 Fossil Source Energy Consumption

The Source Energy Factors discussed in the previous section may be useful in evaluating the efficiency of a building, but they tell us very little about other factors of interest such as fossil fuel or renewable energy consumption. Thus, this document suggests consideration of a number of additional consumption factors, including the Fossil Source Energy Factor, the subject of this section, and the Renewable Source Energy Factor, which will be discussed later.

3.3.1 Fossil Source Energy Factor

The Fossil Source Energy Factor is a measure of the amount of source energy produced by the combustion of fossil fuel. Measures which consume less Fossil Source Energy than others will benefit the State by reducing demand for fossil fuels as well as by reducing the emissions and other externalities associated with fossil fuel combustion.

Clearly, a fossil fuel's Fossil Source Energy Factor will be equal to its Source Energy Factor. But, for systems powered by electricity, the Fossil Source Energy Factor of the electricity delivered to them will depend on the specific mix of resources used to generate the delivered electricity. If the source of electricity is site-sourced solar PV, wind, etc. then the Fossil Source Energy Factor will be zero. Computing the Fossil Source Energy Factor for grid-supplied electricity requires consideration of the grid's electricity generation resource mix.

Electricity Generation Resource Mix A Fossil Source Energy Factor for the electricity delivered in New York State can be found by considering the mix of generation resources used in the State. The analyses in this document rely on the EIA eGrid data, most recently reported by EIA for 2010 and shown in Table ??.

Table 10: Electricity Generation Resource Mix (%), (2010 eGRID Data)

eGRID Region	Coal	Oil	Nat Gas	Other Fossil	All Fossil	Nuc-lear	Hydro	Bio-mass	Wind	Renew-able
NYC/Westchester	0	1.3	57.4	0.5	59.2	39.9	0.5	0	0.5	1
Long Island	0	6.9	85.5	3.6	96.0	0	4.0	0	0	4
Upstate	15.3	0.8	22.2	0.3	38.3	28.9	28.2	1.6	2.7	32.5
New York State	9.9	1.5	35.7	0.7	47.8	30.6	18.2	1.6	1.9	21.7
United States	44.8	1.0	24	0.4	70.2	19.6	1.4	6.2	2.3	9.9

When added together, the various fossil sources (Coal, Oil, Gas, and Other Fossil) comprise about 47.8% of electricity generation within the three New York eGrid subregions during 2010. Thus, to compute the Fossil Source Energy Factor for grid supplied electricity in New York State, one would multiply the Source Energy Factor of the grid (3.34) by .478 and so arrive at a value of 1.6.

Fossil Source Energy Factors in each of New York's grid subregions The Fossil Source Energy Factor for each of New York's sub-grids can be computed by dividing the Source Energy Factor for electricity delivered from those sub-grids by the portion of their electricity that is generated from fossil fuel sources. In reality, each of the New York sub-grids has a unique Source Energy Factor, however, for this analysis, we will follow the common practice of attributing the same Source Energy Factor to all grid-supplied electricity. Given this assumption, Table ?? estimates the Fossil Source Energy Factor for electricity delivered by each of New York's grids.

Table 11: Fossil Source Energy Factor For Delivered Electricity (using 2010 eGRID Data)

eGRID Region	Source Energy Factor	Fossil Fuel Generation %	Fossil Source Energy Factor
NYC/Westchester	3.34	59.2	1.98
Long Island	3.34	96.0	3.21
Upstate	3.34	38.6	1.29
New York State	3.34	47.8	1.60
United States	3.34	70.2	2.34

3.3.2 Fossil Source Energy Consumption Factor

The Fossil Source Energy Consumption Factor measures the portion of consumed energy which is derived from combustion of fossil fuels and is found using Equation ??. In general, solutions which have lower Fossil Source Energy Consumption Factor values should be preferred over those with higher values.

$$FossilSourceEnergyConsumptionFactor = \frac{FossilSourceEnergyFactor}{SystemCOP} \quad (8)$$

Fossil Source Energy Consumption Factors for New York State are plotted in Figure ?? and presented in tabular form in Table ?? on page ??.

Generation mix impacts all grid-powered solutions As the grid becomes increasingly fossil-free, its Fossil Source Energy Factor will decrease proportionally and so will the Fossil Source Energy Consumption Factor for all applications that rely on grid provided electricity. Thus, once applications have been converted to reliance on grid-supplied energy, the grid operators and regulators have the ability to take actions that

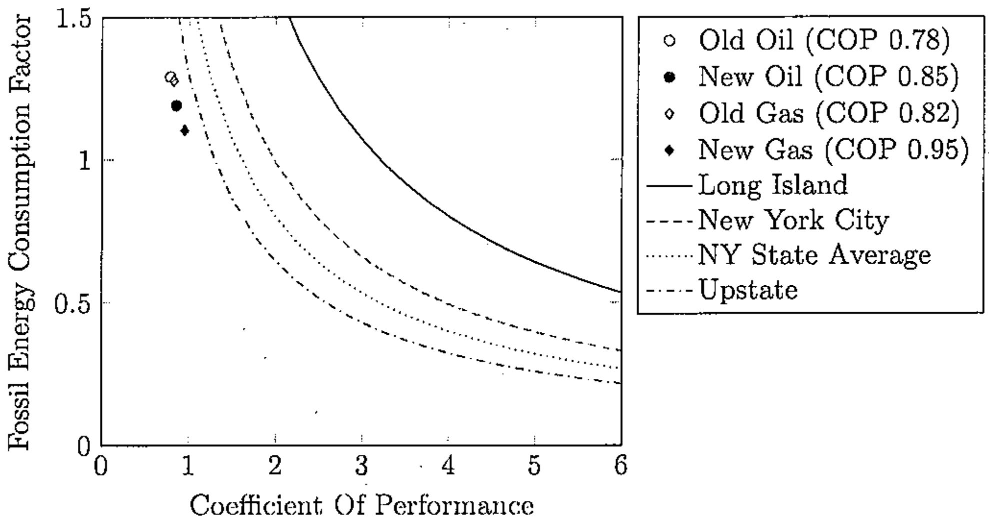


Figure 9: Fossil Source Energy Consumption Per Unit of Useful Heat Output

will reduce the Fossil Source Energy Consumption Factor for a very large number of energy consumers without those users even being aware of what is happening.

On the other hand, the Fossil Source Energy Consumption Factors for systems that rely on direct combustion of fossil fuels are completely independent of reductions in the grid's reliance on fossil fuels. While the Fossil Source Energy Consumption Factor for grid-powered systems should be expected to change over time, the consumption factor for fossil-fueled systems will be constant. For fossil fueled systems, the Fossil Source Energy Consumption Factor can only be reduced by replacing or upgrading the equipment – typically at the expense of the equipment owner.

Just as the Fossil Source Energy Consumption Factor for all grid-powered applications goes down as the portion of fossil fuels in the generation mix is reduced, the opposite effect holds. If the fossil portion of grid-power increases, so will the Fossil Source Energy Consumption Factor for all grid-powered applications.

Today, the fossil portion of the generation mix for the New York City/Westchester County grid is very low. It is so low in large part because the New York City grid gets 39.9% of its power from nuclear power. If the Indian Point nuclear plant were to be shut down and its portion of the generated power was replaced by fossil resources, probably natural gas, rather than non-fossil resources such as wind or solar, the Fossil Source Energy Consumption Factor for all grid-powered applications in New York City would increase dramatically.

3.3.3 Relative Fossil Source Energy Consumption

The relative benefits of heating alternatives change dramatically when we calculate the potential percentage reductions in Fossil Source Energy Consumption rather than computing reductions in Source Energy Consumption as in Section ??. For instance, while replacing existing equipment with ASHP units will increase Total Source Energy consumption in all cases except when replacing Electric Resistance systems, in most cases, installing ASHP units will reduce fossil source energy consumption. Similarly, conversions from existing existing heat pumps to Energy Star compliant oil or gas systems would reduce Source Energy Consumption but such conversions would increase fossil fuel consumption quite dramatically.

A relative Fossil Source Energy Consumption measure can be computed using Equation ??.

$$RelativeFossilSourceEnergyConsumption_{alt-1} = \frac{FossilSourceEnergyConsumptionFactor_{alt-1}}{FossilSourceEnergyConsumptionFactor_{alt-2}} \quad (9)$$

The Relative Fossil Source Energy Consumption factors, using New York State average values, are shown in Table ??. GSHP systems consume between 68% and 72% less fossil source energy when they are used to replace Electric Resistance heating systems and consume between 58% and 69% less fossil source energy when replacing fossil fueled systems.

Table 12: Fossil Source Energy Consumption Factors for New York State

New Heating Equipment Type	Site Energy Efficiency (COP)	Fossil Source Energy Consumption Factor			
		NYC	Upstate	Long Island	NY State Average
Energy Star Tier 3 GSHP					
Closed Loop Water-to-Air	3.6	0.55	0.36	0.89	0.44
Open Loop Water-to-Air	4.1	0.48	0.31	0.78	0.39
Closed Loop Water-to-Water	3.1	0.64	0.42	1.03	0.52
Open Loop Water-to-Water	3.5	0.56	0.37	0.92	0.46
DGX	3.6	0.55	0.36	0.89	0.44
Energy Star ASHP					
Split Systems	2.4	0.82	0.54	1.34	0.66
Single Unit	2.34	0.84	0.55	1.37	0.68
Energy Star Furnace					
Oil Furnace	0.85	1.19	1.19	1.19	1.19
Gas Furnace (North)	0.95	1.10	1.10	1.10	1.10
Installed Alternatives					
All Heat Pumps (Avg)	2.4	0.82	0.54	1.34	0.67
Electric	1.0	1.98	1.29	3.21	1.60
Oil Furnace	0.78	1.29	1.29	1.29	1.29
Propane Furnace	0.78	1.29	1.29	1.29	1.29
Gas Furnace	0.82	1.28	1.28	1.29	1.28

3.3.4 Fossil Source Energy Break Even COP

Given the Fossil Source Energy Consumption Factor (FSECF) for one alternative and the Fossil Source Energy Factor (FSEF) for a second alternative, we can compute the COP at which the second alternative will consume the same amount of Fossil Source Energy as the first; when the two Fossil Source Energy Consumption Factors will be the same. This COP value is known as the "Fossil Source Energy Break Even COP" and can be calculated using Equation ??.

$$FSECF_2 = FSECF_1 \text{ when } COP_2 = \frac{FSEF_2}{FSECF_1} \tag{10}$$

A number of Fossil Source Energy Consumption Break Even COP values are computed in Table ??.

Should Long Island increase minimum COP or decrease Fossil Source Energy Factor? Clearly, the Fossil Source Energy BreakEven COP values are highest on Long Island. Equipment installed on Long Island must be almost twice as efficient as the State average in order to achieve the same Fossil Source Consumption levels as are achieved in other parts of the States. This is, of course, because Long Island uses the highest portion of fossil fuels in its generation mix and thus Long Island's grid-supplied electricity has the highest Fossil Source Energy Factor in New York State. As will be seen later, this high reliance on fossil fuels results in Long Island's grid-powered solutions producing CO_2 and other emissions at higher rates than in other parts of New York State.

Fortunately, even though the BreakEven COPs for heat pumps on Long Island are high, they are still lower than the minimum COPs criteria established for GSHPs by Energy Star regulations. Thus, any Energy Star compliant GSHP installed in place of a fossil fuel furnace on Long Island will, in fact, reduce the use of fossil fuel for heating.

Those who seek to reduce Long Island's reliance on fossil fuels to a point similar to that of other parts of New York State have two primary policy options available to them:

Table 13: Fossil Source Energy Reductions By Replacing Old Equipment

	Fossil Source Energy Reduction By Replacing Old Equipment				
New Heating Equipment Type	Old Heat Pumps	Electric	Oil Furnace	Propane Furnace	Gas Furnace
Energy Star Tier 3 GSHP					
Closed Loop Water-to-Air	33%	72%	64%	64%	64%
Open Loop Water-to-Air	41%	78%	69%	69%	68%
Closed Loop Water-to-Water	23%	68%	58%	58%	58%
Open Loop Water-to-Water	31%	71%	63%	63%	63%
DGX	33%	72%	64%	64%	64%
Energy Star ASHP					
Split Systems	0%	58%	46%	46%	46%
Single Unit	-2%	57%	45%	45%	44%
Energy Star Furnace					
Oil Furnace	-71%	29%	8%	8%	7%
Gas Furnace (North)	-58%	34%	15%	15%	14%

Table 14: Fossil Source Energy BreakEven COP for Grid-Powered Alternatives in New York State

Fossil BreakEven COP for Grid-Powered Alternatives in NYS						
	When Replacing					
eGrid Region	Oil		Propane		Gas	
	Old	New	Old	New	Old	New
NYC/Westchester	1.5	1.7	1.5	1.7	1.6	1.9
Upstate NY	1.0	1.1	1.0	1.1	1.1	1.2
Long Island	2.5	2.7	2.5	2.7	2.6	3.0
NY State Average	1.3	1.4	1.2	1.4	1.3	1.5

- Require that Long Island residents install heat pumps with higher COPs than would be required in other parts of the state.
- Reduce the use of fossil fuels in generating electricity on Long Island. (For instance, by adding solar or wind power to the Long Island grid.)

Either policy can lead to similar reductions in fossil fuel use, however, heat pumps with higher than normal COPs are typically more expensive than those with lower COPs. Given this, it is likely that the residents of Long Island will not think kindly of regulations that require them to spend more of their own money on heating and cooling equipment in order to compensate for the utility's fossil-heavy generation mix.

Policies that reduce the use of fossil fuels in generating Long Island's electricity could be implemented without requiring that private citizens install exceptionally efficient heat pumps. Also, as will be discussed later, if Long Island were to install more heat pumps, the revenues of its utility would increase as grid-supplied electricity replaced point-of-use combustion of fossil fuels and so transferred revenues from the fossil fuel providers to the electrical utility. This additional revenue would pay for at least some of the incremental costs of converting to fossil-free generation resources.

Minimal gains today prepare for greater gains in the future Converting from fossil fuel furnaces to GSHP on Long Island will have a small, but positive impact on reducing fossil fuel use on Long Island today. But, these immediate reductions in fossil fuel use may not seem sufficient to motivate much effort in encouraging these conversions. Nonetheless, it is important to remember that once a site has converted to grid-powered solutions, any future fossil fuel use will be dependent on the Fossil Source Energy Factor of the grid. Every building converted means at least one fewer furnaces burning fossil fuel on Long Island. Given this, it doesn't make sense to wait until the grid is "clean" before converting buildings to GSHP heating/cooling. Instead, it would make sense to aggressively convert fossil fuel furnaces to GSHP while working in parallel to reduce the Fossil Source Energy Factor of the Long Island grid. Then, as the grid becomes less reliant on fossil fuels, the benefit would be seen in a reduction of the Fossil Source Energy Consumption Factor for every heat pump on Long Island.

As noted earlier, the transition from a reliance on point-of-use combustion of fossil fuels to a reliance on electricity will take time. Buildings typically replace their heating/cooling systems only once every twenty years or so. Thus, the rate of conversion will inevitably be slow. This argues for beginning the conversion process as soon as possible and accepting the initially limited benefits in anticipation of enjoying higher benefits in the future, as the Fossil Source Energy Factor for Long Island power is reduced. Any delay in conversion simply delays when the benefits of cleaner electricity production will be fully realized.

3.4 Renewable Source Energy Consumption

Just as it is useful to distinguish the portion of Source Energy generated from fossil fuels from that Source Energy generated by other means, it is useful to identify that portion of the consumed energy which is derived from renewable sources. Ideally, all energy would come from clean, renewable sources.

Renewable Source Energy is usefully divided into at least two categories:

- **Site-Sourced Renewable Energy:** Energy which is produced or harvested from resources available on or close to the same site where it is consumed. Rooftop solar PV, solar thermal, and various heat pump systems produce or harvest site-sourced renewable energy.
- **Grid-Sourced Renewable Energy:** That portion of the grid-supplied energy energy whose source was a renewable energy resource. By adding together the contributions of Biomass, Hydro and Wind, as shown in Table ?? on Page ??, we find that about 21.7% of grid-supplied energy in New York is "renewable." This will be considered by some to be an underestimation since it does not account for the renewable energy consumed in the process of refining nuclear fuel.

3.4.1 Site-Sourced Renewable Energy

Although fossil fueled systems will rely on a tiny amount of renewable energy due to their use of grid-supplied electricity, it is such a small amount that it isn't worth computing. Much more interesting is the ability of heat pumps systems to harvest site-sourced renewable energy from their environment – either the air, ground or water. The amount of renewable energy harvested by these systems, relative to the delivered energy that they consume, can be computed using Equation ??.

$$SiteSourcedRenewableEnergy = \frac{COP - 1}{COP} \tag{11}$$

For example, 66%[14] of the heat output of a heat pump with a COP of 3 will be site-sourced renewable energy while the remaining 33% will have been grid-supplied. Similarly, the output of a heat pump with a COP of 4 will be 75% site-source renewable energy.

It should be noted, however, that we are typically concerned with the portion of renewable energy relative to the Source Energy consumed. The method for calculating this number is discussed in section ??.

3.4.2 Grid Sourced Renewable Energy

When considering a grid-powered system, the renewable energy factor must be adjusted to recognize the portion of the grid's source energy that was generated using renewable energy. Ideally, the grid's generation mix would contain only renewable resources and thus any grid-powered system would be able to claim 100% renewable sources for its output. But, that is not yet the case in any of New York State's grids. As seen

[14] $.66 = \frac{(3-1)}{3}$

in Table ??, only about 21.7% of New York's power comes from such renewable sources and even then, most of the use of renewable resources is limited to the Upstate grid. The New York City/Westchester County grid's generation mix includes only about 1% renewable resources and the Long Island generation mix includes only about 4% renewable resources today. One can, of course, expect that the reliance on renewable resources will increase in the future.

We can use Equation ?? to compute the number of grid-supplied units of renewable energy in each unit of heat output by a system.

$$GridSourcedRenewableEnergy = SourceEnergyConsumptionFactor * GridRenewablePortion \quad (12)$$

For example, if a grid-powered heat pump system with a COP of 3.1 has a Source Energy Consumption Factor of 1.08 and the grid has a renewable portion of 21.7%, then 0.23 units of grid-supplied renewable energy will consumed in producing each unit of the system's output.

3.4.3 Net Renewable Energy Portion

To compute a system's net reliance on renewable energy, we need to consider both how much Source Energy is consumed (see Equation ??) as well as the various sources of renewable energy. Equation ?? shows the method for computing Net Renewable Energy Portion.

$$NetRenewablePortion = \frac{SiteSourcedEnergy + GridSourcedRenewableEnergy}{SiteSourcedEnergy + SourceEnergyConsumptionFactor} \quad (13)$$

For example, for each unit of heat output, the grid-powered heat pump system in the example of Section ?? would consume 0.68 units of Site Sourced Renewable Energy and 0.23 units of Grid Sourced Renewable Energy for a total of 0.91 units of renewable energy. This would be divided by the total energy consumed; 0.68 units of Site Sourced Renewable Energy and 1.08 units of grid-supplied Source Energy or a total of 1.76 units of energy. The resulting Net Renewable Energy Factor would be $0.52 = \frac{0.68+0.23}{0.68+1.08} = \frac{0.91}{1.76}$.

Computations of Site-Sourced Renewable Energy and Net Renewable Energy Factors are shown in Table ?? and plotted in Figure ??.

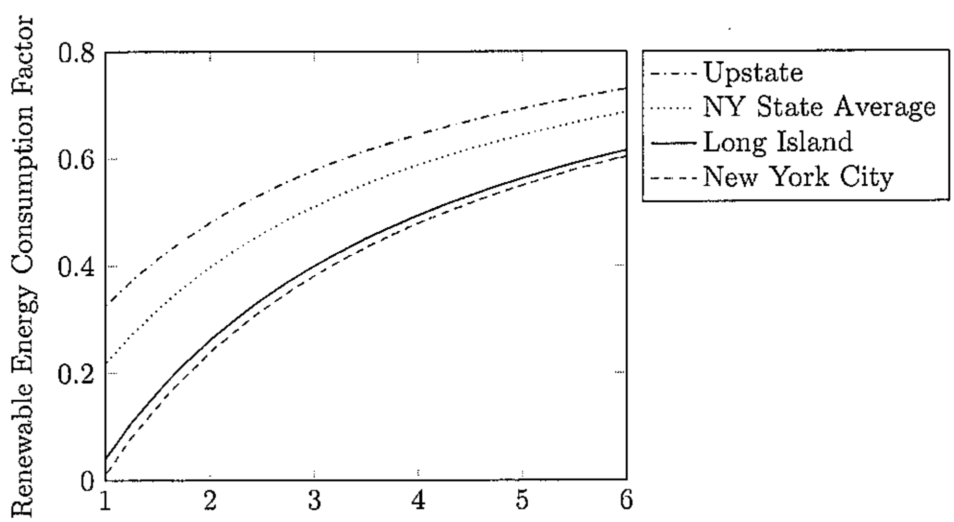


Figure 10: Renewable Energy Consumption Per Unit of Useful Heat Output

It should be clear from these tables and plots that grid-supplied renewable energy today has a significant effect on a heating system's renewable energy portion only in the Upstate grid since only the Upstate grid includes a significant amount of renewable energy in its grid generation mix. Nonetheless, the fact that heat pump systems are so effective at harvesting site-sourced renewable energy ensures that such systems will exploit renewable energy much more than the alternatives.

Additionally, it should be noted that renewable energy use by ground source heat pumps is very high even in areas, such as New York Cit and Long Island, whose grids rely today so little on renewable energy resources. This is because such heat pumps harvest the bulk of their energy from on-site renewable resources.

Table 15: Renewable Source Energy Consumption Factors for New York State

Heating Equipment Type	Site Sourced Renewable Energy (%)[1]	Net Renewable Energy (%)[2]			
		NYC	Upstate	Long Island	NY State Average
Energy Star Tier 3 GSHP					
Closed Loop Water-to-Air	72.2	44.3	62.0	46.0	56.0
Open Loop Water-to-Air	75.6	48.7	65.0	50.2	59.4
Closed Loop Water-to-Water	67.7	39.2	58.6	41.1	51.9
Open Loop Water-to-Water	71.4	43.4	61.4	45.1	55.2
DGX	72.2	44.3	62.0	46.0	56.0
Energy Star ASHP					
Split Systems	58.4	30.3	52.4	32.4	44.8
Single Unit	57.3	29.4	51.9	31.5	44.1
Installed Alternatives					
All Heat Pumps (Avg)	58.3	30.2	52.4	32.4	44.8
Electric	0.0	1.0	32.5	4.0	21.7

[1] Site Sourced Renewable Energy as a percent of total heat output.
[2] Renewable energy relative to total energy consumed (Site Sourced + Grid Sourced)

4 Emissions

It is well known that the combustion of fossil fuels produces CO_2 emissions that enhance Global Warming and accelerate Climate Change. Thus, much attention is given to quantifying the impact of these emissions, now and in the future, as well as on reducing them. Less well known is the fact that fossil fuel combustion produces a host of other emissions, such as $PM_{2.5}$, NO_x, SO_x, etc. which have greater near-term impacts on health and environment.

4.1 CO_2 Emissions

Emissions of pollutants such CO_2 are a critical factor to consider because of their negatives effects, not only on the direct producers of those pollutants but on all members of society. Decisions that result in a reduction of fossil fuel combustion will produce the greatest reductions in emissions.

As shown in Table ??, the majority of all New York State CO_2 emissions are the result of direct, point-of-use combustion of fossil fuels to meet the needs of buildings and transportation. Only 23% of CO_2 emissions are produced as a result of generating electricity even though electricity accounts for almost one-third of all the energy consumed in the State. As noted before, electricity generation is not the problem... If total emissions are to be reduced, there is much more potential for reductions in emissions from transportation and heating applications.

Table 16: CO_2 Emissions From Fuel Combustion in New York State

Fuel Type	Share of Total CO_2 Emisssions[1]
Electricity Generation	18%
Net Imports of Electricity	5%
Transportation	42%
On-site Combustion (Thermal/Heating)	35%

[1] See: Page 11 in *New York State Energy Plan 2014, Volume II: Technical Appendix re: Impacts and Considerations*:[?]

Non-electric emissions reductions may be most cost-effective Not only is it the case that non-electricity emissions are more than three times larger than emissions from electrical generation, it is often the case that the cost of reducing emissions from non-electric use of fossil fuels is much lower than the cost of reducing equivalent emissions in the electricity generation sector. Thus, while reducing electricity industry emissions might seem to be somewhat easier, given that the industry is state-regulated and has a much smaller number of installations than the millions of vehicles and buildings in the State, it may be much more cost-effective to reduce emissions from non-electric applications.

This was recently recognized and emphasized by the New York State Public Service Commission, in comments on the EPA's proposed Carbon Pollution Standards for electrical generation units (111(d)). The New York PSC wrote:

> Requiring New York to seek dramatic reductions in the electricity generation sector may ... have unintended consequences in broader GHG emission reduction policy and strategy. ...
>
> New York, like many other cold-weather states, has a large space heating (or "thermal) load, the vast majority of which is met through fossil fuel combustion. Unique to New York is the significantly large portion of this thermal load that is met through petroleum distillate (i.e., "heating oil"); in the residential sector this distillate thermal load approaches 30% of all housing units in the State. When compared to New York's electricity sector, the thermal load sector is considerably more GHG-intense. To meet the State's overall GHG reduction policy, New York will be looking to make more "productive" investment in the thermal load sector, achieving greater levels of GHG reduction per dollar of investment.

> ... if New York is asked to dedicate a disproportionate amount of its limited investment resources in seeking less productive emissions reduction in the electricity sector, this is likely to sacrifice a level of investment in the more intensive thermal load sector, eroding progress towards overall GHG mission reductions.[?]

The impact of CO_2 emissions is independent of source Although CO_2 emissions may be more intense in one location than another, the effect of CO_2 emissions is global and not dependent on the location of emission. The impact of each incremental CO_2 emission is felt over a span of hundreds of years. During that time, the emitted CO_2 becomes thoroughly mixed in the atmosphere and the oceans. As a result, if one is concerned about limiting the concentration of CO_2 in the environment, it really doesn't make sense to be more concerned about emissions from one source or location as opposed to any other. The emission of one pound of CO_2 from an electrical generation plant has precisely the same effect as the emission of one pound of CO_2 from an oil or gas furnace.

Efforts to reduce CO_2 emissions will be most effective if they identify and exploit the most cost effective means of CO_2 emission reductions.

4.1.1 Grid Electricity Emissions

New York State is served by three eGrid sub-regions. Each of these regions relies on a distinct mix of generating units whose emissions factors vary dramatically. As has been seen in earlier discussions, Long Island relies much more heavily on fossil fuels than do other areas of the State. Thus, while state-wide average emissions factors provide useful information for some purposes, when estimating emissions, it is most informative to consider the specific location of the site consuming the electricity.

Upstate New York and New York City/Westchester County benefit from some of the cleanest electrical generation in the country. Thus, grid-powered heating systems installed in those areas will be able to claim the "nation's lowest" heating-related emissions.

The EPA publishes detailed information describing emission factors, or emission rates, for each of twenty-six electricity grid sub-regions in the United States.[?] Each of these eGrid sub-regions contains a number of power generation and distribution facilities that are interconnected to form a single source of power.. While some of the generation facilities in each sub-region are cleaner or dirtier than others, the power delivered to the end users served by a sub-region is a mix of the power generated by all of the facilities in that sub-region. As a result, it isn't necessarily the case that a building sited near a "clean" generator is using power that is any cleaner than any other building in the same sub-region. When evaluating the emissions associated with grid supplied electricity, it is appropriate to use the emissions factors for the sub-region as a whole.

Source CO_2 Emissions Factors This document relies on the EPA's data for 2010 which is the most recent available. Using procedures defined by the EPA in [?], the eGrid Emissions Factors have all been adjusted to assume a 5.85% Grid Loss Factor to account for losses in transmission and distribution systems.[15]

Since 2010, it is quite likely that the three eGrid sub-regions[16] which serve New York State have decarbonized somewhat due to re-firing of existing coal plants with natural gas and the addition of new hydro, solar and wind generation. Thus, the eGrid Emission Factors should be considered conservative. The Source Emission Factors used in this paper are shown in Table ??.

4.1.2 Fossil Fuel Emissions

The EPA's *Emission Factors for Greenhouse Gas Inventories* has been used to estimate the Source Emissions Factors for fossil fuels delivered to a site.[?] These emissions factors must be adjusted to compensate

[15] The Grid Loss Factor of 5.85% is an average value for the Northeast. Thus, it may not correctly describe New York's sub-regions. New York City is likely to have a lower Grid Loss Factor since it is such a compact sub-region.

[16] NYC/Westchester County, Upstate, and Long Island.

Table 17: EPA eGrid New York Sub-Regions Source Emission Factors (2010)

eGrid Acronym	Generation (GWh)	Total Output Emission Rates[1] CO_2 (lbs/kWh)	CH_4 (lbs/GWh)	N_2O (lbs/GWh)	NO_x (lbs/MWh)	SO_2 (lbs/MWh)
NYC/Westchester	40,917	0.6224	23.81	2.80	0.2692	0.0926
Long Island	12,148	1.3361	81.49	10.28	0.9449	0.5510
Upstate NY	88,552	0.5458	16.30	7.24	0.4225	1.1156[2]
New York State (Avg)	141,617	0.6357	24.06	6.22	0.4230	0.7716
US Average	4,125,847	1.2324	24.14	18.26	1.1187	2.6433

[1] These rates do not include Grid Loss factor adjustment for distribution and transmission losses.
[2] Upstate is the only one of the three regions to use any coal.

for the efficiency of fuel use on site. The pre-adjustment values used are shown in Table ??.

Table 18: Fossil Fuel Emissions Factors

Fuel Type	Emissions Factors[1] CO_2 (lbs/kWh)	CH_4 (lbs/GWh)	N_2O (lbs/GWh)
Fuel Oil (#2)	0.5564	22.57	4.51
Propane and Liquid Propane	0.4729	22.57	4.51
Natural Gas	0.3991	7.52	0.75

[1] See: Table 1 in EPA *Emission Factors for Greenhouse Gas Inventories*[?].

Natural Gas isn't as clean as it looks... It is important to recognize that the published emissions factors for natural gas don't take into consideration the large quantity of natural gas (methane or CH_4) that is lost through venting and leaks. It is estimated that between one and three percent of total natural gas production is released to the atmosphere between the point of production and the point of use.

4.1.3 CO_2 Emissions Factors

Given a Source Emissions Factor and a site-specific COP value, one can compute the site-specific CO_2 Emissions Factor by dividing the Source CO_2 Emissions Factor by the efficiency (COP) of on-site energy consumption as shown in ??.

The emissions factors for various equipment option are shown in Table ??.

$$CO_2EmissionsFactor = \frac{SourceCO_2EmissionsFactor}{COP} \tag{14}$$

4.1.4 CO_2 BreakEven COP for Grid-Powered Alternatives

When considering grid-powered alternatives, such as heat pumps, one must compare the emissions from fossil fuel alternatives to the emissions that come from generating, transmitting and distributing the grid-power. Given the appropriate emissions factors, one can then compute a "BreakEven COP" that shows at what COP the grid-powered alternative and the fossil fuel alternative will have equivalent emissions. Any grid-powered alternative having a COP greater than the BreakEven COP will generate fewer emissions than the given fossil fuel alternative.

The CO_2 Emission BreakEven COP is computed simply by dividing the grid's CO_2 emission factor by the fossil fuel's CO_2 emission factor as shown in Equation ??.

$$BreakEvenCOP_2 = \frac{GridEmissionFactor}{FuelEmissionFactor} \tag{15}$$

Table 19: CO_2 Emissions Factors for New York State eGrid Sub-regions

	Efficiency (COP)	CO_2 Emissions (lbs/kWh) NYC/ Westchester	Upstate	Long Island
Grid Electricity				
Generated		0.62	0.55	1.34
Delivered (est. 5.82% loss)		0.66	0.58	1.42
Energy Star Tier 3 GSHP				
Closed Loop Water-to-Air	3.6	0.18	0.16	0.39
Open Loop Water-to-Air	4.1	0.16	0.14	0.35
Closed Loop Water-to-Water	3.1	0.21	0.19	0.46
Open Loop Water-to-Water	3.5	0.19	0.17	0.41
DGX	3.6	0.18	0.16	0.39
Energy Star ASHP				
Split Systems	2.4	0.28	0.24	0.59
Single Unit	2.34	0.28	0.25	0.61
Energy Star Furnace				
Oil Furnace	0.85	0.65	0.65	0.65
Gas Furnace (North)	0.95	0.42	0.42	0.42
Installed Alternatives				
All Heat Pumps (Avg)	2.4	0.28	0.24	0.59
Electric	1	0.66	0.58	1.41
Oil Furnace	0.78	0.71	0.71	0.71
Propane Furnace	0.78	0.61	0.61	0.61
Gas Furnace	0.82	0.49	0.49	0.49

For instance, as Table ?? shows, the NYC grid emits 0.6224 lbs_{CO_2}/kWh. An existing oil based system will consume oil at an efficiency of 78% and, as shown in Table ??, the delivered oil will have an emissions factor of 0.56 lbs_{CO_2}/kWh. An oil based system has a CO_2 emissions factor of 0.7179 lbs_{CO_2}/kWh ($0.56/0.78 = 0.7179$). Thus, the CO_2 BreakEven COP for a grid-powered alternative replacing an oil system in New York City would be about 0.9 ($0.6224/0.7179 = 0.8670$).

The CO_2 BreakEven COP of 0.9 tells us that in New York City, any grid-powered heating system with a COP greater than 0.9 will produce fewer CO_2 emissions than a typical existing furnace burning No. 2 oil. Given that the least efficient Energy Star compliant heat pump system has a COP of 2.34, any heat pump system installed in New York City will produce fewer CO_2 emissions than a typical oil furnace.

4.1.5 Social Cost of Carbon

While measures of the relative amount of carbon emissions have their uses, it is sometimes difficult to get a sense of the actual impact of those emissions. Few people have a good sense of what it means to emit a "pound of CO_2" or what damage might be caused by it over the next several years or decades. We all know that reducing carbon emissions, as well as emissions of any green house gas or pollutant is a "good thing," but that doesn't help us quantify or understand the benefit of any particular emission reduction.

The EPA, other federal agencies, and a growing number of others use the "Social Cost of Carbon" (SCC) as a means to estimate and quantify the climate benefits of alternatives. The SCC is an estimate of the net present value of the economic damage associated with small increases in carbon dioxide (CO_2) emissions, conventionally one metric ton (2204.62 lbs), in a given year. This dollar figure also represents the value of damages avoided for a small emissions reduction (i.e. the benefit of a CO_2 reduction.)

The SCC is meant to be a comprehensive estimate of climate change damages; however, given current modeling and data limitations, it does not include all important damages. As noted by the *IPCC Fourth*

Table 20: CO_2 BreakEven COP for Grid-Powered Alternatives in New York State

CO_2 BreakEven COP for Grid-Powered Alternatives in New York State						
eGrid	Total Emissions			Non-Baseload Emissions[1]		
SubRegion	Oil	Propane	Gas	Oil	Propane	Gas
NYC/Westchester	0.9	1.1	1.4	1.7	2.0	2.5
Long Island	2.0	2.3	2.9	2.2	2.5	3.2
Upstate NY	0.8	1.0	1.2	1.9	2.2	2.7

[1] "Non-baseload values should not be used for assigning an emission value for electricity use in carbon footprinting or GHG emissions inventory efforts. ... Non-baseload emission rates are the output emission rates for plants that combust fuel and have capacity factors less than 0.8, weighted by generation and a percent of generation determined by capacity factor. The non-baseload emissions and generation include only emissions and generation from combustion sources and exclude emissions and generation from plants that have high capacity factors." [?]

Assessment Report,[17] "it is very likely that [SCC] underestimates" the damages.

A summary of the Social Cost of Carbon estimates used by the Federal Government[18] is shown in the first five columns of Table ?? below. These estimates were generated by using three integrated assessment models, three discount rates and five scenarios producing 45 separate distributions for the global SCC. In Table ??, the three "Average" values are based on the average SCC across all models and socio-economic scenarios. The fourth value, "95th percentile," was chosen to represent higher-than-expected economic impacts from climate change further out in the tails of the SCC distributions. The authors of the Federal study providing these estimates emphasize the importance and value of considering all four SCC values. However, for the purposes of this paper, we will follow common practice and only use the "3% Average" SCC estimates.

The SCC values increase over time as the concentration of CO_2 in the atmosphere increases and additional emissions become more critical. While this means that the benefit of new carbon emission reductions will be higher in future years, it also implies that delaying the reductions will cost a great deal. Given that new HVAC equipment, such as oil and gas furnaces, has a lifetime of 20 years or more, any installation of such equipment today essentially locks in significant, costly and avoidable emissions for 20 years or more. Those choosing to install fossil fueled systems should be aware of the social cost of their decision.

The last row in Table ?? shows the net present value (NPV) of the annual SCC values for the period of 2015 to 2050. While the SCC for a single year shows the net present value of the expected damage from additional emissions in just that year, the NPV in the last row shows the net present value of the damages that will accumulate over the period if a source of emissions is active throughout that period.

In theory, if society accepts the correctness of the SCC computations, it should be willing to spend today any amount equal to or less than the NPV of the expected damages in order to eliminate those damages. Any amount of spending, as long as it is less than the NPV of the damages prevented, would result in a "profit" to society.

The last five columns in Table ?? show the estimated aggregate Social Cost of Carbon for New York State from 2015 to 2050 assuming that the space heating fuel consumption mix and volumes remain the same as those found by the 2009 EIA Residential Energy Consumption Survey.

Social Cost of Carbon for New York Alternatives Given Emissions Factors and a Social Cost of Carbon, we can use Equation ?? to compute the expected Social Cost of each kilowatt hour of heat delivered to a building.

$$SocialCostOfCarbonFactor = CO_2EmissionsPerkWh * SocialCostOfCarbon \qquad (16)$$

[17] http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm

[18] http://www.epa.gov/climatechange/EPAactivities/economics/scc.html

Table 21: Social Cost of Carbon, 2015-2050 (2011 Dollars)[1]

	Discount Rate and Statistic[2] ($/metric ton of CO_2 emissions)[4]				SCC Assuming 2009 Usage Unchanged[1] ($ millions/year using 3% Avg. Scenario)				
Year	5% Avg	3% Avg	2.5% Avg	3% 95th	Electric[2]	Oil	Propane	Gas	Annual Total
2018	13	43	65	128	25	557	21	713	1,315
2019	13	45	66	132	27	584	22	748	1,381
2020	13	46	68	137	27	598	22	766	1,414
2021	13	46	69	140	27	598	22	766	1,414
2022	14	47	71	143	28	612	23	784	1,447
2023	14	48	72	146	28	626	23	802	1,480
2024	15	49	73	150	29	640	24	819	1,513
2025	15	50	74	153	30	654	24	837	1,545
2026	16	51	75	159	30	668	25	855	1,578
2027	16	52	76	162	31	682	25	873	1,611
2028	16	53	77	166	32	696	26	891	1,644
2029	17	54	78	170	32	710	27	909	1,677
2030	17	55	80	173	33	722	27	925	1,707
2031	18	56	81	176	33	724	27	926	1,710
2032	18	57	82	179	33	737	28	944	1,743
2033	19	58	83	184	34	751	28	962	1,776
2034	19	59	84	187	35	765	29	980	1,808
2035	20	60	85	190	35	779	29	998	1,841
2036	20	61	87	190	36	793	30	1,015	1,874
2037	21	62	89	193	37	807	30	1,033	1,907
2038	21	63	90	198	37	821	31	1,051	1,940
2039	22	64	91	201	38	835	31	1,069	1,973
2040	22	65	92	204	39	849	32	1,087	2,006
2041	24	66	93	207	39	863	32	1,104	2,039
2042	24	67	94	210	40	877	33	1,122	2,071
2043	25	68	95	214	40	891	33	1,140	2,104
2044	25	69	96	217	41	904	34	1,158	2,137
2045	26	70	98	220	42	917	34	1,174	2,167
2046	26	72	99	223	42	932	35	1,194	2,203
2047	27	73	100	225	43	946	35	1,211	2,236
2048	27	74	101	229	44	960	36	1,229	2,269
2049	28	75	103	232	44	974	36	1,247	2,302
2050	28	76	104	235	45	988	37	1,265	2,335
NPV[3]	277	1,190	1,875	3,671	704	15,497	579	19,841	36,620

[1] 2009 Usage data is from EIA Residential Energy Consumption Survey.
[2] Uses simple average emissions for three eGrid sub-regions. Not weighted.
[3] Net Present Value using discount rate of the scenario.
[4] Does not include the social cost of other emissions such as HFC, CH_4, N_2O or $PM_{2.5}$.

As shown in Table ??, the Social Cost of Carbon for fossil fueled systems is largely independent of location, on the other hand, the SCC for grid-powered systems will depend on the fuel mix used for electricity generation within each sub-region. As expected, the SCC for grid-powered systems is highest on Long Island, and much lower in the Upstate and New York grids. The SCC for any GSHP system is lower than that of any ASHP or fossil fueled system.

Table 22: Social Cost of Carbon for New York State eGrid Regions

		Social Cost of Carbon (¢/kWh of heat)			
	Efficiency (COP)	NYC/ Westchester	Upstate	Long Island	Statewide Average
Grid Electricity					
Delivered (est. 5.82% loss)		1.17	1.03	2.51	1.12
Energy Star Tier 3 GSHP					
Closed Loop Water-to-Air	3.6	0.32	0.28	0.70	0.31
Open Loop Water-to-Air	4.1	0.29	0.25	0.61	0.27
Closed Loop Water-to-Water	3.1	0.38	0.33	0.81	0.36
Open Loop Water-to-Water	3.5	0.33	0.29	0.72	0.32
DGX	3.6	0.32	0.28	0.70	0.31
Energy Star ASHP					
Split Systems	2.4	0.49	0.43	1.05	0.47
Single Unit	2.34	0.50	0.44	1.07	0.48
Energy Star Furnace					
Oil Furnace	0.85	1.16	1.16	1.16	1.16
Gas Furnace (North)	0.95	0.74	0.74	0.74	0.74
Installed Alternatives					
All Heat Pumps (Avg)	2.4	0.49	0.43	1.05	0.47
Electric	1	1.17	1.03	2.51	1.12
Oil Furnace	0.78	1.26	1.26	1.26	1.26
Propane Furnace	0.78	1.07	1.07	1.07	1.07
Gas Furnace	0.82	0.86	0.86	0.86	0.86

Maximum Potential Reduction in Social Cost of Carbon Given an estimate of SCC and estimates of the amount of space heating load currently served by the various installed systems, we can compute an estimate of the theoretical benefit that would be achieved by replacing all existing systems with new Energy Star compliant equipment. Such an estimate, for the New York State residential space heating market in 2015, is presented in Table ??. Note: This estimate is based on the impossible assumption that all existing heating systems would be replaced in 2015. It would be more reasonable to expect a conversion over time. Given that about 5% of buildings in the State replace their heating systems annually, 5% might be a good rate to assume.

4.2 Other Emissions

4.2.1 Health and Mortality

In addition to the Social Cost of Carbon, we should also consider the Social Cost of non-Carbon Pollutants emitted as a result of fossil fuel combustion.

To Do:

Table 23: Potential Social Cost of Carbon Reduction in NY Residential SH Market (2015)

	SCC Reduction By Replacing Old Equipment ($millions)									
	Electric[1]		Oil Furnace		Propane Furnace		Gas Furnace		Total	
Current Consumption (QuadBTU)[2]	0.007		0.138		0.006		0.256		0.407	
New Heating Equipment Type	$[3]	%	$[3]	%	$	[3]%	$[3]	%	$[3]	%
No Replacement	-23	0	-510	0	-19	0	-657	0	-1,198	0
Energy Star Tier 3 GSHP										
Closed Loop Water-to-Air	14	61	332	65	11	58	316	48	673	55
Open Loop Water-to-Air	15	65	357	69	12	63	361	55	745	61
Closed Loop Water-to-Water	12	52	304	59	10	53	263	40	590	49
Open Loop Water-to-Water	13	57	328	64	11	58	308	47	662	54
DGX	14	61	332	65	11	58	316	48	673	55
Energy Star ASHP										
Split Systems	10	43	247	48	7	37	158	24	423	35
Single Unit	9	39	239	46	7	37	143	22	399	33
Energy Star Furnace										
Oil Furnace	-.7	-3	41	8	-2	-11	-224	-34	-186	-15
Gas Furnace (North)	8	74	211	41	6	32	91	14	325	27

[1] These values are somewhat overstated since EIA includes existing heat pumps in their estimates of Electric heat.
[2] QuadBTU is an abbreviation for "quadrillion BTU," the equivalent of 293 billion kWh or 293 TWh. Estimates taken from EIA Residential Energy Consumption Survey for 2009. Table CE4.2 `http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=consumption#end-use-by-fuel`
[3] Millions of dollars.

- $PM_{2.5}$ Emissions: Consider using BenMap[?] data, probably RSM method to compute cost of $PM_{2.5}$ emissions.
- Clean Heat program in New York City addressed only 1% of city's buildings yet reduced mortality rate by 700+ per year. Use GHG Inventory data to show progress...

5 Cost Factors

Whatever an alternative's benefits or impacts may be, its acquisition must be financially feasible. Ideally, an alternative would offer a lower Levelized Cost of Energy (LCOE) as a result of low up-front capital costs and low to zero marginal costs. But, in order for it to be "affordable," the timing of expenses must meet the constraints of the funder's cash flows. Thus, there are several financial metrics that must be considered:

- Marginal Costs: The costs associated with operating the asset. Primarily "fuel" costs.
- Capital Costs: The cost of initially purchasing or acquiring the asset.
- Affordability: Largely driven by the timing of required payments. For instance, high up-front capital costs can make a system with low LCOE unaffordable for those who don't have sufficient free cash or the ability to borrow it.

Of the alternatives discussed in this paper, Ground Source Heat Pumps will have the highest up-front capital costs but the lowest marginal costs. The Fossil Fuel alternatives will typically have low up-front capital costs but high and volatile marginal cost of operation due to the need to purchase and consume expensive fossil fuel.

5.1 Fuel Costs

"Fuel" costs, either fossil fuels or electricity, make up the bulk of marginal costs for heating and cooling systems. For fossil fueled or electric resistance systems, fuel costs will also make up the bulk of all costs over the lifetime of the equipment. For heat pump systems, fuel costs will constitute a much smaller percentage of total costs.

5.1.1 Historical Fuel Costs

EIA data reporting the average cost for various fuels and electricity during the 2013/2014 Oct-March heating season was used when computing fuel costs. The fuel costs used in this report, and those of several previous years, can be seen in Table ?? and in Figure ??. All costs are converted to ¢/kWh to add consistency and make comparisons easier.

Table 24: New York Average Fuel Prices during Heating Season (2005-2014)

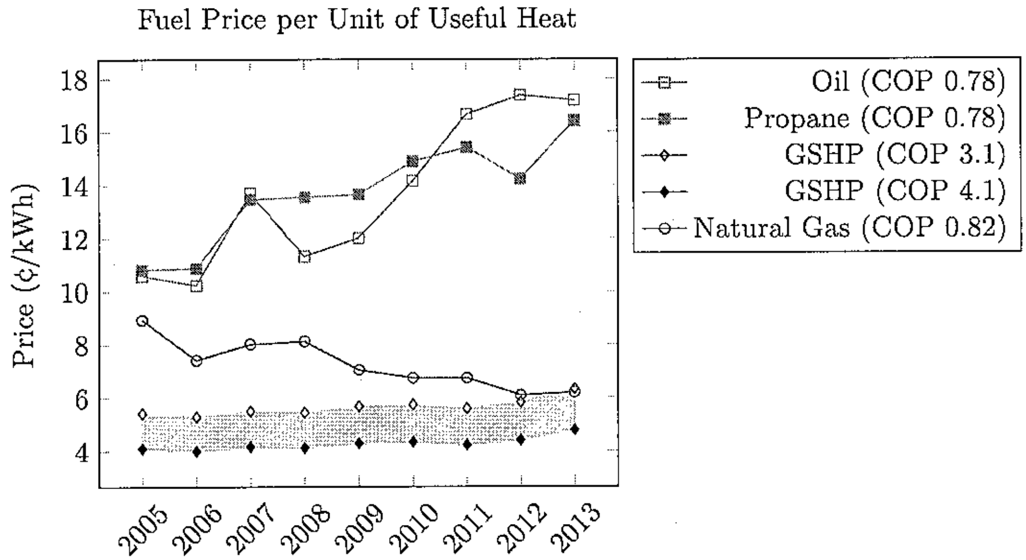
New York Average Heating Season Fuel Prices (Oct-Mar)[1]							
Heating Season	Electricity	Oil		Propane		Natural Gas	
(Oct-Mar)	¢/kWh	$/gal	¢/kWh	$/gal	¢/kWh	$/therm	¢/kWh
2005/2006	16.77	2.62	8.26	2.26	8.44	1.76	7.32
2006/2007	16.37	2.53	7.98	2.27	8.48	1.46	6.08
2007/2008	17.03	3.39	10.69	2.81	10.50	1.58	6.57
2008/2009	16.86	2.80	8.83	2.83	10.57	1.60	6.66
2009/2010	17.57	2.97	9.37	2.85	10.65	1.39	5.78
2010/2011	17.77	3.50	11.04	3.11	11.62	1.33	5.53
2011/2012	17.32	4.12	13.00	3.22	12.03	1.33	5.53
2012/2013	18.05	4.30	13.56	2.87	11.10	1.20	4.99
2013/2014	19.61	4.25	13.41	3.43	12.81	1.22	5.08
2014/2015[9]	*na*	3.62	11.42	2.87	10.72	*na*	*na*

[1] Oil data:[?], Propane:[?], Gas: [?]

[9] 2014/2015 data is incomplete. No gas data available. Others are only through Dec 15.

Different fuel cost factors would have been used if another time period or an average of recent heating seasons had been used.[19] Also, cost factors vary considerably within the state, particularly in those areas whose electricity providers offer special pricing or incentives to encourage one or another form of heating system.

Figure 11: Price per Delivered kWh (2005-2013)



Note: See Figure ?? on Page ?? to see prices adjusted to a common base of $/kWh useful heat.

Fuel Price Volatility The price of most fossil fuels has varied significantly over time, much more than has the price of grid power. This pattern of low price volatility for grid supplied energy and high price volatility for fossil fuel prices is almost certain to continue in the future. Already, over 50% of New York's grid supplied power comes from renewable resources such as wind, solar and hydro that have very low marginal costs. Thus, the grid's exposure to the volatility of fossil fuel prices is dampened. As the grid comes to rely more and more on low marginal cost resources in the future, its price volatility will be reduced. Future changes in grid prices are most likely to be more driven by requirements to incur capital expense or by changes in the utilization of the grid's fixed assets.

Fossil fuel prices, on the other hand, are very much influenced by political events and considerations and are regularly impacted by decisions of foreign governments or cartels to influence global economic affairs. The susceptibility of US fossil fuel prices to these foreign concerns is, of course, only expected to increase if the law is changed to permit increased exportation of the US's fossil fuel resources.

Thus, planners must take into consideration the volatility of prices as well as their absolute level at any particular moment.

5.1.2 Fuel Cost per Unit of Useful Heat

From simple price data, we can see evidence of the volatility of costs, however, in order to compare costs between alternatives, we must convert the costs to a common unit such as Fuel Cost per Unit of Useful Heat produced by the heating system. This is done by dividing the per unit cost of fuel, as delivered, by the COP of the alternative used to consume that fuel. Equation ?? shows the method of calculation.

[19] Oil costs for the 2014/2015 heating season will be much lower than in recent years due to over-production by OPEC. But, there is little question that oil prices will rise again in the future once the goals of those setting OPEC policies have been achieved.

$$FuelCostPerUnitUsefulHeat = \frac{FuelCost_{kWh}}{COP} \tag{17}$$

The Fuel Cost per Unit of Useful Heat for the alternatives considered is shown in Table ?? and plotted in Figure ??.

Oil and propane systems have had significantly higher fuel costs than GSHP systems for quite some time, although the recent temporary drop in oil prices will undoubtedly decrease the degree to which oil is more expensive for at least the 2014/2015 heating season.

The cost to fuel Natural Gas systems, once almost twice as high as that of GSHP systems, has fallen since 2009 and now equals the cost to fuel the least efficient Energy Star compliant GSHP systems.

Table 25: Fuel Cost per Unit of Useful Heat in New York State (2013/14)

		Cost Per Unit (cents/kWh)		
	Efficiency (COP)	Delivered Energy	Useful Heat	Rank
Energy Star Tier 3 GSHP				
Closed Loop Water-to-Air	3.6	19.6	5.4	3
Open Loop Water-to-Air	4.1	19.6	4.8	1
Closed Loop Water-to-Water	3.1	19.6	6.3	7
Open Loop Water-to-Water	3.5	19.6	5.6	5
DGX	3.6	19.6	5.4	3
Energy Star ASHP				
Split Systems	2.4	19.6	8.2	8
Single Unit	2.34	19.6	8.4	10
Energy Star Furnace				
Oil Furnace	0.85	13.5	15.9	11
Gas Furnace (North)	0.95	5	5.4	2
Installed Alternatives				
All Heat Pumps (Avg)	2.4	19.6	8.2	9
Electric	1.0	19.6	19.6	14
Oil Furnace	0.78	13.5	17.3	13
Propane Furnace	0.78	12.8	16.4	12
Gas Furnace	0.82	5.1	6.2	6

5.1.3 Relative Fuel Costs

The relative savings achieved by selecting one fuel over another is shown in Table ??.

5.1.4 Maximum Potential Fuel Cost Savings

A 2010 study by researchers at ORNL[?] estimates that replacing all existing space heating, space cooling and water heating equipment in all existing single-family homes in the nation would result in annual savings of $52.2 billion in energy expenditures, a 48.2% reductions in such costs.

The portion of those savings that are available to residents of New York are substantial, given that New York is not only a populous state but also the state that consumes the most heating oil each year. A rough estimate of the total fuel cost savings available to New York residents is shown in Table ?? for the various alternatives. Clearly, for those buildings that convert to GSHP rather than other alternatives, there would be additional savings as a result of higher efficiency cooling and, potentially, water heating.

Table 26: Relative Fuel Cost Savings for New York State (2013/14 Heating Season)

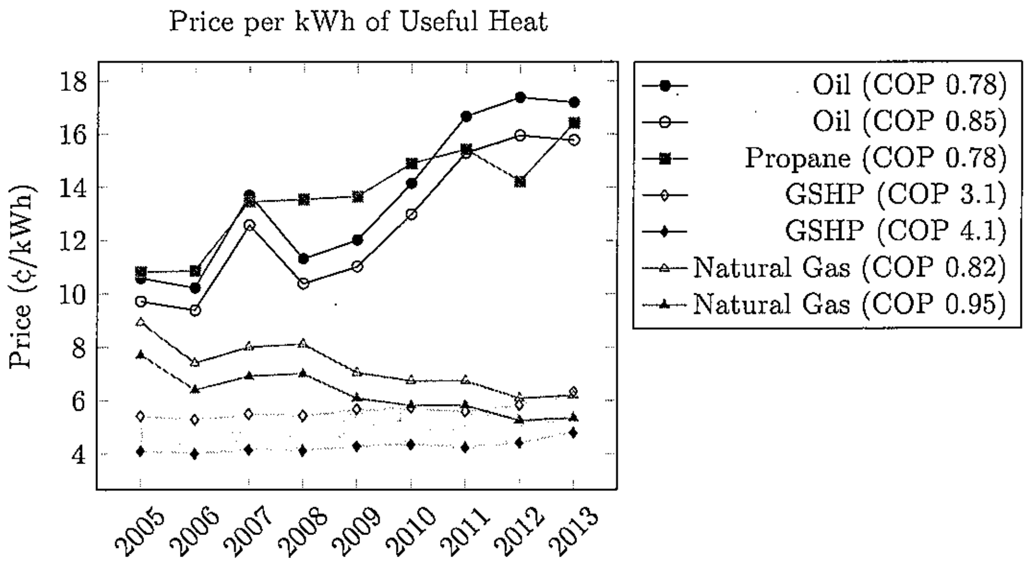
	Fuel Cost Reduction By Replacing Old Equipment									
	Old Heat Pumps		Electric		Oil Furnace		Propane Furnace		Gas Furnace	
Current Fuel Cost (¢/kWh)	7.9¢		19¢		16.7¢		16.7¢		6.1¢	
New Heating Equipment Type	¢	%	¢	%	¢	%	¢	%	¢	%
Energy Star Tier 3 GSHP										
Closed Loop Water-to-Air	2.6	33	13.7	72	11.4	68	11.4	68	.8	13
Open Loop Water-to-Air	3.3	41	14.4	76	12.0	72	12.0	72	1.5	24
Closed Loop Water-to-Water	1.8	23	12.9	68	10.5	63	10.5	63	0	-1
Open Loop Water-to-Water	2.5	31	13.6	71	11.2	67	11.2	67	.7	11
DGX	2.6	33	13.7	72	11.4	68	11.4	68	.8	13
Energy Star ASHP										
Split Systems	0	0	11.1	58	8.8	53	8.8	53	-1.8	-30
Single Unit	-0.2	-2	10.9	57	8.6	51	8.6	51	-2.0	-33
Energy Star Furnace										
Oil Furnace	-7.4	-93	3.7	20	1.4	8	1.4	8	-9.2	-151
Gas Furnace (North)	2.7	34	13.7	72	11.4	68	11.4	68	.8	14

Table 27: Annual Energy Bill Savings After Replacing Old Equipment

	Reduction in Energy Spending After Replacement ($ millions)				
New Heating Equipment Type	Electric	Oil Furnace	Propane Furnace	Gas Furnace	Total of Viable[1]
Current Spending ($ millions)	390	5,258	229	3,751	9,627
Energy Star Tier 3 GSHP					
Closed Loop Water-to-Air	282[2]	3,593	156	504	4,030
Open Loop Water-to-Air	295	3,796	165	900	4,256
Closed Loop Water-to-Water	264	3,324	145	-19	3,733
Open Loop Water-to-Water	278	3,545	154	412	3,978
DGX	282	3,593	156	504	4,030
Energy Star ASHP					
Split Systems	227	2,761	120	-1,117	3,109
Single Unit	223	2,699	117	-1,239	3,040

[1] Only those conversions considered "economically viable" are summed in this column. Those conversions not considered likely to occur are marked with shading in the table.
[2] Shaded cells mark potential conversions that are unlikely to occur since they are not economically viable without changes to costs or significant increased state incentives. (e.g. GSHP installations must generate sufficient savings to pay up-front capital costs.)

Figure 12: Price per kWh of Heat (2005-2013)



Note: Fuel prices have been adjusted to a common unit of useful heat to make comparison easier. See Table ?? for the actual, unadjusted price history.

5.1.5 Fuel Cost BreakEven COP for Grid-powered Alternatives

Table ?? shows the COP at which any grid-powered alternative has lower fuel costs than a fossil-fueled alternative. The BreakEven COP is computed by dividing the cost of grid-supplied power by the efficiency adjusted cost of fuel consumed by the alternative. See Equation ??.

$$CostBreakEvenCOP = \frac{GridPowerCost}{FuelCost \;/\; FuelBurningEquipmentCOP} \tag{18}$$

Given that the least efficient Energy Star compliant GSHP has a COP of 3.1, any Energy Star compliant GSHP system will have lower fuel costs than the alternatives in all cases except when replacing new, Energy Star compliant natural gas furnaces. However, there exist many GSHP units which are more efficient than the Energy Star minimum and that will have sufficiently high COP so that they will cost less to operate than any fossil fueled alternative.

Table 28: Fuel Cost BreakEven COP for Grid-Powered Alternatives in New York State

Fuel Cost BreakEven COP for Grid-Powered Alternatives in New York State (2013/2014)						
	Replacing Old Equipment			Replacing New Equipment[1]		
	Oil	Propane	Gas	Oil	Propane	Gas
Grid Powered @ 19¢/kWh	1.10	1.16	3.06	1.19	1.41	3.55

[1] Energy Star Compliant

5.2 Capital Costs

While ground source heat pumps are the "best" alternative in many cases, they also have the highest capital costs – primarily due to the expense of the ground heat exchanger. However, those costs are reduced by a variety of State, local, utility, and Federal benefits and incentives.

Federal tax incentives include a 30% tax credit for residential installations and a 10% tax credit for commercial or third party owned systems. Commercial and third-party installations may also take advantage of five-year property classification for Federal MACRS depreciation which has a present value as high as 28%. Thus, commercial and third-party owned systems have up to 38% of their costs covered by Federal incentives before other incentives are considered.

To Do: Capital Costs for GSHPs in New York are hard to discuss since there appear to be no reliable surveys of those costs at present and because drilling or trenching expenses vary dramatic depending on local geological conditions and maturity of the local market (e.g. Prices are lower when there is competition). Efforts are being made to get good, Statewide estimates of costs and will be incorporated into future drafts.

6 Impact on Utilities

6.1 Baseload Demand Growth

Replacing fossil fueled equipment with electrically powered equipment will generate additional revenue for electricity producers at the expense of fossil fuel producers. The additional demand on electrical generators will be seen primarily as an increase in non-peak, baseload demand. This increased revenue will tend to reduce the pressure to increase electricity rates in the future and thus benefit all users of electricity. In fact, it is entirely possible that if large numbers of fossil fuel burners were converted to grid-supplied energy, the result could be reductions in electric rates.

Conversions are unlikely to occur when they are not "cost-effective" without increased subsidies or third-party ownership. Such conversions, those from existing natural gas to new heat pumps, would either increase home owner's costs or would not generate sufficient annual savings to cover the cost of up-front capital or risk associated with increased indebtedness with an acceptable return on investment.

While increases in actual baseload demand, and the revenues expected from them, will depend entirely on the pace of conversion and the mix of new technologies chosen, it is useful to compute the maximum technically feasible growth in electricity industry revenues. This is done in Table ?? which shows that an increase in spending on the order of $2 billion (about 10% of current annual spending) would result from cost-effective conversions. In that table, the revenue impact potential of all conversions options is shown. Those conversions unlikely to occur, because they are not cost-effective, are shown with shaded text.

Table 29: Change in Residential Electric Space Heating Spending After Replacing Old Equipment

	Change in Electricity Spending After Replacement ($ millions)				
New Heating Equipment Type	Electric	Oil Furnace	Propane Furnace	Gas Furnace	Total of Viable[1]
Current Spending ($ millions)	390	5,258	229	3,751	5,877
Energy Star Tier 3 GSHP					
Closed Loop Water-to-Air	-282[2]	1,665	72	3,247	1,456
Open Loop Water-to-Air	-295	1,462	64	2,851	1,231
Closed Loop Water-to-Water	-264	1,933	84	3,771	1,753
Open Loop Water-to-Water	-278	1,713	74	3,340	1,509
DGX	-282	1,665	72	3,247	1,456
Energy Star ASHP					
Split Systems	-227	2,496	109	4,868	2,377
Single Unit	-223	2,559	111	4,990	2,447

[1] Only those conversions considered "economically viable" are summed in this column. Those conversions not considered likely to occur are marked with shading in the table.
[2] Shaded cells mark potential conversions that are unlikely to occur since they are not economically viable without changes to costs or significant increased state incentives. (e.g. GSHP installations must generate sufficient savings to pay up-front capital costs.)

To Do: Need similar calculations for commercial and industrial spending changes.

6.2 Increased Asset Utilization

Because utilities must size their infrastructure to handle peak load conditions, they experience less than optimal asset utilization whenever they experience non-peak demand. Non-peak demand conditions are, of course, the normal state for an electricity grid. In many areas, peak load only occurs for a few hours each year, yet the grid must be capable of satisfying that peak load.

Any increase in baseload demand, as long as it doesn't also cause an increase in peak demand, will result in higher utilization asset levels and thus higher profitability of fixed cost assets. This higher utilization level will result in reduced pressure to increase rates and may even allow utilities to reduce rates.

6.3 Decreased Peak Demand

Winter Peak In New York State, as in most other states, peak electricity demand normally occurs on the hottest days of the summer months, when heating is not an issue. However, in some parts of New York, particularly those that rely heavily on cheap municipal electricity to power electric resistance heaters, there are also "Winter Peaks," on particularly cold days. Given that GSHP units are between three and six times more efficient than Electric Resistance heaters, the retrofitting of existing resistance heaters to GSHP units should dramatically reduce the severity of Winter Peak conditions.

Summer Peak Although this paper primarily focuses on issues related to heating, it should be remembered that ground source heat pumps, because their COP is not linked to external air temperature, are more efficient at providing cooling during the peak load conditions that normally occur on very hot summer days. Increased cooling efficiency during peak periods reduces the difference between peak and baseload demand and thus reduces the pressure on utilities to incur the capital cost of developing increased peak capacity.

While increased baseload demand allows utilities to better utilize existing assets, decreased peak demand will allow utilities to invest less in additional peak capacity that will be rarely utilized. The result is lower pressure to increase rates, increased profits for the utilities and perhaps even lowered rates.

The value of reduced summer peak demand is significant. As an example, consider that ConEd has proposed paying up to $150 million in order to eliminate 41 megawatts of peak demand in the Brooklyn/Queens Demand Management project. Thus, they are offering to pay $3.65 per watt of reduced demand. Given that installation of a GSHP unit in a residential unit in that area would reduce summer peak load by between 1.5kWh and 2.0kWh, if ConEd were to pay for conversions to GSHP, then they should be willing to pay between $5,487 and $7,317 of the conversion costs per building. That is a substantial portion of the cost of conversion, particularly when combined with the existing Federal tax incentives.

It can also be noted that PSEG, which operates the Long Island Power system, has a program which subsidizes GSHP installations.[?] They plan to spend about $1.50/watt for reductions in residential demand and $2.25/watt for commercial demand reduction.

7 Statewide Impact

This section needs considerable work.

7.1 Balance of Payments

In New York State, expenditures on electricity tend to stay in-state while expenditures on fossil fuels tend to flow out-of-state. (See: Table ??) Thus, a transfer of revenue from the fossil fuel industry to the electrical industry will result in increased spending within New York, even if total spending on fuel is reduced.

Table 30: Out-of-State Energy Expenditures ($ Millions 2012)[1]

Fuel Type	Total	Out-Of-State	% Out-of-State
Coal	110.8	94.2	85%
Natural Gas	7,297.3	3,596.3	49%
Gasoline	19,561.8	15,917.6	81%
Other Petroleum	15,235.5	12,939.5	85%
Electricity	21,683.8	6,369.6	29%
Total	63,865.3	38,917.1	61%

[1] See: NYSERDA Patterns and Trends: New York State Energy Profiles: 1998-2012.

7.2 Jobs

Since much of the GSHP installation cost is labor, and those costs are higher than for alternatives, converting to GSHP will increase employment.

References

[BG13] Elizabeth C. Battocletti and William E. Glassley. Measuring the Costs and Benefits of Nationwide Geothermal Heat Pump (GHP) Deployment – Final Report, February 2013. http://cgec.ucdavis.edu/files/2014/08/08-28-2014-DE-EE0002741_Final%20Report_28%20Feb%202013.pdf Results of a three year effort to evaluate the costs/benefits of GHP installation in the 30 largest U.S. metropolitan regions.

[BMG+14] Nichola Bianco, Kristin Meek, Rebecca Gasper, Michael Obeiter, Sarah Forbes, and Nate Aden. Seeing is believing: Creating a new climate economy in the United States, October 2014. http://www.wri.org/sites/default/files/seeingisbelieving_working_paper.pdf.

[Con] ConEdison. A Brief History of ConEdison Steam. http://www.coned.com/history/steam.asp.

[Cuo] Governor Cuomo. Executive Order 88 Guidelines. http://www.nypa.gov/BuildSmartNY/Guidelines.pdf. Accessed: 19-Dec-2014.

[DQ12] Art Diem and Cristina Quiroz. How to Use eGRID for Carbon Footprinting Electricity Purchases in Greenhouse Gas Emission Inventories, July 2012. http://www.epa.gov/ttn/chief/conference/ei20/session3/adiem.pdf.

[DT07] M. Deru and P. Torcellini. Source Energy and Emission Factors for Energy Use in Buildings, June 2007. http://www.nrel.gov/docs/fy07osti/38617.pdf.

[EIAa] EIA. Heating Fuel Comparison Calculator. http://www.eia.gov/tools/faqs/heatcalc.xls.

[EIAb] EIA. New York Price of Natural Gas Delivered to Residential Consumers (Dollars per Thousand Cubic Feet). Monthly data, http://tonto.eia.gov/dnav/ng/hist/n3010ny3m.htm.

[EIAc] EIA. State Rankings: New York State – Energy Consumption and Expenditures. http://www.eia.gov/state/data.cfm?sid=NY#ConsumptionExpenditures.

[EIAd] EIA. Weekly New York No. 2 Heating Oil Residential Price (Dollars per Gallon). http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=W_EPD2F_PRS_SNY_DPG&f=W.

[EIAe] EIA. Weekly New York Propane Residential Price (Dollars per Gallon). http://tonto.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=W_EPLLPA_PRS_SNY_DPG&f=W.

[EPAa] EPA. eGRID Website. http://www.epa.gov/cleanenergy/energy-resources/egrid/. The Emissions & Generation Resource Integrated Database (eGRID)is a comprehensive source of data on the environmental characteristics of almost all electric power generated in the United States.

[EPAb] EPA. Energy Star Furnaces Key Product Criteria. http://www.energystar.gov/index.cfm?c=furnaces.pr_crit_furnaces.

[EPAc] EPA. Energy Star Geothermal Heat Pump Key Product Criteria. http://www.energystar.gov/index.cfm?c=geo_heat.pr_crit_geo_heat_pumps.

[EPAd] EPA. Environmental Benefits Mapping and Analysis Program (BenMAP). http://www.epa.gov/air/benmap/.

[EPAe] EPA. EPA Energy Star Air-Source Heat Pumps and Central Air Conditioners Key Product Criteria. http://www.energystar.gov/index.cfm?c=airsrc_heat.pr_crit_as_heat_pumps.

[EPA13] EPA. EPA Energy Star Portfolio Manager Technical Reference Source Energy, July 2013. https://portfoliomanager.energystar.gov/pdf/reference/Source%20Energy.pdf.

[EPA14] EPA. Emission Factors for Greenhouse Gas Inventories, April 2014. http://www.epa.gov/climateleadership/documents/emission-factors.pdf.

[FWPL04] Philip Fairey, Bruce Wilcox, Danny S Parker, and Matthew Lombardi. Climatic Impacts on Heating Seasonal Performance Factor (HSPF) and Seasonal Energy Efficiency Ratio (SEER) for Air-Source Heat Pumps. *ASHRAE Transactions*, 110(2), 2004. http://www.fsec.ucf.edu/en/publications/html/FSEC-PF-413-04/index.htm.

[Int] International Passive House Association. Main Website. http://www.passivehouse-international.org/.

[KGK95] Steve Kavanaugh, Christopher Gilbreath, and Joseph Kilpatrick. Cost Containment for Ground-Source Heat Pumps, December 1995. http://geoheat.oit.edu/pdf/tp72.pdf.

[Liu10] Xiaobing Liu. Assessment of National Benefits from Retrofitting Existing Single-Family Homes with Ground Source Heat Pump Systems. Technical Report ORNL/TM-2010/122, Oak Ridge National Laboratory, August 2010. http://btric.ornl.gov/pdfs/Liu_GSHP_Report_8-30-2010.pdf.

[MRZ14] Joseph J. Martens, John Rhodes, and Audrey Zibelman. New York State Comments on Proposed Carbon Pollution Emissions Guidelines for Existing Stationary Sources: Electric Utility Generating Units, 79 FR 3430 (June 18, 2014), December 2014. http://www.dec.ny.gov/docs/administration_pdf/nyscomments.pdf.

[NRE12] NREL. NREL Geothermal Policymaker's Guidebooks, Policy Options for Geothermal Heating and Cooling, April 2012. http://www.nrel.gov/geothermal/guidebooks/heating_cooling/policy_options.html.

[NYC] NYC. One City: Built to Last (Transforming New York City's Buildings for a Low-Carbon Future. http://www.nyc.gov/html/builttolast/assets/downloads/pdf/OneCity.pdf. Often referred to as the Mayor's "80x50" plan. See also: NYC "Built To Last" website: http://nyc.gov/BuiltToLast.

[NYC14] NYC. Inventory of New York City Greenhouse Gas Emissions. http://www.nyc.gov/html/planyc/downloads/pdf/NYC_GHG_Inventory_2014.pdf, November 2014.

[NYS] NYS. New York State Energy Plan. http://energyplan.ny.gov/. Accessed: 19-Dec-2014.

[NYS14] NYSERDA. Energy Efficiency and Renewable Energy Potential Study of New York State, April 2014. https://www.nyserda.ny.gov/-/media/Files/EDPPP/Energy-Prices/Energy-Statistics/14-19-EE-RE-Potential-Study-Vol2.pdf Warning: Optimal Energy, Inc. was involved in preparation of this document.

[PO10] Pacific Northwest National Laboratory and Oak Ridge National Laboratory. Guide to Determining Climate Regions by County, August 2010. http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/ba_climateguide_7_1.pdf.

[PSE14a] PSEG. Utility 2.0 Long Range Plan, July 2014. https://www.psegliny.com/files.cfm/2014-07-01_PSEG_LI_Utility_2_0_LongRangePlan.pdf.

[PSE14b] PSEG. Utility 2.0 Long Range Plan Update Document, October 2014. https://www.psegliny.com/files.cfm/Utility20-Document-100614.pdf.

"This project's aggressive approach to energy issues will impact parks across the city."

— Gale Brewer, Manhattan Borough President

BKSK

BKSK Architects
28 W. 25 Street
New York, NY 10010
bksk.com

Washington Square Park House

Completed 2014
NYC Dept. of Parks & Recreation, client
BKSK Architects LLP, architect
BuroHappold, MEP engineer

Last summer the NYC Department of Parks and Recreation hosted a ribbon cutting for the final phase of Washington Square Park's 6-year renovation. BKSK served as the architect of a central feature of this phase, a new park house that is on track to receive LEED Platinum certification.

Combined with energy load reduction measures, such as high performance envelope design, and photovoltaic panels that offset 34% of the electrical load, the implementation of a ground-source heat pump system has resulted in the park house using 55% less energy than a comparable building with a conventional system.

Some of the other key sustainable elements of this project include maximized daylight, the specification of low- or no-VOC building materials, the use of locally sourced stone, and the use of reclaimed wood. All of these strategies help to minimize environmental impact while addressing the needs of both the NYC Parks staff and the public. The deceptively modest park house includes a substantial program in its 3,100 square feet, including public restrooms, offices, storage, and unique mechanical spaces, most notably the pumps that operate the park's historic display fountain.

BKSK

BKSK Architects
28 W. 25 Street
New York, NY 10010
bksk.com

PARTNERS
Stephen Byrns
Harry Kendall
George Schieferdecker
Joan Krevlin
Julia Nelson
Todd Poisson

ASSOCIATES
John Englund
Stacey Jattuso
David Kubik
David O'Neil
Keith Pitocchi
Jennifer Preston

GEORGE SCHIEFERDECKER AIA, LEED AP BD+C
PARTNER, BKSK ARCHITECTS LLP

George Schieferdecker was the lead architect of the Park House in Washington Square, a new 3,1000 s.f. administration and public restroom building targeting LEED Platinum certification. He is a founding partner of BKSK, a firm committed to socially, contextually, and ecologically engaged architecture. Born in the Netherlands and raised in the United States, George has developed a fine-grained awareness of place and an affinity for modern buildings that are responsive to their historic contexts. His most notable work includes 25 Bond Street, an award-winning multifamily dwelling in NoHo, Plainsboro Public Library, the 52nd Street Theater Project, and the East End Temple. One of his current works is an ambitious net-zero energy learning center in Lambaye, Senegal, a BKSK pro-bono project. George holds degrees from Middlebury College and Columbia University.

JENNIFER PRESTON LEED AP BD+C
ASSOCIATE / DIRECTOR OF SUSTAINABLE DESIGN, BKSK ARCHITECTS LLP

Jennifer Preston leads the research and development of sustainable architectural solutions for BKSK. Her expertise has helped project teams identify key opportunities for reducing energy loads and implementing the most advanced sustainability protocol. With her leadership, BKSK joined the AIA 2030 Commitment. Her most recent projects include the new Athletic Center for Sacred Heart School (targeting LEED Gold), the Park House at Washington Square, and a new resilient playground at the Battery—a project at the forefront of "The Dryline" implementation. She is currently the project manager for BKSK's ambitious net-zero energy learning center in Lambaye, Senegal. Jennifer serves as an adjunct at Columbia University's Graduate School of Architecture, and has taught at Columbia's Earth Institute. She is a co-founder of the NYC+NJ Living Building Collaborative, serves on the Steering Committee for the AIA-NY Committee on the Environment (COTE), and is a member of the national Sustainable Design Leaders group.

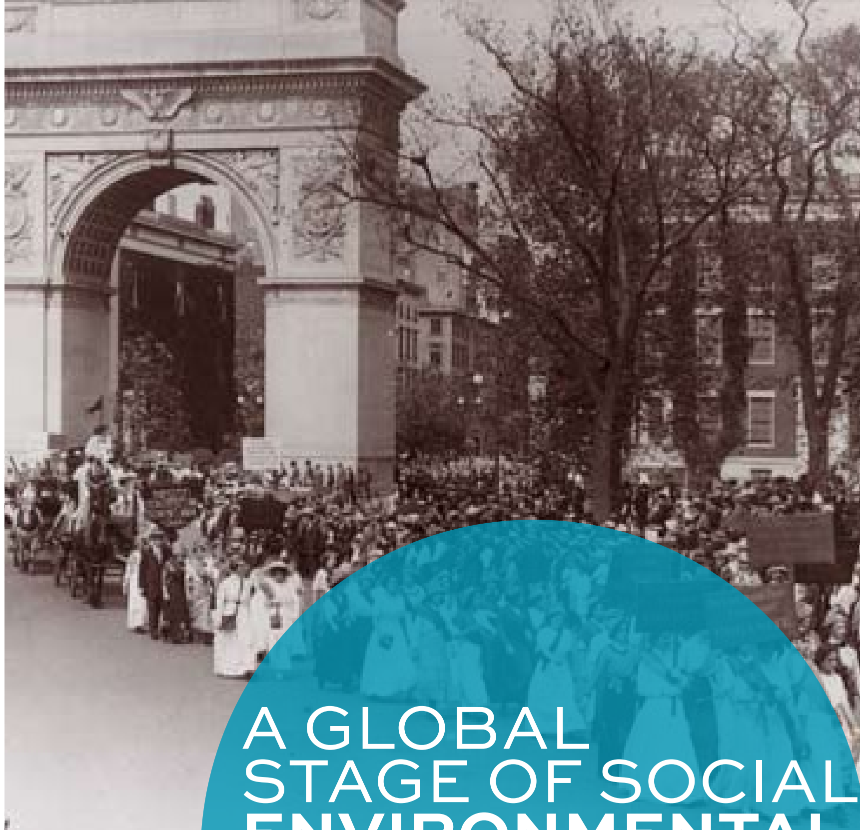
MICHAEL McGOUGH PE
PRINCIPAL, BURO HAPPOLD ENGINEERING

Michael McGough, a principal at BuroHappold, was the lead mechanical engineer for the new Park House at Washington Square. With more than 25 years of experience designing and managing the design of MEP systems for commercial, hospitality, civic, education and cultural facilities, Michael contributes a unique perspective that focuses on balancing the client's needs, user comfort, sustainability and cost. Currently managing several large-scale commercial projects in New York City, his earlier work includes the award-winning, LEED Platinum-rated Genzyme Headquarters in Cambridge, MA. Dedicated to mentoring the next generation of engineers, Michael has taught and lectured extensively at Columbia and Harvard universities. He is currently an active member of the Columbia University Mechanical Engineering Department's External Advisory Board and co-authored the abstract "Energy Dynamics of Green Buildings, an Alternative to the Traditional Heating, Ventilating and Air Conditioning Course" in the ASME International Mechanical Engineering Congress and Exposition, Innovative Curricula category.

WASHINGTON SQUARE PARK HOUSE

A MODEL FOR LOW CARBON DESIGN

BKSK

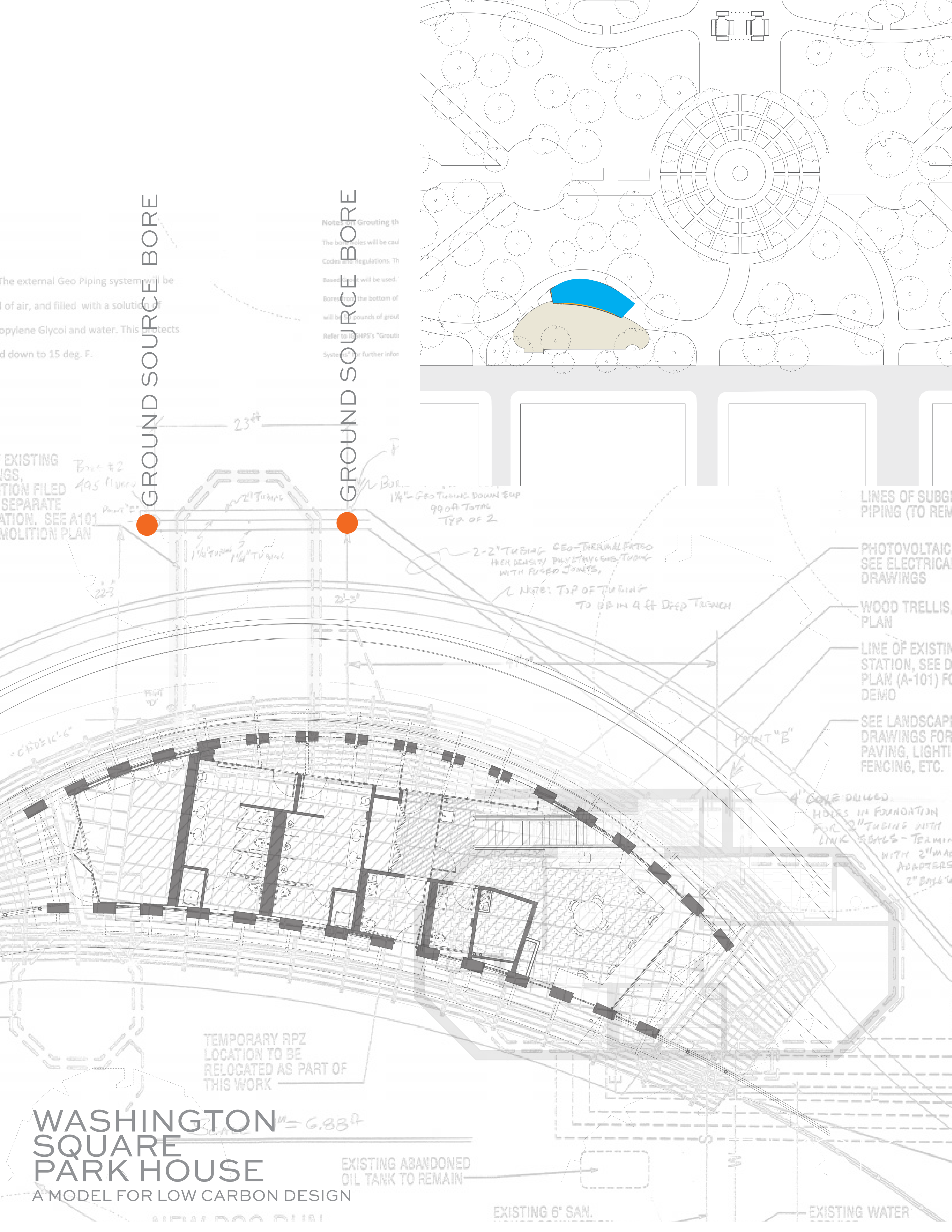


A GLOBAL STAGE OF SOCIAL **ENVIRONMENTAL** AND POLITICAL CHANGE

WASHINGTON SQUARE PARK HOUSE

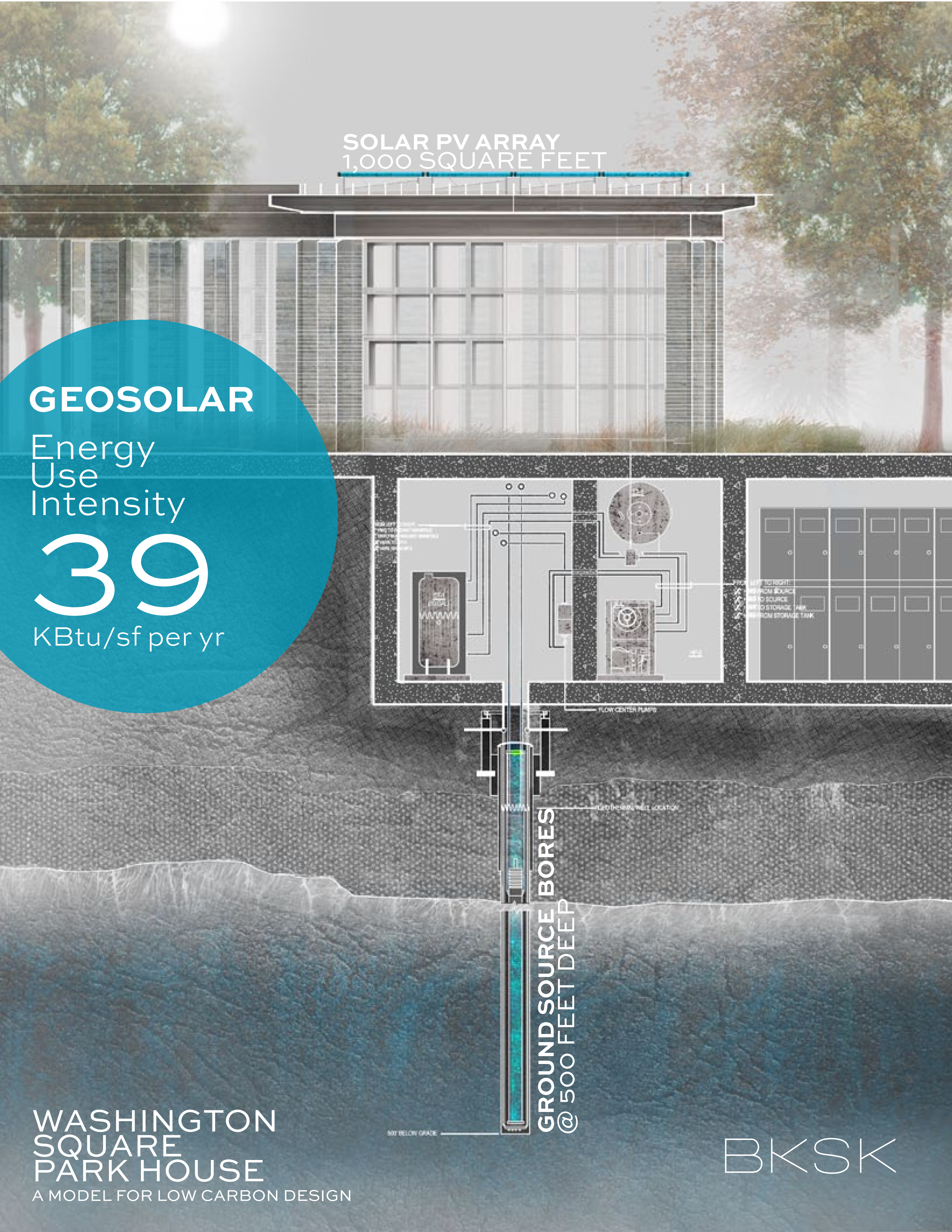
A MODEL FOR LOW CARBON DESIGN

BKSK



WASHINGTON SQUARE PARK HOUSE

A MODEL FOR LOW CARBON DESIGN



GEOSOLAR

Energy Use Intensity

39

KBtu/sf per yr

WASHINGTON SQUARE PARK HOUSE

A MODEL FOR LOW CARBON DESIGN

BKSK

GROUND SOURCE HEAT

Overview: Geothermal exchange utilizes a heat pump to capture the stable temperature of the earth to pre-heat and pre-cool a building's comfort systems. This is different than geothermal energy, which is not available in New York City.

Benefits: • Highly efficient • Highly cost-effective and durable relative to other heating and cooling systems • Can reduce heating & cooling costs 25-75% compared to conventional systems • Low maintenance • Little or zero emissions • Quiet operation

Challenges and Opportunities: • Not practical for all sites • High initial costs (drilling & exploration) • Open systems present risks due to unknown geological conditions • Federal tax credits incentives exist to offset installation costs (Expires 12/31/16) • Special financing is available from Energy Star® and other organizations

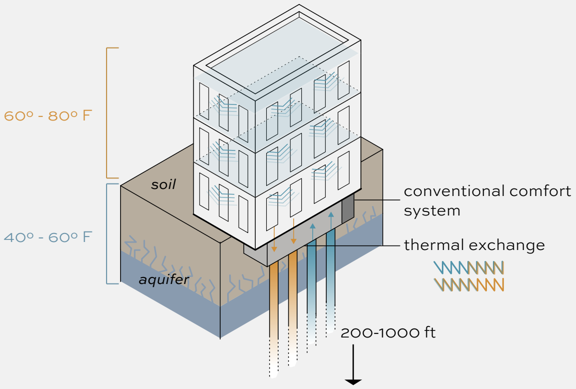
Process: A geothermal exchange system consists of a heat pump, a heat exchange component, and a delivery system.

The heat exhange component uses two thermally conductive materials - a source and a sink - to transfer energy, heat, and cooling between the two materials.

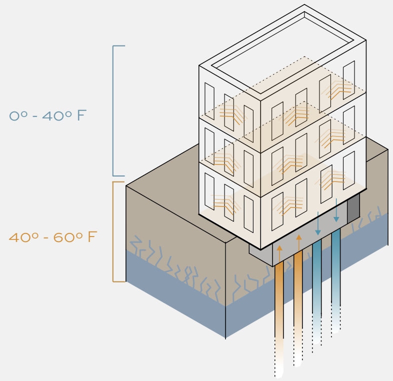
Water-to-water systems use water to carry heating or cooling through the building. Examples include: radiant underfloor heating, baseboard radiators, and conventional cast iron radiators. Water-to-water systems are preferred for pool heating or domestic hot water pre-heating.

Water-to-air systems use forced air to carry heating or cooling through a building. They are often used to replace forced air furnaces and central air conditioning systems. Variable designs allow for split systems, high-velocity systems, and ductless systems.

$30,000 - $50,000 per pump



SUMMER COOLING: GROUND AS SINK



WINTER HEATING: GROUND AS SOURCE

Case Studies:

Washingston Square Park House: New York, NY : 3,100 sq. ft.
www.bkskarch.com/work/washington-square-park-house

Historic Front Street: New York, NY: 150,000 sq. ft.
www.cookfox.com/project.php?id=Historic-Front-Street

Additional Resources:

NYC Geothermal Heat Pump Manual

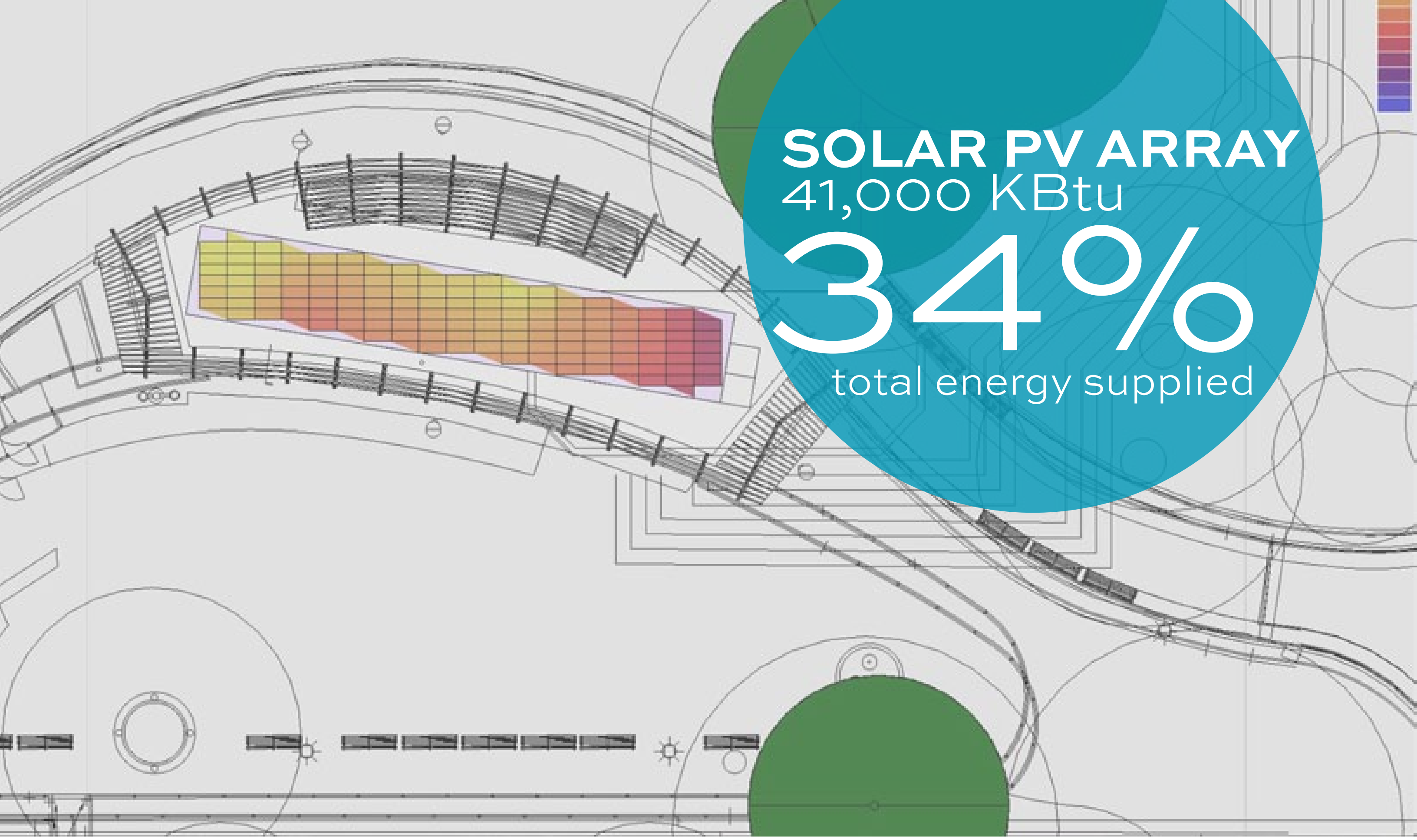
http://home2.nyc.gov/html/ddc/downloads/pdf/geotherm.pdf

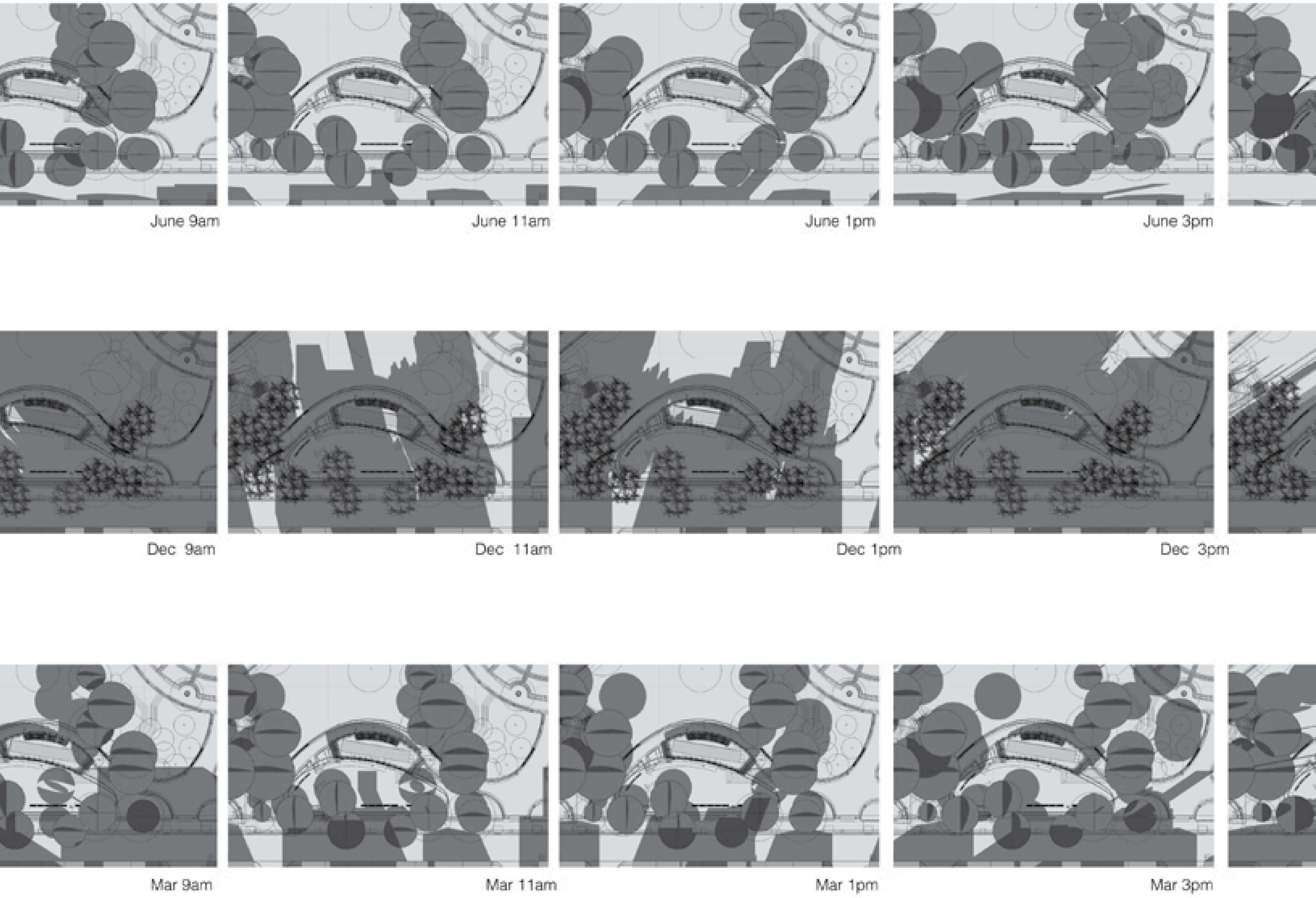
WASHINGTON SQUARE PARK HOUSE

A MODEL FOR LOW CARBON DESIGN

BKSK


SOLAR PV ARRAY
41,000 KBtu
34%
total energy supplied
WASHINGTON
SQUARE
PARK HOUSE
A MODEL FOR LOW CARBON DESIGN
BKSK


SOLAR PV ARRAY
41,000 KBtu
34%
total energy supplied


June 9am
June 11am
June 1pm
June 3pm
Dec 9am
Dec 11am
Dec 1pm
Dec 3pm
Mar 9am
Mar 11am
Mar 1pm
Mar 3pm

ANNUAL GREENHOUSE EMISSIONS FROM

2.2

CARS

CO2 EMISSIONS FROM

11,296

POUNDS OF COAL

ANNUAL CARBON SEQUESTERED BY

8.6

ACRES

http://www.epa.gov/cleanenergy/energy-resources/calculator.html#results

CENTER FOR ARCHITECTURE
GENERAL THEOLOGICAL SEMINARY
QUEENS BOTANICAL GARDEN
TIMES SQUARE TKTS BOOTH
BROOKLYN CHILDREN'S MUSEUM
WEEKSVILLE HERITAGE CENTER
STATEN ISLAND MUSEUM
BRONX ZOO LION HOUSE
CORNELL TECH CAMPUS
PS62
EAST 93RD STREET
FRONT STREET
23 GRAMERCY PARKSOUTH

AND 100
OTHER
PROJECTS
THROUGHOUT
NYC

WASHINGTON SQUARE PARK HOUSE

A MODEL FOR LOW CARBON DESIGN

PRESENTED BY

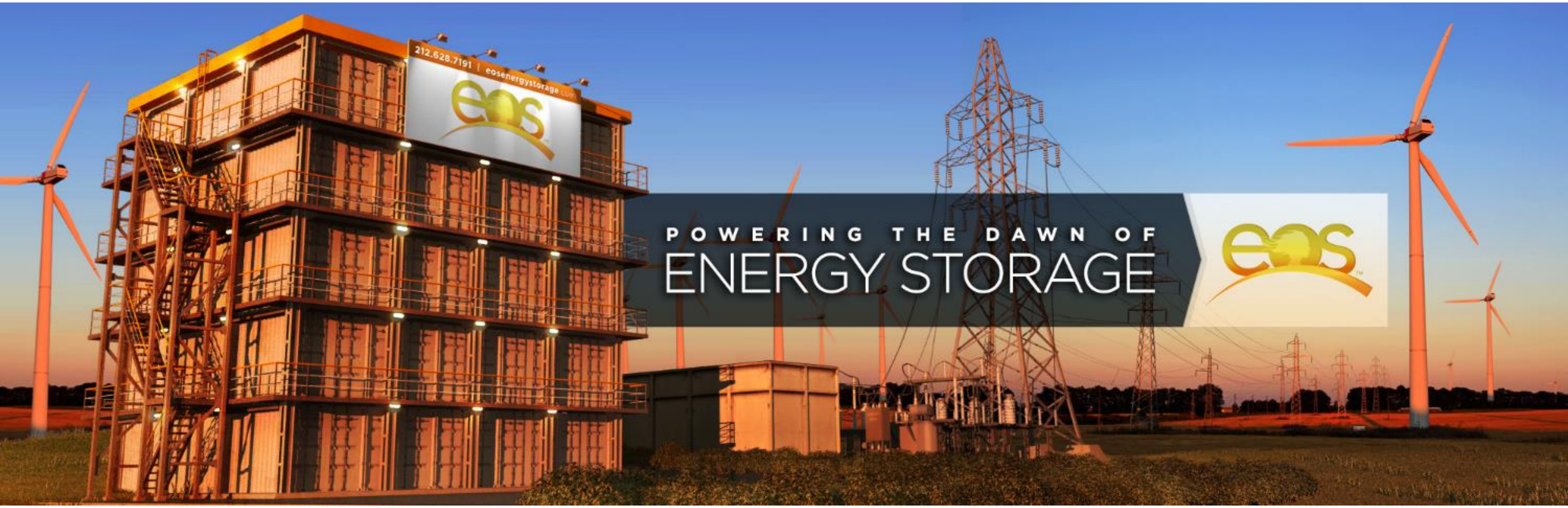
GEORGE SCHIEFERDECKER, AIA
PARTNER, BKSK ARCHITECTS

JENNIFER PRESTON, LEED AP BD+C
DIRECTOR OF SUSTAINABLE DESIGN, BKSK

MICHAEL McGOUGH, PE
PRINCIPAL, BUROHAPPOLD ENGINEERING

more info: **www.bksk.com**

BKSK



NYCCC on Environment Protection: Site-Sourced & Stored Renewable Energy Conference

Eos Energy Storage
Philippe Bouchard, VP Business Development

February 27, 2015

Eos Energy Storage Overview

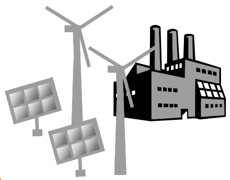
THE MISSION

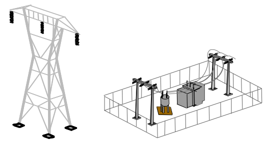
Eos develops and commercializes cost effective energy storage solutions which are not only less expensive than other battery technologies, but less expensive than the most economical alternative used today to provide the same services

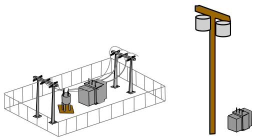
THE SOLUTION

- **Product** - Eos' Aurora 1000|4000 is a safe, long-lasting DC battery system capable of providing 1MW of power for 4 hours of continuous discharge and millisecond response time.
- **Price** - At a price of $160/kWh in volume, the Aurora solution is the lowest cost energy storage product on the market. Affordable extended warranties and capacity guarantees ensure long-life.
- **Technology** – The Aurora product employs Eos' proprietary zinc hybrid cathode (Znyth™) battery technology, built on 21 patents and patent applications with over 600 claims
- **Availability** - Eos is currently taking orders for delivery in 2016 and beyond.

Today's Electricity Grid is Massively Overbuilt & Under Utilized…





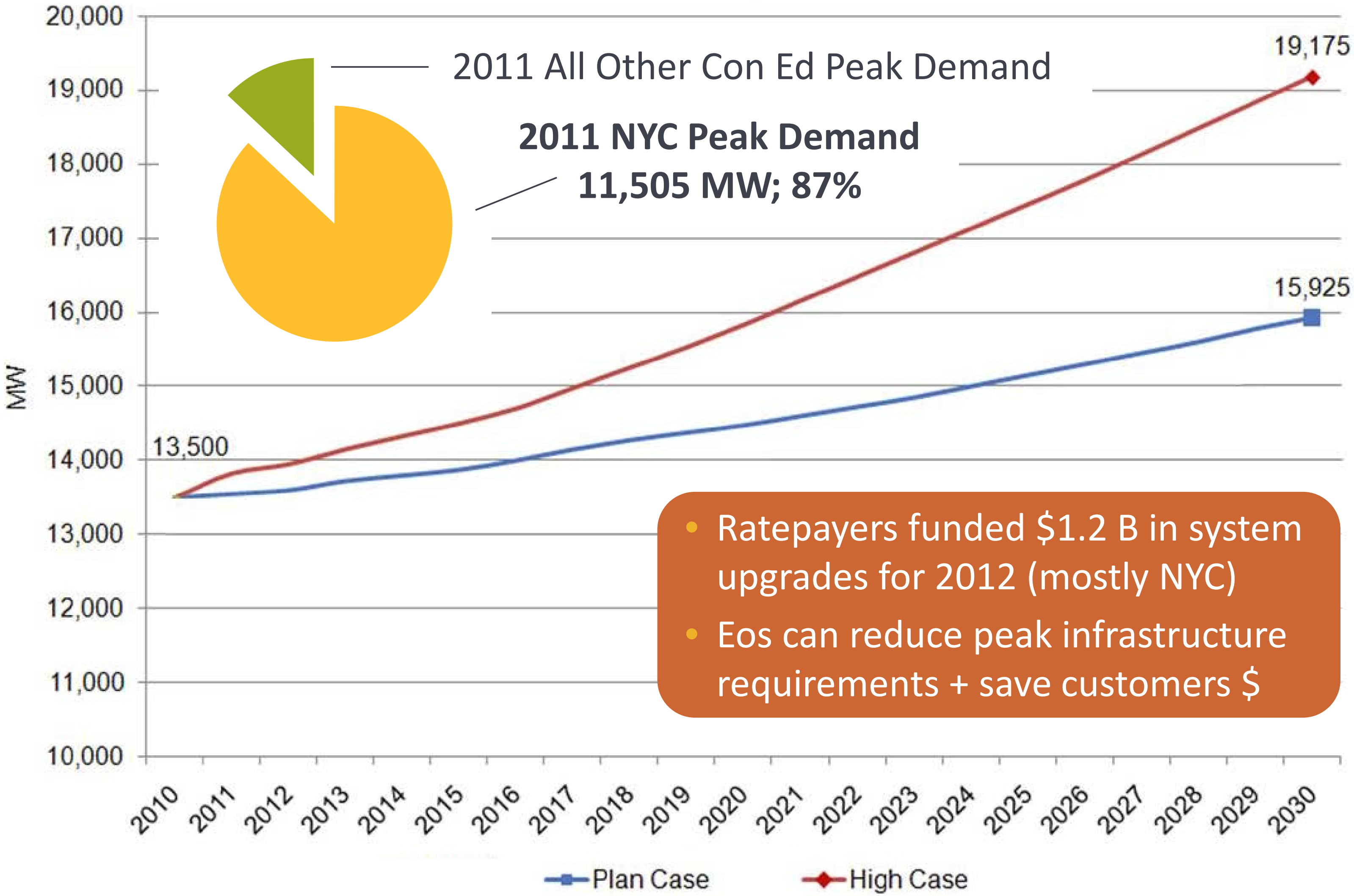


	Generation	Transmission	Distribution
# in U.S.	**17,350 plants**	**164,000 miles**	**3 million miles**
Utilization	**47%**	**43%**	**34%**
Projected spend 2010-2030	**$505B**	**$298B**	**$582B**
Projected underutilization	**~$1.4 TRILLION of future US infrastructure will be underutilized without storage**		

Energy storage unlocks value in existing assets by increasing low rates of utilization

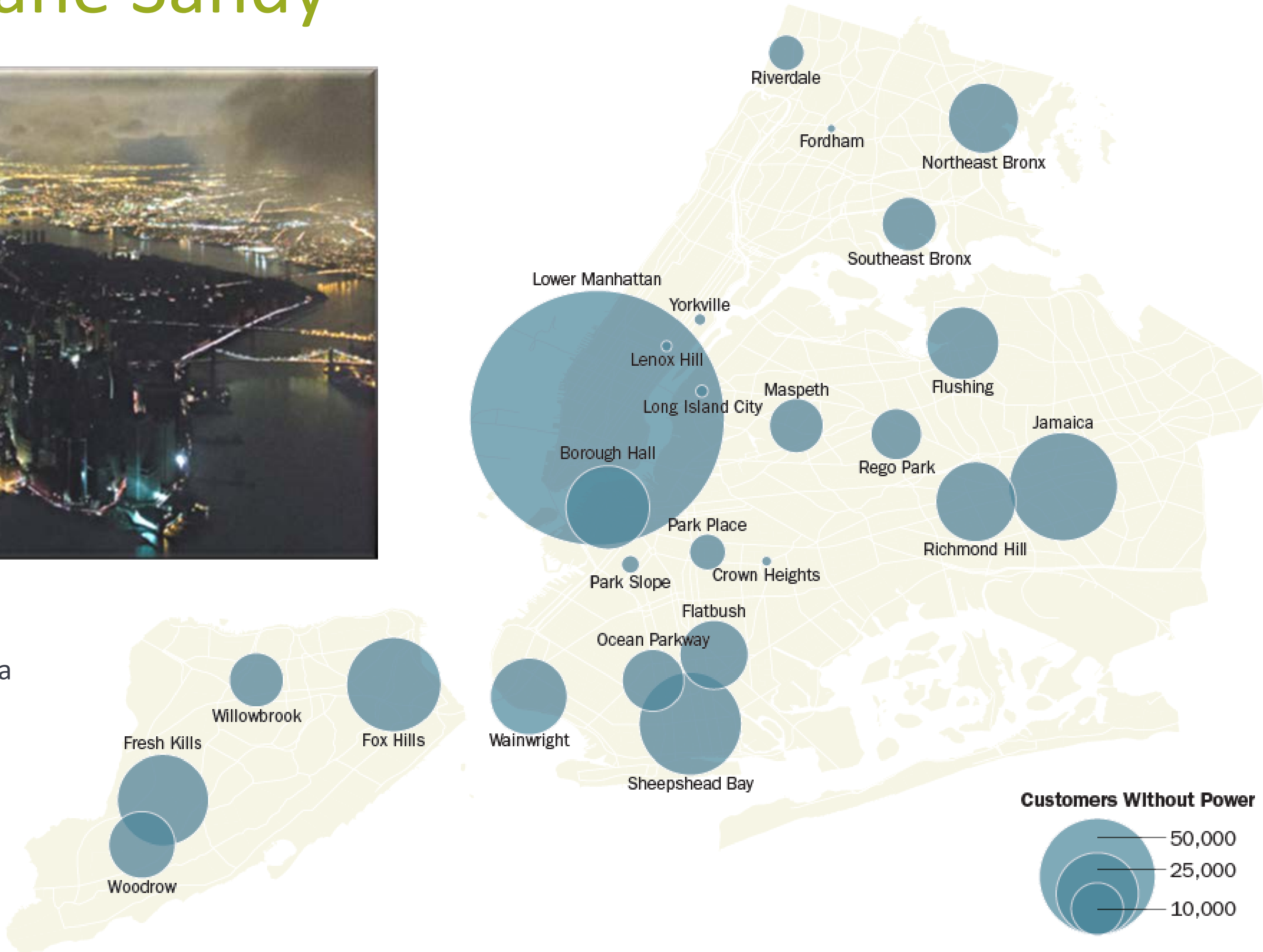
Sources: "Electric Power System Asset Optimization." NETL, March 2011; "The Power of Five Percent." The Brattle Group, May 2007

Con Ed Peak Demand Forecast 2010-2030



1) Con Ed Electric System Long Range Plan. http://www.coned.com/publicissues/PDF/ESLRP%20Appendices%20December%202010%20Final.pdf
2) http://af.reuters.com/article/energyOilNews/idAFL1E8H57PD20120605

Hundreds of Thousands without Power in NYC After Hurricane Sandy

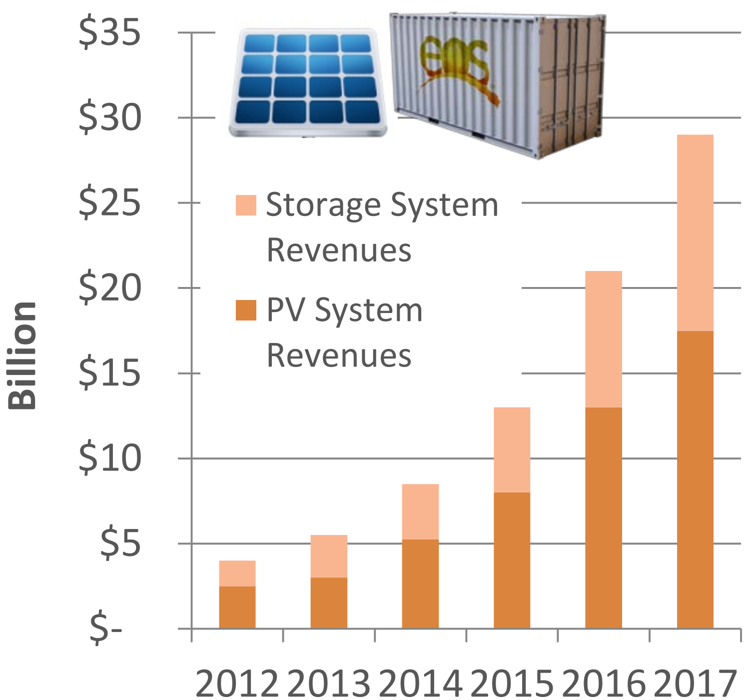


Source: Huffington Post, Consolidated Edison / Note: Data as of Wednesday Oct. 31 at 12 p.m. EST. Areas with fewer than 250 outages not shown

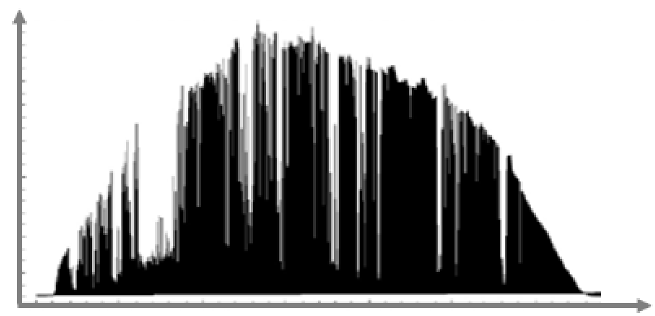
Energy storage combined with distributed generation will enhance grid resiliency / reliability

Storage will become increasingly necessary as intermittent renewables continue strong growth

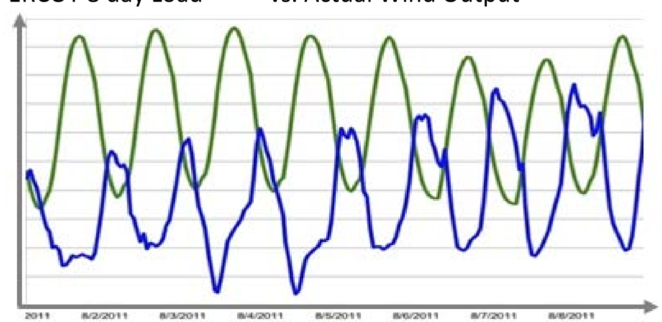
2017: >7x Growth in Solar + Storage >> Utilities Need Storage to smooth and shift supply



AZ one day solar output



ERCOT 8 day Load vs. Actual Wind Output



- Storage can smooth the intermittent output of PV/wind facilities, reducing strain on utility grids
- Eos can store and shift the output of renewables that generate at off peak times, better balancing energy supply with demand

Energy storage allows utilities to effectively integrate more renewables; demand naturally increases as more renewables are deployed

‘Perfect Storm’ Market Drivers Define Requirements for Battery Storage

Aging Infrastructure & Extreme Weather Threaten Power Reliability

Rising Electricity Costs Encourage Efficiency & Self-Generation

Energy Storage Requirements

- Low Cost/kWh
- Extremely Long Life
- High Energy Density
- High Efficiency
- Zero Emissions
- 100% Safe

Variable Roof Top Solar PV Causes Grid Instability

Customers & Utilities Struggling with Increasing Demand

Eos Introduces Industry's Lowest Cost Energy Storage Product : Aurora 1000|4000

BATTERY MODULES → RACKING/ CONTAINER → MANAGEMENT SYSTEM → **AURORA 1000|4000**

The Aurora 1000|4000 is a 1MW/4MWh DC battery system comprised of 4x250kW/1MWh sub-systems in 8.5x8x24ft NEMA rated enclosures

- ✓ **Round Trip Efficiency**: >75% at 100% DoD
- ✓ **Cycle Life**: >5,000 cycles
- ✓ **Expected Calendar Life**: >15 years
- ✓ **Self Discharge**: 0.5% per day
- ✓ **Operating Temperature**: 10-45C
- ✓ **System Voltage**: 320-960 min/max V_{DC}; 768 nominal V_{DC}
- ✓ **Response Time**: millisecond response

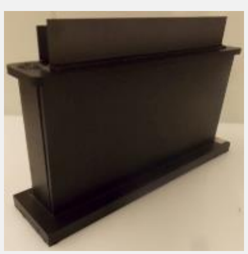
The Aurora 1000|4000 is a containerized DC battery system that is being sold for a volume price of $160/kWh for delivery starting in 2016

Inside the Eos Product: Technology Overview

System

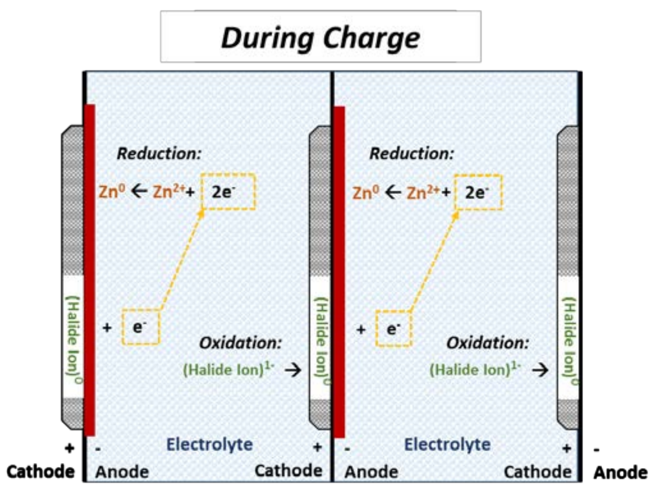
Battery

Cell

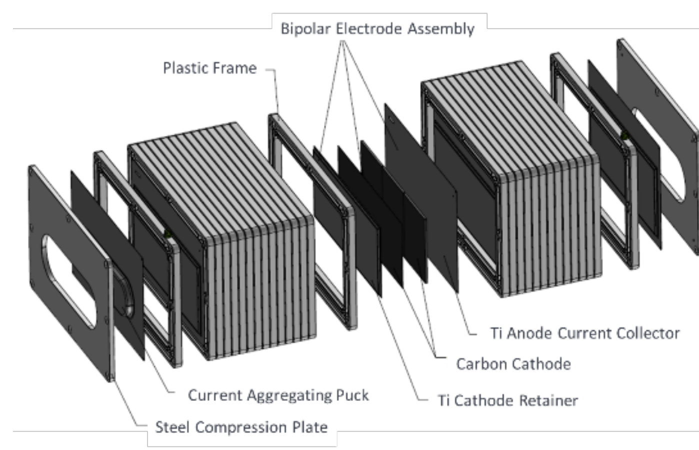


- **Eos' Chemistry**:
  - Zinc hybrid cathode technology (Znyth), using abundant, low-cost materials
  - Aqueous, near neutral electrolyte enables the technology to provide high energy capacity while remaining inherently safe
- **Design Features**:
  - Proprietary corrosion-resistant coating on current collectors enables long cycle life
  - Designed for simple, low-cost manufacturing and rapid scale up
- **IP Portfolio**: 21 patents and patent applications pending in the U.S. and major market countries with over 600 claims
- **Validation**: Safety and cost estimates independently confirmed by DNV GL

Low-Cost Znyth Chemistry



Scalable Sub-Module Design



Genesis Partners Drive Product Demonstration & Deployment

Eos Genesis collaboration includes:

1. ***Detailed business case analysis*** to identify value drivers for storage
2. ***Product development*** to meet the requirements of the business case
3. ***Testing and evaluation*** of Eos' Znyth™ battery technology
4. ***Pilot demonstration and commercial roll out*** of Eos Aurora systems

Together Eos' Genesis Partners represent:

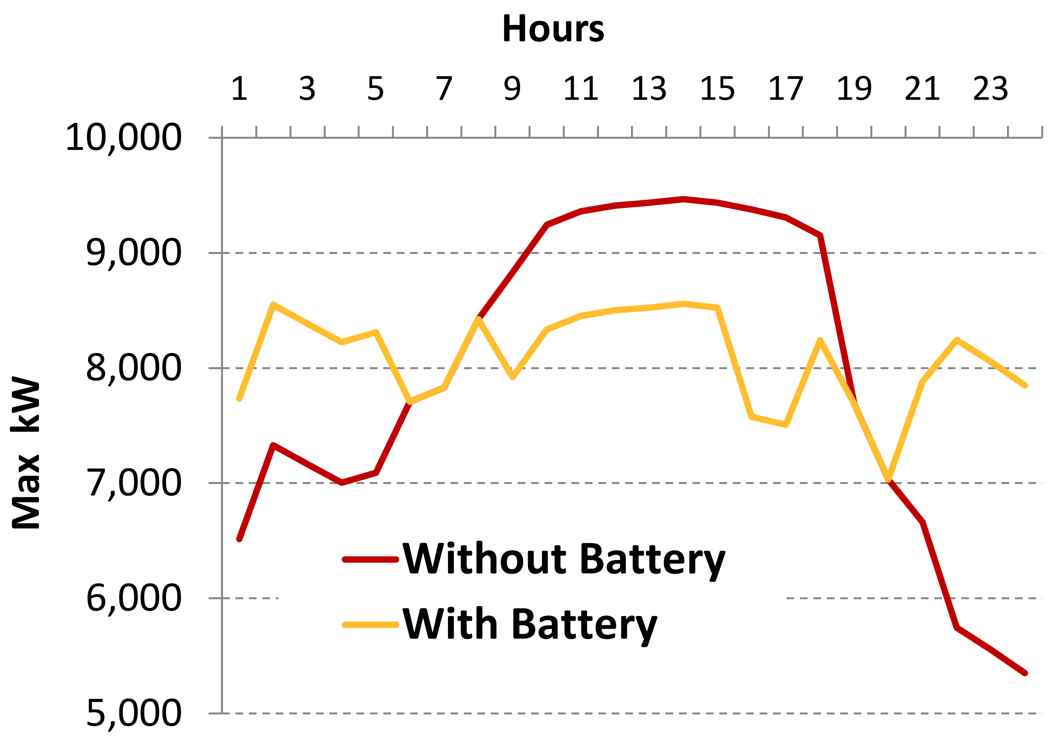
91 M
Customers

385
GW Generation

1.8 M
Miles of T&D

70+
Countries

Behind-the-Meter Storage in NYC



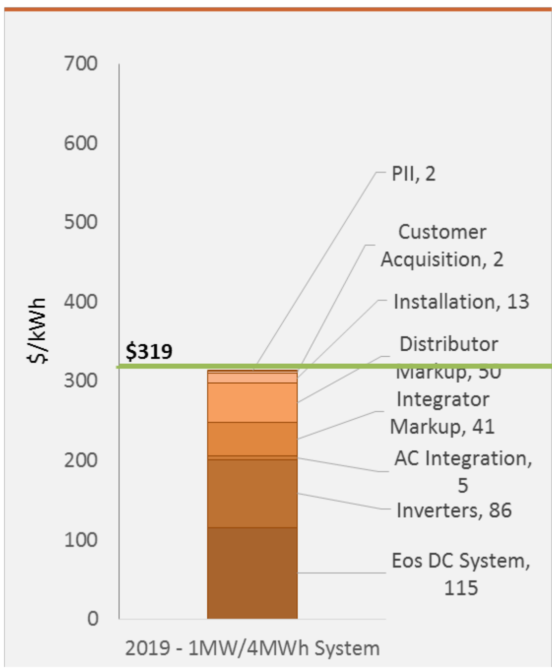
Benefits
Economic: 1. Demand Charge Reduction 2. TOU Retail Rate Arbitrage 3. Demand Response / Program Revenue **Reliability:** 1. Power Quality 2. Reliability

Storage can balance charge/discharge profile to reduce monthly peak; programmatic utility benefits are key driver of business case in New York

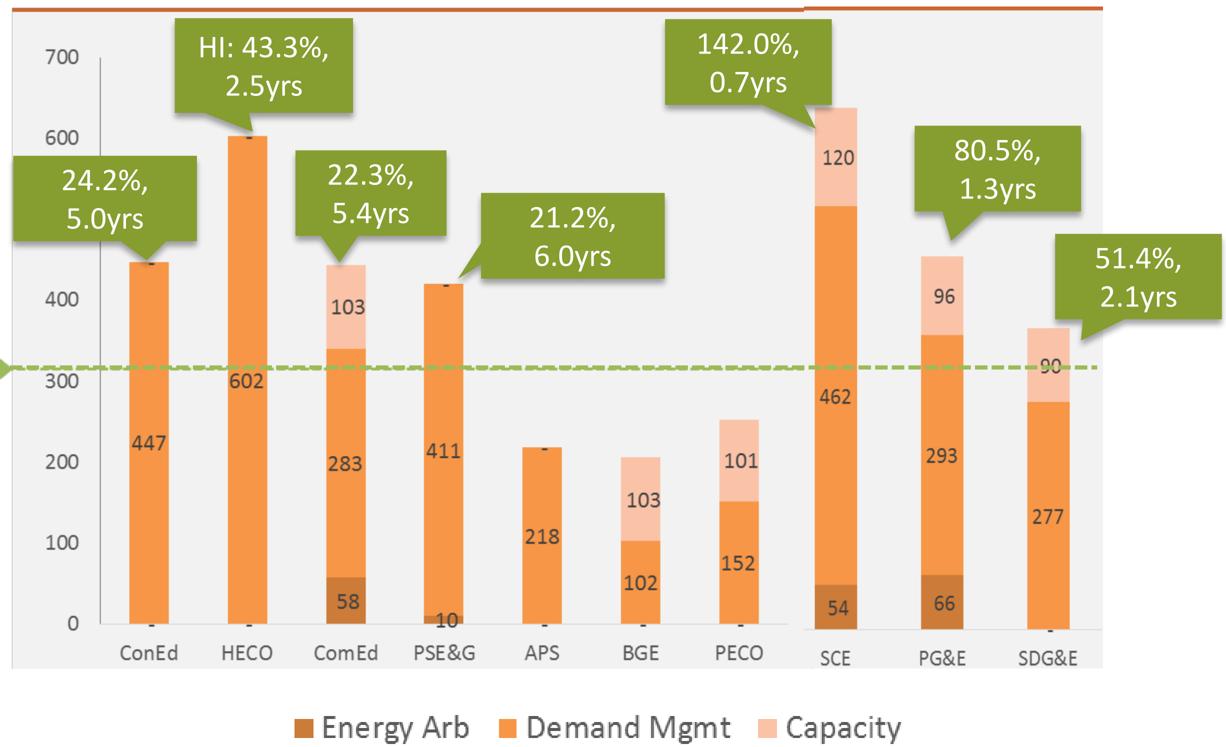
Behind-the-Meter: Eos Aurora 1000|4000 Highly Profitable in Major Retail Markets

Eos has worked with utility partners to evaluate the use of energy storage for behind-the-meter energy and demand management. Energy storage at Eos cost and performance shown to be highly profitable, with **IRRs of 20-140% and payback periods of <1-6 yrs in major markets.**

NPV Cost (1MW/4MWh)



NPV Benefits (IRR and payback shown in green)

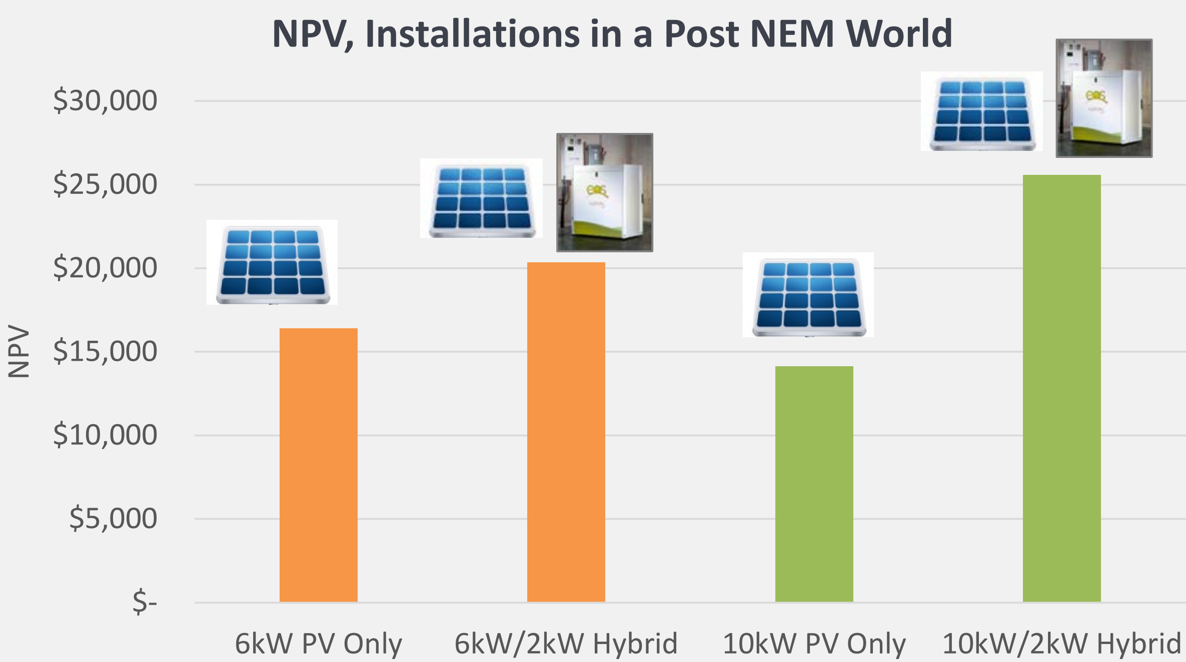


Behind-the-Meter: Storage adds additional value when combined with residential solar PV

	Solar PV	Solar PV + Storage
Bill Impacts	• Reduces retail rate energy consumption • Monetizes value of excess production via NEM payments or wholesale power	• Store and shift excess PV to arbitrage retail rates vs. wholesale rates
Backup Power	• No backup power available • Does not mitigate need for on-demand backup power	• Generate and store power for use during blackouts • Reduce reliance on expensive and polluting diesel generators

Behind-the-Meter Storage, Paired with Solar: Strong Value for Residential Customers

The value of energy storage also bolsters the business case for residential electric customers by offsetting their peak demand charges, delivering higher NPVs for hybrid PV and storage installations and expanding the business opportunity for larger solar installations.



- Hybrid PV and storage installations deliver strong IRRs of ~16% and NPV value in excess of $20-25K
- Sample case reflects installation in Southern California Edison's Barstow area, assuming that net metering is phased out in 2018 and reduced SGIP incentive

Eos - Con Ed Van Nest Demonstration Project

conEdison   nyserda Energy. Innovation. Solutions.

- **Overview -** Eos awarded a $250,000 “Bench to Prototype” grant from NYSERDA to demonstrate its Eos battery system within Con Ed’s territory
- **Application –** Installation and operation behind-the-utility-meter to shave system peak load and reduce customer demand charge

Installation location = ConEd Building #1 at Van Nest facility

System currently on test at DNV GL facility in Rochester, NY. System will be installed at ConEd Van Nest facility in the Bronx upon successful permitting with NYC DOB

Recommendations

1. **Streamlining Adoption** – work with city agencies (NYC DOB, FDNY, etc) to streamline processes for permitting and installing energy storage in NYC buildings
2. **Improve Resiliency** – Dedicate municipal facilities as community accessible microgrids and solicit market-based solutions; Integrate with NY Prize programs
3. **Engage in 'Reforming the Energy Vision'** – Integrate NYCC initiatives with ongoing REV proceeding to drive utility regulatory reform with NYCCC objectives
4. **Lead by Example** – Partner with the private sector to make NYC municipal facilities green, resilient, and cost-effective through programmatic implementation of storage

Orders can be placed at sales@eosenergystorage.com

www.eosenergystorage.com

3 east 80th street, new york, ny 10075
p. +1.212.628.7191
f. +1.212.628.7193