COMBINED HEAT AND POWER
MARKET POTENTIAL FOR NEW YORK STATE

FINAL REPORT

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EXECUTIVE SUMMARY

Businesses and industry in New York State that employ on-site power generation with heat recovery can dramatically reduce both energy consumption and its associated environmental impacts. This approach, called *combined heat and power* (CHP – also known as cogeneration), is already an important generating resource in New York with approximately 5,000 MW of capacity installed at 210 sites. The industrial sector accounts for 78% of the existing CHP capacity in the State. Over half (54%) of the capacity is concentrated in the metals, paper, and chemicals industries. The remaining capacity (46%) is divided equally between other industrial processes and the commercial/institutional sector. Important questions include: how much new CHP could be installed in the next decade in New York State, what benefits would this yield, and what actions can policymakers and planners pursue in order to promote market penetration of clean and efficient CHP?

CHP TECHNOLOGY

There are numerous commercial and emerging technologies that can be used for combined heat and power. In most cases, small power generation consists of a heat engine, or prime mover that creates shaft power that, in turn, drives an electric generator. In a CHP application, the heat from the prime mover is recovered to provide steam or hot water to meet on-site needs. In some cases, the heat can be used directly in place of process heat. By combining the electrical and thermal energy generation in one process, CHP can have an overall efficiency of 70-80% compared with 30-33% for simple-cycle electric generation.

CHP technologies are capable of burning a variety of fuels, but in the United States, and especially in New York State, the economics, availability, and environmental cleanliness of using natural gas make it by far the most preferred fuel for CHP technologies. Selecting a CHP technology for a specific application depends on many factors, including the amount of power needed, the duty cycle, space constraints, thermal needs, emission regulations, fuel availability, utility prices and interconnection issues. **Table ES-1** summarizes the characteristics of each CHP technology. The table shows that CHP covers a wide capacity range from 50 kW reciprocating engines to 50 MW gas turbines.

Table ES-1. Comparison of CHP Technologies

	IC Engine	Steam Turbine	Gas Turbine	Micro-turbine	Fuel Cells
Technology Status	Commercial (3% of existing CHP capacity in NY, 66% of sites)	Commercial (14% of existing capacity, 13% of sites)	Commercial (83% of existing capacity*, 21% of sites)	Early entry	Early entry/ development
Electric Efficiency (LHV)	25-45%	5-15%	25-40% (simple) 40-60% (combined)	20-30%	40-70%
Size (MW)	0.05-5	0.01-100	0.5 -50	0.025-0.25	0.2-2
Installed cost ($/kW)	800-1500	800-1000	700-900	500-2000	>3000
O&M Cost ($/kWh)	0.007-0.015	0.004	0.002-0.008	0.005-0.015	0.003-0.015
Availability	92-97%	Near 100%	90-98%	90-98%	>95%
Start-up Time	10 sec	1 hr-1 day	10 min –1 hr	60 sec	3 hrs-8 hrs
Fuels	natural gas, biogas, propane, liquid fuels	All	natural gas, biogas, propane, distillate oil	natural gas, biogas, propane, distillate oil	hydrogen, natural gas, propane
NO_x Emissions (lb/MWh)	0.4-10	Function of boiler emissions	0.3-2	0.4-2	<0.05
Uses for Heat Recovery	hot water, LP steam, district heating	LP-HP steam, district heating	direct heat, hot water, LP-HP steam, district heating	direct heat, hot water, LP steam	hot water, LP-HP steam
Thermal Output (Btu/kWh)	1,000-5,000	n/a	3,400-12,000	4,000-15,000	500-3,700
Useable Temp (F)	200-500	n/a	500-1,100	400-650	140-700

* 94% of gas turbine CHP capacity in New York State combines gas turbine topping cycle and a steam turbine bottoming cycle for higher electrical efficiency

TECHNICAL POTENTIAL FOR NEW CHP

This report evaluates the technical potential[1] for new CHP in commercial, institutional, and industrial sites by screening a comprehensive facility database according to size and application criteria that would allow a high-load factor, high-thermal utilization CHP system to operate. The technical potential for new CHP is an estimation of the remaining market size constrained only by technological limits—the ability of CHP technologies to fit existing customer energy needs. The technical potential for new CHP includes sites that have the energy consumption characteristics that could apply CHP. The technical potential for new CHP does not consider screening for other factors such as ability to retrofit, owner interest in applying CHP, capital availability, natural gas availability, and variation of energy consumption within customer application/size class. All of these factors affect the feasibility, cost and ultimate acceptance of CHP at a site and are critical in the actual economic implementation of CHP. The technical potential for new CHP as outlined in this report can be useful in understanding the general sense of the opportunity for CHP in New York State, and providing information on applications, sizes and regional distribution of the market.

Table ES2 summarizes the application-by-application analysis of the technical potential for new CHP for the downstate and upstate regions in five size ranges. The report identifies nearly 8,500 MW technical potential for new CHP in New York at 26,000 sites. This technical potential for new CHP is split evenly between the upstate and downstate markets. Upstate has a greater industrial sector potential and downstate has greater commercial sector potential. While existing CHP in New York is concentrated in very large plants, only 16 sites remain that could support a plant size greater than 20 MW for internal power consumption. Close to 74% of remaining capacity is below 5 MW.

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[1] Existing CHP was subtracted from the total number of sites in estimating the technical potential for new CHP. While there are 5,000 MW of existing CHP, only about 1,500 MW is used to directly offset customer needs. The remaining 3,500 MW are available to be sold into the electric grid system.

Table ES2. Summary of Remaining Industrial and Commercial Technical Potential for New CHP (MW)

Size Range	Industrial		Commercial		Total	
	Sites	MW	Sites	MW	Sites	MW
State Total						
50 to 500 kW	3,894	300	16,048	1,240	19,942	1,540
500 kW to 1 MW	428	195	3,867	1,584	4,295	1,778
1 MW to 5 MW	434	685	1,280	2,256	1,714	2,940
5 MW to 20 MW	63	488	149	1,240	212	1,728
> 20 MW	9	280	7	210	16	490
Total	4,828	1,948	21,351	6,529	26,179	8,477
Downstate*						
50 to 500 kW	2,160	185	9,919	723	12,079	909
500 kW to 1 MW	143	73	2,520	977	2,663	1,050
1 MW to 5 MW	111	211	804	1,335	915	1,546
5 MW to 20 MW	10	88	108	848	118	935
> 20 MW	0	0	5	150	5	150
Total	2,424	556	13,356	4,033	15,780	4,589
Upstate						
50 to 500 kW	1,734	115	6,129	517	7,863	632
500 kW to 1 MW	285	122	1,347	606	1,632	728
1 MW to 5 MW	323	474	476	920	799	1,394
5 MW to 20 MW	53	401	41	393	94	793
> 20 MW	9	280	2	60	11	340
Total	2,404	1,392	7,995	2,496	10,399	3,887

* Downstate market consists of LIPA, Consolidated Edison and Orange and Rockland service areas. Upstate is made up of the remainder of the state.

The analysis of CHP technical potential for new CHP reveals the following characteristics:

- **The bulk of the technical potential for new CHP exists at commercial/institutional facilities** – Unlike existing CHP installations in which 78% of the capacity is in industrial applications, almost 70% of the technical potential for new CHP (6,500 MW) is in commercial and institutional facilities.

- **The majority of the technical potential for new CHP is in the smaller size range** – 74% of the technical potential for new CHP is below 5 MW in size. 39% is below 1 MW in size. For commercial/institutional applications, 43% of the remaining capacity is below 1 MW in size. 25% is below 1 MW in size for the remaining industrial sector potential.

- **The majority of the technical potential for new CHP is in three utility service areas** – 78% of the CHP technical potential for new CHP in terms of capacity is included in Consolidated Edison (38%), Niagara Mohawk (28%) and Long Island Power Authority (12%) service areas.

Analysis of the results shows that existing market penetration of CHP is small except for large industrial applications. Penetration of CHP into the commercial/institutional and light industrial markets has been minimal to-date. This is likely due to a combination of factors: Deficiencies in small CHP technologies and systems, lack of an adequate sales and service infrastructure for small systems, low familiarity of users and building owners of CHP systems and benefits, and a number of critical market and regulatory hurdles as outlined in Section 8.

It should also be noted that the technical market for CHP could be further expanded in the commercial/institutional sectors with advanced technologies that utilize thermal energy for non-traditional applications. The technical potential for new CHP is limited in commercial/institutional applications due to the lack of adequate thermal energy needs in many building types. Advanced technologies such as heat-activated cooling and thermally regenerated desiccants can expand the economic applications of CHP by providing a base thermal load in building types that do not currently have adequate thermal needs. Cost effective CHP systems in smaller sizes (below 100 kW) would also expand the potential market and increase application of CHP.

CHP ECONOMICS

A general economic analysis of CHP was performed for five size ranges. For each size range, an appropriate current and advanced CHP technology was characterized and the application parameters of sites (operating factor and thermal utilization) were estimated. Net power costs were estimated from these CHP systems based on the following assumptions: 80-90% load factor, 70-90% thermal utilization, and natural gas fuel cost of $5.00-6.00/MMBtu. The smaller systems were assumed to have lower load factors and higher fuel costs. The net power cost is the fully amortized cost of providing power from the CHP system after the avoided boiler fuel is subtracted from annual operating costs. **Figure ES1** shows the range of net power costs for the chosen systems and application parameters. These net power costs are below the prevailing average power costs for most customers of similar size in the state. Current electric and gas prices in New York State were evaluated in detail to determine the actual impacts that the current tariff structure, including standby charges, will have on project economics. In addition, future price tracks were determined based on the New York State 1998 Energy Plan (High Case) for electricity supply with a continuation of current delivery tariff structure. Standby tariffs proved to be so critical to the economic competitiveness of CHP that specific scenarios were developed to reflect moderation of the current charges. For the base case (business-as-usual) it was assumed that the standby charges would remain at current levels (upstate standby charges for the base case were modified – essentially set at two-thirds of Niagara Mohawk's Rule 12 charge -- to approximate the recently adopted SC-7 Standby Service Rates approved by the New York Public Service Commission). For the accelerated case, it was assumed that standby charges would be further reduced to one third to one-half of the base case values, to a level consistent with states such as Illinois and Texas. The impact of completely eliminating standby charges was also calculated though only as a benchmark; this outcome was not considered in the market analysis. The results of the payback analysis are summarized in **Table ES3.** In the market analysis, a payback of 2 years or less was assumed to be acceptable to all customers. A payback of 8 years or more was assumed to rule out any market penetration. A linear relationship was assumed between these two values.

Figure ES1. Net Power Costs from CHP as a Function of Size

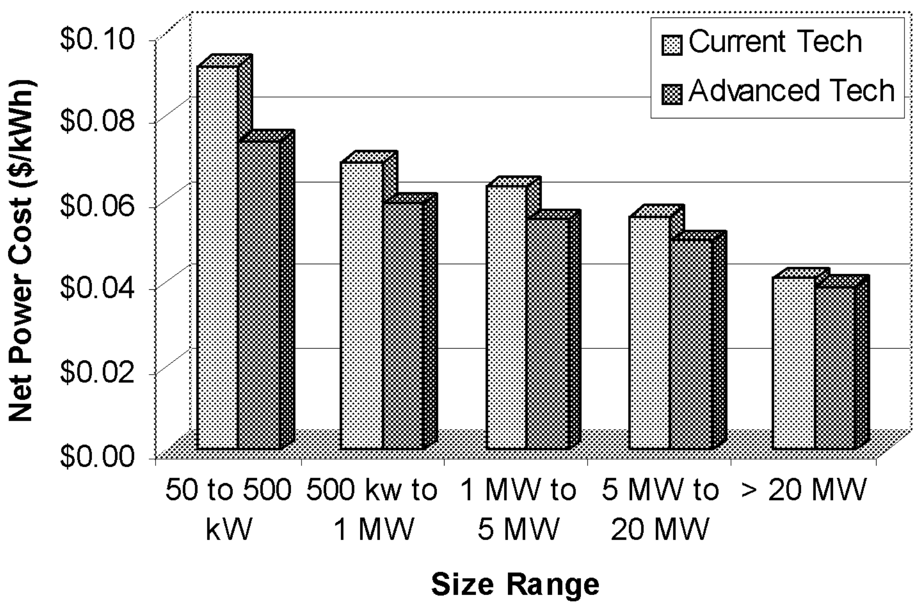


Table ES3. Summary of Paybacks for All Cases (Years)

CHP Paybacks (years) Scenario	100 kW Engine	800 kW Engine	5 MW Turbine	10 MW Turbine	50 MW Turbine
Current Technology, Upstate					
Full Standby* and CTC	7.7	4.5	6.9	5.0	2.8
No Standby or CTC	2.9	1.9	3.1	2.5	1.7
Reduced Standby and CTC	4.2	2.7	4.3	3.3	2.1
Current Technology, Downstate					
Full Standby and CTC	10.6	3.4	3.0	2.5	1.3
No Standby or CTC	3.5	1.7	1.6	1.5	0.9
Reduced Standby and CTC	4.5	2.1	1.9	1.7	1.0
Advanced Technology, Upstate					
Full Standby* and CTC	4.6	2.7	4.3	3.4	2.4
No Standby or CTC	1.7	1.2	2.2	1.8	1.4
Reduced Standby and CTC	2.5	1.6	2.9	2.4	1.8
Advanced Technology, Downstate					
Full Standby and CTC	5.7	2.3	2.0	2.1	1.2
No Standby or CTC	2.2	1.2	1.1	1.2	0.8
Reduced Standby and CTC	2.8	1.4	1.3	1.4	0.9

*Full standby for upstate is based on 2/3 of Niagara Mohawk's Rule 12 tariff structure. Reduced standby rates are 1/3 of full standby in downstate and ½ of full standby in upstate to reflect levels consistent with states such as Illinois and Texas

The following conclusions can be drawn concerning these results:

- Standby charges have a major impact on CHP market competitiveness. With the modification of the current upstate standby charges, CHP competitiveness is marginally improved. With more significant reductions to standby charges, the competitiveness of CHP increases significantly.

- Advanced technology improves competitiveness in all sizes. This improvement is greatest in the smaller customer size categories.

- Without standby charges, CHP would be economic in all size ranges for both the upstate and downstate markets. While this may not represent a realistic case, reducing the current standby charge impact by two-thirds would open up the economic markets for CHP in all customer size ranges considered.

- Paybacks generally improve as the CHP system size increases. This improvement reflects the increase in efficiency and reduction in cost for larger CHP systems. An exception to this trend is seen in the comparison of the 800 kW and 5 MW systems. A large reciprocating engine was chosen as the representative technology for the 800 kW system. For the 5 MW system, an industrial gas turbine was selected. In this size range, large engines compete somewhat better than small turbines.

MARKET PENETRATION SCENARIOS

Penetration of the economic market will be based on the degree of economic advantage for CHP compared to separately purchased fuel and power, the prevailing size of the CHP market, the speed with which the current market can *ramp-up* in the development of new projects, and the sites remaining with economic potential. These factors were combined into a simple market-estimating model that defines projected year-by-year market penetration. The analysis was undertaken for upstate and downstate regions in five size ranges for CHP equipment that reflect the differences in equipment performance and application needs. Two scenarios were considered:

- *Base Case* – business as usual based on current CHP technology and current standby rates (standby rates in the upstate region were estimated to be two-thirds of Niagara Mohawk's Rule 12 level -- to approximate the recently adopted SC-7 Standby Service Rates approved by the New York Public Service Commission).

- *Accelerated Case* – based on gradual evolution from current to advanced technology, immediate reduction of standby charges to one-half of the base case level (for both upstate and downstate markets), immediate implementation of CHP Initiatives that offer tax incentives equivalent to 10% of initial cost, and increase in customer awareness and adoption rates.

The results of these cases are summarized in **Table ES4.** In the *Base Case*, an additional 764 MW of CHP is projected to be installed by the year 2012. Nearly 70% of this capacity will be in the downstate region. The greater penetration of CHP in the downstate region is due to a somewhat higher technical potential for new CHP (54% to 46%), higher power costs, and somewhat lower standby charges. Even with a moderation of the current upstate standby rates (two-thirds of Rule 12) assumed in the *Base Case*, market penetration lags in all sizes except the greater than 20 MW size range. The upstate region has a greater potential for large industrial systems.

In the *Accelerated Case* scenario, CHP is economic in all size ranges in both the upstate and downstate regions. Cumulative market penetration reaches nearly 2,200 MW statewide. The regional split is more balanced than in the *Base Case*, but still about 60% of the market penetration is projected for the downstate region.

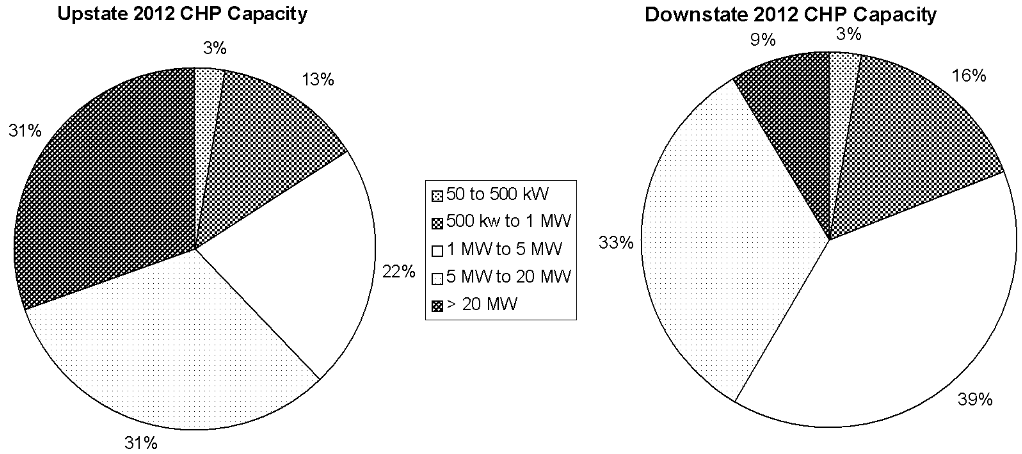
Figure ES2 shows the cumulative market penetration for the year 2012 by size range for the *Accelerated Case* in the upstate and downstate regions. The smallest size category, 50-500kW, accounts for only about 3% of the total added installed CHP in both regions. The 500kW to 1 MW size accounts for 13 and 16% of the total added capacity in the upstate and downstate regions respectively. In the larger size systems, the two regions diverge significantly in the composition of market share. In the downstate region, the largest market penetration is achieved by 1-5 MW systems accounting for 39% of total added CHP market penetration. In the upstate region the largest market penetration is achieved in the largest sized systems, over 20 MW, with a penetration share of 31% (compared to 9% of the downstate total in the big systems).

Table ES4. CHP Market Penetration by Size and Region for 2007 and 2012 (MW)

Market Segment and Region	Base Case			Accelerated Case		
	Upstate	Downstate	Total	Upstate	Downstate	Total
2007						
50 to 500 kW	0.0	0.0	0.0	5.6	8.6	14.2
500 kW to 1 MW	3.1	20.8	23.9	24.9	47.4	72.4
1 MW to 5 MW	0.0	54.9	54.9	48.3	123.0	171.3
5 MW to 20 MW	19.3	40.2	59.5	63.9	104.2	168.1
> 20 MW	88.4	52.8	141.2	151.3	64.9	216.2
2007Total	110.8	168.7	279.4	294.0	348.1	642.1
2012						
50 to 500 kW	0.0	0.0	0.0	24.0	37.4	61.4
500 kW to 1 MW	7.5	84.1	91.6	113.8	217.3	331.1
1 MW to 5 MW	0.0	204.1	204.1	184.0	515.2	699.1
5 MW to 20 MW	60.8	147.2	208.0	267.2	436.3	703.4
> 20 MW	169.8	90.0	259.8	260.5	113.5	374.0
2012 Total	238.2	525.4	763.6	849.4	1,319.7	2,169.1

The economics and market penetration analysis included in this report are not meant to be predictions of eventual market development, but as an indication of how certain market scenarios affect CHP economics and potential market penetration using a simplified market model. The objective is to determine how robust the economics might be under various scenarios, what critical factors impact economics and deployment of CHP, and which of these factors impact target markets and applications of interest to policymakers and planners.

Figure ES2. Comparison of 2012 CHP Market Share for the Accelerated Case: Upstate and Downstate Regions



Upstate Capacity 2012 – 850 MW **Downstate Capacity 2012 – 1320 MW**

BENEFITS OF CHP

CHP contributes economic savings, energy savings, reduction in criteria pollutants, and a reduction in emissions that contribute to global warming. A summary of these benefits for the base and accelerated market penetration cases is shown in **Table ES5**.

Table ES5. CHP Benefits in New York

CHP Benefits	Base Case	Accelerated Case
User Savings		
2012 Annual ($million)	$109	$487
Cumulative Savings ($million)	$536	$1,825
Net Present Value ($million)	$253	$808
Energy Savings		
2012 Annual (trillion Btu)	25	74
2002-2012 Savings (trillion Btu)	118	316
Emissions Savings Annual (2012)		
NOx (tons/year)	3,210	10,282
SO2 (tons/year)	9,778	27,766
CO2 (1000 tons/year)	1,259	3,854

The economic savings realized by the customer drives market penetration of CHP. The net savings reflect the cost of purchased electricity and fuel saved less the operating and capital charges on the CHP system. In the *Accelerated Case*, the user economic benefits reach nearly $500 million/year by the end of the forecast period. In the *Base Case*, the user benefit, based on a much lower market penetration, is $109 million/year. The total stream of user benefits is equal to the savings attributable to the cumulative CHP market penetration in each year. In the *Accelerated Case*, the total stream of user benefits equals $1.8 billion with a net present value (using a 10% discount rate) of $800 million.

When comparing fossil-fueled scenarios, CHP systems use less fuel than central station power plants and separate boilers because the exhaust heat is utilized productively in meeting *on-site* thermal needs rather than being wasted as it is in central power stations. The total energy savings from CHP over the forecast period in the *Accelerated Case* equal about 316 trillion Btu. The rate of savings equals 74 trillion Btu/year by the end of the forecast period.

The CHP generation is projected to emit less NOx than the avoided utility generation emissions[2] in all sizes except the 0.5-1.0 MW size range which, for purposes of the market forecast, was based on lean burn engine technology with no exhaust clean-up. However, CHP market penetration provides NOx reduction in all sizes when avoided boiler emissions are accounted for. The total NOx emissions reduction for the *Accelerated Case* is 10,282 tons/year by 2012. The *Accelerated Case* contributes 3.2 times the NOx reduction as the *Base Case*.

CHP market penetration has the potential for large reduction of SO2 emissions. The gas-fired CHP technology emits almost no SO2 whereas the average fossil-based emissions for central station generation by 2012 are expected to remain very significant. Avoided boiler emissions are also very small due to the assumption that this amount is all gas-fired. The total avoided SO2 emissions in the *Accelerated Case* amount to nearly 28,000 tons/year by 2012. In the *Base Case*, the total avoided emissions are 9,800 tons/year by 2012. The *Accelerated Case* increases SO2 savings by a factor of 2.8 compared to the *Base Case*.

CHP market penetration also reduces CO2 emissions. CO2 emissions contribute to global warming. CO2 emissions depend on the overall energy efficiency of the process and on the type of fuel being combusted. Natural gas contributes less CO2 per unit of energy than does oil or coal. Therefore, CHP provides benefits in two ways, by increasing the efficiency of energy use and by substituting natural gas for oil and coal. CO2 emissions reduction for the A*ccelerated Case* reaches 3.9 million tons/year by 2012. The *Base Case* provides a 1.3 million-tons/year reduction.

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[2] Calculations assumed that future CHP penetration would back-out the average emissions from the average fossil mix component of future generation.