Combined Heat and Power in New York State's Deregulated Electricity Market

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ABSTRACT

Emerging *distributed generation* (DG) technologies such as fuel cells and microturbines offer potential to self-generate electric power at emissions competitive to central station generation. When heat is recovered for useful purposes, i.e., *combined heat and power* (CHP), these options can provide an end-user with an efficient and reliable energy supply option. CHP systems can exceed 80% fuel-use efficiency and can reduce NOx and other air pollutant emissions when compared to the traditional "make heat, buy electricity" model employed by most energy users. that there is nearly 13 GW of remaining CHP technical potential in New York State. The bulk (nearly 70%) of the remaining potential, 9.1 GW at 21,000 sites, is in the commercial/institutional sector in building CHP (BCHP) applications. BCHP applications use smaller DG systems with higher per-unit costs ($/kW) that are not likely to compete with separately provided cooling, heating and power, unless there is an adequate thermal load. Also, the presently practiced permitting and utility interconnection procedures and associated costs present a significant hurdle to the smaller BCHP projects. This paper presents a public benefit overview of NYSERDA's DG-CHP program, examines environmental aspects of the CHP use and reviews hurdles such as utility interconnection, exit fees, and standby/backup charges.

Introduction

The 2001 energy crisis in the State of California illustrated the supply-demand disparities and the associated vulnerabilities of a deregulated electricity market. Since then, the process of electric utility deregulation in several states across the country has teetered. Nevertheless, in New York State the deregulation process is nearly complete. According to the recently published New York State Energy Plan, more than 80% of the electricity generating capacity formerly owned by investor owned utilities (IOUs) has been sold to independent power producers (New York State Energy Planning Board 2002). This generating capacity is now traded in a competitive wholesale electricity market operated by the New York Independent System Operator (NYISO). As a result, all electricity customers formerly served by regulated IOUs may now choose an alternative commodity provider that transmits via the utility owned and operated electricity lines (grid).

Alternatively, a customer may install an on-site generating system, also referred to as a distributed generation (DG)[1] system. A DG unit may be designed to meet a customer's needs for premium, standby (backup or peakshaving), or baseload power. It is usually more cost-effective to size a DG system to meet a portion of the user's baseload electricity requirements and to have the user connected with the grid for supplemental power needs beyond the DG capacity and/or

[1] In this paper, the scope of distributed generation is limited to non-renewable based on-site generation.

for standby service during outages or planned maintenance. Establishing such "interconnection" to the utility grid enables a distributed generator to export excess power, if any, to the others on the grid. The success and broader acceptance of DG is closely linked with a customer's ability to establish a bidirectional grid interconnection (Leslie 2000; Adlerfer, Eldridge & Starrs 2000).

New York State Energy Research and Development Authority (NYSERDA) supports research to develop technologies that help New York State conserve energy and reduce emissions. NYSERDA also helps New York State businesses develop energy and environmental products. In 1998, NYSERDA was named the administrator of the System Benefits Charge (SBC) established by the New York State Public Service Commission (NYSPSC). The SBC program, named **New York Energy $mart Program**[SM], is designed to ensure that important R&D and energy efficiency programs that result in consumer benefits are continued in a deregulated electric-utility environment. A paper describing NYSERDA's strategy for promoting DG and its applications such as combined heat and power (CHP) was published recently (Patibandla et al. 2001).

DG Applications and Benefits

Distributed generating options include turbines (steam, combustion, micro), reciprocating engines (diesel, natural gas), and fuel cells (phosphoric acid, molten carbonate, solid oxide, alkaline, proton exchange membrane (PEM)) as well as renewables such as photovoltaic and wind systems. The scope of this paper is limited to DG systems operating on fossil fuels. Neither the renewables nor fuels such as anaerobic digester gas, landfill gas, and biomass derivative fuels are considered. The fossil fuel based systems offer a wide range of capacity starting at a 2 kW PEM fuel cell to a 250 MW gas turbine at prices ranging from more than $5,000 per kW for fuel cells to $500 per kW for large turbines. Overviews of these generating options are available in the literature (Energy Nexus Group et al. 2002; Onsite Sycom Energy Corp. 2000; Elliott and Spurr. 1999; Kaarsberg et al. 1998). A comparison of nominal simple cycle electric efficiencies, NO_x and CO_2 emissions from various DG and central station power generation technologies is shown in Table 1.

The large-scale combined cycle gas turbine plant, as identified in Table 1, operates at an electrical efficiency approaching 60% with low emissions of nitrogen oxide (0.3 lb./MWh). With the exception of some of the fuel cell technologies, the smaller, and more conventional distributed generation technologies (small gas turbines, reciprocating engines) tend to operate at a lower overall efficiency and with higher overall emissions. However, an accurate performance comparison between these conventional DG technologies and central plants needs to include the additional benefits associated with on-site generation. In many instances a DG system operated in a CHP configuration will exceed the performance of the combined cycle plant. NYSERDA's DG-CHP program seeks to encourage the deployment of a wide-range of clean DG technologies, and the development of a realistic strategy for improving air quality over time.

One of the main advantages of a DG system is that it can be integrated with a variety of commercial, institutional, and residential applications to provide both electrical and thermal energy. Most central plants, because of stringent permitting requirements, are located too far from a thermal host site to make CHP an affordable option. In a few instances where a thermal customer is located near a central plant, the installation is typically limited to an industrial application. Expanding the deployment of DG systems beyond the industrial sector will promote greater energy efficiency at the local/community level by allowing small businesses, schools, and homes to utilize these on-site technologies.

Table 1: Representative Simple Cycle Electric Efficiencies, NO_x and CO_2 Emissions from Various DG and Central Station Power Generation Technologies

Technology	Electrical Efficiency (%)	Fuel	CO_2 Emissions (#/MWh)	NO_X Emissions (#/MWh)
Central Plant Generation				
Combined Cycle Gas Turbine	60	NG	725	0.30
Simple Cycle Gas Turbine	40	NG	1,088	0.60
Distributed Generation				
Small Industrial Gas Turbine	30	NG	1,450	0.66
Compression IC Engine	42	Diesel	1,381	12.70
Compression IC Engine (w/SCR)*	38	Diesel	1,526	4.40
Spark IC Engine (w/lean burn)	38	NG	1,145	2.10
Spark IC Engine (w/TWC)**	32	NG	1,359	0.40
Microturbine	25	NG	1,740	0.45
PEM Fuel Cell	35	NG	1,243	0.02
Phosphoric Acid Fuel Cell	40	NG	1,088	0.02
Molten Carbonate Fuel Cell	50	NG	870	0.002

* SCR: Selective Catalytic Reduction
** TWC: Three-Way Catalyst

Regardless of electricity options, most utility customers generate their own thermal energy (steam, hot water, hot air, refrigeration, etc.) onsite. A holistic approach to meeting one's energy needs is to use an onsite system that generates the required electric and thermal energy. *Combined Heat and Power (CHP)*[2]*, or cogeneration,* is the coincident production and use of electrical or mechanical power and thermal energy. In a situation where a customer's electricity baseload is met by a DG system, the thermal output could be recovered resulting in higher energy efficiency and lower emissions at a lower cost than the option of using central station power supplied via transmission and distribution (T&D) infrastructure and separate on-site production of heat. The thermal energy recovered from the onsite system may be used in industrial processes or for space heating; and/or for refrigeration or space cooling via an absorption chiller. Use of DG in a CHP application (DG-CHP) represents an opportunity to improve energy-efficiency and to reduce environmental impact associated with power generation/use. Though the realized energy and environmental benefits depend on the technology and the application, DG-CHP

[2] In this paper, CHP is defined as a DG unit that serves a portion of or the entire electricity and thermal loads of a site at a minimum of 60% overall fuel-use efficiency.

systems can exceed 80% fuel-use efficiency and can offset NOx and other air pollutant emissions produced by the site's previously used stand-alone boiler.

Figure 1. NOx Emission Reductions Through Combined Heat and Power Applications

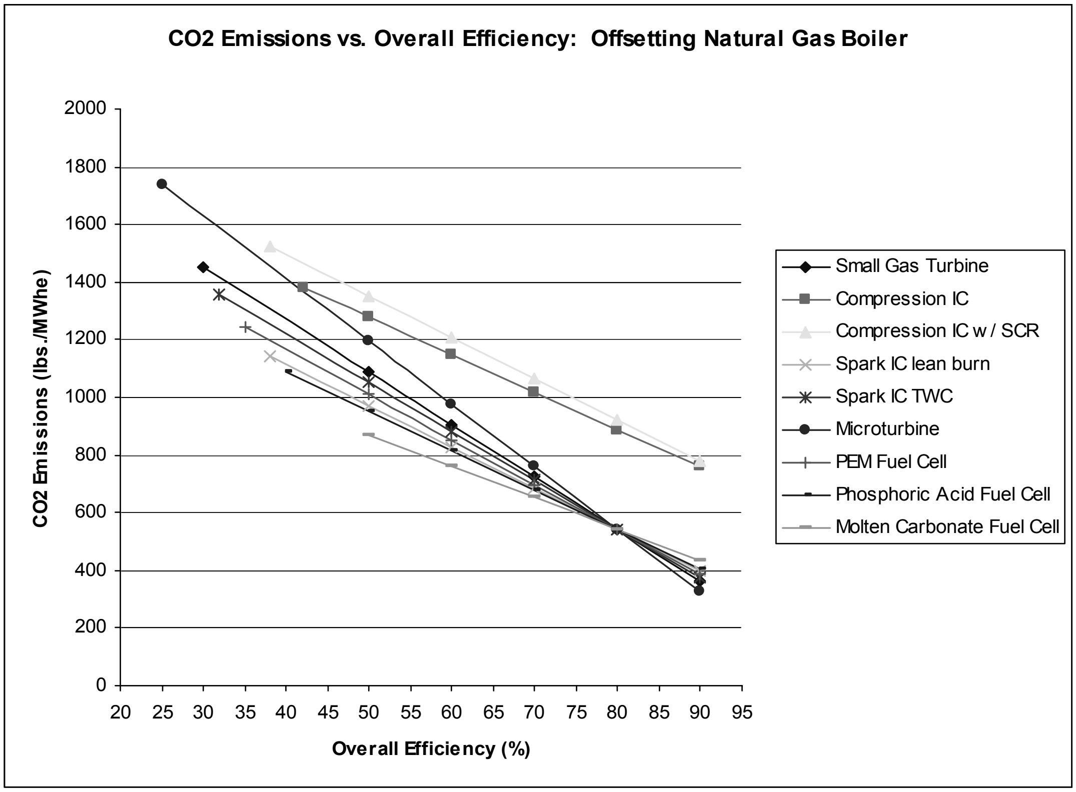

Figure 1 illustrates how the utilization of waste heat can serve to reduce emissions of nitrogen oxide (NOx). NOx emissions are plotted against overall (electric + thermal) efficiency. It is assumed that the thermal output recovered from each of the listed DG systems is utilized to offset the consumption of natural gas fired in a conventional boiler. Boiler NOx emissions are assumed to be 0.57 lbs./MWh (Cleaver Brooks. 2nd Edition). It is interesting to note that NOx emissions can be reduced below zero at high overall efficiency levels. Boilers operating on heating oil typically produce three times more NOx than a natural gas-fired unit, and as such, the resulting emission offsets associated with displacing oil consumption can be significantly greater. Adoption of an output-based emission standard crediting boiler emission offsets provides for a more accurate measure of overall on-site system performance.

In a deregulated electricity market, grid-connected DG can enhance the performance of the grid and affords the capability to more accurately match electrical supply and demand. Such strategically located DG, can not only alleviate grid congestion by avoiding the need to transmit every kW of power consumed by an end-user over the existing T&D infrastructure, but also could reduce the need for grid expansions and/or upgrades. In addition, the proximity of supply to the load could reduce the location-based marginal pricing (LBMP)[3] paid by a market

[3] New York State Independent System Operator (NYSISO) defines LBMP as the cost to provide the next MW of

participant - such as a distribution company - potentially lowering the market clearing prices, and ultimately reducing energy prices paid by end-users.

Recent technological advancements in DG and the onset of deregulated electricity market furthers the potential for CHP growth, providing an opportunity to improve the efficiency of power generation and to mitigate the associated air pollution. Recognizing this opportunity, NYSERDA initiated a concerted effort in 2000 to promote development of CHP applications and deployment of CHP technologies. NYSERDA's CHP program is currently supporting a number of projects, ranging from studies to provide guidance and road-mapping for further program development to demonstration projects to improve and evaluate technologies/applications.

New York State's DG-CHP Potential

Presently, New York State is home to some 210 CHP sites with a cumulative electric capacity of 5,070 MW. Much of this installed capacity is concentrated in a few large merchant plants - 12 sites ranging in capacity from 100 to 1,034 MW provide 60% of the total CHP capacity (Energy Nexus Group et al. 2002). Natural gas fired turbines are the principal prime movers used at these sites. While large capacity, industrial-based, merchant CHP systems dominate the installed capacity; the commercial and institutional sector actually has a greater number of operating sites than the industrial sector.

An upcoming NYSERDA sponsored CHP Market Assessment Report (Energy Nexus Group et al. 2002) estimates as much as 12,800 MW of remaining CHP technical potential for New York State – (see Table 2).

Table 2: New York State's Remaining CHP Technical Potential in Megawatts by System Size

CHP System Size	*Industrial Sector*	*Commercial/Institutional Sector*
50 to 500 kW	584	2,098
500 kW to 1 MW	321	2,495
1 MW to 5 MW	1,085	2,800
5 MW to 20 MW	788	1,513
> 20 MW	825	315
Total	3,603	9,221

This CHP technical potential is a year 2000 snapshot based on existing manufacturing and commercial/institutional facilities and their current electric and thermal energy consumption. The analysis considers only traditional hot water-steam/electric power CHP. No estimate was made for mechanical drive applications or for uses of thermal energy other than hot water or steam. Also, no consideration of economics is included. The technical potential for CHP in terms of MW capacity was estimated assuming that the CHP systems would be sized to meet the

load, at a specific location in the grid.

average electric demand for most applications. For the majority of the target markets there is a reasonable match between electric to thermal ratios of the application and the power to heat output of existing CHP technologies. The technical potential estimates were derived using a screening tool applied to the existing institutional/commercial and industrial sites that meet the following criteria:

- relatively coincident electric and thermal loads
- thermal energy loads in the form of steam or hot water
- electric-to-thermal demand (E/T) ratios in the 0.5 to 2.5 range, and
- moderate to-high operating hours (>4000 hours per year)

Buildings Sector CHP Potential

As shown in this analysis, the bulk of the remaining technical potential, nearly 43% or 5500 MW, is in systems smaller than one megawatt in size. Also, nearly 84% of that 5500 MW (i.e. 4600 MW) is in the institutional (schools, hospitals, universities, etc.) and commercial (office buildings, hotels, restaurants, etc.) sectors where the thermal energy is used in buildings applications, often referred as BCHP. Thermal loads most amenable to CHP systems in commercial/institutional buildings are space heating and hot water requirements. The simplest thermal load to supply is hot water. Retrofits to the existing hot water supply are relatively straightforward, and the hot water load tends to be less seasonally dependent than space heating, and therefore, more coincident to the electric load in the building. Meeting space heating needs with CHP can be more complicated. Space heating is seasonal by nature, and is supplied by various methods in the commercial/institutional sector, centralized hot water or steam being only one. For these reasons, primary targets for CHP in the commercial/institutional sectors are those building types with electric to hot water demand ratios that are consistent with those of an appropriate CHP system.

Technology development efforts targeted at heat-activated cooling/refrigeration and thermally regenerated desiccants could expand the application of CHP by increasing the thermal energy loads in certain building types. Use of CHP thermal output for absorption cooling and/or desiccant dehumidification could increase the size and improve the economics of CHP systems in existing CHP markets such as schools, lodging, nursing homes and hospitals. Use of these advanced technologies in applications such as restaurants, supermarkets and refrigerated warehouses provides a base thermal load that opens these applications to CHP.

The Report (Energy Nexus Group et al. 2002) also forecasts economically viable market potential for CHP under *Business-As-Usual* and *Accelerated* scenarios by the year 2020, the results of which are summarized in Table 3. The two scenarios are defined as follows:

Business-as-Usual – Use of presently available DG technologies and continuation of current levels of utility standby service charges.

Accelerated Case – Assuming a gradual adoption of advanced technologies such as fuel cells, immediate reduction of standby charges to one-third of their current level, immediate implementation of tax incentives equivalent to 10% of initial cost, and increases in customer awareness and adoption rates.

Table 3. Summary of Cumulative CHP Market Penetration in Megawatts by System Size for 2020

CHP System Size	Business as Usual	Accelerated
50 to 500 kW	0	555
500 kW to 1 MW	371	991
1 MW to 5 MW	673	1,807
5 MW to 20 MW	495	1,590
> 20 MW	567	1,026
Total	2,106	5,969

Unlike the technical potential, the 1 MW and smaller size ranges represent a smaller portion of the economically viable market penetration. For these size ranges, in the *Business-as-Usual* scenario, the cumulative market penetration between now and 2020 equals about 17% (371 MW) of the 2,100 MW. The Report (Energy Nexus Group et al. 2002) concludes that the perpetuation of standby charges minimizes any economic advantage to the end-user and consequently the CHP market penetration in the smaller size categories. In the *Accelerated* scenario, cumulative market penetration reaches nearly 6,000 MW statewide but only about a quarter (1546 MW) of which is in the smaller (≤ 1 MW) systems.

Overall, the improvement in market climate assumed for the accelerated case results in an additional 3,862 MW of CHP market penetration over the forecast period. While it is difficult to determine exactly the impact of the various assumptions that make up the accelerated case due to interaction among them, the Report (Energy Nexus Group et al. 2002) estimates that the reduction in standby charges is responsible for about 45% of the increase in market penetration, the increase in customer awareness/developer effort and the CHP initiatives are jointly responsible for about 40%, and the improvement in technology cost and performance is equal to about 15%.

Issues Facing CHP

The buildings CHP applications use smaller DG systems with higher per-unit costs ($/kW) that are not likely to compete with separately provided cooling, heating and power, unless there is an adequate thermal load. Besides the economics, widespread use of the DG-CHP applications faces some major institutional hurdles, namely utility interconnection requirements, air permitting issues, and standby service rates.

Utility Interconnection Requirements

The IOUs that have become distribution companies in the deregulated electricity market are still left with the responsibility to maintain a safe and reliable grid that is capable of supplying high quality power to all users. Some barriers to interconnection stem from the IOU revenue issues that include the need for collecting apportioned amounts of stranded costs in the forms of exit fees and/or standby service charges to remain "revenue neutral." The key to the success of small DG is the ability to safely, reliably and economically interconnect with the existing utility grid system. Interconnection requirements vary by state and/or utility. Compliance often requires lengthy negotiations that add cost and time to a DG-CHP system installation. These requirements can be especially burdensome to smaller systems (i.e., under 1 MW). Non-standardized requirements make it difficult for equipment manufacturers to design and produce modular packages at any reasonable economies of scale. Efforts are underway by state regulators to streamline this process. In 1999, NYSPSC issued an order standardizing the interconnection requirements (SIR) for small (≤ 300 kVA) distributed generation units on radial distribution systems only (New York State Public Service Commission. 1999). In New York State, though the radial systems dominate the grid, urban centers, such as New York city, Albany, and Buffalo, are served by network systems. It is, therefore, imperative that the SIR be broadened to cover network systems and to DG unit sizes of about 1 MW.

Air Permitting Issues

Like interconnection, air-permitting issues add cost, complexity, and uncertainty. States like California and Texas have issued guidelines to begin regulating new DG without addressing existing units (California Environmental Protection Agency. 2001; Texas Natural Resource Conservation Commission. 2001). In addition, the Regulatory Assistance Project (RAP) developed model emissions standards for smaller-scale electric generation sources (RAP. 2001). These standards are summarized in Table 4. All standards recognize CHP. However, based on the emissions of current technology (see Table 1 and Figure 1), large combined cycle turbines with selective catalytic reduction (SCR), a few DG technologies such as high-temperature fuel cells, and the gas-fired engines with three-way catalyst (TWC) currently meet the 2003 requirements. In 2001, New York State Department of Environmental Conservation (NYSDEC) is currently developing emission standards for DG technologies that currently fall below the regulatory radar. NYSERDA's DG-CHP program is intended to provide NYSDEC with the necessary information in support of realistic emissions standards for DG systems, allowing for an efficient wholesale emissions trading market including NO_x, SO_x, CO, VOC, and CO_2. In developing these rules, it is important to ensure that the benefits of DG-CHP are captured through a wide spread use of environmentally clean, energy efficient, and economically viable technology and application options.

Standby Service Rates

The optimal and economic use of DG-CHP for most customers requires integration with the utility grid for back-up, supplemental power needs, and, in selected cases, for marketing or wheeling generated power. The cost of providing such service needs to be transparent and should reflect the true costs of serving a generating customer and ensure a fair and equitable share of the stranded costs are included. Strategically located DG systems can obviate the need for, or at least defer, new investment in T&D. NYSPSC issued an opinion requiring all IOUs to file standby service rates (New York State Public Service Commission. 2001). Niagara Mohawk and National Grid jointly were the first IOUs to submit a Standby Service Rate filing (SC-7). The rates are in the process of negotiation and are expected to be finalized by June 2002, after which

Table 4. DG-CHP Emission Standards (lbs/MWh)

<table>
<tr><th colspan="5">California Standards effective 1/1/2003</th></tr>
<tr><th>Pollutant</th><th colspan="2">DG with CHP[1]</th><th>DG with Wind or Solar Electric[2]</th><th>After 1/1/2007</th></tr>
<tr><td>NO_x</td><td colspan="2">0.7
(0.5 for DG only)</td><td>1.0</td><td>0.05</td></tr>
<tr><td>CO</td><td colspan="2">6.0</td><td>6.0</td><td>0.08</td></tr>
<tr><td>VOCs</td><td colspan="2">1.0</td><td>1.0</td><td>0.02</td></tr>
<tr><th colspan="5">Texas Standard for units Έ 10 MW operating > 300 hrs effective 6/1/2001[3]</th></tr>
<tr><th>Pollutant</th><th colspan="2">East TX</th><th>West TX</th><th>Landfill/Digester/Oil-Field Gas</th></tr>
<tr><td>NO_x</td><td>0.47</td><td>0.14
(After 1/1/2005)</td><td>3.11</td><td>1.77</td></tr>
<tr><th colspan="5">The Regulatory Assistance Project (RAP) -– Model Base-Load Generators Standard[4]</th></tr>
<tr><th>Pollutant</th><th colspan="2">1/1/03-12/31/05</th><th>1/1/06-12/31/08</th><th>After 1/1/2009</th></tr>
<tr><td>NO_x</td><td colspan="2">0.5-0.47</td><td>0.3-0.27</td><td>0.15-0.07</td></tr>
<tr><td>PM-10</td><td colspan="2">0.08</td><td>0.05</td><td>0.02</td></tr>
<tr><td>CO</td><td colspan="2">0.60</td><td>0.30</td><td>0.10</td></tr>
<tr><td>CO_2</td><td colspan="2">1400</td><td>1400</td><td>1400</td></tr>
</table>

[1] Integrated CHP must achive 60% efficiency
[2] Wind /Solar must produce 35% of the total electric output
[3] Different limits apply to units greater than 10 MW and for units operating less than 300 hours per year
[4] Different limits modeled for emergency and peaking generators

time all other IOUs in New York will follow. The equitable settlement of these standby tariffs will have a profound effect on future DG market penetration in New York.

Summary

The onset of deregulated electricity market in New York State and in other states across the nation and the development of numerous viable CHP applications offer a unique opportunity to promote DG-CHP. Use of DG-CHP could result in spurring economic development in addition to the obvious energy-efficiency and air quality benefits. However, the widespread use of DG-CHP faces hurdles such as utility interconnection, exit fees, and standby service charges in the near-term. NYSERDA's CHP program is currently supporting 40 demonstration projects that are expected to result in installation of over 40 MW of generating capacity for a peak demand reduction of 30 MW. NYSERDA and similar organizations in other states have a unique opportunity to promote CHP for improving end-use energy-efficiency and for providing environmental benefits.

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