THE ROLE OF CHP IN ADDRESSING TEXAS'S NEED FOR POLLUTION REDUCTION AND GROWTH IN ENERGY DEMAND

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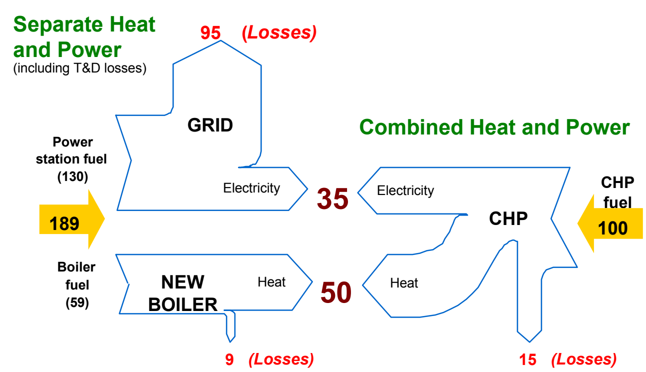
EXECUTIVE SUMMARY

Texas is facing both increasing demand for electricity capacity and increasing criteria pollutant non-attainment in urban areas. Traditionally, solving either of these problems would exacerbate the other, but today Texas has a great opportunity to expand the use of combined heat and power (CHP) to ease both problems simultaneously. This report outlines the history and potential for CHP in Texas, as well as policy responses that will further this power generation technology in the market, lowering the potential for blackouts and declining air quality.

Figure ES-1. Schematic Comparing Combined and Separate Heat and Power Systems



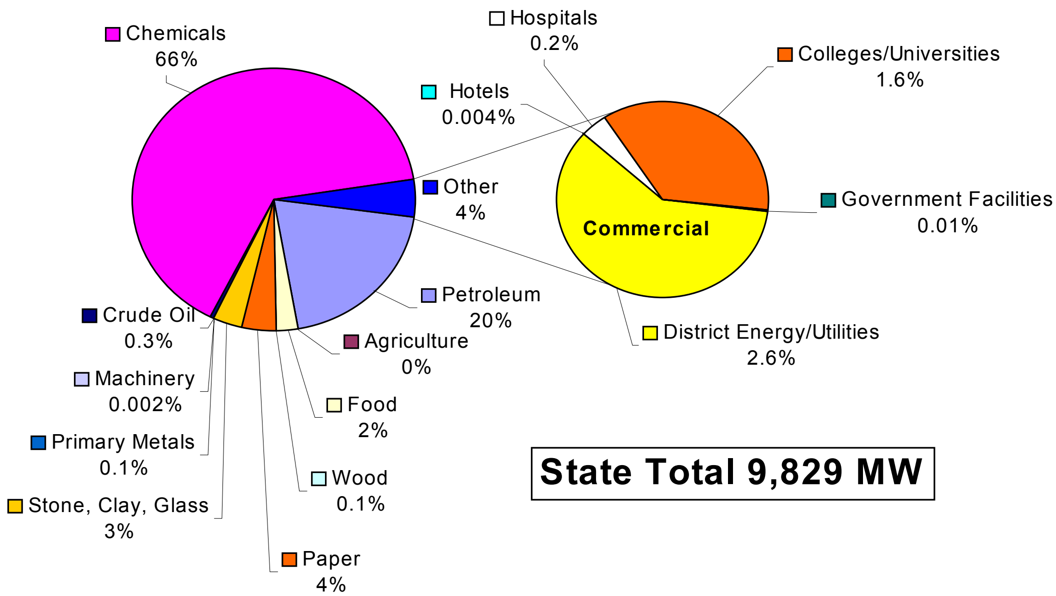
CHP (also known as cogeneration) generates electricity (and/or mechanical energy) and thermal energy in a single, integrated system (see Figure ES-1). This contrasts with common practice of separate heat and power (SHP) where electricity is generated at a central power plant, and on-site heating and cooling equipment is used to meet non-electric energy requirements. The thermal energy recovered in a CHP system can be used for heating or cooling in industry or buildings. Because CHP captures the heat that would otherwise be rejected in traditional separate generation of electric or mechanical energy, the total efficiency of these integrated systems is much greater than from separate systems (e.g., in the example at right, the CHP system has an efficiency of 85% while the separate systems have a combined efficiency of only 45%).

CHP is inherently more efficient than any equivalent traditional system owing to the production of two or more usable energy outputs from a single fuel source. In a CHP system, heat created in electricity generation is recaptured and used, reducing the amount of waste heat from the power generation process. By using only one fuel for two processes, CHP produces fewer emissions than traditional power distribution. CHP also allows for on-site generation of power and heat, cutting the need for transmission infrastructure.

This technology approach is good news for Texas, which, without increased CHP use, will need to build more transmission infrastructure over the coming years to avoid shortages. CHP will solve Texas's potential transmission capacity shortage by opening a way for companies to decrease reliance on the grid for both heat and power. The application can help prevent blackout/brownouts for residents and industries during peak periods.

Texas already leads the country in CHP, with 10% of its base of power comprised of CHP (see Figure ES-2). However, further potential exists in the commercial and industrial segments for additional capacity in excess of 20,000 megawatts (MW)

Figure ES-2. CHP Capacity in Texas by End-User Sector



Source: Onsite Energy 2000c

In order for this potential to be realized, Texas must take policy steps to make the use of CHP appealing to industry, thus easing the stress on the grid and in the air. A variety of motivational tactics exist that the Texas legislature could employ to make CHP more appealing to industry. After concluding that CHP is a practical way to provide Texas with solutions to some of its air and power problems, we recommend the following four actions for the Texas legislature to maximize the use of CHP.

Output-Based Environmental Permitting

Output-based environmental permitting is a simple concept that is used for setting emissions rates for cars. The rate is determined by dividing emissions by the usable output of the system (for cars it is grams per mile). However, most stationary sources are permitted based on emissions per unit of fuel consumed (e.g., pounds per million Btu [lb/MMBtu]) or based on the concentration of a pollutant in exhaust gases (e.g., parts per million [ppm]). Neither of these approaches credits the efficiency of the system. From the perspective of meeting Texas's energy needs while addressing its environmental challenges, an output-based strategy for allocating emissions will insure that the state gets the most usable energy for each pound of pollution emitted. Since CHP is inherently efficient, output-based environmental permitting will provide an incentive to implement CHP.

Electric Utility Regulation

Texas has been a leader in removing regulatory barriers to CHP and distributed energy. The Texas Public Utility Commission (TPUC) has developed model CHP interconnect language that is now being used in other states. While significant progress has been made, more work remains. The Commission staff is currently working on tariff and contract provisions. This work needs to be supported and accelerated. In addition, Texas has yet to fully address the issue of stranded costs as part of its utility restructuring process. One suggestion exempts CHP from the competitive transition charges, similar to the actions taken by New Jersey, Illinois, Massachusetts, and California.

Development of Energy Parks

Most of the CHP installed in Texas is at large industrial or institutional facilities. Historically, the user has owned these facilities but in the past two decades, the trend has shifted to ownership by a third party. If the heating and cooling loads for a number of smaller users could be aggregated, the demands of the various users would be better balanced and provide an attractive opportunity for a developer. These *energy parks* would provide heating, cooling, and high-quality electric power to customers. A CHP system is the most cost-effective way to generate these energy products.

Energy parks could be a particularly important strategy for emerging Internet server farms. These buildings have very large, high-reliability power requirements, and represent a significant portion of the projected load growth for the Austin and Dallas-Fort Worth regions. A significant portion of this load is cooling, which could be met with absorption refrigeration drive using the heat from a CHP system. Unfortunately, current siting and permitting regulations were not established with these technology and energy service relations in mind, and they could unduly hinder development of these parks. The state needs to identify these hurdles and take steps to addresses them so that CHP energy parks can be created to meet the needs of these growing loads.

Property Tax Treatment of CHP

Problems with federal tax depreciation treatment of CHP are documented. While the state cannot address these issues, it could compensate in part by offering favorable state tax treatment to clean and efficient CHP systems. Our recommendation is to define clean and efficient CHP systems as pollution reduction equipment that would exempt the equipment from local property taxes.

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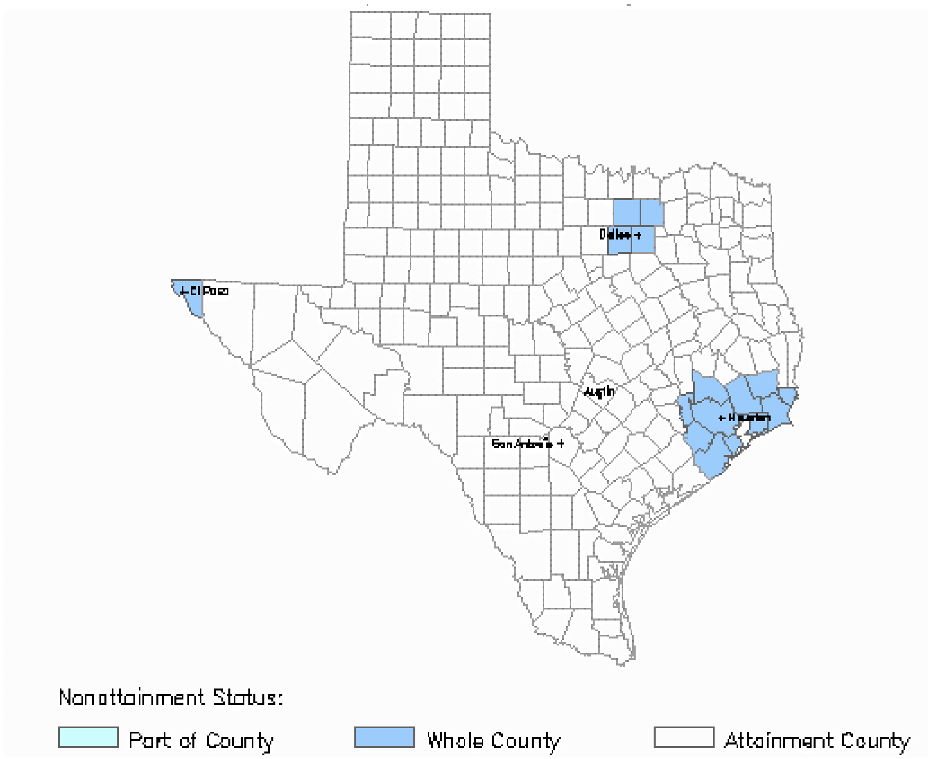
INTRODUCTION

Texas is at a crossroads, faced with growing demand for electricity and a need to reduce emissions of criteria pollutants, especially nitrous oxides (NO_x), from existing levels. During the summer of 2000, the state experienced localized power constraints due to high demand and insufficient transmission resources (NERC 2000). In addition, many of the major metropolitan regions (see Figure 1) face air quality levels that do not meet national standards (EPA 2001a, 2001b). The primary pollutant of concern is ozone (or smog), which results from NO_x emissions. The solutions to these problems are linked because new emission sources will need to be permitted if the demand for electrical generation capacity is to be met, while at the same time total emissions must be reduced. Therefore, new electricity generation must be highly efficient and clean.

Figure 1. Ozone Non-Attainment Counties in Texas



Source: EPA 2001b

In response to these crises we suggest the following action: Texas should recognize the efficiency resources that already exist in the state, especially combined heat and power systems, also called cogeneration. CHP produces both electricity and heat energy that can be used for a variety of industrial and commercial purposes including cracking petroleum and air conditioning. It produces one-tenth of the NO_x of the fleet average power plant and one-third of the NO_x of most cleaned-up plants. Furthermore, heat wasted in conventional generation is captured and used to meet thermal loads, both heating and cooling, which would otherwise be satisfied by burning additional fuel. This report provides a review of the status of CHP in Texas, projects the potential for additional capacity, and discusses what steps can be taken to realize this efficient energy source as a viable option.

BACKGROUND

Power plants are the largest single source of the NO_x causing air quality problems in Texas (EIA 1998). Overall reductions of 88% have been mandated for the Dallas-Fort Worth area, 90% for the Houston/Galveston area (see the appendix), and 50% for rural Texas. Reducing these emissions is even more important, however, on the hottest days of the year when both pollution and electricity usage peak.

Only about 28% of the energy consumed to make electricity comes through the plug; the rest is lost in generation, transmission, transformers, and distribution lines. More energy is lost in the inefficiency of appliances and industrial equipment. CHP not only significantly reduces line, transformer, and distribution losses but it also provides heat directly for industrial uses or for air conditioning through the use of absorption chilling. Thus, it can be up to three times as efficient as power produced by utilities off-site (Elliott and Spurr 1999). Moreover, placing generation close to the load enhances the reliability of the power grid and defers the need to construct new transmission capacity to meet demand during periods of peak electricity consumption.

CHP does not use new technologies. In the early days of the electric industry, industrials often generated their own power on-site, with the same boilers they used to generate steam for their processes. When America’s cities electrified, power plants were frequently located within pre-existing central steam plants. These power plants were used for heat and driving industrial motors. Chicago, St. Louis, New York, and Seattle still have central steam plants. CHP makes use of these proven technologies, thus making it a low-risk decision (Caston 1998). As will be discussed, CHP already is an important part of the Texas energy system: the new Austin City Hall and Computer Sciences complex has a CHP system that serves six blocks downtown. In addition, Abbott Laboratories is building a CHP facility north of Austin and will sell excess steam and power. Both installations strengthen the grid and assure reliable power for the state’s capitol.

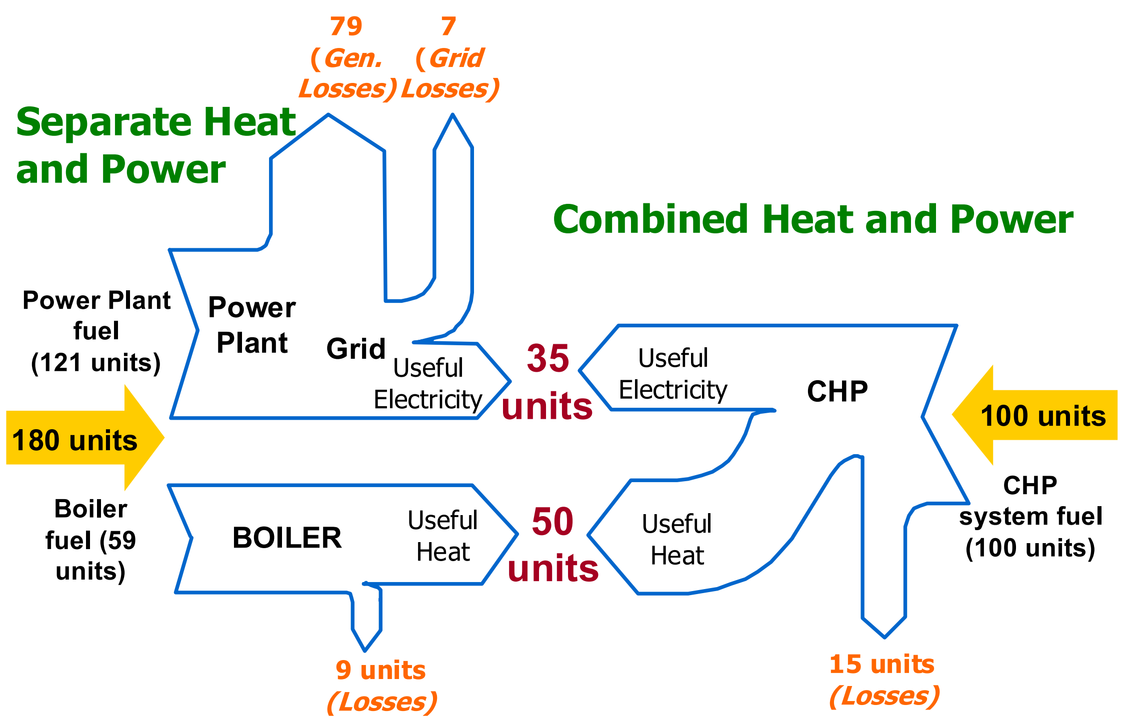
Texas's installed CHP capacity comprises almost 10% of the state's installed base of electric generation capacity, more than any other state (Onsite 2000a). However, Texas has the ability to use CHP even more extensively: there is an unrealized potential for more than 20,000 MW of CHP, or about one-third of the state’s generating capacity (Onsite 2000b). About one-third of the potential (7,200 MW) is in commercial facilities such as office buildings, hospitals, and apartment buildings, with the balance in existing industrial facilities. Moreover, these numbers do not include projected installation in the booming commercial markets surrounding the Dallas-Fort Worth area.

We contend that utilization of CHP can contribute to the solution of the energy and environmental crises facing Texas, while providing an economic opportunity for the state. This report reviews the untapped potential of CHP in Texas, both statewide and in particular regions of crisis. Furthermore, it supports CHP investment in Texas to increase available electricity and reduce emissions.

ROLE FOR CHP

CHP is not a technology, but an approach to applying technologies. A CHP system produces, in series, two or more usable energy outputs from a single fuel source. In general they are grouped into power (which is usually electricity but can be any combination of electrical or mechanical) and thermal (which is usually steam or hot water but can also include hot gas or air, and chilled water or brine). By combining the production of these energy streams, much of the waste heat that would result from conventional separate generation of heat and power can be avoided, as shown in Figure 2.

Figure 2. Schematic Comparing Combined and Separate Heat and Power Systems



Additional Electricity Generation Capacity

Wherever there is a need for thermal energy, either for heating or cooling, a potential exists for producing electricity with CHP. We are most familiar with CHP at large industrial facilities that have a significant steam load (Onsite 2000a). About two-thirds of Texas's CHP potential resides in this area and can be used to meet the expanding energy needs in this sector. However, due to technology development in the past decade, CHP systems can also be installed at smaller industrial and commercial facilities, and are increasingly being designed into commercial building applications (Onsite 2000b). The remaining third of the state's potential is in this market segment. If a significant portion of the cooling load is met with heat-driven absorption refrigeration, the total potential for commercial applications would be much greater. CHP with thermal cooling could help meet the needs of the growing high-tech sector. One application, the construction of energy parks, is a particularly attractive option for meeting the commercial sector's energy needs (Kaarsberg, O'Connor, and Watson 2000).

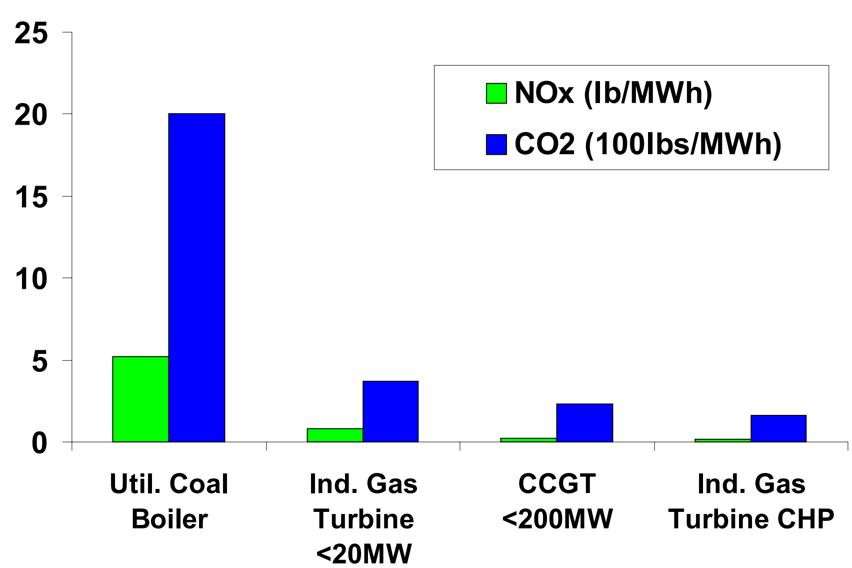
Electrical Transmission Constraints

As demand for electricity grows, the need to site new transmission capacity increases. By moving electrical generation closer to the users, demands on the transmission infrastructure can be reduced. In addition, losses associated with electricity transmission can be avoided. The Electric Reliability Council of Texas (ERCOT) indicates that the ability to site new transmission in time to meet anticipated load growth poses one of the greatest threats to reliability in Texas (NERC 2000). Distributed power systems can provide this new capacity more quickly than siting new transmission capacity; this issue has lately become a contentious one. Distributed power can offer a solution to existing transmission constraints by meeting some existing loads with on-site generation, thus removing loads from the grid and freeing up capacity for other customers (Elliott and Spurr 1999).

Criteria Pollutant Emission Rates

Because of its inherent greater efficiency, CHP will be cleaner than an equivalent non-CHP system. In essence, the emissions from what would otherwise be two separate systems are shared by a single combined system (see Figure 2). This benefit is demonstrated when emissions are looked at in an output basis (as discussed in the Policy Response section). Figure 3 compares the emissions rates for several different generation configurations, showing that CHP systems produce fewer emissions than even combined cycle generation turbines (CCGT).

Figure 3. Comparison of Emission Rate for Various Generation Configurations



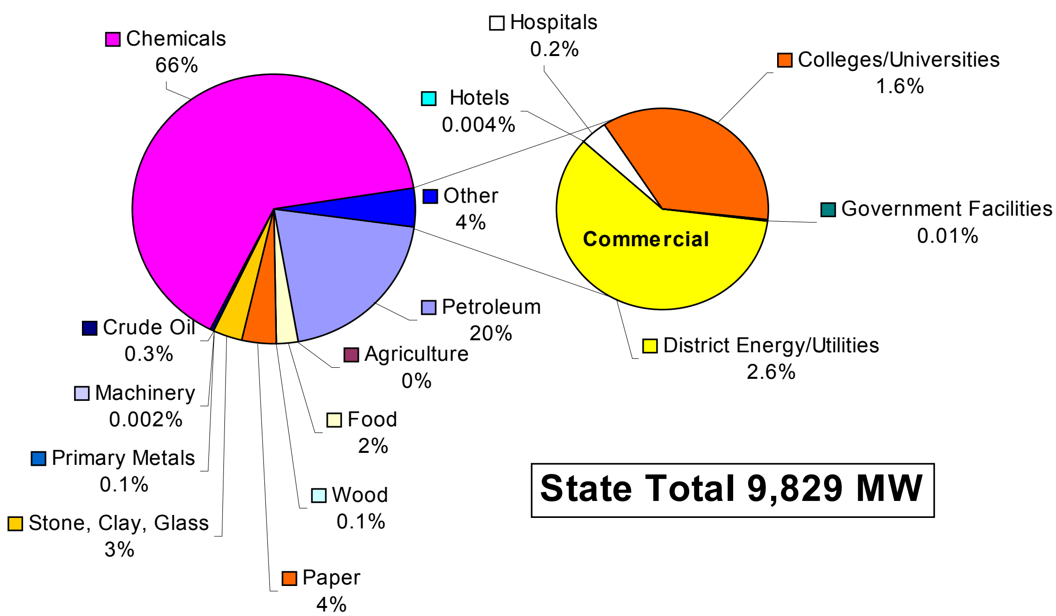
Source: Bluestein 2000

CHP OPPORTUNITIES

Current Capacity

The installed CHP capacity in the United States is 52,800 MW as of 1999 (Onsite 2000a, 2000b). Texas leads the states in installed capacity CHP with 9,829 MW (21% of national) at 110 sites (Onsite 2000c). Most of the capacity (88%) is natural gas-fueled. Figure 4 describes the breakdown of current CHP capacity in Texas by sector.

Figure 4. CHP Capacity in Texas by End-User Sector



Source: Onsite Energy 2000c

CHP Potential in Texas

While it already has CHP in use, Texas has the technical potential to install much more. Analysis indicates that a technical potential exists to more than double the existing CHP capacity based on systems sized to meet existing on-site thermal and electric loads (Elliott and Spurr 1999). Additional capacity could result for facilities designed to generate excess power to sell to the grid. If new loads, such as the projected Internet data centers, are considered, the potential could be even higher.

Onsite Energy (2000c) projects that the potential exists for additional CHP capacity of over 20,000 MW. About a third of the potential (7,330 MW) is in the commercial sector and two-thirds (13,400 MW) in industry. The chemical and petroleum industries account for 56% of the potential industrial capacity. Because these estimates are based on existing site steam demand and do not consider the additional potential capacity that could result from merchant

CHP facilities, these figures may underestimate the actual potential capacity. In addition, if potential thermal capacity were increased through the use of technologies such as absorption chillers, the total capacity could increase substantially, particularly in commercial applications.

The following tables and figure quantify the current capacity and capacity potential. Table 3 describes the current CHP load by sector for both commercial and industrial applications. Tables 1 and 2 outline industrial and commercial potential. Figure 5 presents the current fuel and technology mix of the installed CHP in Texas.

Table 1. Industrial CHP Potential in Texas

Size	Potential (MW)
100 kW–1 MW	2,050
1–5 MW	3,250
5–20 MW	1,800
>20 MW	6,300
Total	13,400

Chemicals and Refining (SICs 28 & 29) potential = 7,500 MW (56 % of total)

Table 2. Commercial CHP Potential in Texas

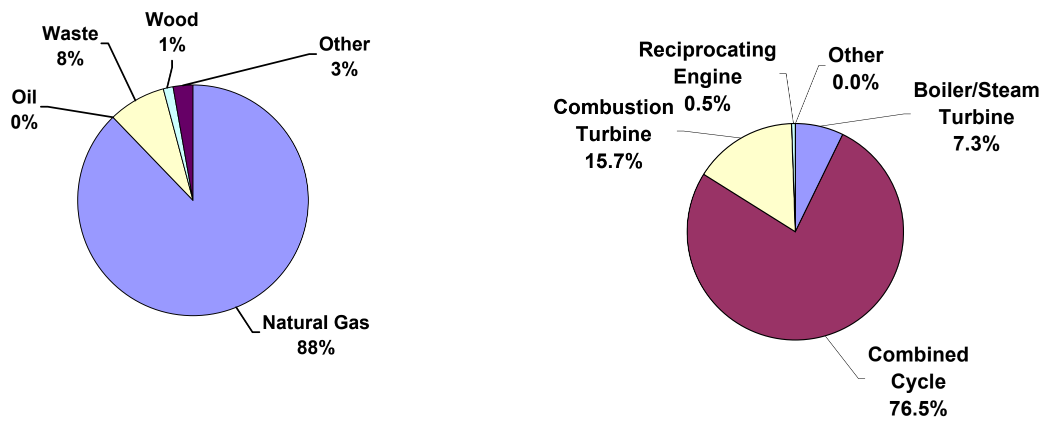
Application	Capacity (MW)	Percent
Apartments	1,500	20.5
Office Buildings	1,470	20
Schools	1,240	16.9
Hospitals	622	8.5
Colleges	500	6.8
Nursing Homes	400	5.5
Hotels/Lodging	350	4.8
Other	1,248	17
Total	7,330	

Table 3. Current CHP Capacity and Number of Sites by Fuel and Application (where capacity is listed in normal text and number of sites in italics).

Class	Application\Fuel	Coal	Natural Gas	Oil	Waste	Wood	Other	Totals
COMMERCIAL	SIC 4903 District Energy/Utilities		*1* 258.00					*1* 258.00
	SIC 6512 Commercial Buildings		*1* 14.30					*1* 14.30
	SIC 7011 Hotels		*1* 0.12	*1* 0.24				*2* 0.36
	SIC 8060 Hospitals		*5* 18.78					*5* 18.78
	SIC 8220 Colleges/Universities		*9* 156.86					*9* 156.86
	SIC 9100 Government Facilities		*1* 1.00					*1* 1.00
	Commercial Totals Commercial Totals		*18* 449.06	*1* 0.24				*19* 449.30
INDUSTRIAL	SIC 01 Agriculture		*1* 2.00					*1* 2.00
	SIC 20 Food		*5* 237.31		*2* 6.00			*7* 243.31
	SIC 24 Wood					*2* 8.04		*2* 8.04
	SIC 26 Paper		*2* 76.00			*2* 113.20	*3* 174.60	*7* 363.80
	SIC 28 Chemicals		*35* 6,317.31		*4* 67.00		*2* 38.50	*41* 6,422.81
	SIC 29 Petroleum Refining		*15* 1,168.08		*7* 726.75		*2* 68.46	*24* 1,963.29
	SIC 32 Stone, Clay, Glass		*3* 335.55					*3* 335.55
	SIC 33 Primary Metals		*2* 9.66					*2* 9.66
	SIC 35 Machinery		*1* 0.15					*1* 0.15
	Industry Totals Industry Totals		*64* 8,146.07		*13* 799.75	*4* 121.24	*7* 281.56	*88* 9,348.62
OTHER	SIC 13 Crude Oil		*3* 30.87					*3* 30.87
	Other Totals Other Totals		*3* 30.87					*3* 30.87
TOTALS TOTALS			*85* 8,625.99	*1* 0.24	*13* 799.75	*4* 121.24	*7* 281.56	*110* 9,828.78

No. of Sites	12
Electric Capacity MW	6,000.26

Figure 5. Texas CHP Capacity by Fuel Source and Prime Mover Technology



Source: Onsite 2000c

POTENTIAL FOR EMISSIONS REDUCTIONS FROM CHP IN TEXAS

To illustrate the potential impact of CHP on emissions in Texas, Onsite Energy compared the emissions levels from three different CHP technologies with the emissions from the existing statewide fossil fuel fleet of central station power plants in Texas (Onsite 2000c).

Methodology

Onsite employed the following calculation methodology to estimate the impact in emissions due to implementation of the CHP technologies. A CHP emissions and performance profile was based on commercially available technology for each size range of the technical potential. This included an industrial gas turbine, a gas reciprocating engine, and a phosphoric acid fuel cell.

We made several assumptions to represent a realistic picture of the average usage profile. The calculation assumed an annual utilization of 6,000 hours for each technology. We assumed that 80–90% of the available thermal energy would be utilized productively in the CHP mode.

We further assumed that utility average emissions would be displaced by CHP implementation. The emissions from the fossil portion of the existing statewide fleet were the baseline to which CHP emissions were compared. These values are derived from EIA data on utility emissions.

Losses in the transmission and distribution (T&D) system require that more electricity be generated than is ultimately delivered to the customer. For the comparison to base-load grid power, we assumed that these losses equal 5%.

Technology Profiles and Baseline Emissions

Table 4 presents the performance and emissions profiles of the CHP technologies used in this analysis while Table 5 provides emissions summaries of the state's central station power generation fleet.

Table 4. CHP Technologies

Technology	Electric Output (kW)	Electric Efficiency (% HHV)*	Recoverable Heat (Btu/kWh	Heat Used (%)	NO_x Emissions (lb/MWh)	SO_2 Emissions (lb/MWh)	CO_2 Emissions (lb/MWh)
Gas Turbine	5,200	27.6	5,736	90	1.060	negligible	1,485
Gas Engine	1,100	34.1	3,570	80	2.362	negligible	1,202
PA Fuel Cell	200	35.9	3,500	80	0.035	negligible	1,140

*HHV = higher heating value

Table 5. Texas Utility Generation Summary

Source/Fuel	Generation (MWh)	SO_2 (1,000 tons/year)	SO_2 (lb/MWh)	NO_x (1,000 tons/year)	NO_x (lb/MWh)	CO_2 (1,000 tons/year)	CO_2 (lb/ MWh)
Coal	132,627,000	584	8.81	462	6.97	146,904	2,215
Petroleum	137,000	0	0	0	0	118	1,723
Gas	120,201,000	0	0	140	2.33	74,473	1,239
Utility Fossil	252,695,000	584	4.62	602	4.76	221,495	1,751
Nuclear	38,685,000	0	0	0	0	0	0
Hydro	1,419,000	0	0	0	0	0	0
Renewable	0	No data	No data	No data	No data	No date	No data
Utility Total	289,069,000	584	4.04	602	4.17	221,495	1,532

Source: EIA 1998 data

Emissions Reductions

Potential NO_x savings from the three CHP technologies are shown in Table 6 while SO_2 and CO_2 savings are presented in Tables 7 and 8, respectively.

Table 6. NO_x Impact

Technology	CHP Electric Output (kW)	CHP Output (MWh/ yr)	CHP Emissions (lbs/ MWh)	Texas Ave. Fossil Fuel Emissions (lbs/MWh)	Boiler Emissions (lb/ MMBtu)	Avoided NO_x Texas (tons/yr)	Avoided NO_x Texas (tons/MW CHP capacity)
Comparison to Existing Fossil Generation							
Gas Turbine	5,200	31,200	1.060	4.76	0.035	64.949	12.49
Gas Engine	1,100	6,600	2.362	4.76	0.035	9.108	8.28
PA Fuel Cell	200	1,060	0.035	4.76	0.035	3.051	15.26

Table 7. SO_2 Impact

Technology	CHP Electric Output (kW)	CHP Output (MWh/yr)	CHP Emissions (lbs/MWh)	Texas Average Fossil Fuel Emissions (lbs/MWh)	Boiler Emissions (lb/MMBtu)	Avoided SO_2 Texas (tons/yr)	Avoided SO_2 Texas (tons/MW CHP capacity)
Comparison to Existing Fossil Generation							
Gas Turbine	5,200	31,200	0.0	4.62	0.0	75.630	14.54
Gas Engine	1,100	6,600	0.0	4.62	0.0	15.999	14.54
PA Fuel Cell	200	1,200	0.0	4.62	0.0	2.909	14.54

Table 8. CO_2 Impact

Technology	CHP Electric Output (kW)	CHP Output (MWh/yr)	CHP Emissions (lbs/MWh)	Texas Average Fossil Fuel Emissions (lbs/MWh)	Boiler Emissions (lb/MMBtu)	Avoided CO_2 Texas (tons/yr)	Avoided CO_2 Texas (tons/MW CHP capacity)
Comparison to Existing Fossil Generation							
Gas Turbine	5,200	31,200	1,485	1,751	120	17,594	3,383
Gas Engine	1,100	6,600	1,202	1,751	120	3,514	3,195
PA Fuel Cell	200	1,200	1,140	1,751	120	671	3,353

POLICY RESPONSE

We suggest four policy responses that will help create a favorable climate in which CHP can provide a maximum contribution to the environmental and electricity capacity needs of Texas. Each strategy is summarized below, and discussed in greater detail in the following sections.

Output-Based Emissions Standards

Background

There are several good reasons to support output-based standards for all emission sources. The most important is that output-based standards inherently encourage energy efficiency, a primary goal of U.S. energy and environmental policy (Elliott and Spurr 1999). Secondly, output-based standards make a direct link between the economic value provided by a process (its product or output) and the environmental cost it exacts (its emissions). This link will be increasingly important in a deregulated electric utility industry. Finally, uniform adoption of output-based standards would reduce the confusion of the current system, which uses many different units of measure.

Energy efficiency is an important national policy goal for several reasons. From an environmental perspective, increased energy efficiency reduces emissions of all pollutants from a process, as opposed to traditional control measures that deal with pollutants one by one. Efficiency improvement is also the primary approach available for control of CO_2 emissions. Pollution-producing activities are the means of providing some societal value (heat, light, transportation, manufacturing, etc.). Emissions are increasingly being recognized as a cost that society bears to "purchase" some good—the output of the process. In this perspective, it is important to know the emissions cost of each product. Output-based standards directly relate the emissions cost to the useful output. This is particularly constructive when there are several process alternatives to produce an item with societal value.

As a simple example, it is useful to be able to link the kilowatt-hour of electricity generated to the emissions generated for that kilowatt-hour, not just for one plant but for different plants and technologies. The energy (i.e., kilowatt-hours) are a benefit that society gets from the process and we should be able to directly evaluate the emissions "cost" of a kilowatt-hour regardless of how it is generated. This cost is a function of efficiency as well as direct combustion emissions, and output-based standards provide this more complete perspective. Output-based standards encourage a holistic view of regulated processes, directly relating emissions to the useful output of the process.

This linkage becomes increasingly valuable in a deregulated electric utility industry. As electricity increasingly becomes a commodity that is traded between different regions, the environmental attributes of the traded energy will become more important. The consistent way to track these attributes is in terms of the traded commodity (i.e., mass/kWh).

Finally, the emission regulation system is burdened with a variety of different regulatory systems including input-based, concentration, hourly, and other standards limits. An output-based approach provides a common denominator for a given application that allows consistent, useful comparisons.

Components of Output-Based Regulation

The units of measurement for emissions standards vary by source type based largely on historical convention. The largest and most common emissions sources, boilers and combustion turbines, use either input basis (pounds per million British thermal units or lb/MMBtu) or concentration standards (parts per million or ppm). Neither measure reflects efficiency. If a change in the process causes more fuel to be burned and more pollutants to be emitted, neither an input nor a concentration standard will reflect the increase and the source has no environmental regulatory reason or incentive to respond to the increased emissions.

Conversely, output-based standards inherently encourage energy efficiency by directly registering the emissions impact of a change in efficiency. Under an output-based standard, a decrease in efficiency causes an increase in emissions per unit output and requires the source to respond either by restoring its baseline efficiency or reducing its emission rate. Moreover, increases in efficiency anywhere in the regulated process allow the source to produce more of its sellable product within the environmental limit. Thus the output-based standard provides a built-in market incentive for efficiency.

Furthermore, precedent exists for output-based regulation in other applications. The list includes:

- Gram/horsepower-hour—used for stationary reciprocating engines;

- Pound/ton product—used for some industrial processes such as glass smelters and cement kilns; and
- Gram/mile—used for automotive emissions.

The primary focus of regulators today is applying output-based regulation to power generation (lb/MWh) and large non-power steam boilers ($lb/MMBtu_{out}$). Although this represents a change in approach, no basic technical or operational barrier to this change exists and it offers a variety of policy benefits.

One question associated with an output-based standard is where to draw the line that defines the output. For example, a pound per output standard for a process could include only the combustion source or it could include the combustion source and other equipment directly linked to the process. Taking electric generation as an example, the standard could be just pound of emissions/MMBtu of steam produced by the boiler or it could be pounds of emissions/kWh at the buss bar[1] (NEMW 2000).

Since the broad goal of output-based standards is to link emissions to the final output of the process, the circle should be drawn as widely as possible within the application. Increasing efficiency anywhere in the process will reduce the ultimate emissions and help the environment and should therefore be recognized and rewarded in the same way. For example, increasing the efficiency of the steam cycle in a power plant reduces the amount of fuel burned and the ultimate pollutants as much as reducing emissions in the boiler itself. Moreover, there are many different electric generation technologies with different processes that result in the same output. The ultimate measure would reward emission reductions of any kind, independent of the specific technology. An output-based standard should be designed to encourage and reward such efforts by including the entire generation process.

At the same time, the regulation should not try to include the point of use. This type of regulation is current practice and only addresses supply process. End-use efficiency must be addressed separately for both policy and practical reasons. For example, industrial boilers are used to supply many different processes. While it would be nice to encourage the efficiency of these processes at the same time as the efficiency of the steam generation, it is really the steam generation process that is being regulated. Attempting to measure, track, and regulate all of the different end-uses as part of steam generation regulation becomes so complex that it destroys the system. Like the electric generation case, the regulation should focus on the complete energy conversion and regulate $lb/MMBtu_{out}$ at the boiler exit. Output-based standards should be based on the final output of the system as much as possible.

Output-based regulation is very important in promoting CHP systems (Elliott and Spurr 1999). CHP is an important way of increasing efficiency and decreasing emissions, and as such, government policies should seek to encourage it. Output-based standards will generally reward CHP by including all of the useful heat and electricity output as the product. More complete recovery of the available energy should be reflected in the lower emissions per unit of output.

[1] The buss bar is the device that ties the generation into the electrical distribution system.

There has been much productive work in the last year in developing the methodologies and approaches to the application of output-based standards. The U.S. Environmental Protection Agency (EPA) has developed guidance documents on output measurement and monitoring, and application of output-based allocation in an allowance-trading program (EPA 2000). Now is a particularly opportune time for this effort because a number of the standards are being revised pursuant to the Clean Air Act Amendments of 1990. All current limits for existing sources are being organized and restated in federal operating permits. This is a good time to pursue an overhaul and normalization of air emission standards to an output basis, which would provide energy and efficiency benefits to the environment and the regulated community and simplify regulation for the regulators and the regulated community.

Electric Utility Regulation

While the concept of connecting a CHP facility to the grid may seem straightforward, both technical and regulatory issues complicate it. A site avoids many of these issues if it disconnects from the electricity grid. While some sites that install CHP can do this, these are very much the exception. Most sites will require a permanent connection to the grid to:

- Insure a reliable supply of electricity in case of an outage of the on-site generation;
- Provide a source of additional electricity to meet requirements in excess of the available on-site generation capacity; and
- Provide a market for any excess power generated by the CHP system.

We can group these regulatory issues into three categories: technical interconnection; contract provisions; and restructuring-induced.

Technical Interconnection Issues

The interconnection of a facility with on-site generation to the electricity grid must synchronize the voltage and frequency of the on-site generation with power from the grid. There must also be a means to handle, in a safe and orderly manner, the unscheduled loss of power from either source. These protections include preventing "back feeding" the grid if there is an outage, which could pose a safety risk to both utility workers and the public. This equipment also protects on-site equipment from damage caused by power disturbances resulting from the two sources of generation. The TPUC has developed the model legislation in this area (TPUC 2000). In addition, a technical interconnection standard is under development by the Institute of Electrical and Electronic Engineers (NARUC 2000).

Contract Provisions

Interconnection contracts will have several components. Electricity demand above the on-site generation amount should be priced as would any other service, with both an energy and a demand component. However, the power that may be required to backup the on-site generation should be priced differently. The utility must make investments in both generation reserves and T&D to meet this eventuality. The pricing must be higher to allow them to recover these costs since there is not an ongoing consumption of energy that can be used to recover them. Unfortunately, there has been little consistency in how these prices are set by utilities. Some utilities have set these interconnection and standby charges at levels that will make on-site generation uneconomic.

In addition, a utility may charge a facility that installs on-site generation an "exit" fee. Regulators have intended this fee to recover investments made by the utility to service customers in anticipation of their future demand for power, such as T&D capacity, transformers, and other infrastructure. In some cases, these fees can be at levels that will make CHP uneconomic. While there may be a legitimate justification for recovering some of these investments, some utilities have chosen to include many costs in these fees that are difficult to justify. In addition, regulators have not afforded other businesses, like telephone companies, the opportunity to charge exit fees so it is unclear why regulators should afford electric utilities this right.

Electric Utility Restructuring Issues

Electric utility restructuring has resulted in a set of fees that utilities are allowed to charge to cover the cost of transition (often called competitive transition charges or CTCs). These fees can be used to recover the cost of uneconomic investments ("stranded costs") such as nuclear power plants. While these fees are only temporary, the charges can be substantial. A new CHP facility may be required to continue to pay these charges based on their historical usage even if they no longer are using the power. Six states exempt new CHP facilities from these fees. An additional five states including Texas exempt some facilities (in Texas, facilities less than 10 MW are exempt) from these fees (Ferrey 2000).

Also, some utilities have been given additional rate flexibility. They have used this flexibility to offer price breaks to facilities considering on-site generation. These rates are frequently well below those charged other customers and are usually sufficient to discourage the installation of a CHP facility (Alderfer, Eldridge, and Starrs 2000). Texas has yet to fully address the transition issues as part of its utility restructuring process.

Development of Energy Parks

Power parks are business parks with distributed on-site power generation and a robust communications infrastructure. CHP is well suited to these power parks because a district energy system can be constructed to effectively share a central power, heating, and cooling system among all the customers. Energy is the lowest common denominator commodity that is needed by all customers. Power parks are particularly well suited to the needs of high tech firms that require very high power reliability (Kaarsberg, O'Connor, and Watson 2000).

The reliability for most of these data center firms is 99.9999% power, referred to in the industry as six 9's of reliability. These computer facilities have experienced explosive growth in the past two years, with global installations increasing from an estimated 5 million square feet in 1999 to 45 million square feet by the end of 2001. These data centers are clustered at the nodes of the Internet backbone. Texas has five such nodes: Austin, Dallas, El Paso, Houston, and San Antonio and all these areas have seen rapid growth of these facilities (Elliott, Shipley, and Brown 2001).

Energy parks can be an ideal solution for the needs of data centers. Not only do these facilities need highly reliable power, they need lots of it. Supplying power for these facilities can create problems for utilities because of the magnitude of the request, often in the hundreds of megawatts, and the short lead times demanded. Most data centers have a lead-time of less than a year, while most utilities need 3 or more years to plan for such a large unanticipated demand. In addition, to obtain the reliability required, the installation of backup generation on site is necessary. Most of these generators are diesel engines (Elliott, Shipley, and Brown 2001). These emergency generators are loosely regulated in the state of Texas. State air quality regulations allow these generators to be installed without emissions controls and with a restriction of no more than 876 hours per year of operation. Local building codes may further restrict the hours of operation to limit community noise impacts. These largely uncontrolled diesel engines are among the dirtiest power generation technologies, and in the quantities required by these data centers would represent a significant threat to the environment (Shipley, Elliott, and Brown 2001).

On the other hand, if the data center's load was handled by a clean and efficient CHP system, the utility would not be required to find the additional capacity to serve the load in a timeframe incompatible with its planning process. By having generation on-site with grid backup, greater reliability can be achieved. Also, since about half of the electric load is cooling, efficient thermal cooling (i.e., absorption refrigeration) could make use of the heat from the CHP system to reduce the electricity generation required and increase system efficiency (Elliott, Shipley, and Brown 2001).

Property Tax Treatment of CHP

One recent study (Elliott and Spurr 1999) found that a national investment of $1 billion in CHP technology over the next 10 years could save $2.5 billion in energy costs. CHP systems can be very cost effective. The hurdles discussed above can delay projects, increasing their cost and discouraging prospective candidates from proceeding with implementation. Because of the importance of new, efficient, and clear generation to the state of Texas, it may be appropriate to provide temporary incentives to offset the additional costs resulting from these barriers, until they can be addressed

One proposal is to create a short-term (4-year) property tax credit for combined heat and power plants at new and existing commercial facilities in non-attainment areas. This incentive would encourage the construction of CHP facilities that would reduce the emissions of NO_x and other pollutants from power plants, assure the stability and reliability of the grid in threatened areas, and reduce energy costs. Such a credit could be based on Rule 30TAC 277.2 or Statute Chapter 11.31 of Texas's tax code.

It would be necessary to model such a credit to pin down potential emissions reductions, costs, locations, and impact on the grid. Discussing the particulars of these issues is beyond the scope of this report.

CONCLUSIONS

Combined heat and power can represent an important component in Texas's plan to address its two-fold problems of electric power growth and serious air quality non-attainment in urban areas. While significant CHP potential exists in the state, the overall plan will need to include other elements such as expanded efficiency programs and efforts to modernize the electricity generation infrastructure. With Texas as the national leader in CHP, the experience necessary to implement this expanded capacity exists in the state. To realize this potential will take a concerted effort by the state's leaders to address a number of different market and regulatory barriers. The state has already made a good start with recent initiatives by the TPUC and Texas Natural Resources Conservation Commission (TNRCC). More work still needs to be done, keeping in mind that the environmental, energy, and economic future of Texas are linked.

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APPENDIX: CHP POTENTIAL IN THE HOUSTON/GALVESTON AREA

Introduction

The converging energy and environmental crisis in Texas is most pressing in the Houston-Galveston area. Combined Heat and Power may represent a potential resource to meet growing power demands in the Houston/Galveston metropolitan area while minimizing impact on the environment. Power generation systems create large amounts of heat in the process of converting fuel into electricity. For the average central station power plant, over two-thirds of the energy content of the input fuel is converted to heat and wasted. As an alternative, an end-user with significant thermal and electric needs can generate both its thermal and electrical energy in a single combined heat and power system located at or near its facility. Combined heat and power can significantly increase the efficiency of energy utilization, oftentimes reducing emissions of criteria pollutants and CO_2, and lowering a user's operating costs.

Onsite Energy has performed a preliminary analysis of the potential for increased use of CHP in the Houston/Galveston area. This analysis produced a preliminary estimate of the technical potential for CHP in the industrial and commercial/institutional sectors.

It should be noted that the market estimates are preliminary and do not include the following factors:

- The analysis is based on existing facilities only. Any future growth in the market based on the expected economic growth of various commercial/institutional and industrial market sectors was not included.

- The analysis is based on typical CHP installations currently found in commercial/institutional and industrial applications. No estimate was developed for new CHP applications that might become economic with advances in technologies such as thermally activated cooling, or new industries and applications that will be significant electricity consumers.

- The analysis presents an estimate of the technical potential in terms of number of existing facilities that could utilize commercially available CHP and the potential CHP capacity based on on-site power demands at those facilities. No economic screening was performed.

- The estimated market potential does not consider existing CHP capacity in the Houston/Galveston area. Existing capacity would need to be subtracted from the estimated market potential.

Technical Potential for CHP in the Houston/Galveston Metropolitan Area

Target near-term CHP applications would have the following characteristics:

- High electric intensity and high load factors
- Average electricity demand greater than 100 kW
- Thermal loads in the form of hot water or steam
- Electric to thermal energy ratio of 0.2 to 2.5
- Concurrent thermal and electric loads

Commercial CHP

A review of energy consumption intensity data for commercial/institutional building types as presented in CBECS (EIA 1995) is shown in Table A-1. Electric intensities are taken directly from the CBECS data for each building type. Space heating and water heating data in CBECS reflect fuel energy inputs for each category. These fuel inputs were modified to reflect building thermal demands using a conversion efficiency of 85%. The building types are compared in terms of *energy intensity* and *electric/thermal energy ratio (E/T)*. Energy intensity, measured in kilowatt-hours per square foot, is an indication of the importance of energy use in the application. Applications with high-energy intensity are more likely to have large electric loads and to be interested in finding ways to reduce energy costs. Electric/thermal energy ratio is the ratio of electric power used to thermal energy used, measured in like units. A typical engine-based CHP system would have an E/T ratio of approximately 0.85 (3,413/4,000). Applications that provide this constant ratio throughout the year would make maximum utilization of the CHP system. Applications with a higher ratio would either throw away a portion of the recoverable thermal energy or would have to be specifically sized (smaller) to the thermal load. Applications with an E/T below 0.85 would only provide a portion of the site's thermal energy requirements or would have an arrangement to export excess power to either the utility or to another user. Such low E/T applications are very common in industrial applications, much less common in the commercial sector.

Table A-1. Energy Intensities for Commercial/Institutional Buildings

	Electricity Use (TBtu)	Electric Intensity (kWh/sq ft)	Space Heating (MMBtu/unit)	Water Heating (1,000 Btu/ sq ft)	E/T Ratio (Total)	E/T Ratio (Water Heating)
Education	221	8.4	32.8	17.4	0.67	1.94
Health Care	211	26.5	55.2	63	0.9	1.69
Lodging	187	15.2	22.7	51.4	0.82	1.19
Food Service	166	36	30.9	27.5	2.47	5.25
Food Sales	119	54.1	27.5	9.1	5.93	23.86
Office	676	18.9	24.3	8.7	2.3	8.72
Mercantile Service	508	11.8	30.6	5.1	1.33	9.29
Public	170	12.7	53.6	17.5	0.72	2.91
Public Order	49	11.3	27.8	23.4	0.89	1.94
Religious	33	3.5	23.7	3.2	0.52	4.39
Warehouse/Storage	176	6.4	15.7	2	1.45	12.85
Other	75	22	59.6	15.3	1.18	5.77
Apartment Buildings		5,875 kWh/unit	N/A	25 MMBtu/unit	N/A	0.8

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 consistent with the range of the CHP system, e.g., education, health care, lodging, and certain public order and public assembly applications. Office buildings and certain warehousing and mercantile/service applications could be target applications for CHP if space-heating needs are incorporated.

Table A-2 presents the specific building types most amenable to engine-driven CHP based on an analysis of existing CHP in the commercial/institutional sectors and a review of available building energy characteristics.

Table A-2. CHP Target Applications—Commercial, Existing Technology

Application	CHP System Size	Thermal Demand
Hotels/Motels	100 kW–1+ MW	Domestic hot water, space heating, pools
Nursing Homes	100–500 kW	Domestic hot water, space heating, laundry
Hospitals	300 kW–5+ MW	Domestic hot water, space heating, laundry
Schools	50–500 kW	Domestic hot water, space heating, pools
Colleges/Universities	300 kW–30 MW	Centralized space heating, domestic hot water
Commercial Laundries	100–800 kW	Hot water
Car Washes	100–500 kW	Hot water
Health Clubs/Spas	50–500 kW	Domestic hot water, space heating, pools
Country/Golf Clubs	100 kW–1MW	Domestic hot water, space heating, pools
Museums	100 kW–1+ MW	Space heating, domestic hot water
Correctional Facilities	300 kW–5 MW	Domestic hot water, space heating
Water Treatment/Sanitary	100 kW–1 MW	Process heating
Large Office Buildings	l0O kW–1+ MW	Domestic hot water, space heating
Apartment Buildings	50 kW–1+ MW	Domestic hot water

Industrial CHP

CHP is used in a variety of industrial applications. Table A-3 lists the primary industrial applications for CHP based on an analysis of existing CHP and a review of industrial energy characteristics such as E/T ratios and thermal energy needs (i.e., hot water or steam).

Table A-3. CHP Target Applications—Industrial

SIC	Application	E/T Ratio	Thermal Demand
20	Food Processing	0.40	Hot water, steam
22	Textiles	0.80	Hot water, low pressure steam
24	Lumber Products	4.00	Low pressure steam
25	Furniture	3.60	Hot water, steam
26	Paper Products	0.90	Steam
28	Chemicals	0.40	Steam
29	Petroleum/Refining	0.40	Steam
30	Plastic Products	2.00	Hot water, low pressure steam
33	Primary Metals	2.50	Steam, hot water wash
34	Fabricated Metal Products	2.50	Low pressure steam, hot water wash
35	Machinery	3.20	Low pressure steam, hot water wash
37	Transportation Equipment	1.40	Low pressure steam, hot water wash
38	Instruments	1.20	Low pressure steam, hot water wash
39	Misc. Fabrication	3.00	Low pressure steam, hot water wash

CHP Technical Potential

Table A-4 lists the number of *industrial* sites for the CHP target applications in size categories based on average electric demands of 100–1,000 kW, 1–5 MW, 5–20 MW, 20–100 MW, and > 20 MW.

Table A-4. CHP Target Applications—Number of Establishments as a Function of Average Site Electric Demand

	Industrial CHP Market Potential, Houston/Galveston Metro Area						
SIC	**Application**	**Establishments**					
		100-1,000KW	**1–5 MW**	**5–20 MW**	**20–100 MW**	**>100 MW**	**Total**
20	Food Processing	48	26	3	1	0	78
22	Textiles	13	1	0	0	0	14
24	Lumber & Wood Prods	42	4	0	0	0	46
25	Furniture	19	1	0	0	0	20
26	Pulp & Paper	44	6	1	2	0	53
28	Chemicals	147	99	67	10	14	323
29	Petroleum/Refining	34	20	9	7	13	70
30	Rubber & Plastics	133	29	1	0	0	163
33	Primary Metals	82	26	3	0	0	111
34	Fabricated Metal Prods	344	42	3	1	0	390
35	Machinery	318	37	2	0	1	357
37	Transportation Equipment	43	3	1	0	0	47
38	Instruments	107	15	1	0	0	123
39	Misc. Fabrication	27	1	1	0	0	29
	Total	1401	310	92	21	28	1824

Table A-5 lists the potential MW capacity of CHP systems sized to meet site demands based on the industrial establishments identified in Table A-4.

Table A-5. CHP Target Applications—MW CHP Capacity Potential as a Function of Average Site Electric Demand

	Industrial CHP Market Potential, Houston/Galveston Metro Area						
SIC	**Application**	**Potential**					
		100–1,000kW	**1–5 MW**	**5–20 MW**	**20–100 MW**	**<100 MW**	**Total**
20	Food Processing	120	65	38	50	0	273
22	Textiles	7	3	0	0	0	9
24	Lumber & Wood Products	21	10	0	0	0	31
25	Furniture	10	3	0	0	0	12
26	Pulp & Paper	22	15	13	100	0	150
28	Chemicals	74	248	838	500	2,100	3,759
29	Petroleum/Refining	17	50	113	350	1,950	2,480
30	Rubber & Plastics	67	73	13	0	0	152
33	Primary Metals	41	65	38	0	0	144
34	Fabricated Metal Prods	172	105	38	50	0	365
35	Machinery	159	93	25	0	150	427
37	Transportation Equipment	22	8	13	0	0	42
38	Instruments	54	38	13	0	0	104
39	Misc. Fabrication	14	3	13	0	0	29
	Total	797	775	1,150	1,050	4,200	7,972

Table A-6 lists the number of *commercial/institutional* sites for CHP target applications in the same size categories.

Table A-6. Commercial CHP Target Applications—Number of Establishments as a Function of Average Site Electric Demand

Commercial/institutional CHP Market Potential, Houston/Galveston Metro Area				
Application	Establishments			
	100-1,000kW	1–5 MW	>5 MW	Total
Hotels/Motels	219	26	22	267
Nursing Homes	75	13	0	88
Hospitals	60	29	5	94
Schools	660	23	0	683
Colleges/Universities	39	9	3	51
Commercial Laundries	17	0	0	17
Car Washes	23	0	0	23
Health Clubs/Spas	49	0	0	49
Golf Clubs	50	0	0	50
Museums	16	2	0	18
Correctional Facilities	11	8	0	19
Water Treatment/Sanitary	148	3	0	151
Extended Service Restaurants	515	12	0	527
Supermarkets	233	5	0	238
Refrigerated Warehouses	16	0	0	16
Apartments	150	25	10	185
Office Buildings	750	50	5	805
Total	3,031	205	45	3,281

Table A-7 lists the potential MW capacity of CHP systems sized to meet site demands based on the commercial/institutional establishments identified in Table 6.

Table A-7. CHP Target Applications—MW CHP Capacity Potential as a Function of Average Site Electric Demand

Commercial/Institutional CHP Market Potential, Houston/Galveston Metro				
Application	Establishments			
	100-1,000kW	1–5 MW	>5 MW	Total
Nursing Homes	38	33	0	70
Hospitals	30	73	75	178
Schools	330	58	0	388
Colleges/Universities	20	23	45	87
Commercial Laundries	9	0	0	9
Car Washes	12	0	0	12
Health Clubs/Spas	25	0	0	25
Golf Clubs	25	0	0	25
Museums	8	5	0	13
Correctional Facilities	6	20	0	26
Water Treatment/Sanitary	74	8	0	82
Extended Service Restaurants	255	30	0	288
Supermarkets	117	13	0	129
Refrigerated Warehouses	8	0	0	8
Apartments	75	63	100	238
Office Buildings	375	125	50	550
Total	1,516	513	424	2,452

Houston, Texas

Population and Growth Projection

Houston, the county seat of Harris County, is located on the upper Gulf coastal plain of Texas. The fourth most populous city in the United States with 1.9 million residents, Houston is the largest city in the South and Southwest. The Houston metropolitan area (3.7 million population) ranks tenth among the country's metropolitan areas. The larger Houston-Galveston-Brazoria Consolidated Metropolitan Statistical Area (CMSA) includes eight counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller. The CMSA consists of three Primary Metropolitan Statistical Areas (PMSAs): Houston (Chambers, Fort Bend, Harris, Liberty, Montgomery, and Waller); Galveston-Texas City (Galveston County); and Brazoria (Brazoria County). Over the next 25 years, the Houston CMSA's population is expected to increase by more than 50%.