Consolidated Edison Company of New York, Inc.

Steam Operations

Assessment of the End to End Efficiency of the Steam System

Joint Proposal Study #1

April 30, 2011

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1. <u>Executive Summary</u>

The 2010 Steam Rate Order required Consolidated Edison Company of New York, Inc. ("Con Edison" or the "Company") to examine the end-to- end efficiency of the Con Edison steam system ("Study #1"). As part of this effort, the Company performed the following analyses and review:

1. The actual 2010 end to end efficiency of the Con Edison steam system.
2. The forecasted 2015 end to end efficiency of the Con Edison steam system.
3. The manufacturer efficiency ranges of different types of combined heat and power (cogeneration or "CHP") technologies and boiler-only technologies that a customer can install in its building in lieu of using Con Edison steam.
4. The energy use efficiency of the different types of combined heat and power technologies and boiler-only technologies installed in a proxy Manhattan commercial customer's building, in lieu of Con Edison steam.
5. The estimated efficiency of a district energy system constructed in Manhattan.

End to end efficiency is defined as the total amount of energy used (electrical and thermal) by a customer divided by the total fuel input. Only the electric energy used by the customer that was produced by steam system cogeneration (for the steam end to end efficiency calculation) and the electric energy produced by the customer-sited sources were accounted for in these end to end efficiency assessments. All efficiency values within this report are High Heating Value ("HHV").

One assumption that was common for all of the foregoing cases was that there were no building equipment heat losses. This is so because every building is different and there are too many different types of equipment configurations that could be possible. The following tables summarize the findings of this study. Figure 1 shows the end to end efficiency of the Con Edison steam system for 2010 and 2015. Figure 2 shows the end to end efficiency of various district energy system options. Figure 3 shows the efficiency of various types of manufacturers' equipment that could be used by a customer. Figure 4 shows the end to end efficiency of a proxy customer's building based on the type of equipment used to provide energy to that building.

Figure 1

Steam System End to End Efficiency Results	
2010 Con Edison Steam System	60%
2010 Con Edison Steam System – Winter	62%
2010 Con Edison Steam System – Summer	57%
2015 Con Edison Steam System	60%
2015 Con Edison Steam System – Winter	63%
2015 Con Edison Steam System – Summer	57%

Figure 2

District Energy System End to End Efficiency				
District System Type	Chilled Water	Hot Water	Combined Chilled and Hot Water	Combined Chilled and Hot Water with Cogeneration
Calculated End to End Efficiency	72%	68%	70%	74%

Figure 3

Efficiency Range (Manufacturers' Ideal Ratings)		
Technology	Minimum Efficiency	Maximum Efficiency
Gas Turbine w/o duct firing	21%	79%
Gas Turbine w/ duct firing	21%	95%
Reciprocating Engine	34%	59%
Microturbine	26%	64%
Fuel Cell	36%	81%
Steam Boiler	79%	79%
Hydronic Boiler	82%	82%
Electric Resistance Heating	35%	35%

Figure 4

Proxy Customer End to End Efficiency		
Technology	Annual Operation Building Efficiency	Seasonal Operation Building Efficiency
Gas Turbine w/ duct firing	37%	67%
Reciprocating Engine	46%	73%
Microturbine	56%	63%
Fuel Cell	63%	73%
Steam Boiler	79%	N/A
Hydronic Boiler	82%	N/A
Electric Resistance Heating	35%	N/A

Figure 5 illustrates how the efficiencies of various types of technologies compare with the Con Edison steam system. Except for Con Edison, the Technology Efficiencies within are not reduced for aging, fouling, blowdown, any condensate losses, leaks, meter error, unit cycling, or start up fuel.

Figure 5
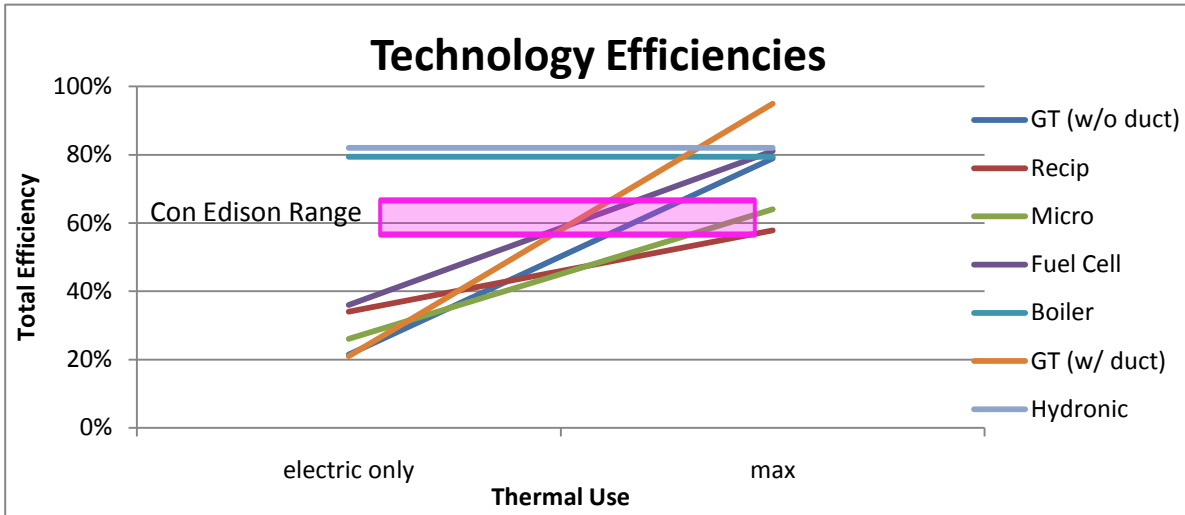
The end to end efficiency of the Con Edison steam system was 60% annually ranging from 57% in the summer to 62% in the winter and compared favorably to many of the alternative technologies. Since Con Edison is, in effect, a large distributed generator, its equipment sees high thermal and electrical loads throughout the year and can operate at higher efficiencies more often than most of the alternate technologies that a single supplier can use in trying to meet its electrical and thermal needs. Moreover, as the graph above shows, if the thermal loads are not being fully utilized, the efficiencies for all the technologies except the Con Edison steam system and boilers can be low depending on the building load factor and equipment sizing. Conversely, if a building or hospital complex has a high electric and thermal load factor, it will realize higher efficiencies. One size does not fit all when it comes to customer-sited steam and cogeneration choices. Moreover, there are factors other than energy efficiency that should be considered in evaluating whether to utilize Con Edison Steam or whether to go with customer-sited boilers or some form of CHP. If a customer decides to exit the steam system, that customer will need to invest significant capital in a new system and will incur annual fuel, maintenance, and incremental property taxes. Based on the findings of Joint Proposal Study # 4, *Assessment of the Costs and Benefits of Alternatives to Steam Supply,* various first and annual costs associated with the installation of new alternative energy sources may preclude the customer from realizing an acceptable payback period.

2. __Objective__

The objective of this study is to determine the end-to-end efficiency of the Con Edison steam system. In order to put this steam system efficiency in perspective, the Company evaluated the efficiency of various combined heat and power and boiler technologies and used these values to estimate the end to end efficiency for each technologies based on the load profile of a Manhattan commercial proxy customer. The Company also evaluated the end to end efficiency of a district energy system in Manhattan.

3. __Scope of Work__

The Company developed the following scope of work in consultation with Department of Public Service Staff ("Staff") for purposes of developing the end to end efficiency of the steam system:

1. Develop the end to end efficiency of the steam system based on historical and forecasted dispatch of the steam units and fuel burned.

Actual fuel, production unit performance, steam variance, and operating information for historical year 2010 were utilized to develop an accounting of the energy input to all steam and steam-electric units on the Con Edison steam system. Auxiliary power and energy used for heating fuel oil for steam and electric production (cogeneration units only) and steam variance energy was deducted, as well as any energy lost within the customer's premises where the customer does not recover it. A similar model was developed utilizing the latest 2015 PROMOD run to show any differences attributable to changes in dispatch, fuel prices, and excluding Hudson Avenue as a generating station. A diagram showing the energy losses from start to finish is provided for the historical case and the forecasted case.

2. Develop the end-to-end efficiency of various CHP Units (gas fired combustion turbine/heat recovery steam generator, fuel cells, micro turbines, and reciprocating engines) as well as gas fired steam-only boilers installed in a commercial building.

Manufacturers' data as well as EPA information for gas fired combustion turbine/heat recovery steam generator, fuel cells, micro turbines, reciprocating engines, and gas fired steam-only boilers installed were utilized to determine the base efficiency for each of these configurations. Auxiliary power, start up fuel usage, low and extremely high load factor operating inefficiencies, and dumped steam was accounted for. These were calculated by utilizing typical building load shapes. Condensate recovery was credited where applicable. A diagram showing the energy losses from start to finish is provided for each of the foregoing configurations.

3. At the request of Staff, the Company added the following scope items to the project:
    a. Proxy customer efficiency using hot water boilers.
    b. Proxy customer efficiency using electric heating.
    c. The end to end efficiency of a district energy system using a previously developed study for the Hudson Yards area.
    d. Seasonal end to end efficiency values for using both 2010 actual and 2015 projected inputs

4. **Descriptive Work Plan**

The Company's analyses were guided by the following work plans, developed in consultation with Staff.

Steam System

Calculate the end to end efficiency of the Con Edison steam system based on historical and forecasted dispatch of the steam units and the fuel burned. 2010 actual fuel input, steam sendout, electricity cogenerated, and customer steam sales will be used in the first part of this effort. 2015 forecasted fuel input, steam sendout, electricity cogenerated, and customer steam sales will be used in the second part of this effort.

End to End Efficiency – 2010 Actual and 2015 Projected
• Determine the fuel oil and natural gas used.
• Convert the Steam and cogenerated electric outputs to common units of energy (Btu).
• Calculate and add the auxiliary electric power usage from steam-only units.
• Determine the line losses for steam and electric.
• Evaluate the 2005 Goldman Copeland Assessment ("GCA") of condensate re-use for the 100 largest steam customers.
• Determinate the outputs of steam and electricity from official meter readings, which are in lb of steam and MW of electricity for the Con Edison units and Brooklyn Navy Yard Cogeneration Partners plant ("BNY").
• Discuss the accuracy, standards, and quality assurance that go into fuel oil, natural gas, steam, and electric measurement and metering for both generating stations and customers. Meter readings, tank soundings, meter calibrations, instrument error, and annual fuel oil inventory will be part of this discussion. The Company will provide a calculation with details on the error associated with each energy type being measured to demonstrate the level of impact such error has on the overall end to end efficiency.
• Discuss the Industry Codes (e.g., ASME, API, IEEE, ASTM) and the procedures used by the Company to describe the level of energy measurement accuracy.
• Based on the foregoing inputs, calculate the end to end efficiency on a Btu basis. End to End Efficiency = [(net steam Btu + net electric Btu)/gross fuel input Btu] x 100. Develop a model to vary the inputs, determine the sensitivity of any one of the parameters, and the range of outcomes for end to end efficiency.

- For the 2015 end to end efficiency calculation, estimate the Steam Variance using 2015 steam sales forecast.
- Perform 2015 PROMOD run for new fuel prices, sales forecasts, steam peaks, outage schedule, dispatch criteria, and other information.
- Input of all of the foregoing data into the end to end efficiency calculation, including consideration of auxiliary power for production, meter and measurement error, and the condensate losses determined in the first part of this assessment for the 2015 end to end efficiency calculation.

CHP and Boilers

Calculate the end to end efficiency of CHP units, as well as gas fired steam-only boilers installed in a commercial building.

- Obtain actual monthly steam and electric end use for a typical commercial (SC-2) steam customer from the Company's customer system.
- Identify specific commercially available equipment technical information for each of the technology configurations previously identified above. Develop a configuration using the identified equipment that matches the customer's steam peak. Develop an equipment dispatch profile for the selected configuration, based on the building loads.
- Calculate the CHP and boiler system efficiency for a year including any losses within the building.
- Provide energy diagrams for all cases.
- Provide a set of line graphs that illustrate CHP and boiler system efficiencies across a range of electric and thermal loads. Each line in the graph will be based on efficiency ranges for the identified configuration technologies.
- Discuss the inputs, assumptions, and findings. For example,
  - Discuss how equipment configuration and dispatch practice affects CHP system efficiency.
  - Con Edison assumes the same level of accuracy, due diligence for calibration and proof testing of measurement and meter devices, standards and frequency by customers in maintaining boilers clean when they foul with oil ash as the Company maintains for its system.

Additional Scope Items

- Determine the end to end efficiency for a building utilizing hot water boilers.
- Determine the end to efficiency for a building utilizing electric radiant heat.
- Review the 2007 District Energy Study for the Hudson Yards and provide a best estimate for what the end to end efficiency for such a district energy system would be.
- For the months of January through April and November and December, determine the steam system end-to-end efficiency for 2010 Actual and 2015 Forecast.

- For the months of May through October, determine the steam system end-to-end efficiency for 2010 Actual and 2015 Forecast.

5. <u>Con Edison Steam End to End Efficiency</u>

Approach

In calculating end to end efficiencies the Company used a consistent methodology for Con Edison, customer technologies, and district energy. Input fuel, thermal output, and electric output were all converted into MMBtu (1 million Btu) units. The final end to end efficiency was calculated by dividing the total energy used by the customer (electric and thermal) by the total fuel input. Refer to Appendix pages A1 to A18 for calculation details and input summaries.

Data References

To accurately determine the end to end efficiency of the Con Edison steam system, the Company needed to consolidate and analyze a large quantity of information from various sources, including:

- Con Edison Fuel Inventory Management System ("FIMS")
  - Fuel burn, net steam production, and cogenerated electric production.
  - The BNY fuel, steam production, and electric production.
- Con Edison PROMOD (Production Model)
  - 2015 projections for fuel, steam production, and electric production.
  - Steam variance.
  - Electrical line losses.
  - The estimated condensate heat recovery value was calculated based on a previously developed 2005 study by Goldman Copeland Associates.
- Con Edison Plant Information System ("PI")
  - Weighted average steam enthalpy, ER6 cogeneration in fuel and electric production.
- Department of Environmental ("DEC") Protection Representative
  - Weighted average city water enthalpy.

Measurement Uncertainties

As part of this study, a methodology was developed to integrate the measurement uncertainty or error associated with the measurement/metering of steam, natural gas, fuel oil, and electricity into a composite error factor that could be applied to the calculated end to end efficiency of the steam system. A summary table, which illustrates the measurement uncertainty for the Con Edison steam system, can be found in the Appendix section of this report (Appendix page A18). The actual 2010 steam, electric, gas, and fuel oil quantities were checked by comparison against standard measurement instruments, and on an integrated basis were determined to be within 0.02% of these standards. This error value was determined to be insignificant.

The Company judged that this measurement uncertainty can also be reasonably applied to the customer sited solutions and the district energy configuration, assuming a similar level of meter inspection and calibration to professional standards. Below are the component contributions of the Fuel Oil, Natural Gas, Steam, and Electric measurement/meter uncertainties.

Fuel Oil

The primary fuel oil burned at the Con Edison generating stations is low sulfur #6 fuel oil. Less than 20% of Con Edison's steam production comes from this fuel type. In 2010, approximately 17% of steam produced came from #6 fuel oil. This fuel type is utilized primarily as a back up to natural gas and during high load periods (#6 fuel oil is shipped via a barge into the generating stations). The #6 fuel oil supply for 74th Street Generating Station and the Ravenswood A-House Steam Plant is managed by the current owner of the Ravenswood Electric Generating Station, TransCanada Ravenswood. When fuel barges make deliveries to the generating stations, the quantity and quality of oil supplied is measured using American Petroleum Institute Standards. A certified independent inspector is required to make such measurements and sample the fuel oil for sulfur content and calorific content testing for every delivery received. The sulfur content must be below 0.30 % and the calorific value for #6 fuel burned is about 148,000 Btu/gal. #6 fuel oil must be kept hot and is re-circulated from storage tanks to the boiler fronts to keep it flowing and ready for use. As such, the generating stations utilize main fuel oil meters and recirculation fuel oils in order to account for the actual amount of fuel oil burned.

Data showing the fuel oil measurement uncertainties were obtained from the fuel oil barge delivery receipts, micro motion main meter proving calibration sheets, and micro motion recirculation meter proving calibration sheets. This data as well as data from the recirculation meter for the Con Edison Ravenswood A-House were considered.

There were twenty-one fuel oil delivery barges to the Hudson Avenue, East River, and 59th Street Generating Stations in 2010. The Company's FIMS reports show what was certified delivered and what was measured before and after the barge and tank readings. This error was calculated by multiplying the error times the quantity for each barge delivery. Then all were summed and then divided by the delivered quantity to obtain the error.

This also included the metering errors obtained from fuel meter calibration reports from TransCanada . This covered both the main and recirculation fuel oil meters at 74th Street and the Ravenswood A-House.

Consistent with the Con Edison Fuel Oil Quality Assurance Program, all barge delivery quantities are verified by an independent qualified API Inspector and annually, on September 1st, a fuel oil inventory is performed on all Con Edison plant tanks to verify the used quantities, inventory and deliveries during the year. The 74th Street and Ravenswood A-House main and recirculation meters are calibrated annually by TransCanada Ravenswood.

For 2010, the fuel measurement error was -0.0281%.

Fuel Gas

The accuracy of the Company's generating stations' natural gas meters was determined to be -0.0393%, which is based on the weight averaged for the natural gas quantities delivered in 2010. This calculation is based on the Company's Gas Metering report that also looks at the results of meter accuracy tests obtained from vendors testing the meters against their standards. American Gas Association standards are utilized.

In addition, consistent with Con Edison procedures, all meter pressure, delta pressure, and temperature transducers are calibrated quarterly. The turbine meters are changed out and tested every seven years and the ultrasonic meters are changed out and tested every two years. This helps to ensure measurement accuracy of natural gas.

For 2010, the natural gas measurement error was -0.039%.

Electricity

Electric meter data was obtained from the Company's meter calibration records. Consistent with Con Edison procedures, electric generation meters are calibrated on an annual basis.

The electric meters associated with East River Cogeneration Units 1, 2, and 6 were calibrated and, according to Con Edison's Electrical Engineering Department, the errors were weight averaged to the megawatts generated during the year. An error of 0.00995% was obtained.

Steam

The steam sendout metering errors were obtained from each generating station's monthly sendout sheets that list the correction factor applied to its steam flow. Steam meter data was obtained from monthly steam usage reports from the generating stations. Meter calibration checks are performed semi-annually by each station's Results group pursuant to Company procedures. In addition, the Company performs annual calibration checks on the meters.

These corrections were weight averaged to the individual flows and a composite error of 0.049% was obtained.

Integrated Error Calculation Approach

The fuel input error was obtained by multiplying the error for oil times 17% for the percentage of fuel oil used in 2010 plus the error in gas times 83% for the percentage of natural gas used in 2010 to obtain an input error of -0.0374%.

An output error of 0.0370%.was obtained by multiplying the error for electric times the MMBtu for electric for 2010 plus the error for steam times the MMBtu for steam divided by the sum of MMBtu for electric and steam.

To determine the largest magnitude of error, the error in efficiency was obtained by adding 1 to the error in output and subtracting the error in input from 1, and dividing this ratio times the 60% end to end efficiency yielded a value of 59.979% and by subtraction from 60% for an error of 0.02% in efficiency.

Steam Condensate Reuse and Heat Recovery

General

To accurately evaluate the end to end efficiency of the steam system, the energy discharged in the form of steam condensate needs to be included in the analysis. Since this condensate reuse and heat recovery process occurs on the customer side of the system, it is difficult to determine its impact on the overall system effect. In 2005, Goldman Copeland Associates prepared a study for the Company detailing the condensate energy recovery and reuse strategies being implemented by the Company's top 100 customers. The study was titled "Assessment of the potential for customer recovery/reuse of steam condensate." Based on this study, the Company approximated the quantity of energy recovered as well as the volume of condensate that was reused by all customers. These values were included in the overall end to end calculation of the steam system. Detailed calculation sheets can be found in the Appendix section of this report on pages A23 to A27. Based on the age of the data used in the study, GCA recently advised that the total volume of condensate collected and reused may be as high as 50% compared to the 30% listed in the report. This increase is based on GCA's involvement in the commercial building energy services industry and experience with

retrofits and installations of heating, ventilation, air conditioning, and other building energy systems in Manhattan. Moreover, to apply these values to the entire system, SC-1 customers should be removed as these small customers are unlikely to recover the capital cost associated with condensate recovery. Based on the foregoing, the Company analyzed the following scenarios:

1. Scenario # 1: Condensate water and heat recovery based on the study.
2. Scenario # 2: Condensate water and heat recovery based on the study with all SC-1 customer steam sales removed.
3. Scenario # 3: Condensate water recovery 30% to 40% with all SC-1 customer steam sales removed.
4. Scenario # 4: Condensate water recovery 30% to 50% with all SC-1 customer steam sales removed.

After examining these various scenarios, the Company decided to utilize Scenario # 3 in the steam end to end efficiency calculation to determine the quantity of heat recovery. This value was determined to be the most accurate representation of the current steam system customer base.

Condensate Reuse

Based on the survey results documented in the GCA study, the top 100 steam customers produce 1,362,432,000 gallons of steam condensate per year. Of this produced volume, a total of 544,972,800 gallons were collected for reuse. The intended use for this collected water was for cooling tower make-up.

While 554,972,800 gallons of steam condensate was collected, only 46% of this collected volume (250,837,985 gallons) was actually reused for cooling tower make-up. This is mainly due to the season disparity of steam condensate produced and cooling tower make-up required. The majority of steam condensate will be produced in the winter time when steam loads are high but the cooling tower make-up water loads are low. The result of this phenomenon is that a portion of the collected water is discharged to the sewer.

As per assumptions listed in the report and discussions with GCA, the majority of the cooling tower water collected for reuse will be coupled with a heat recovery process. This is mainly due to the temperature of the condensate being too high for use in the cooling tower. Cooling towers typically have a design supply temperature of 85°F.

Based on the above analysis and information, the Company calculated that 18.4% of steam condensate produced by the top 100 customers is collected and reused. This result was then applied to the entire steam system in the end to end calculation.

Condensate Heat Recovery

As stated above, the top 100 steam customers produce 1,362,432,000 gallons of steam condensate per year. Of this produced volume, thermal energy was recovered from a total of 663,643,800 gallons. The intended use for this recovered thermal energy was for domestic water heating.

A number of properties utilized a combined steam condensate reuse and thermal recovery strategy while others simply captured the thermal energy without reusing the condensate to offset potable water.

Based on the analysis and information listed above, the Company calculated that about 16% of available thermal energy wasted in the form of condensate, by the top 100 customers, is captured and used for domestic water heating. This result was derived from considering only SC2 and SC3 steam customers. The 16% is a proxy for condensate energy recovery.

Worksheet Navigation

2010 Con Edison End to End Efficiency

Fuel Sheet – Appendix Page: A1

This page consists of data from FIMS. Fuel oil and gas are expressed in millions of Btu's, steam flow is expressed in thousands of pounds, and electricity is expressed in megawatts. Brooklyn Navy Yard data for the same quantities were obtained from Company data. At the bottom of the fuel sheet, the quantities were summed up and for steam they were grouped as HP (high pressure), package boilers ERRP duct and BNY steam for both millions of Btu's and thousands of pounds of steam.

The electrical quantities were summed up for ERRP, BNY, and ER6 (when in cogeneration mode) production units for both millions of Btu's and megawatts.

The East River 6 quantities for cogeneration mode were determined by using PI to determine the MW for this unit for the year when steam flow was less than 20 Mlb. Where steam flow is less than 20 Mlb/hr, the MW produced were not used for this study. For the year 2010, PI determined that only 18% of the MW were for the cogeneration mode and so only 18% of the MW and fuel were allocated to this unit for the study.

Tank Farm Heating Steam – Appendix Page: A2

This page is a breakdown of the tank farm steam usages for each plant as this must be added to the fuel as it is broken out of fuel for the FIMS report and is not included as part of the fuel. As noted, ER6, ER 7, South Steam Station, and Hudson Avenue use a factor to determine the usage and the Ravenswood A-House uses a meter.

Auxiliaries – Appendix Page: A3

This page is a breakdown of the electrical auxiliaries used at the generating stations that were determined to be included in the form of input fuel in the study as it is not normally accounted for but must be in order to account for energy needed by the auxiliary equipment to operate the boilers. As shown, 60th Street, 74th Street, 59th Street Package, East River South Steam Station, and Ravenswood A-House all have electric meters to determine the kilowatt usage. This usage includes all energies to operate not only auxiliaries but computers, lighting, and other gadgets and gizmos, used by station personnel as this usage is part of the auxiliary usage in all power plants in general and is netted out of the gross unit output. As such, the Company has only taken 75% of the total amount towards production and utilized in the end to end efficiency calculations. Hudson Avenue and 59th Street Annex Boilers use estimates to determine the auxiliary consumption.

End to End – Appendix Page: A4

This page displays the end to end diagram and the fuel, steam, and megawatts quantities. In addition, a third column was added to break down the steam and megawatts to millions of Btu's in order to be able to express efficiency by dividing the useful output Btu's by the fuel input Btu's. As noted at the bottom of the sheet, the tank farm and auxiliary Btu's are added to the fuel input Btu's in order to capture and charge the system properly. The megawatts were converted to Btu's by using the universal 3,412 Btu's per kilowatt hour. The steam energy was converted from pounds using the conversion factor of 1,192.82 Btu's per pound. This was determined by weight averaging all the steam sendout enthalpies for the year 2010 by using PI to arrive at 1,215.3 Btu/lb. The DEP was contacted to determine the average enthalpy of the cold city water coming into New York City for year 2010. These temperatures are obtained internally from the water in the piping coming into the City. This value was 22.48 Btu/lb obtained from the steam tables using the DEP values of 40 psig water pressure and 54.25 F degrees. Subtraction of the incoming City water enthalpy from the steam system weighted average enthalpy yields an enthalpy of 1,192.82 Btu/lb, which represents the energy supplied to the water to make steam for sendout.

At the top of the energy diagram the cogenerated megawatts are displayed and linked to the totals that are lower on the sheet, continuing to the right is the conversion of megawatts to millions of Btu's and further to the right the quantities are reduced by 6.6% for the average Con Edison transmission losses for the year 2010 in order to obtain the useful energy delivered to the customers' wall.

At the bottom of the energy diagram the steam sendout in thousands of pounds is linked to the tabulated sum further down on the sheet. Continuing to the right the steam is converted from thousands of pounds to millions of Btu's using the derived enthalpy of 1,192.82 Btu/lb. Further to the right the 2010 steam variance, which is the difference between Con Edison sendout meters from customer meters, times the 1,192.82 Btu/lb was subtracted from the sendout Btu's as this energy is lost through traps as condensate

from thermal losses in the steam distribution system. The remaining energy represents the delivered energy to the customer. Further right shows that the energy is not all consumed by the customer and all the condensate is rejected at a temperature of 180 F degrees and 14.7 psia. This information was obtained from customer surveys by Con Edison's Building Services group. Further to the right shows the Btu's that are on their way to the sewer. These Btu's are lowered due to the 2005 GCA Report and were discussed with GCA in order to update to present day 2010. The Company determined that 16% of the normally rejected Btu's are reclaimed. At the extreme right is the useful thermal energy utilized by the customers, which is the sendout Btu's minus the variance loss and sewer Btu's.

The end to end efficiency was obtained by summing the useful megawatt and thermal Btu's by the total fuel Btu's (including tank farm and auxiliaries) and was found to be 60%.

2010 End to End Winter and Summer Efficiencies

The FIMS data for 2010 was segregated to the period May through October to be called the summer period and January through April and November and December to be called the winter period. The BNY data for thermal and electrical Btu's and pounds of steam and megawatts were obtained from their Qualified Facility ("QF") report (thermal), Load Profile Display Report ("LPDS") - steam and Table A from Energy Management-megawatts. The fuel input for the electrical and steam from BNY was obtained by first calculating the Electric Heat Rate from BNY for all of 2010 as 5,346 Btu/kWh. Then the winter and summer output net megawatts were multiplied by the BNY Electric Heat Rate (5,346 Btu/kWh) to obtain electric fuel input. Then knowing that 54% of BNY is electric, the Company determined the total input by dividing the electric input by 0.54. The steam input was obtained by subtracting the total input Btu's from the electric input Btu's. The same methodology was conducted for each of these periods as was done for the year. The seasonal efficiency values were determined to be 62% for the winter and 57% for the summer. When combined, these values yield the overall annual efficiency of 60%. The detailed seasonal efficiency calculation sheets can be found in the Appendix on pages A5 to A10.

2015 End to End Year, Winter and Summer

Data for fuel, steam and megawatts were obtained from PROMOD runs for each period and again the BNY fuel input was obtained by using the 5,346 Btu/kWh electric heat rate for year 2010 and multiplying that heat rate by the megawatts for the different periods to obtain electric heat input and then dividing this result by the electric load ratio 0.54 to obtain total fuel input for BNY as PROMOD doesn't determine fuel input Btu's, only steam and megawatt Btu's. The tank farm and auxiliary usage was determined from the monthly quantity aggregate for 2010 and its summer and winter periods are applied to each 2015 PROMOD case. The same enthalpy value for steam input 1,192.82 Btu/lb for 2010 was used for each of the other periods for both 2010 and 2015. The same electric transmission loss (6.6%) was used for each of the actual 2010 and 2015 periods as well as

16% recovery of condensate. The steam variance loss was determined from the monthly actual values for year 2010 and summer and winter losses and these same percentages were applied to each of the year, summer and winter periods, respectively, in the PROMOD models. The detailed 2015 projected system efficiency calculation sheets can be found in the Appendix on pages A11 to A17.

Results

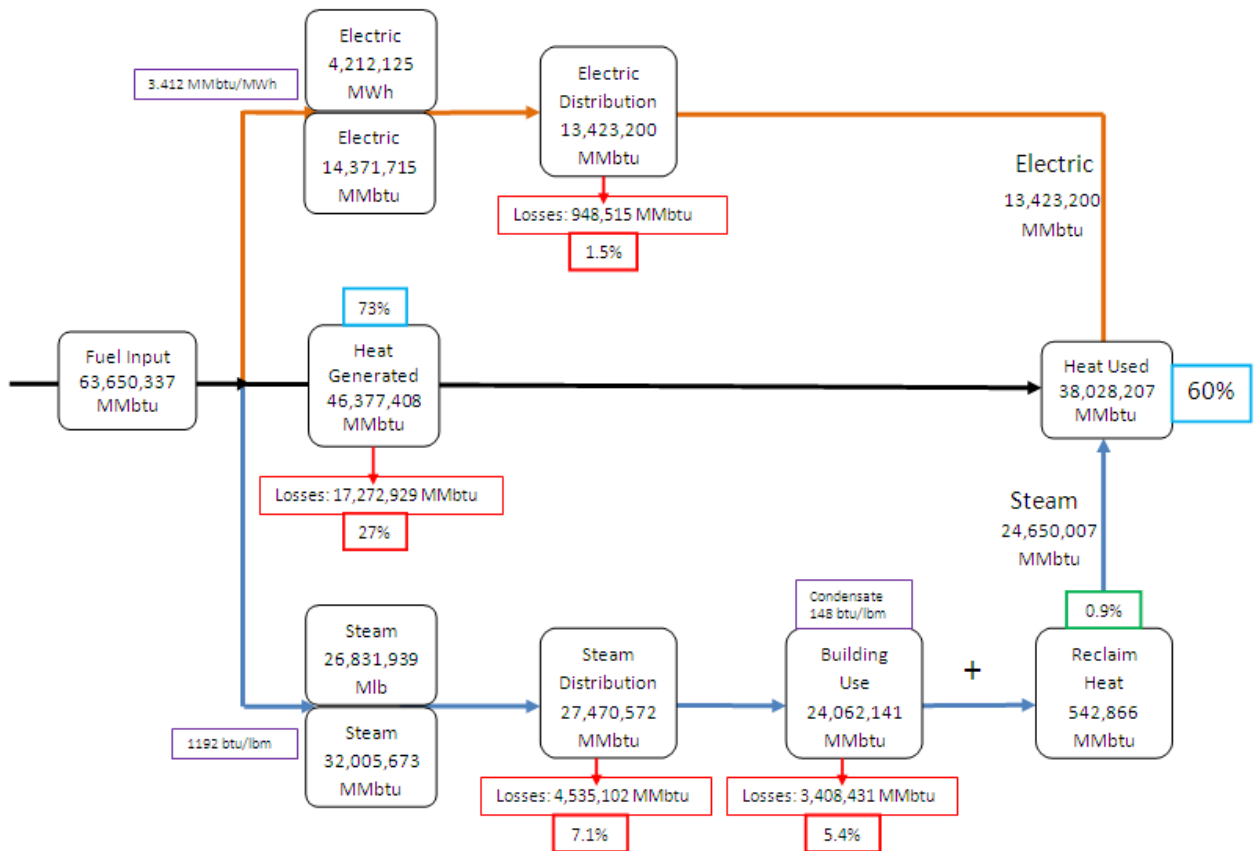The following table summarizes the results of the end to end efficiency of the Con Edison steam system.

Con Edison Steam System

Steam System End to End Efficiency Results	
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2015 Con Edison Steam System – Summer	57%

For Year 2010, actual data was utilized to develop the efficiencies. The analysis considered the gross fuel that was used to produce steam and cogenerated electricity, any auxiliary light and power taken from the grid for production of steam and cogenerated electric, fuel used to heat #6 fuel oil, steam variance (line losses in the steam distribution system), and any energy that was not recovered from hot condensate that was discharged to the sewer. For any cogenerated electricity, the gross fuel input for such production was considered as well as transmission and distribution losses up the customer's premises. Meter accuracy for steam, natural gas, fuel oil, and cogenerated electricity were also considered in this assessment. Purchased steam and purchased cogenerated electricity from BNY were included. For year 2015, the Company utilized its production/dispatch model, PROMOD, as well as applied other parameters, such as steam variance, auxiliary power, tank farm heating fuel, and customer side condensate losses. As the table shows, the differences between 2010 and 2015 are insignificant. All results are High Heating Value ("HHV"). The summer period is May through October and the winter is January through April, November and December.

2010 Steam System Efficiency

The Con Edison 2010 steam system efficiency varies from 57% in summer to 62% in winter with an average annual efficiency of 60%. The efficiency leaving the central generating stations, including the steam and electric generated by BNY varies from 71% in summer to 75% in winter with an annual average of 73%. Annually, the energy losses with respect to the entire system are 27% in generation, 11.5% in steam distribution and building condensate loss, and 1.5% electric distribution losses. The following diagram illustrates the 2010 end to end efficiency for the steam system:

Electric
4,212,125 MWh

3.412 MMbtu/MWh

Electric
14,371,715 MMbtu

Electric Distribution
13,423,200 MMbtu

Losses: 948,515 MMbtu
1.5%

Electric
13,423,200 MMbtu

73%

Fuel Input
63,650,337 MMbtu

Heat Generated
46,377,408 MMbtu

Losses: 17,272,929 MMbtu
27%

Heat Used
38,028,207 MMbtu

60%

Steam
24,650,007 MMbtu

Condensate 148 btu/lbm

0.9%

Steam
26,831,939 Mlb

1192 btu/lbm

Steam
32,005,673 MMbtu

Steam Distribution
27,470,572 MMbtu

Losses: 4,535,102 MMbtu
7.1%

Building Use
24,062,141 MMbtu

Losses: 3,408,431 MMbtu
5.4%

+

Reclaim Heat
542,866 MMbtu

2015 Steam System Efficiency

The estimated Con Edison 2015 steam system efficiency varies from 57% in summer to 63% in winter with an average annual efficiency of 60%. PROMOD runs for 2015 were made and the fuel, megawatts and steam flow determined. The BNY fuel input, which is not determined by PROMOD, was calculated by taking the electric actual heat rate from year 2010 and multiplying it by the respective period megawatts for 2015 to determine electric fuel input, and then divided by the electric ratio for BNY, which is 0.54, to obtain total fuel input and from this the electric heat input was subtracted to obtain steam heat input.

6. District Energy System End to End Efficiency

The Company examined the end to end efficiency of the following district energy distribution systems:

1. Chilled Water
2. Hot Water
3. Combination Chilled and Hot Water
4. Combination Chilled and Hot Water with Electric Cogeneration

The information utilized in the end to end study was taken directly from the District Energy Feasibility Study for the Manhattan West Side (Hudson Yards Area), dated June 5, 2007. This study was prepared for the Company by Constellation Energy Projects & Services Group, Inc. ("Constellation"). The Constellation study provided plant load profiles, equivalent full load hours for each plant, and a map of the area with proposed district energy distribution piping, a pipe sizing chart, and single line diagrams for each of the proposed systems.

Approach

Chilled Water System

Based on the building load data analysis conducted by Constellation, the diversified peak cooling load for the area was calculated to be 45,909 tons. A cooling load profile for the area was reviewed and the equivalent full load cooling hours were determined to be 1,026. As stated in the report, to keep capital costs and pipe sizing reasonable, the conceptual design specified two separate chilled water production facilities. When combined, these two facilities would consist of the following equipment:

- Thirteen water cooled dual compressor variable speed electric driven centrifugal chillers with a peak capacity of 3,850 tons; each would operate using a $14^{o}F$ temperature difference. Twelve chillers would be required to operate at full load and one chiller would be a standby unit providing N+1 redundancy.
- Thirteen variable speed chilled water pumps with a maximum flow rate of 5,775 gallons per minute. Twelve pumps would be required to operate at full load and one pump would be for standby providing N+1 redundancy.
- Thirteen induced draft cooling towers with variable speed fans. Each tower would be rated for 3,850 tons of heat rejection and would operate using a $15^{o}F$ temperature difference. Twelve towers would be required to operate at full load and one tower would be for standby providing N+1 redundancy.
- Thirteen constant speed condenser water pumps with a maximum flow rate of 6,160 gallons per minute. Twelve pumps would be required to operate at full load and one pump would be for standby providing N+1 redundancy.

The district chilled water system end to end efficiency analysis utilized the data listed and made the following assumptions in order to determine overall system efficiency:

1. Chilled/Condenser water pump operating horsepower – the pump operating horsepower was calculated based on the distance of the furthest piping loop, pressure loss through the equipment, and pressure losses from valves and fittings in the system. Since these values are not known, certain assumptions were made based on standard industry best practices and similar equipment cut sheets. The district energy study provided site map was used to determine the maximum piping loop distance.
2. Motor efficiency – it was assumed that high quality 90% efficient motors were utilized.
3. Auxiliary pumps – various assumptions were made to include the energy associated with operating the chemical feed and water filtration pumps. The pump size and operation hours were estimated based on standard industry best practices.
4. Free cooling (winterization of cooling towers) – the district energy study did not include a free cooling option in the system design therefore a free cooling credit was not included in this analysis.
5. Thermal Losses – it was assumed that the thermal loss of the distribution system would be 10%, which includes thermal conduction losses as well as pipe and valve failures.
6. Chiller efficiency and cooling tower fan size – these values were determined by reviewing actual equipment cut sheets of similar equipment.

Based on the assumptions and data indicated above, the overall end to end efficiency of the proposed district chilled water system was calculated to be 72%. Detailed calculations and an associated energy diagram can be found in the Appendix section of this report on pages A19 and A35.

Hot Water System

Based on the building load data analysis, conducted by Constellation, the diversified peak heating load for the area was calculated to be 707 MMBtu/hr. A heating load profile for the area was reviewed and the equivalent full load cooling hours were determined to be 1,982. Unlike the district chilled water system, the hot water system will be limited to a single facility. This facility would consist of the following equipment:

- Six high efficiency natural gas fired hot water boilers. Each boiler would be rated for 150 MMBtu/hr of hot water production. Five boilers would be required to operate at full load and one would be a standby providing N+1 redundancy.
- Six variable speed hot water pumps with a maximum flow rate of 3,000 gallons per minute. Five pumps would be required to operate at full load and one would be a standby providing N+1 redundancy.

The district hot water system end to end efficiency analysis utilized the data listed above and made the following assumptions in order to determine overall system efficiency:

1. Hot water pump operating horsepower – the pump operating horsepower was calculated based on the distance of the furthest piping loop, pressure loss through the equipment, and pressure losses from valves and fittings in the system. Since these values are not known, certain assumptions were made based on standard industry best practices and similar equipment cut sheets. The district energy study provided site map was used to determine the maximum piping loop distance.
2. Motor efficiency – it was assumed that high quality 90% efficient motors were utilized.
3. Auxiliary pumps – various assumptions were made to include the energy associated with operating the chemical feed pumps. The pump size and operation hours were estimated based on standard industry best practices.
4. Thermal Losses – it was assumed that the thermal loss of the distribution system would be 10%, which includes thermal conduction losses as well as pipe and valve failures.
5. Electric Losses were assumed to be small, 1%.
6. Quantity of blow down and system make-up water – a value for boiler water blowdown was assumed based on Con Edison boiler plant operation experience. The energy associated with heating the make-up water was included in the calculation.
7. Free heating (exhaust gas heat recovery) – the district energy study report did not include a heat recovery option in the system design; therefore no heat recovery credit was included in this analysis.

Based on the assumptions and data indicated above, the overall end to end efficiency of the proposed district hot water system was calculated to be 68%. Detailed calculations and an associated energy diagram can be found in the Appendix section of this report on pages A20 and A36.

Combined Chilled and Hot Water System

To calculate the overall end to end efficiency of a combined chilled and hot water system, the Company combined the two analyses listed above into a single conglomerate analysis that would represent all of the energy delivered versus the energy consumed by the system. Once all of the energy units were converted to similar terms (kilowatt hours - kWh), the energy inputs for each section were combined and compared to the energy delivered. The combined efficiency of the chilled and hot water district energy system was calculated to be 70%. Detailed calculations and an associated energy diagram can be found in the Appendix section of this report on pages A21 and A37.

Combined Chilled and Hot Water System with Cogeneration

In an alternate scenario, the Constellation report proposed that a natural gas fired turbine cogeneration plant be added to the combined district chilled and hot water system. The turbine would have an overall capacity of 7.5 MW with a thermal heat production large enough to offset the capacity of a single boiler in the proposed boiler plant (150

MMBtu/hr). The operating hours of the cogeneration plant were assumed to be 3,120 hours per year (260 days at 12 hours per day). Based on these operating hours, the plant would supply a total of 22,464,000 kWh of electricity to the grid for customer purchase. Since the Constellation report does not describe a means to recover the heat input for cooling use, it is assumed that the heat from the cogeneration plant is used for the hot water system only. Any excess heat captured is released into the atmosphere if it is not used by the hot water system.

When the district chilled and hot water plants are coupled with a small cogeneration plant, the resulting end to end system efficiency was calculated to be 74%. Detailed calculations and an associated energy diagram can be found in the Appendix section of this report on pages A22 and A38.

Results

Based on the analysis conducted by the Company, the various district energy systems examined offer efficiencies that range from 68% to 74%. The combined chilled and hot water system offers the greatest overall system efficiency while the hot water system will operate at a slightly lower efficiency.

District Energy System End to End Efficiency				
District System Type	Chilled Water	Hot Water	Combined Chilled and Hot Water	Combined Chilled and Hot Water with Cogeneration
Calculated End to End Efficiency	72%	68%	69%	74%

7. <u>Alternative Technologies Description</u>

New York City customers have a number of options to choose from when considering whether to produce their own energy for building use. As part of its analysis, the Company examined popular cogeneration and heat producing equipment that may be used to meet the needs of New York City energy customers. Different manufacturers for each technology were reviewed. The following is a list of the technologies that were utilized in the study as well as their associated operating properties. Please note that this analysis does not take into account the economics of such technologies.

Technology	Model	Fuel In (MMBtu)	Steam/Hot Water Out (MMBtu)	Net Electric Out (MWh)
Gas Turbine w/ HRSG	Saturn 20	18.48	10.44	1.16
Fuel Cell	UTC Model 400	3.79	1.71	0.40
Micro Turbine	MT250	3.17	1.20	0.24
Recip Engine w/ HRSG	Caterpillar 3520C	20.00	4.77	1.99
Steam Boiler	CB 300HP Boiler	15.25	12.11	N/A
Hydronic Boiler	Crest FBN3500	3.85	3.22	N/A
Electric Heating	CeramiCircuit 1445-C	9.80	N/A	1.00

Different technologies have certain advantages and disadvantages as far as size, turndown ratio, and ability to cycle on and off frequently, see below:

Technology	Major Advantages	Major Disadvantages
Gas Turbine w/ HRSG	Exceptional efficiency, especially when duct firing is utilized	Large, cannot be cycled
Microturbine	Limited capacity per unit.	Not designed to be cycled on and off
Steam Boiler	High, constant efficiency, closed loop system.	No electric production, cannot be cycled
Hydronic Boiler	High, constant efficiency, closed loop, excellent turndown ratio	No electric production, cannot be cycled. Existing steam customers may need a new distribution system
Fuel Cell	High Efficiency	Takes 8 hours to turn on, cannot be cycled, cannot turndown lower than 75%, must replace cells every 7 years
Reciprocating Engine w/ HRSG	Can be cycled on and off	Low efficiency
Electric Heating	Convenient	Very Poor efficiency

8. Technology Efficiencies Based on a Proxy Customer

Approach

The mission was to choose a proxy customer that best represented an average steam customer. The proxy customer information used for this analysis is as follows:

- Service Class: 2
- Size: 600,000 sq. ft.
- 2010 Annual Steam Consumption: 16,245 Mlb
- 2010 Annual Electric Consumption: 38,990 MWh
- 2010 Peak Steam Load: 18.1 Mlb/hr
- 2010 Peak Electric Load: 6.1 MWh

A spreadsheet analysis was performed for each of the different technologies listed above. The spreadsheet contains a variety of inputs, calculations, references, and outputs. The team reviewed different scenarios by quickly modifying the inputs and reviewing the results. A summary sheet for each individual technology can be found in the Appendix section of the report on pages A28 to A32.

Assumptions

There are a number of assumptions that were made when preparing the analysis of the proxy customers. The assumptions utilized include but are not limited to the following:

1. Annual Operation: Unit was on year round, also ramped up in summer months to shave the Electric Peak and cut costs, which resulted in dumped steam in most cases, hence lowering the overall thermal efficiency in these cases.
2. Seasonal Operation: Customer's steam load was matched as closely as possible to the equipment's rated output. In most cases this involved shutting the unit down and supplementing the building's load with a small boiler for hot water from April to November.
3. Equipment Selection: The amount and size of the equipment was selected to meet the customer's steam peak load. Backup boilers were included to replace the load of the largest production unit in the building in case it was to trip off.
4. Load Profiles: Formulated using our engineering knowledge and tailored around the building's monthly demands as well as peak load.
5. Fuel Input: Manufacturer values were assumed to be LHV (Low Heating Value) unless otherwise stated. A conversion of 10% (increase) was factored into this input number allowed us to come up with the true fuel input in HHV (High Heating Value).
6. Under certain conditions, the fuel inputs were increased 1% for each case to account for fouling and auxiliary power.
7. Building Energy Load: The building cannot take in any more energy than its 2010 total demand.
8. Building Equipment: The end to end efficiency assumed there were no building equipment heat losses. Blowdown losses were not factored in.

Worksheet Navigation
In this particular worksheet there is an executive summary on the first tab showing the Manufacturer's cited efficiency ranges as well as proxy building efficiencies for annual and seasonal operation for each technology tested:

- Gas Turbine with HRSG
- Micro Turbine
- Steam Boiler
- Hydronic Boiler
- Fuel Cell
- Reciprocating Engine
- Electric Radiant Heating

After the Executive Summary each type of technology is displayed, beginning with a summary tab for the technology, then a tab with the specs of the equipment used as well as a year load profile for the building (annual operation). The next tab extracts information from the building's load profile to calculate the thermal efficiency of the technologies dispatch. The following two tabs also display a load profile then thermal efficiency, this time for seasonal operation. The exception to this format is the boiler worksheets where we only have annual operation directly matching the load of the building, because there are no electric considerations. Also the electric heating tab just shows the general efficiency, no considerations are made for the type of building, because the heat rate of electric delivered to the customer will not change.

Results

Technology Efficiency

Efficiency Range (Manufacturers' Ideal Ratings)		
Technology	Minimum Efficiency	Maximum Efficiency
Gas Turbine w/o duct firing	21%	79%
Gas Turbine w/ duct firing	21%	95%
Reciprocating Engine	34%	59%
Microturbine	26%	64%
Fuel Cell	36%	81%
Steam Boiler	79%	79%
Hydronic Boiler	82%	82%
Electric Resistance Heating	35%	35%

The efficiencies of different technologies ranged from 21% to 95% depending on how well the load source utilized the steam producing capability of the technology. These efficiencies are HHV and were based on manufacturer's data sheets for new installations. These efficiencies reflect net steam and electric output with gross fuel input. It is the Company's technical opinion that such efficiency ratings represent ideal, test/laboratory conditions and that actual performance will be less than indicated. For example, start up fuel, cycling fuel, blowdown, meter error, and fouling have not been applied to these efficiency ratings.

Line losses and customer side condensate losses will be minimal when these configurations are installed within a customer's premises. Losses in efficiency for boiler blowdown, on the steam or hot water production equipment, have not been included. All but the two boiler configurations are cogeneration. One must note that while the steam boiler and hydronic boiler configurations reflect high efficiencies, the building they serve is still taking in electricity from the grid, which is not reflected in the end to end efficiency. Therefore comparing boiler efficiency to the other types of technology as well as the Con Edison steam system is not a direct apples-to-apples comparison.

Alternative Technologies to Steam for a Proxy Commercial Customer

The results of the end to end efficiency of different types of technologies that customers can install in their building in lieu of Con Edison steam are represented in the following tables for a proxy commercial building.

Proxy Customer End to End Efficiency		
Technology	Annual Operation Building Efficiency	Seasonal Operation Building Efficiency
Gas Turbine w/ duct firing	37%	67%
Reciprocating Engine	46%	73%
Microturbine	56%	63%
Fuel Cell	63%	73%
Steam Boiler	79%	N/A
Hydronic Boiler	82%	N/A
Electric Resistance Heating	35%	N/A

The proxy customer monthly steam loads were maximized in each technology to determine the building's annual efficiency.

10. Conclusions

2010 Steam System Efficiency

The Con Edison steam system efficiency varies from 57% in summer to 62% in winter with an average annual efficiency of 60%. The efficiency leaving the central generating stations, including the steam and electric generated by BNY, varies from 71% in summer to 75% in winter with an annual average of 73%. The energy losses with respect to the entire system are 27% in generation, 11.5% for steam variance and customer condensate loss, and 1.5% electric distribution losses.

2015 Steam System Efficiency

The estimated Con Edison 2015 steam system efficiency varies from 57% in summer to 63% in winter with an average annual efficiency of 60%. PROMOD was run for 2015 annual and seasonal periods. The fuel megawatts and steam flow determined. The BNY fuel input is not determined by PROMOD and was obtained by calculating the electric actual heat rate from year 2010 and multiplying it by the respective period's megawatts for 2015 to determine the electric fuel input. This in turn was divided by the electric ratio for the BNY, which is 0.54, to obtain total fuel input and from this the electric heat input was subtracted to obtain steam heat input.

Different technologies have certain advantages and disadvantages as far as size, turndown ratio, and ability to cycle on and off frequently:
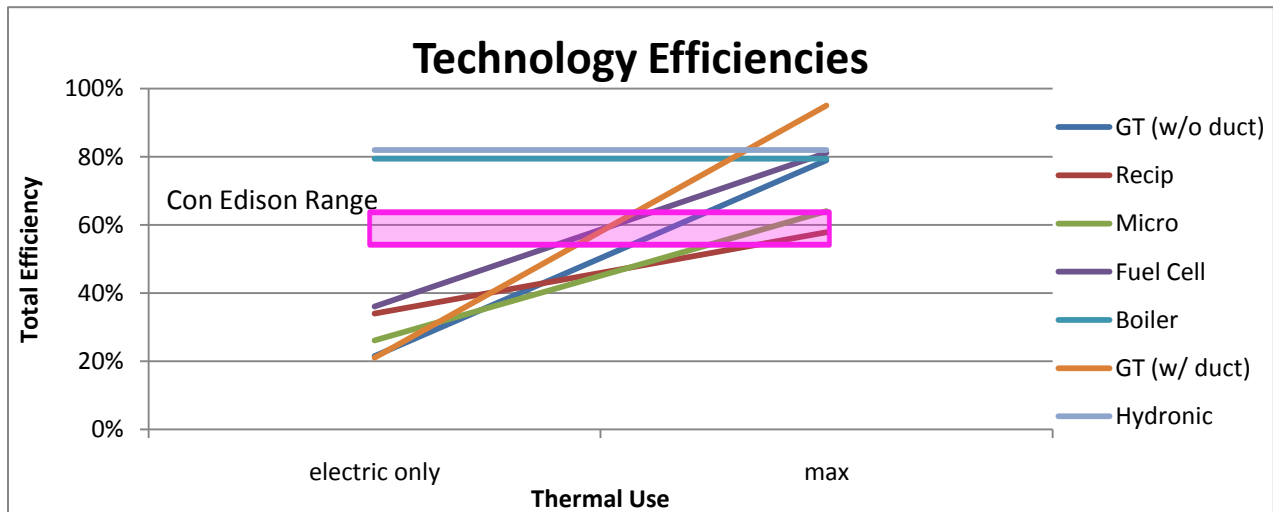
As the graph illustrates, if the thermal loads are not being fully utilized, the efficiencies for all the technologies except the Con Edison steam system and boilers (which are really not cogeneration technologies and not what most customers would opt for to replace Con Edison as they want both heat and power) are poor as they are in the 20% to 40% range. Boiler only options will still have to rely on the electric grid for light, power, and possibly cooling, all fed with an electric efficiency of about 35%.

One cannot only consider energy efficiency when considering whether to utilize Con Edison Steam or whether to go with customer-sited boilers or some form of CHP. For example, the latter choice requires a significant capital investment for a new system and annual expenses for fuel, maintenance, and incremental property taxes. Based on the findings of Joint Proposal Study # 4, *Assessment of the Costs and Benefits of Alternatives to Steam Supply,* various first and annual costs may prevent the customer from realizing an acceptable payback period.

Proxy Customer

The proxy customer monthly steam loads were maximized in each technology to determine its annual efficiency. We note that customers run their equipment for maximum electric production rather than steam production as this study dictated. This would mean that the proxy customer would experience lower efficiencies than indicated by the above-described study and would not be a good fit for a new technology except boilers that are flexible to their steam demands, which would result in the proxy customer continuing to purchase all its electric at 35% efficiency. A separate analysis of the end to end efficiency for this customer using these technologies and supplemented with purchasing electric to meet their requirements, showed an end to end efficiency varying from 35% to 39%.

These efficiencies are HHV and were based on manufacturer's data sheets for new installations. As indicated above, we believe that actual performance will be less than indicated in the foregoing graph, which reflects ideal laboratory conditions. Accordingly, start up fuel, cycling fuel, aging, fouling, and auxiliary power consumption have been applied to these efficiency ratings. Line losses and customer side condensate losses will be minimal when these configurations are installed within a customer's premises. As such, no loss in efficiency has been applied.

The proxy commercial building is an existing Con Edison steam heat and hot water customer located in Manhattan that has a winter steam peak demand of 18 Mlb/hr and summer electric peak demand of 6 MW. For the cogeneration configurations, the end to end efficiencies are low when looked at on an annual basis (Annual Operation Building Efficiency). This is because the production equipment is sized to meet the winter steam peak and when there is a very low thermal load in the building during the summer, and the equipment is required for electric production, there is no place to put the steam produced. As such this excess steam is vented to the atmosphere and is a loss. For the Seasonal Operation Building Efficiency, the Company assumed that there was a supplemental boiler in addition to the cogeneration equipment. The cogeneration equipment was operated in the winter and not during the summer. It was assumed that in

the summer, the building would take electricity from the grid and run the boiler for its thermal load. Doing this did increase the efficiency but did increase the capital investment and electric purchases for the building. This clearly indicates that there exists a balance between energy efficiency and cost efficiency. The two boiler configurations reflect higher efficiencies than those of the cogeneration configurations. However, under the boiler cases the building they serve is still taking in electricity from the grid, which is not reflected in the end to end efficiency. Therefore comparing boiler efficiency to the other types of technology as well as the Con Edison steam system is not a direct comparison.

This study revealed how important it is to match the customer thermal and electric loading to the technology in order to realize improved efficiency.

In general only large, steady high load usage customers, such as hospitals and databanks, will be able to utilize the new technologies with any degree of suitable efficiency.

The new technologies in general generate much more thermal heat than electrical supply causing customers to make large outside electrical purchases to meet their electrical requirements that offset the efficiency gains because of the high heat rate of 9,192 Btu/kWh.

Con Edison's efficiencies were 60% annually, ranging from 57% in the summer to 62% in winter and compared favorably to all the technologies. Since Con Edison is a large distributed generator, its equipment sees high thermal and electrical loads throughout the year and so can operate at higher efficiencies than a single supplier trying to meet its electrical and thermal needs. The months April through October for most customers in this area of the United States do not have a large enough thermal load to be able to utilize the cogeneration technologies efficiently.

The district energy systems examined operated between 68% and 74% with the cogeneration plant being the most efficient. Since the energy content of steam is significantly greater than that of water, at first glance it would appear that the efficiency of these water based systems should be lower than the Con Edison steam system. However, the district energy systems reviewed are closed systems where a portion of the energy delivered is returned to the plant. This is not true for the Con Edison steam system. Furthermore, even though the district system piping network would be larger than the Con Edison steam system, the overall thermal losses would be less. This is due to the lower temperature disparity between the fluid and the surrounding material as well as the elimination of condensate removal losses. There is very limited potential for district energy systems in Manhattan. This is due to physical constraints and interferences in the street that will impact the many large diameter pipes required. The small campus like district energy configuration only makes sense for an area not currently served with steam and not as a replacement for existing steam service.

Appendix Section