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Ensuring emergency power for critical municipal services with natural gas-fired combined heat and power (CHP) systems: A cost–benefit analysis of a preemptive strategy

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Abstract

Electric power failures in the aftermath of disasters cripple the delivery of critical emergency services. While emergency generators are available in some facilities, these systems are designed for short-term use and support limited functions. The substantial investment required to ensure emergency power for all critical services is difficult to justify because of the uncertainty associated with the likelihood and magnitude of future disasters. Investment evaluations change when a new source of emergency power is considered. This study evaluates the costs and benefits of a program to preemptively install new building-sited electric combined heat and power (CHP) generation technologies to ensure reliable long-term power for critical municipal services in hurricane-prone regions of the US. Three municipalities are selected for this analysis: Houston, Texas; Miami, Florida; and Charleston, South Carolina. Analysis indicates that costs of such a program can, in some cases, provide net energy bill savings regardless of the occurrence of a disaster.

Keywords: CHP; Distributed generation; Emergency power

1. Introduction

Emergency generators in disaster-prone areas are typically designed for short-term use for only the most vital municipal services. Post-disaster health care, shelter and public safety are extremely limited and in some cases virtually non-existent, largely due to electric system failures (US House of Representatives, 2006). Evaluating the future benefits of more extensive emergency power systems as part of a risk management process is difficult because of uncertainty associated with the likelihood and magnitude of future natural disasters. The expected benefit of additional investments in emergency generation equals the product of estimated benefits and the probability of occurrence. The probability of a disaster at any one specific location is exceedingly small, resulting in limited expected benefits. Consequently, existing emergency generation systems are typically determined by minimal requirements specified in existing health and safety codes.

Cost–benefit calculations for expanding municipal emergency power capabilities can change substantially, however, by considering a different source of emergency power available with new building-sited combined heat and power (CHP) electric generation (US Department of Energy, 2000, 2002). Instead of traditional emergency generator applications, these technologies are integrated in building energy systems to continuously provide some portion of a facility's electricity and thermal energy needs, including space heating, water heating and air conditioning. In the event of a power outage, these systems continue to operate, providing power for critical services. The economic benefit during normal daily operation helps offset some or all of their costs.

While CHP systems are widely recognized as useful for emergency power applications (Hordeski, 2005; Gulf Coast CHP Application Center, 2006), no analysis has been conducted to evaluate the costs and benefits of a program to preemptively install CHP systems to provide critical

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Table 1
Characteristics of three study locations

	Charleston	Houston	Miami
Mean January temperature, °C (°F)	8.8 (47.9)	11.0 (51.8)	20.1 (68.1)
Mean July temperature, °C (°F)	27.6 (81.7)	28.7 (83.6)	28.7 (83.7)
Population (2005)	106,712	2,016,582	386,417

Sources: Comparative Climatic Data, National Climatic Data Center, US National Oceanic and Atmospheric Administration, 2001, US Census Bureau, 2005.

emergency services for an entire municipality. Economics of CHP systems depend on (1) hourly energy use characteristics of critical service buildings, (2) CHP system characteristics and (3) electric and natural gas prices. Under the right circumstances, CHP systems can provide net economic savings over time, reducing the cost of expanding critical services emergency power systems.

This paper evaluates the costs and benefits of preemptive municipal disaster preparedness programs to provide minimum levels of CHP-generated electric power required for critical disaster management, safety, health and temporary shelter services during widespread and prolonged central electric system outages in hurricane-prone areas of the US.

Three municipalities are selected for this analysis: Houston, Texas; Miami, Florida; and Charleston, South Carolina. These locations are all in the "strike zone" of Caribbean-spawned hurricanes and each reflects different climate characteristics as indicated in Table 1.

Variations in hourly heating and cooling energy use help determine system configuration and energy cost savings that can occur with CHP systems. As indicated in Table 1, Miami has by far the warmest climate in the winter season (January). All three locations are characterized by warm summer seasons requiring substantial air conditioning. Municipalities range in size from Charleston, with a population of 106,712, to Houston, with over 2,000,000 inhabitants.

The remainder of this paper is organized as follows. The next section describes new CHP technologies and potential CHP economic advantages relative to emergency-only generators. Section 3 identifies critical service building facilities used in the analysis and describes the development of hourly electricity and natural gas load data required for CHP system design and economic analysis. The next section discusses CHP system design and economic analysis methodology. Analysis results are then presented, with the final section providing a summary of this research.

2. New building-sited combined heat and power technologies

Recent advances in CHP technologies provide building-sited electric generation that can serve both as an emergency source of electric power and as an integral component in meeting the daily energy needs of most commercial buildings. These CHP systems provide electricity and utilize waste heat from the generation process in existing building thermal applications such as space heating and domestic water heating. Thermal energy can also be used in an absorption refrigeration cycle to provide air conditioning and refrigeration. CHP systems, also referred to as cogeneration and distributed generation systems (DG), have been used for decades in large industrial plants and some large commercial complexes; however, recent technology extensions provide smaller, more economical units packaged with heat exchangers, remote monitoring and control capabilities and thermal applications such as absorption air conditioning. While these systems cost more than electric-only emergency generators, they can provide daily savings in energy costs that pay for part or all of the system over time.

Modern CHP systems include: (1) a prime mover, (2) heat exchangers, (3) end-use applications and (4) controls and monitoring systems. Natural gas engines are the most common prime mover; however, microturbines, fuel cells and sterling engines are also used. Heat exchangers transfer waste heat to useful thermal end-use applications. Controls and monitoring systems provide for offsite monitoring and continuous maintenance practices to limit unscheduled downtimes.

CHP systems with capacities as small as 6 kW are available (Aisin, 2006); one larger packaged system, the United Technologies PureComfort product, includes from four to six 60 kW microturbines with a double-effect absorption chiller/heaters in balanced electric–thermal designs (United Technologies, 2006). Manufacturer and installer-provided warranties along with the remote sensing and control capabilities of these systems allow building owners to take advantage of CHP technology with no onsite engineering expertise or maintenance responsibilities. CHP systems are being used in offices, restaurants, grocery stores, nursing homes, and other commercial and institutional buildings. Fewer than 5000 of the new smaller CHP systems have been installed in the US in the last 5 years (Jackson, 2005); however, a series of studies indicate that their market share could potentially reach as much as 20 percent of the US commercial, government and institutional sectors (US Department of Energy, 2000).

Table 2 shows a cost comparison between an electric-only emergency generator and a CHP system for a 5800 square meter (61,400 square foot) nursing home in Miami. Both systems provide the same generation capacity, 120 kW, providing approximately 54 percent of non-emergency electricity use for the entire facility or 100 percent electricity use in a system designed to support one-half of the facility during an emergency. The CHP system costs twice as much as the electric-only system; however, it provides daily energy cost savings that are not available with the electric-only system. This example includes a natural gas engine with 31.7 percent electric efficiency and the ability to use 48.7 percent of the natural gas input

Table 2
Economics of standby electric-only and combined heat and power systems

	Emergency electric generation only	Combined heat and power
Capacity (kW)	120	120
Installed cost ($/kw)	450	953
Installed cost ($)	54,000	114,360
Avoided costs		
Electric ($)		79,534
Natural gas ($)		32,357
Operating cost ($)		12,007
Natural gas gen. cost ($)		66,976
Annual savings ($)		32,908
Net present value of investment ($)	(54,000)	170,531
Simple payback (years)		3.5

energy for thermal applications. The system has an overall efficiency of 80.4 percent. These cost and efficiency data are taken from US Department of Energy (2002). By generating electricity on site, annual utility electric bills are reduced by $79,500. Use of waste heat in the building saves an additional $32,357 in annual natural gas bills. Deducting $66,976 in natural gas costs to fuel the prime mover and operating and maintenance costs of $12,007 provides a net annual energy cost savings of $32,908. These annual cost savings along with the installation cost provide a net present value of $170,531 and a payback of 3.5 years, assuming constant costs and a discount rate of 3 percent.

As indicated in the Table 2 example, savings in avoided natural gas and electricity costs are critical components in the economic analysis that are offset, to some extent, by natural gas fuel used to run the onsite generator and other operating and maintenance costs. The onsite electric generation process can be more or less efficient and therefore more or less costly to generate a single kWh of electricity compared to purchase from the local utility; however, the overall economic attractiveness of CHP systems depends to a large extent on avoided natural gas costs resulting from the onsite use of waste heat.

The relationship between utility-provided electric and natural gas prices also plays an important role in CHP economics. The relationship between these two energy prices depends primarily on the mix of generating fuels used by the utility. Systems with heavy oil and natural gas use generally provide the most attractive (largest) electric–natural gas price spreads. The extent to which natural gas price increases impact CHP system economics depends on the impact these prices have on the price of utility-generated electricity. For example, an increase of 20 percent in natural gas prices without any increase in electricity prices boosts the payback in Table 2—4.4 years, an increase of 27 percent. However, if the 20 percent natural gas price increase also causes utility-generated electricity prices to increase by 10 percent, the payback actually falls by 3 percent to 3.4 years. Thus, in areas where CHP economics are attractive because of heavy reliance on natural gas and oil as utility-generating fuels, the temporal correlation of fossil fuel prices with utility-generated electric prices provides reasonably stable economics over time.

CHP waste heat utilization provides overall system efficiencies as much as 80–90 percent (Maine Public Utilities Commission, 2001). The extent to which onsite waste heat can offset the cost of CHP equipment is determined by the nature of hourly electric and thermal demands in the building across all hours of the year. Different building types have distinctive hourly energy use profiles reflecting building functions and weather impacts; consequently, the economics of preemptively developing emergency power capabilities with CHP systems depends on detailed hourly building analysis of the individual building types used to provide critical services.

Most hurricane damage to electric systems occurs because of wind and wind-related damage without interrupting natural gas delivery. Consequently, supply reliability is not considered in this study.

3. Critical service facility requirements and hourly energy use characteristics

Critical disaster mitigation functions considered in this analysis include: (1) disaster management and public safety, (2) health and (3) shelter services. We assume that disaster management and public safety functions of local governments can be met in disaster situations with 10 percent of total municipal floor space. Required health care needs are specified as 50 percent of hospital beds and 50 percent of nursing home beds. Shelter requirements for 5 percent of the population are met with approximately 25 percent of existing school buildings. These specifications reflect input assumptions in the analysis. As indicated below, the assumptions are converted to building requirements, or, more specifically, to the number of buildings consistent with typical building sizes in the individual building-type categories. Detailed results of analysis for each of the individual functions/building type are reported in a later section to allow analysis using alternative input assumptions on minimal critical services requirements.

Detailed energy use and other characteristics of representative buildings in these locations were developed from the US Department of Energy's Commercial Buildings Energy Consumption Survey (CBECS, US Department of Energy, 1992, 1995). While more recent CBECS data are available, we had access to detailed billing information for only the 1992 and 1995 data. CBECS data were pooled, and a proportional post-stratification using US Commerce Department county-level data on establishments by employee size categories (County Business Patterns, 2000) was used to develop a national sample of 12,499 commercial buildings across the US. Average local government, hospital, nursing home and school buildings within metropolitan statistical areas were developed with data for the largest half of the building population in each

Table 3
Number of facilities and square feet required to support 100,000 population center

Building type	Building size		Number of buildings		
	Square meters	Square feet	Charleston	Houston	Miami
Disaster mgmnt/Pub safety	19,881	214,000	1	1	5
Hospital	65,030	700,000	1	2	3
Nursing homes	8,826	95,000	2	5	24
Shelter (schools)	11,520	124,000	5	16	82

building category consistent with a program that installs CHP systems in larger buildings.

Table 3 shows the size of each of the representative buildings. In this preliminary analysis, a single-building characterization was used for each of the three locations, in part, to provide economic comparisons where only weather and energy prices varied across locations. Buildings consistent in size exist in all three municipalities. The number of buildings required to meet the capacity targets above was developed using information from the CBECS survey data and the US Commerce Department's Statistical Abstract of the US (2006). For example, there are approximately 278 hospital beds per 100,000 people in the US, requiring 139 hospital beds to meet the 50 percent capacity figure used in the analysis. CBECS data indicate that approximately 93 square meters (1000 square feet) are required per bed, yielding a hospital floor space requirement of 13,000 square meters or 139,931 square feet per 100,000 population. Since the representative hospital used in this analysis has 65,030 square meters, one hospital is required in Charleston, two in Miami and three in Houston to meet the minimum capacity requirements.

Approximately 5000 square meters (53,820 square feet) per 100,000 people are required to meet the 10 percent of total municipal floor space required for disaster management and public safety operations, requiring one representative municipal building in Charleston and Miami and five in Houston.

The US nursing home ratio of 672 beds per 100,000 people yields a 50 percent capacity requirement of 336 beds per 100,000 people. A CBECS-based floor space per bed ratio of 29 square meters per bed (311 square feet/bed) requires two, five and 24 nursing homes in the three cities.

The analysis assumes that schools can most easily be equipped for emergency shelter with a space requirement of 9.3 square meters (100 square feet) per person. This per-person space requirement is 63 percent of CBECS hotel/motel space requirements assuming a room occupancy of four people; it is also the same as the per-student space requirement in the CBECS school data. Approximately 25 percent of a city's educational floor space is required for emergency shelter under these assumptions. Five schools are required in Charleston, 16 in Miami and 82 schools in Houston.

The economics of using CHP to provide emergency power depends in part on hourly electric and thermal energy use in each of these facility types in each of the three locations. Energy use characteristics of the representative buildings were developed from a sample of office buildings, hospitals, nursing homes and schools extracted from the national CBECS database for regions and climate characteristics consistent with the three locations. Energy use detail for each of the representative buildings includes hourly whole-building electric and natural gas use, along with space heating, air conditioning and water heating hourly energy use for each of the 8760 h in the year.

4. CHP system design and economic analysis methodology

CHP system designs can be complicated. The prime mover in this study has been restricted to natural gas engines, the most frequently selected prime mover. Natural gas engines apply a reliable technology that has been used for decades and, more importantly for most of the facility types, has higher electric generation efficiency. That is, the ratio of generated electricity to waste heat is higher and more compatible with the end-use (space heat, water heat, etc.) needs of most of the facility types considered here. Natural gas systems are also less expensive.

Limiting the prime mover choice to a natural gas engine does not resolve all system design issues, however. Larger engines cost less per kW capacity; however, CHP systems must be sized to maximize the cost savings from onsite use of waste heat and avoided electricity costs. These calculations depend on natural gas prices and electric rate structures. US utilities charge commercial, government and institutional facilities based on monthly electricity use, maximum monthly 15-min electricity use and monthly natural gas use with rate structures that include declining blocks. Waste heat can be applied to space heating and domestic water heating and to at least a portion of the air conditioning loads. Other uses of waste heat, such as desiccant dehumidification, are not yet fully commercialized and are not included in this analysis.

The analysis in this study extracted survey records from the CBECS databases and conducted analysis of monthly billing data to determine hourly load profiles for a sample of facilities consistent with the representative buildings identified in Table 3 for each of the three locations. Facility data included whole building hourly electric loads, air conditioning hourly electric loads and hourly thermal loads for domestic water heating and space heating.

Alternate prime mover sizes provide different levels and ratios of electric and thermal energy; consequently, system size and hourly end-use energy requirements determine the appropriate electric–thermal balance. CHP designs considered (1) water heating, (2) space heating and absorption and (3) air conditioning thermal application separately and in combination. Various-sized prime movers were considered along with waste heat applications to offset thermal uses in the buildings. An optimal system design was determined for each representative building in each municipality based on economic analysis that considered avoided electricity and natural gas costs, operating costs and installation costs. All data on CHP system characteristics and costs were taken from the US Department of Energy 2002 study.

2004 electricity and natural gas rates for local utilities were applied for the three locations. 2004 was selected rather than 2005 to avoid the energy price spikes caused by Hurricane Katrina damage to natural gas delivery systems.

5. Cost–benefit analysis

Cost–benefit analyses of CHP applications for each of the representative schools, nursing homes, hospitals and municipal buildings were conducted at each of the three locations. A net present value analysis is used. Net present value is calculated by summing the discounted stream of financial benefits over the life of the equipment and subtracting the installation cost. A positive net present value indicates beneficial investment and shows the present value of future savings. The stream of benefits includes avoided electric and natural gas cost minus natural gas cost of fuel used to run the CHP generator and annual operating and maintenance costs. CHP systems are assumed to have 10-year service lives and 5 percent is used as the discount factor. Each of these factors is included in Tables 4 and 5. This analysis uses 2004 electric and natural gas prices; alternative price and cost assumptions can be evaluated by adjusting components of the NPV calculations in Tables 4 and 5.

Results summed across all critical service buildings in each of the three geographic locations are shown in Table 4. It is important to note that only energy savings are included as benefits in this analysis; no attempt is made to quantify benefits resulting from extended availability of emergency power in the event of a disaster situation. Consequently, the estimated benefits reported below are actually a lower bound on benefits.

Total installed generation capacity of the systems ranges from 2960 to 21,420 kW across the three municipalities. The CHP emergency systems contribute at least 50 percent of the normal electricity requirements in the buildings; this level of electric service was considered sufficient in all facilities to meet critical needs. Total net annual operating benefits (avoided electric and natural gas costs minus natural gas costs to run the generator minus operating and maintenance costs—operating benefits do not include cost of the equipment) are negative in Charleston (−$924,527) but are sizeable and positive in both Houston and Miami.

Existing rate structures in all three locations are used to calculate marginal increases or decreases in electricity and natural gas costs; these rates can differ significantly from average rates computed by dividing the total bill by total

Table 4
Analysis of emergency power CHP systems in three locations

	Total (Including multiple buildings within categories)		
	Charleston	Houston	Miami
Annual kWh use before CHP	37,225,801	224,221,813	82,171,677
Savings—kWh	20,290,648	138,990,827	54,070,048
System size (kW)	2960	21,420	6720
Annual operating benefits			
Avoided kWh costs ($)	1,035,977	12,643,443	3,797,808
Avoided natural gas costs ($)	471,133	1,871,807	917,054
Annual operating costs			
Generator fuel costs ($)	2,008,364	8,336,406	3,730,098
O&M costs ($)	243,482	1,654,980	514,490
Total net annual operating benefits	−924,527	4,523,864	470,274
System installation cost	1,918,830	19,843,323	4,654,230
Benefit/cost analysis			
Net present value (3% rate, 10 years, $)	−9,922,654	19,320,718	−582,969
Simple payback (years)	N/A	4.4	9.9
$/kW	−3352	902	−87
Marginal energy prices			
Electricity ($/kWh)	0.051	0.091	0.070
Natural gas ($/MMBtu)	8.57	6.25	7.42

Table 5
Cost–benefit analysis of critical building emergency power CHP systems

	Shelter			Nursing home			Hospitals			Office		
	Charleston	Houston	Miami	Charleston	Houston	Miami	Charleston	Houston	Miami	Charleston	Houston	Miami
Annual kWh use before CHP	941,303	951,596	1,064,754	1,925,800	2,364,319	2,873,295	24,186,544	22,643,605	22,952,634	4,481,142	4,303,294	4,863,870
Savings—kWh	467,174	556,498	638,372	1,005,789	1,328,894	1,436,504	14,892,000	16,097,155	16,887,380	1,051,200	2,634,614	2,898,816
System size (kW)	170	120	120	120	170	170	1,750	1750	1750	120	450	450
Annual operating benefits												
Avoided kWh costs ($)	41,518	63,267	56,353	67,355	126,930	113,891	623,870	1,021,608	1,041,533	69,807	268,881	243,639
Avoided natural gas costs ($)	8240	2,531	21,605	46,197	41,610	44,221	134,124	142,330	128,965	23,624	47,727	92,339
Annual operating costs												
Generator fuel costs ($)	46,063	37,228	65,138	101,643	95,134	93,502	1,468,210	707,338	975,992	106,553	175,696	268,396
O&M costs ($)	5606	9090	7660	12,069	15,947	17,238	178,700	131,714	138,376	12,614	26,346	28,988
Total net annual operating benefits	−1911	19,480	5160	−160	57,459	47,372	−888,916	324,886	56,130	−25,736	114,566	38,594
System installation cost	149,600	150,849	114,360	114,360	149,600	149,600	827,750	928,435	928,435	114,360	219,600	219,600
System efficiency	0.82	0.90	0.67	0.55	0.56	0.53	0.90	0.80	0.87	0.78	0.73	0.66
Benefit/cost analysis												
Net present value (3% rate, 10 years, $)	−166,143	17,794	−69,688	−115,745	347,835	260,510	−8,523,282	1,884,172	−442,505	−337,161	772,223	114,517
Simple payback (years)	N/A	7.7	22.2	N/A	2.6	3.2	N/A	2.9	16.5	N/A	1.9	5.7

energy consumption because of monthly peak kW (demand) charges and block structures.

The inability of Charleston savings to pay for the cost of the systems is indicated by a net present value of −$9,922,654, which reflects discounted annual operating cost savings minus CHP equipment and installation costs. Electric and natural gas utility rates in Charleston do not provide a large enough spread to make onsite electricity production economic, even after credit is taken for avoiding natural gas costs by using waste heat. That is, Charleston electric rates are too low and gas rates are too high to make a CHP system economic.

Dividing the net present value by total kW capacity yields a cost of $3352/kW, which is more than eight times the cost of installing diesel generators of similar capacity to be used only when called on in emergencies. Providing Charleston with more widespread delivery of critical facilities' electric services would, under current conditions, be accomplished at less cost with traditional emergency generators.

Costs and benefits in Houston are significantly different. In Houston, the installation of CHP emergency capacity saves $4,523,864 in annual energy operating expenses that, when used to pay the installed cost of CHP equipment, yields a net present value of $19,320,718; in other words, summing all of the discounted operating cost savings over the 10-year lifetime of the equipment and subtracting the cost of the equipment and its installation cost yield a net savings of $19,320,718 for the city. The city of Houston can actually save money by undertaking a preemptive CHP-based emergency power system. The cost per kW of these CHP units is −$902; that is, a present value savings of $901 is achieved with each kW of CHP generation capacity.

While Miami has positive net annual operating benefits of $470,274, the cost of the equipment and its installation more than offset those benefits to provide a negative net present value of −$582,969. Dividing the net present value by total kW capacity of 6720 kW yields a cost of $87/kW that is considerably less than the $450/kW required to install diesel generators of similar capacity to provide critical services power. That is, if Miami were to provide the 6720 kW emergency power capability described in this analysis, using CHP systems would cost $2.4 million less than traditional emergency generators because of the annual operating cost savings that occur with CHP systems.

Comparing Houston and Miami annual operating benefits and costs shows smaller avoided electric savings and greater net natural gas expenditures, explaining the smaller return on CHP investment in Miami. This result reflects lower electric prices and higher natural gas prices in Miami compared to Houston.

Results for the individual representative buildings are provided in Table 5. Table 5 also shows system efficiencies for each building-type application. Efficiencies range from 52 to 90 percent, reflecting the extent to which hourly thermal uses can be supplied with waste heat from the generating process. No single Charleston facility type provides operating cost savings whereas all Houston critical building types show a net present value. Two of the four Miami critical services building types have a negative net present value in Miami.

6. Summary

This paper presents the results of a research study designed to assess costs and benefits of using new combined heat and power (CHP) systems to provide electricity for critical municipal services in the aftermath of hurricane damage on the US Gulf and Southeastern coasts. CHP systems generate electricity at building sites and apply waste heat for domestic water heating, space heating, absorption air conditioning and other uses. These technologies are now available in small sizes and are provided with heat exchangers and controls, simplifying applications in commercial and institutional buildings such as schools, nursing homes, offices and hospitals. These systems can be installed and maintained by third parties requiring no onsite engineering expertise. CHP systems are increasingly being installed because of their economic benefits in many US locations.

A combination of shelter, nursing home, hospital and administrative facilities types are specified to accommodate critical service needs in three municipalities: Houston, Texas; Miami, Florida; and Charleston, South Carolina. These locations are all in the "strike zone" of Caribbean-spawned hurricanes. Building structure and energy use information for representative critical service facilities in three municipalities was developed from a US Department of Energy database extended to provide hourly electric and thermal loads required to analyze CHP system design and performance.

Detailed CHP design and economic analyses were conducted for the representative facilities in each of the locations including use of local utility rate structures, including peak kW (demand) charges and declining block rates.

Analysis results show that CHP systems installed in all four critical service facility types can, under the right circumstances, provide a positive net present value. That is, avoided electricity and natural gas costs associated with waste heat applications can more than offset the cost of the installed equipment and operating costs, providing a net economic benefit to municipal governments who decide to undertake a preemptive CHP-based emergency power capability initiative.

This preliminary analysis found a net present value of more than \$19 million for the city of Houston. While the net present value was −\$582,969 for Miami, that cost is only 20 percent of the cost of expanding emergency power services with traditional diesel emergency generators. Analysis of a Charleston program showed no economic benefit from installation of CHP systems.

Differences in the economic results for the three locations were determined to result primarily from differences in utility electricity rates and natural gas prices.

The results of this study suggest that municipalities should consider utilizing new CHP technologies to extend critical services emergency power capabilities. Depending on hourly energy use characteristics of critical service buildings and electric and natural gas prices, achieving this disaster preparedness goal can potentially pay for itself and even provide net economic benefit to municipal governments.

References

Aisin Seiki Company Ltd., 2006. CHP system specifications at 〈http://www.aisin.co.jp/life/ghp/english/pdf_img/cogene2.pdf〉.

County Business Patterns, 2000. US Department of Commerce. Available at 〈http://www.census.gov/epcd/cbp/view/cbpview.html〉.

Gulf Coast CHP Application Center, 2006 〈http://www.gulfcoastchp.org/Markets/Emergency〉.

Hordeski, M.F., 2005. Emergency and Backup Power Sources: Preparing for Blackouts and Brownouts. The Fairmont Press, Inc., Lilburn, Georgia.

Jackson, J., 2005. Concurrent Engineering: The Missing Ingredient in CHP Market Development. Cogeneration and Onsite Power Production.

Maine Public Utility Commission, 2001. Assessment of Distributed Generation Technology Applications.

Statistical Abstract of the United States, 2006. Dept. of the Treasury. Bureau of Statistics, United States. Bureau of Foreign and Domestic Commerce, United States. Bureau of the Census, US Census Bureau, 2006.

United Technologies, 2006. Web site description of PureComfort systems 〈http://www.utcpower.com/fs/com/bin/fs_com_Page/0,9235,03200,00.html〉.

US Census Bureau, 2005. Annual Estimates of the Population for Incorporated Places over 100,000, Ranked by July 1, 2005 Population: April 1, 2000–July 1, 2005 (SUB-EST2005-01) 〈http://www.census.gov/popest/cities/SUB-EST2005.html〉.

US Department of Energy, 1992, 1995. Commercial Buildings Energy Consumption Survey (CBECS).

US Department of Energy, 2000. The Market and Technical Potential for Combined Heat and Power in the Commercial/Institutional Sector. January 2000.

US Department of Energy, 2002. Integrated Energy Systems (IES) for Buildings: A Market Assessment. Oak Ridge National Laboratory, Ornl/Sub/409200.

US House of Representatives, 2006. A Failure of Initiative, Final Report of the Select Bipartisan Committee to Investigate the Preparation for and Response to Hurricane Katrina, US Government Printing Office. Available at 〈http://www.gpoaccess.gove/congress/index.html〉.