COMBINED HEAT AND POWER IN TEXAS:

STATUS, POTENTIAL, AND POLICIES TO FOSTER INVESTMENT

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- Entergy Texas
- Gulf Coast Combined Heat and Power Application Center
- Texas Combined Heat and Power Initiative
- Texas Hospital Association
- Texas Industrial Energy Consumers
- University of Texas
- San Antonio Water System
- Environmental Defense Fund
- Public Citizen
- StarTex Power
- H-E-B

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E EXECUTIVE SUMMARY

Combined heat and power (CHP), also known as cogeneration, describes systems that simultaneously or sequentially generate electricity and utilize the thermal energy that would normally be wasted. The utilization of waste heat allows CHP systems to operate more efficiently than separate systems used for electricity and heat production. CHP capacity in Texas has grown significantly since the early 1980s when approximately 2,000 MW of CHP capacity was in operation. As of November 2008, **CHP systems account for more than 17,300 MW of generating capacity,** or nearly 20% of the installed capacity in the state. **There is potential for additional economic CHP of roughly 13,400 MW by 2023.**

CHP offers numerous benefits to the plant operator, the electrical grid, and to citizens in general. These benefits can include reductions in fuel consumption and energy costs, deferral of transmission and distribution system upgrades, and reductions in air emissions. Due to the potential benefits of CHP, interest in fostering adoption of CHP in Texas has grown in recent years. This study of CHP in Texas is intended to address the state's interest in policy options available to foster the adoption of CHP.[1]

The study includes the following elements:

1. Review of CHP technologies, costs, and benefits;
2. Characterization of CHP systems currently operating in the state, including the installed capacity, generating technologies, and fuel sources;
3. Estimate of the technical and economic potential for expansion of CHP installations over the next 15 years;
4. Assessment of the regulatory environment surrounding CHP and the barriers to CHP development; and
5. Identification of specific policy options to encourage greater investment in CHP and a recommended approach to selecting among these policies.

Research and analysis for this effort utilized a combination of primary and secondary research methods and modeling of CHP technologies and markets. Major study activities included:

1. A comprehensive literature review of CHP technologies and policies;
2. A survey of 32 facilities in Texas operating CHP systems;
3. Interviews with more than a dozen Texas utilities, industry groups, and other stakeholders; and
4. Application of a proprietary Distributed Generation Technical and Economic Potential (DG-TEP) model developed explicitly to assess the potential for expanded development of DG capacity and customized for this assessment of CHP potential in Texas.

[1] See Public Utility Commission of Texas Project No. 35809, *Request for Proposals for a Study Concerning Combined Heat and Power in Texas*, RFP Number 473-08-00292. This RFP was issued in response to House Bill 3693.

E.1 CHP Technologies, Cost, and Benefits

The primary technologies used for CHP applications are combustion turbines (gas turbines) and combined-cycle units incorporating both combustion turbines and steam turbines. Other technologies used only rarely or in small applications include reciprocating engines, microturbines, fuel cells, and stirling engines. Natural gas is the most common fuel used at CHP facilities in Texas, but other fuels are used to a lesser degree, including industrial waste fuels, wood, and other types of renewables.

Capital costs for CHP systems vary widely by technology type and size of the generating unit. Gas turbines may be as low as $1000/kW for equipment approaching 50 MW in size or as high as $5000/kW for units less than one MW. Reciprocating engines tend to be closer to $1000/ kW regardless of size, while microturbines cost between $2000 and $3000/kW. Fuel cells are particularly expensive, with all size categories up to 5 MW in excess of $5000/kW.

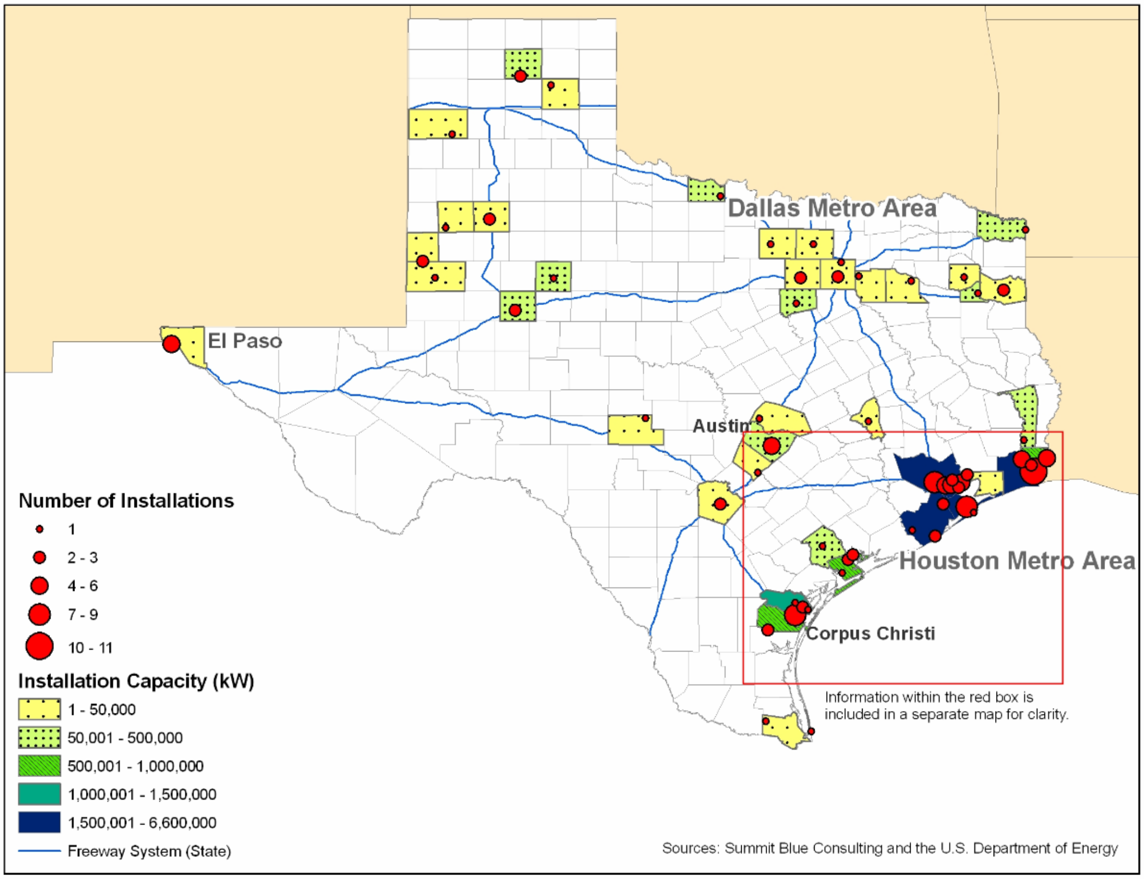
The benefits of CHP installations are widespread and many groups can receive benefits from the systems, including (1) the operator of the site where the CHP unit is located, (2) the grid and utility companies, and (3) ratepayers and society in general. Quantification of many of these benefits can be difficult, but it is apparent that benefits accrue to more parties than just those customers making the decisions whether to invest in CHP. Thus, there may be a public policy role to promote CHP to ensure that beneficial projects are pursued, even if the projects may not, without state support, be economic to the operator or investor.

E.2 Existing CHP Installations in Texas

Texas leads the nation in the use of CHP, with an estimated 135 facilities currently operating CHP systems capable of producing 17,333 MW of power. These facilities were identified primarily from a database of existing CHP installations compiled for the U.S. Department of Energy. The database was supplemented and verified with data from several other sources, including other federal and state government databases and Texas air permit applications.

Additional information about the identified CHP facilities was gained through a survey of 32 existing facilities. This information was used to update the database by removing facilities that are no longer functioning CHP units and by adjusting the values for generating capacity where newly acquired information differed from that in the original database. The resulting list of facilities and their associated generating capacities represents *the most accurate and up-to-date compilation of data on currently operating CHP installations in Texas.* The locations, number of facilities, and installed capacity by county are shown in Figure E-1.

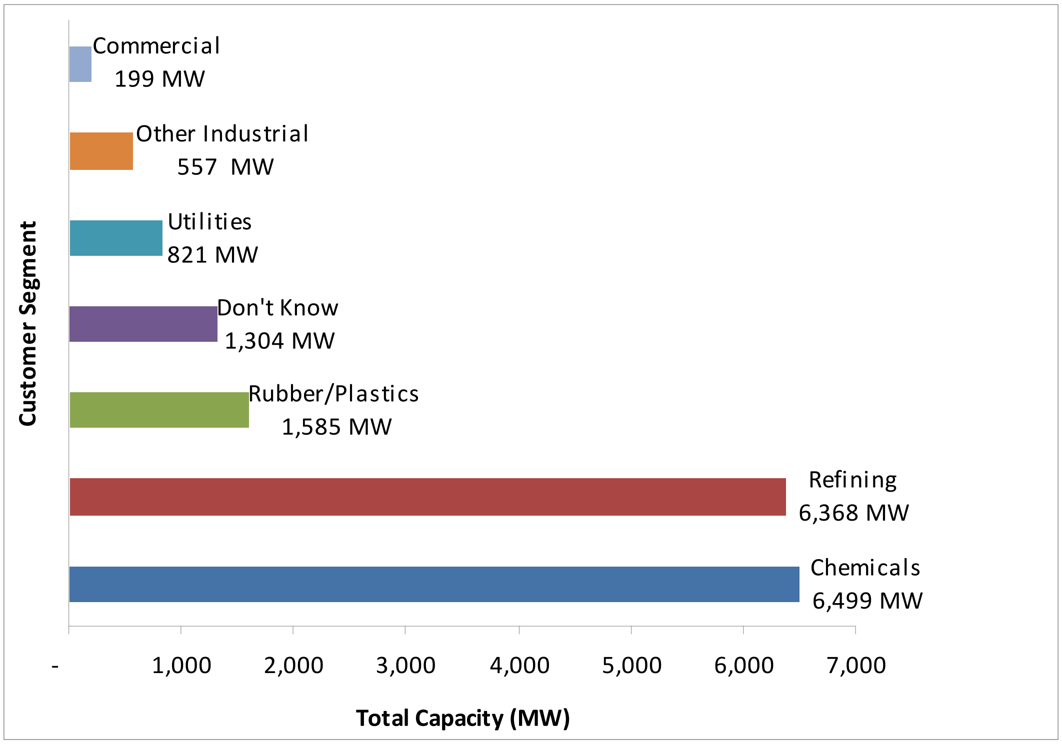
Figure E-1. Map of Existing CHP Installations in Texas



Roughly one-third of these facilities have nameplate capacities under 10MW, another third are between 10 MW and 100 MW, and about a third are over 100 MW. More than half of all CHP capacity is provided by combined cycle units and about one-third by combustion turbines. Steam turbines account for less than 5% of capacity. While other technologies do not account for an appreciable share of capacity in the state, there are 16 reciprocating engines and one fuel cell in operation. Natural gas is used for roughly 90% of the total installed capacity, but nearly 30 mostly smaller facilities use alternative fuels, including wood and other biomass.

Chemical and refining facilities constitute more than half of all CHP facilities in Texas and nearly three-quarters of installed CHP capacity, but there are a diverse number of customer segments incorporating CHP. The next most common groups are colleges/universities, oil/gas extraction, hospitals/healthcare, pulp and paper, food processing, and primary metals. The remaining customer segments each have fewer than three relatively small CHP facilities in Texas. Figure E-2 presents the CHP capacity represented by various customer segments.

Figure E-2. Capacity of CHP Facilities in Texas by Customer Segment



Source: Summit Blue survey of CHP facilities and U.S. DOE

E.3 Potential for CHP in Texas

Analysis of the potential for CHP suggests that by 2023 there could be roughly an additional 13,400 MW of economical CHP opportunities beyond the 17,333 MW already in operation. If all of this potential were realized, total CHP capacity in the state would reach more than 30,000 MW. All but about 2% of the economic potential for new CHP capacity is accounted for by the industrial sector. The economic potential from commercial facilities, while relatively small at 350 MW of additional capacity, represents nearly double the 215 MW of existing commercial-facility CHP capacity in the state.[2] These figures imply that existing CHP installations in Texas represent about 56% of the economic potential. Existing installations in the industrial sector represent 57% of the estimated potential, while the commercial sector has achieved penetration of approximately 38% of the estimated potential.

The importance of the industrial sector for new CHP can be seen in Figure E-3, which shows technical and economic potential by size category for both commercial and industrial facilities under base case assumptions.

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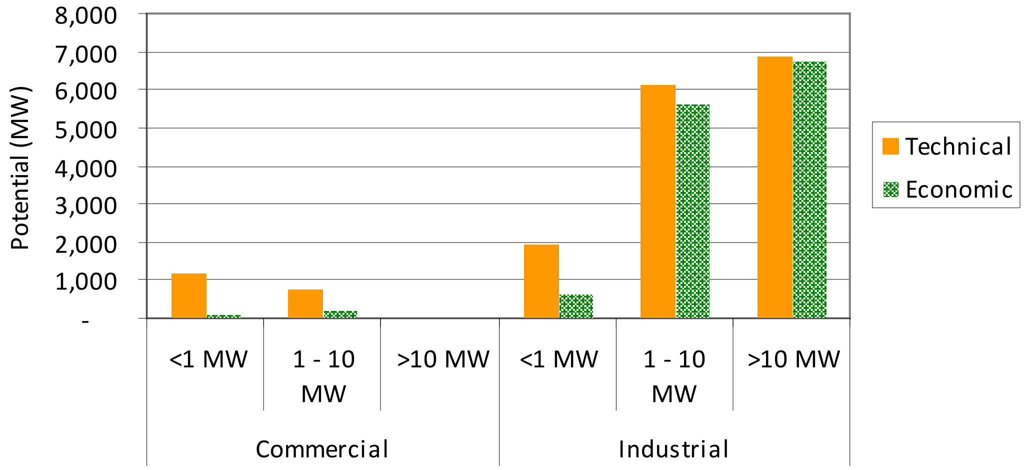
[2] For purposes of penetration rates as a share of estimated potential, the 1,304 MW of capacity not positively identified as either commercial or industrial was assigned proportionally to the two sectors. Thus, the 199 MW of commercial CHP capacity cited above in Figure E-2 becomes 215 MW with the addition of 16 MW allocated from the unknown category.

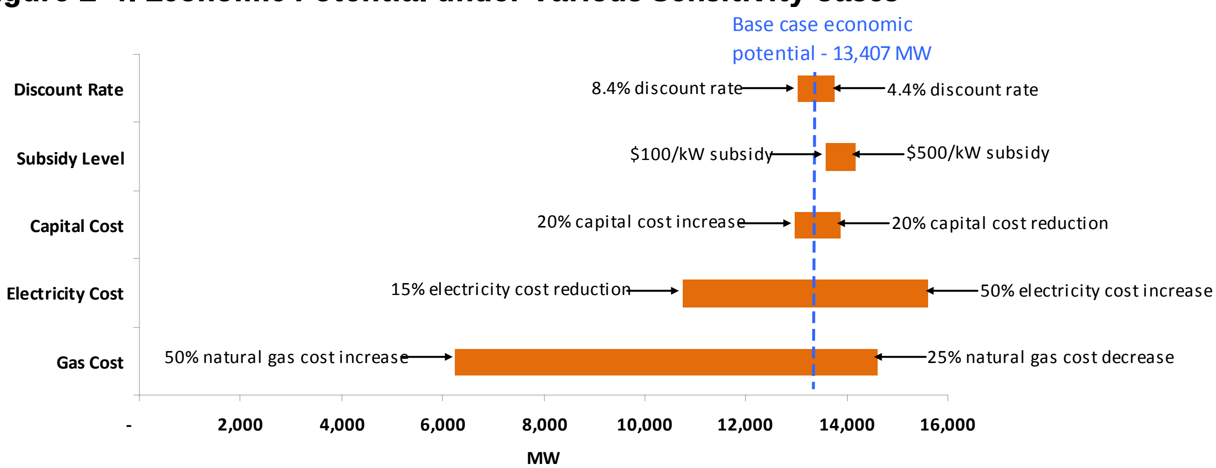
Figure E-3. Base Case Technical and Economic Potential in 2023



Source: Summit Blue Consulting

Several sensitivity scenarios were also evaluated to test how much the potential estimate would change with varying assumptions for natural gas prices, electricity prices (both retail costs and wholesale market prices), and capital costs, as well as with subsidies for CHP development. Economic potential is most sensitive to gas costs, followed by electricity prices. Economic potential decreases dramatically in the high gas cost sensitivity to only 46% of the base case value, illustrating the significance of natural gas price uncertainty on exposure to risk for a long term investment such as CHP. Similarly, the next most significant impact on results is the low electricity cost sensitivity, which reduces the economic potential by 20% (Figure E-4).

Figure E-4. Economic Potential under Various Sensitivity Cases



Source: Summit Blue Consulting

Sensitivity parameters are often dependent on one another. A plausible future scenario is that both gas costs and electricity prices will be high, since electricity prices are largely driven by marginal fuel costs for natural gas, and future regulation of carbon emissions could raise fuel costs above current projections. Under this high gas/high electricity cost scenario, economic potential is estimated at nearly 14,700 MW, or nearly 10% above the base case. Detailed results for all scenarios are presented in Appendix C-2.

E.4 Investment Environment for CHP

Private companies and municipal governments in Texas have invested in CHP to a degree beyond what has occurred anywhere else in the country. The passage of the federal Public Utility Regulatory Policies Act (PURPA) in 1978 created a market for non-utility electric power producers, which allowed for significant expansion in CHP capacity during the 1980s and 1990s. Investment in CHP began slowing as early as 2002 and there has been little change in capacity since 2005, possibly owing to high natural gas prices and the fact that restructuring of the electricity market eliminated the requirement that the host utility purchase excess power generated by a CHP facility. The restructured ERCOT market provides the CHP generator opportunities to sell into the wholesale electricity and ancillary services markets, but participating in the ancillary market is complex and may not be cost-effective for operators of small and medium-sized CHP units.

Various regulatory issues and business considerations contribute to the current environment for CHP investments in Texas. A company's decision to invest in CHP likely will be driven by a combination of factors, including the desire for reduced energy costs, the added reliability of power supply, and other non-economic benefits provided by efficient, onsite generation. Beyond these business-related issues, the regulatory environment in which the facility will operate can also provide critical drivers and barriers. Regulatory issues encompass both the regulatory *requirements* that must be met, as well as regulatory *promotion of CHP*. Some of the barriers resulting from this complex investment environment include the following:

Economic Barriers

- High capital costs
- High operating costs
- Rise and volatility of natural gas prices

Regulatory Barriers

- Grid interconnection
- Permitting
- Wholesale market rules

Customer and Stakeholder Barriers

- Limited on-site space and suitable loads
- Lack of management support
- Lack of technical expertise
- Conflicts between stakeholder goals

E.5 Policy Options to Foster Investment in CHP

The barriers discussed in Chapter 5 have collectively contributed to a decline in development of new CHP capacity in Texas over the past several years. Specific policy options that can lower the identified barriers and foster adoption of CHP are presented in Table E-1. These policy options were identified through an extensive review of policy papers and research studies on CHP in Texas and across the country. The appropriateness of the policies for the Texas market was determined by reviewing the barriers to adoption of CHP and by studying the responses to the CHP facility surveys and the industry, utility, and stakeholder interviews that were conducted for this study.

Table E-1. Policy Options to Foster Adoption of CHP in Texas

Improving the Economics of CHP	Lowering Regulatory Barriers
E1. Provide direct financial incentives for each kW of CHP capacity.	R1. Facilitate interconnection of CHP systems, especially in regions without competition.
E2. Offer a state-funded investment tax credit (ITC) against the Franchise Tax based on the capital investment.	R2. Modify wholesale market rules to facilitate CHP among small customers and neighboring facilities.
E3. Offer property tax abatement for facilities that incorporate CHP capacity.	R3. Modify air permitting rules to encourage greater CHP development.
E4. Provide low-cost financing for CHP projects.	***Promoting Statewide Development of CHP***
E5. Offer a state-funded production tax credit (PTC) against the Franchise Tax based on the energy generated from the facility.	S1. Establish statewide CHP goals to be met through requirements placed on utilities and other market players.
E6. Provide funding to encourage electricity generation from agricultural wastes used for CHP.	S2. Establish a statewide CHP Resource Portfolio Standard.
Supporting Customer Adoption of CHP	S3. Modify state standards and planning procedures to foster adoption of CHP in publicly owned buildings and critical public infrastructure.
C1. Provide education and outreach services to increase customer awareness of CHP opportunities and benefits.	
C2. Provide technical assistance to aid customers interested in CHP.	

The benefits of CHP are summarized in Chapter 2. A persuasive argument can be made that the citizens and ratepayers in Texas will be better off economically and in terms of environmental quality if more CHP system were in operation. There is no precise set of policy options that will most effectively and economically achieve greater adoption of CHP. However, there is a broad policy approach encompassing several key principles that state policymakers can follow to select a desirable and beneficial mix of policies. These principles are as follows:

1. **Consider at least one concrete action to improve the economics of CHP.** Economics is the primary barrier to investment in CHP, and more than 90% of CHP facilities surveyed believe that financial incentives would promote greater use of CHP. While many other barriers exist, removal of these impediments will not increase CHP development if companies cannot expect a reasonable return on investment with a modest level of risk. The economic barriers can be lowered by offering one or more financial incentives (Policy Options E1, E2, E3, E5, and E6) to improve the returns, combined with a method of helping companies to finance their investments (E4). If incentives are provided, they should be offered primarily to smaller systems, mostly at commercial customer sites, since these are less likely to be economic solely from the perspective of the operator. Providing incentives to large facilities may be unnecessary to spur investment and could quickly exhaust limited incentive funds.

   It should be noted that some stakeholders do not believe that economic incentives are necessary, or even a good idea. Several sources of information, including the interviews conducted for this study, raise the point that direct subsidies may not always promote the best projects. While there may be merit to this argument, if the state's objective is to advance CHP to realize its broad benefits to operators, ratepayers, and citizens alike, then incentives may be needed to encourage investment in CHP projects that might not otherwise be pursued.

2. **Assess policy options to reduce as many of the identified barriers as possible.** Even if the economics of a prospective CHP project appear favorable, many non-economic barriers can deter companies from making the investment. The more that barriers can be lowered, even if not completely eliminated, the greater the likelihood that the market will pursue the financial and other benefits offered by CHP. Not all stakeholders agree that there are significant barriers to CHP other than economics, but there is sufficient evidence to suggest that reducing non-economic barriers (Policy Options R1, R2, and R3) will contribute to greater investment in CHP.

3. **Support customers in identifying and assessing CHP opportunities.** Many customers, especially those at smaller and mid-size facilities, are not aware of opportunities for CHP or do not possess the in-house expertise to evaluate the potential benefits. Nearly half of all customers surveyed believe that education and/or technical assistance would lead to more CHP investment. Education and outreach regarding CHP could be expanded (Policy Option C1) and/or technical assistance (C2) could be offered by supporting or administering targeted programs through existing organizations using their established delivery mechanisms.

4. **Consider policy options to directly drive investment in CHP.** An incentive program modeled after the state's energy efficiency goals (Policy Option S1) or a program modeled after the renewable portfolio standard (S2) could provide the mandate and direction needed to spur development of new CHP capacity. These two approaches would each provide financial incentives for investment, but, importantly, they would also ensure that specific entities are responsible for making this investment happen. Fostering CHP in publicly owned buildings and critical public infrastructure (S3) is a less ambitious, but direct, driver of CHP investment that could also assist in the maintenance of government and health services during natural disasters or other emergencies.

Adopting the policy approach described above would provide the state with an excellent opportunity to achieve a large share of the potential for CHP presented in Chapter 4. This approach includes targeted policies that allow the free market to work where the economics of CHP are already good (*e.g.*, at large industrial facilities), while providing financial incentives where the marginal economics may be preventing CHP investments that could otherwise provide significant system and environmental benefits. The ultimate impact of efforts in Texas to foster greater adoption of CHP may be influenced by the extent to which the policies are pursued and the level of funding afforded them.

1 INTRODUCTION

Combined heat and power (CHP), also known as cogeneration, describes systems that simultaneously or sequentially generate electricity and utilize the thermal energy that would normally be wasted. The utilization of waste heat allows CHP systems to operate more efficiently than separate systems used for electricity and heat production. CHP capacity in Texas has grown significantly since the early 1980s when approximately 2,000 MW of CHP capacity was in operation. As of November 2008, CHP systems account for more than 17,300 MW of generating capacity, or nearly 20% of the installed capacity in the state.

CHP offers numerous benefits to the plant operator, the electrical grid, and to citizens in general. These benefits can include reductions in fuel consumption and energy costs, deferral of transmission and distribution system upgrades, and reductions in air emissions. Due to the potential benefits of CHP, *interest in fostering adoption of CHP in Texas has grown in recent years:*

- CHP systems may now qualify for financial incentives applied toward meeting the states energy efficiency goals (PUCT 2008a);
- A CHP industry group has been formed to support CHP applications in the state; and
- The state legislature in 2007 directed the Public Utility Commission of Texas (PUCT) to study the installation and use of CHP technology in the state and to submit a report of its findings (HB 3693).

This study of CHP in Texas is intended to address the legislative request and to provide policy options available to foster the adoption of CHP. The study reviews CHP technologies, benefits, and costs; characterizes CHP systems currently operating in the state; estimates the technical and economic potential for expansion of CHP installations over the next 15 years; and assesses the regulatory environment surrounding CHP and the barriers to CHP development. Research and analysis for this effort utilized a *combination primary and secondary research methods and modeling of CHP technologies,* including:

1) A comprehensive literature review on CHP technologies and policies;
2) A survey of facilities in Texas operating CHP systems (see Appendix A-1 for the survey instrument and Appendix B-2 for the method used to select the sample);
3) Interviews with Texas utilities, industry groups, and other stakeholders (see Appendix A-2 for an example of the interview guides used to ensure consistency and comprehensiveness); and
4) Application of a proprietary Distributed Generation Technical and Economic Potential (DG-TEP) model developed explicitly to assess the potential for expanded development of CHP capacity.

These research and analytic methods are described in more detail in the subsequent chapters. The remainder of this study is organized as follows:

Chapter 2 – Overview of CHP Technologies

Chapter 3 – Characterization of Existing CHP Installations

Chapter 4 – Technical and Economic Potential for CHP

Chapter 5 – Investment Environment for CHP

Chapter 6 – Policy Options to Foster Adoption of CHP

2 CHP Technology Overview

This chapter reviews technologies and fuel sources used for CHP applications, as well as project costs and the benefits of CHP. Common technologies used in a CHP configuration include the following:

- Reciprocating engines;
- Gas turbines;
- Steam turbines;
- Combined cycle units;[3]
- Microturbines;
- Fuel cells; and
- Stirling engines.

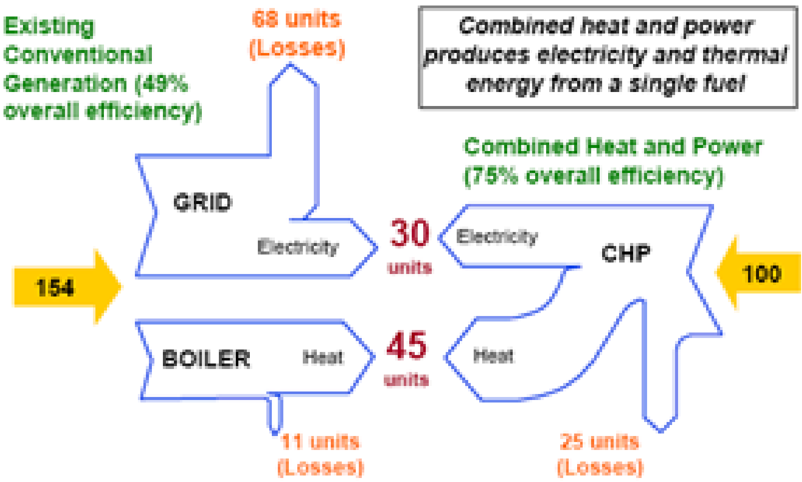
Technology summaries address common applications, sizes, efficiencies, fuels, and the typical range of capital costs. Fuel sources and their common CHP technology applications are then addressed in more detail, while a more detailed discussion of costs is presented in Chapter 4.

2.1 CHP Technology Descriptions

CHP systems involve the simultaneous generation of electricity and heat, and thus are often referred to as cogeneration systems. Depending on the application, electricity or heat can be the primary on-site need, with the other energy source being used on-site to replace either: 1) electricity from the grid, or 2) an additional piece of equipment that provides steam, space heating, water heating, space cooling, or dehumidification. Because one technology, or a group of technologies, such as a boiler/steam turbine system, can provide both electricity and heat, the systems operate more efficiently than a separate electric and heat source. Figure 2-1 compares the energy inputs and outputs for a CHP system and an existing conventional system producing both electricity and heat. The figure shows that, in order to create the same amount of usable energy, the CHP system consumes less energy than the conventional system. The overall efficiency of the CHP unit is 75% compared to the 49% overall efficiency of a conventional system (U.S. EPA 2002).

[3] A combined-cycle unit employs one or more gas turbines, as well as a steam turbine, which is driven by steam produced from the waste heat from the initial combustion driving the gas turbines. Combined-cycle technology has many of the same attributes as gas and steam turbines and is not discussed separately in this chapter. However, references to combined-cycle units are made where appropriate to provide a more complete discussion of CHP technologies.

Figure 2-1. CHP System Compared to a Conventional System



Source: Kaarsberg, Tina and Joseph Roop. "Combined Heat and Power: How Much Carbon and Energy Can It Save for Manufacturers?" Reproduced from U.S. Environmental Protection Agency. "Catalogue of CHP Technologies." Combined Heat and Power Partnership (2002).

Note: The figure above assumes national averages for grid electricity and incorporates electric transmission losses.

CHP systems can be classified in many ways. The California Energy Commission **classifies CHP systems by market segment** in the following manner (CEC 2002):

- Large and medium industrial systems – greater than 25 MW
- Small industrial system – 50 kW to 25 MW
- Smaller commercial and institutional systems – 25 kW+
- Residential – up to 25 kW

Due to a number of refineries with large CHP systems, more than half of the current installed systems in Texas are 25 MW or larger.

Depending on the CHP technology and on the type of businesses using CHP, the **heat recovered from the CHP system can be used for different applications.** Typically, heat is used for one of the following five applications: 1) steam for an industrial process, 2) space heating, 3) water heating, 4) space cooling (through an absorption or adsorption chiller), and 5) dehumidification (with the use of a desiccant).

The project team characterized the CHP technologies based on previous experiences and after review of an extensive list technology papers and research studies on CHP.[4] Table 2-1 provides an overview and comparison of CHP technologies and applications. Market sectors that are applicable to each technology are also included, as well as the advantages and disadvantages of each technology.

[4] US EPA 2002, ONSITE SYCOM Energy Corporation 1999, US EPA 2007, NREL 2003, CEC 2002. References that are not cited here, but that were used for a specific section, are cited within the text.

Table 2-1. CHP Technologies and Their Applications, Market Sectors, Advantages, and Disadvantages

CHP Technology	Typical Size Range	Common Applications					Applicable Market Sectors	Advantages	Disadvantages
		Standby Power	Baseload	Demand Response Peaking	Customer Peak Shaving	Premium Power			
Reciprocating Engine	10s of kW to several MW	X	X	X	X	X	Commercial Buildings, Light Industrial, Utility Grid (larger units), Waste Fuels	Quick start-up time, can operate during part-load conditions, and can load follow, black-start capability, reliable, long-lifetime.	Maintenance costs and emissions tend to be high.
Gas Turbine[a]	500 kW to 10s of MW		X		X	X	Large Commercial, Institutional, Industrial, Utility Grid, Waste Fuels	Reliable, long lifetime, low emissions, large selection of fuel types, and capability to produce high grade heat.	Poor efficiency during part-load conditions, high pressure gas is required for operation.
Steam Turbine[a]	500 kW to 100 MW		X			X	Institutional Buildings/Campuses, Industrial, Waste Fuels	Large selection of fuel types, capability to produce high grade heat.	Slow start-up times.
Microturbine	30 kW to 250 kW	X	X	X	X	X	Commercial Buildings, Light Industrial, Waste Fuels	Compact size, low emissions, few moving parts, and reduced noise.	Only low heat quality, low electrical efficiency, high costs, still an emerging technology.
Fuel Cell	5 kW to 2 MW		X			X	Residential, Commercial, Light Industrial	High electrical efficiency, low emissions, low noise, and modular.	High costs, low heat quality, fuel processing requirements.
Stirling Engine	1 kW to 10s of kW		X	X	X	X	Residential, Commercial	Low noise and large selection of fuel types.	Not commercially developed.

[a] Gas and steam turbines may be combined into a "combined cycle" unit employing the two technologies in series. Combined cycle units are typically only used in the largest CHP applications where there is a significant demand for thermal energy and the generating capacity is several hundred megawatts.

Sources: NREL. "Gas-Fired Distributed Energy Resource Technology Characterizations." Office of Energy Efficiency and Renewable Energy (2003), Table 1, page 1-5; U.S. Environmental Protection Agency. "Catalogue of CHP Technologies." Combined Heat and Power Partnership (2002).

As listed in Table 2-1, the prime movers available for CHP applications include reciprocating engines, combustion turbines (gas turbines), steam turbines, microturbines, fuel cells, and stirling engines. More detailed technology characterizations are provided below and are summarized by size, electric efficiency (LHV[5]), overall efficiency (HHV[6]), types of technologies, fuel, thermodynamic cycle, and heat recovery methods. Additional information on capital costs, operating costs, and heat rates are included in Chapter 4.

Reciprocating Engines

Reciprocating engines convert pressure into linear motion, via pistons, that is then converted into rotating motion. Most stationary reciprocating engines have four strokes to each cycle: the intake stroke, compression stroke, power stroke, and exhaust stroke. In the intake stroke, the piston moves down, allowing air or a fuel/air mixture into the combustion chamber. The compression stroke follows with the piston moving up and compressing the gases. The gases are either ignited by a source, as in the spark ignition type, or the fuel is added to them and they are ignited by the increased temperature caused by the compression, as in the compression ignition type. The combustion of the gases pushes the piston downward, which is called the power stroke. Finally, during the exhaust stroke, gases are released from the chamber. The rotational motion is converted into the power output of the machine.

Reciprocating engines are a well-known and widely used technology. Because of their efficiency, flexibility, and reliability, they can make an economical solution for many smaller CHP applications.

Reciprocating Engines	
Characteristic	**Description**
Size	A few kW to several MW
Capital Cost ($/kW)	$1,100 to $1,600
Electric Efficiency (LHV)	30-50%
Overall Efficiency (HHV)	70-80%
Types of Technologies	Spark ignition (SI) and compression ignition (CI) designs are most applicable to CHP.
Fuel	Diesel and residual oil (compression ignition); natural gas, biogas, liquefied petroleum gas (LPG), and propane (spark-ignition).
Thermodynamic Cycle	Otto cycle for the SI designs and diesel cycle for the CI designs.
Heat recovery	Heat can be recovered from the engine exhaust, engine jacket coolant, lube oil cooler, and turbocharger's intercooler and aftercooler. Steam or hot water is commonly generated.

[5] Low heating value (LHV) defines the energy released during combustion of a fuel and does not include the heat obtained by condensing the water vapor produced by combustion.
[6] High heating value (HHV) defines the energy released during combustion of a fuel and does include the heat obtained by condensing the water vapor produced by combustion.

Gas Turbines

Gas turbine generators, also known as combustion turbines (CTs), are a mature technology. These systems consist of a compressor, a combustion chamber, and a turbine. Air is compressed in the compressor, and fuel is mixed with the air and ignited in the combustion chamber. The gas then enters the turbine's blades at high velocity through a nozzle, causing pressure on the blades. This pressure energy is converted into rotational energy and converted into the power output of the generator.

Gas Turbines	
Characteristic	**Description**
Size	500 kW to 250 MW, with the larger sizes for central power generation
Capital Cost ($/kW)	$1000 to $3500
Electric Efficiency (LHV)	Simple cycle (25-40%) and combined cycle (40-60%)
Overall Efficiency (HHV)	70-75%
Types of Technologies	Not applicable
Fuel	Natural gas, biogas, propane, distillate oil
Thermodynamic Cycle	Brayton cycle
Heat recovery	The exhaust gas can be used directly for process energy or a heat recovery steam generator (HRSG) can be added to the system for steam generation.

Steam Turbines

A steam turbine converts the thermal energy in steam into rotational energy. The turbine consists of both stationary blades, called nozzles, and rotating blades, called buckets. The steam enters the buckets through the nozzles at a high velocity, thus inducing pressure on the buckets and causing them to rotate. The rotational motion is converted into the power output.

Historically, steam turbines have been the primary power generation technology, providing mechanical and electric power and steam for a variety of industrial processes. In contrast with other CHP technologies, steam turbines usually generate electricity as a byproduct of steam generation. While steam turbines are competitively priced compared to other technologies, the costs of the boiler, fuel handling, and overall steam systems and the custom nature of most installations tend to drive up equipment costs. Gas turbines can be added to the steam turbine systems prior to steam generation to create a combined cycle unit. CCs typically have lower heat rates than either CTs or steam turbines alone.

Steam Turbines	
Characteristic	**Description**
Size	50 kW to 1,300 MW, with the larger sizes for central power generation
Capital Cost ($/kW)	$350 to $1000 (excluding boiler and steam system)
Electric Efficiency (LHV)	30-42%
Overall Efficiency (HHV)	80%
Types of Technologies	Two types of steam turbines are used in CHP applications: non-condensing (back-pressure) turbines and extraction turbines.
Fuel	Because a steam turbine does not directly convert a fuel into electrical energy, steam must be created via a boiler or a heat recovery steam generator (HRSG). Boilers can accept many fuel types, including coal, oil, natural gas, and agricultural, forest and urban biomass.
Thermodynamic Cycle	Rankine cycle
Heat recovery	Because steam turbines generate electricity as a byproduct of steam generation, they are recovering useful heat. Exhaust steam from the turbine can also be used in a process or it can be converted to hot water or for use in a chiller.

Microturbines

Microturbines are similar in operation to combustion turbines, consisting of a compressor, a combustion chamber, and a turbine. However, most microturbines contain a recuperator that transfers heat from the exhaust gas to the intake air. This preheating of the intake, or combustion, air reduces the amount of fuel required for ignition in the combustion chamber, thereby increasing energy efficiency.

Microturbines	
Characteristic	**Description**
Size	25 kW to 250 kW
Capital Cost ($/kW)	$2000 to $3000
Electric Efficiency (LHV)	20-30%
Overall Efficiency (HHV)	65-75%
Types of Technologies	Not applicable
Fuel	Natural gas, biogas, propane, distillate oil, liquefied petroleum gas (LPG)
Thermodynamic Cycle	Brayton cycle
Heat recovery	The recuperator on most microturbine designs limits the amount of waste heat available for recovery. Heat can be recovered from the exhaust gas for water heating or low pressure steam.

Fuel Cells

Different from all of the other technologies discussed above, a fuel cell is an electrochemical device consisting of two electrodes, a negative anode, a positive cathode, and an electrolyte. In most configurations, hydrogen or another fuel enters through the anode and an oxidant, such as oxygen enters through the cathode. The hydrogen splits into protons, with a positive charge, and electrons, with a negative charge. The protons are allowed to pass through the electrolyte, while the electrons are forced through a circuit, generating electricity. The electrons then travel to the cathode, where both the protons and electrons react with oxygen. The two byproducts in this system are water and heat.

Fuel cells are an emerging technology. The US Fuel Cell Council has compiled a list of 54 fuel cell products that are commercially available, including PEM, MCFC, and PAFC types.[7]

Fuel Cells	
Characteristic	**Description**
Size	200 kW to 2 MW
Capital Cost ($/kW)	$5000 to $6000
Electric Efficiency (LHV)	40-70%
Overall Efficiency (HHV)	65-80%
Types of Technologies	Phosphoric acid (PAFC), alkaline (AFC), proton exchange membrane (PEM), molten carbonate (MCFC), and solid oxide (SOFC).
Fuel	Primary fuel is hydrogen — can be reformed from many fuel sources, including natural gas, coal gas, propane, and methanol.
Thermodynamic Cycle	Not applicable, use of an electrochemical process.
Heat recovery	Heat created during electrical generation with varied grades of heat depending on the type of fuel cell (i.e., the PAFC and PEM produce lower grades of heat, and the MCFC and SOFC produce higher grades of heat).

Stirling Engines

A stirling engine operates in a closed cycle configuration. A fixed amount of gas, called a working fluid (e.g., air, hydrogen, helium), remains inside a chamber while the heating and cooling sources are external to the engine. The external heat source allows for a large range of fuels for operating the stirling engine. One configuration operates on four cycles: heating, expansion, cooling, and compression. During the heating cycle, the working fluid is heated via an external heat source on the "hot side." The working fluid increases in pressure and expands due to the increase in temperature and the fluid flows to the "cold side." As the hot fluid enters the "cold side," the gas cools and the pressure is reduced. One of the two pistons then compresses the fluid in the "cold side," forcing the fluid to return to the "hot side" and restart the

[7] US Fuel Cell Council. "Commercially Available Fuel Cell Products." Available at http://www.usfcc.com/.

cycle. The transfer of fluid between the "hot side" to the "cold side" causes the two pistons to move. The motion of the pistons is converted into rotational energy. The rotational motion is converted into the power output.

Most stirling engines are currently in the pre-commercial stages,[8] but could be a CHP solution in the future.

Stirling Engines	
Characteristic	**Description**
Size	55 W to 55 kW (reported)
Capital Cost ($/kW)	Not commercial
Electric Efficiency (LHV)	Around 30% (based on the STM Power Model 4-120).
Overall Efficiency (HHV)	Unknown
Types of Technologies	Kinematic and free-piston.
Fuel	A large range of fuels may be used, because the stirling engine is heated externally – fossil fuels, solar, nuclear, waste heat, and biomass.
Thermodynamic Cycle	Stirling cycle
Heat recovery	Heat is recovered from exhaust gases.

The U.S. Department of Energy established a Distributed Energy Program in 2001 to research and develop modular energy systems for on-site use. This program includes distributed generation technology development, such as gas-fired reciprocating engines, gas turbines and microturbines, and integrated energy systems development, focusing on CHP applications and technologies. Within the integrated energy systems development, the program is researching modular, packaged CHP units for "plug-and-play" applications. This research may influence the development and usage of CHP units in the future.

2.2 Fuel Sources

A range of fuel sources are available for CHP applications. The fuel sources are grouped by type (liquid, gaseous, solid, and renewable/solar) and are characterized below:

- Liquid fuel: has the ability to easily be stored on-site; often used in emergency generators.
- Gaseous fuel: natural gas is easy to obtain in Texas; depending on the location, biogas may already be produced as a waste product.

[8] WhisperGen currently has two commercial stirling engine CHP products available. http://www.whispertech.co.nz/

- Solid fuel: has the ability to easily be stored on-site; depending on the location, the fuel may already be on-site as a waste product.

- Renewable fuel: though other fuels included in the gaseous or solid categories may be considered renewable, this category has been created for solar energy systems.

For each fuel listed in Table 2-2, one or more technologies that can accept the fuel are also listed. This list is not meant to be exhaustive, but to showcase possible fuels used with CHP applications. As can be seen in the table, natural gas is one of the most versatile fuels, because it can be used to power all of the technologies described in this section.

Table 2-2. Fuel Sources for Combined Heat and Power Applications

Fuel Type	Common Technology Applications
Liquid Fuel	
Diesel	Reciprocating engine (CI)
Distillate oil	Steam turbines, Gas turbine, Microturbine
Residual oil	Steam turbines, Reciprocating engine (CI)
Methanol	Fuel cell
Liquefied petroleum gas (LPG)	Reciprocating engine (SI), Microturbine
Gaseous Fuel	
Natural gas	Steam turbine, Reciprocating engine (SI), Gas turbine, Microturbine, Fuel Cell, Stirling engine
Biogas	Reciprocating engine (SI), Gas turbine, Microturbine
Propane	Reciprocating engine (SI), Gas turbine, Microturbine, Fuel Cell
Coal gas	Fuel Cell
Hydrogen	Fuel Cell
Solid Fuel[9]	
Nuclear fuel	Steam turbine, Stirling engine
Coal	Steam turbine, Stirling engine
Agricultural biomass (beef cattle manure, cotton gin trash, corn stover, wheat straw, beef meat processing waste, broiler manure, poultry processing waste, dairy cattle manure, rice hulls, hog manure, sugarcane bagasse, peanut shells)	Steam turbine, Stirling engine
Forest biomass (wood energy crops, pulp and paper waste, logging residues, lumber mill residues, forest thinning waste)	Steam turbine, Stirling engine
Urban biomass (municipal solid waste, construction debris)	Steam turbine, Stirling engine
Renewable Fuel	
Solar	Steam turbine, Stirling engine

[9] The agricultural, forest and urban biomass for CHP applications are taken from Bullock *et al.* 2008.

2.3 CHP Benefits

The potential benefits of CHP installations are widespread and many groups can receive benefits from the systems, including (1) the operator of the site where the CHP unit is located, (2) the grid and utility companies, and (3) ratepayers and society in general. The benefits were identified through an extensive review of policy papers and research studies on CHP in Texas and across the country.[10] Table 2-3 below lists some of the potential benefits of CHP which are then discussed in the remainder of this chapter.

Table 2-3. Summary of Potential Benefits from CHP

Benefits to the CHP Operator

- Energy cost savings
- Electricity price stability
- Additional revenue streams through the sale of excess heat or power, the sale of RECs, or the avoidance of other investments
- Improve power reliability and power quality
- Provide reactive power support
- May help qualify for LEED certification
- Provide an efficient method of dehumidification
- Provide public relations and marketing benefits

Benefits to the Grid and Utility Companies

- Operating losses can be reduced
- Defer additional transmission and distribution capacity
- Ancillary benefits
- Improves the overall system reliability
- Defer additional generation capacity
- Reduce peak power requirements
- Allows for modularity
- Fast start capability
- Installation of a CHP unit requires less time
- Benefits from the sale of steam or chilled water
- Increased customer satisfaction
- Thermal reliability
- Natural gas utilities can benefit from increase in sales

Benefits to Ratepayers and Society in General

Environmental Benefits

- Reduces the demand on water
- Reduces the land used for power generation
- Reduces air emissions
- CHP units efficiently use fuel

Economic Benefits

- Builds the CHP industry in Texas
- Add jobs in Texas

2.3.1 Benefits to the CHP Operator

For CHP host sites, a principal economic benefit from the CHP system is **energy cost savings** by producing electricity on-site and avoiding electricity purchases. Economic benefits were discussed in the CHP facility survey and the interviews with Texas stakeholders, and were considered to be a significant influence on the decision to develop and use cogeneration. Reduced utility bills were given a seven on a scale of zero to ten, where zero is “not at all influential” and ten is “very influential.” Respondents to the

[10] US DOE 2007, EPRI 2005, TX CHPI 2007, Bullock and Weingarden 2006, WGA 2006, CEC 2007, Gulf Coast CHP 2008a, Gulf Coast CHP 2008b, CBO 2003.

project team's interviews with industry and utility groups also cited energy savings as a benefit of a CHP system.

Electricity price stability can also be economic benefit. The stability or predictability of the cost of electricity generated by the CHP unit can be higher or lower depending on the fuel used to power the system. For example, if the fuel is biomass or waste fuel produced on site, it is more likely that the electric cost will be stable. In contrast, if natural gas is the fuel and the natural gas price changes over time, the cost of generation may be less predictable.[11] These systems can also give operators energy management control and can be optimized to meet on-site needs.

CHP units can also provide **additional revenue streams through the sale of excess heat or power, the sale of renewable energy credits (RECs), or the avoidance of other investments**. Excess electricity, steam, or chilled water can be sold to the wholesale markets or a third party, providing an additional revenue stream. Additional revenue from the system can also come in the form of RECs for CHP units operating on renewable fuel. CHP systems can also avoid the need to invest in chillers, boilers, or other HVAC equipment on-site.

Improving power reliability and power quality are also possible benefits to the CHP host site. Reliability and disaster preparedness were cited in interviews by non-industry stakeholders as a benefit of a CHP system. Having reliable power is important to many businesses, such as manufacturing plants, data centers, and hospitals, because a power outage can lead to critical data losses, endanger lives, and result in added costs. Because Texas is in a hurricane-prone region, as shown by the recent devastation caused by Hurricanes Rita and Ike, the need for power reliability is crucial at critical facilities like hospitals, senior care facilities, and emergency locations. CHP can provide such power reliability. CHP units can also be more reliable than diesel generators when natural gas supplies are uninterrupted after a major disaster such as Hurricane Katrina. A CHP unit can also eliminate or reduce the need to have another backup generator, such as a diesel generator, and can be designed to operate continuously (Bullock and Weingarden 2006). Respondents to the CHP facility survey also rated having self-generation capability to improve electric reliability as a factor that influenced their company's decision to develop and use cogeneration. On average, respondents rated this factor a six on a scale of zero to ten, where zero is "not at all influential" and ten is "very influential."

In addition, a CHP unit can **provide reactive power support** to companies to improve their power quality. Because reactive power increases line losses for the utility, but does not provide additional sales of electricity, utilities often charge customers for reactive power. Providing reactive power support through the use of CHP can reduce these charges.

CHP may also **help those buildings applying for LEED certification** and can provide an **efficient method of dehumidification** needed in most parts of Texas through desiccant-based dehumidification.

The CHP host site could also receive **public relations or marketing benefits** from the installation due to increased overall efficiency of generating electricity and power. If the fuel use is renewable, the host site may also receive positive publicity for operating an environmentally friendly system. Respondents to the project team's survey also rated improving their business image and green marketing as a factor that influenced their company's decision to develop and use cogeneration. Respondents rated this factor a

[11] Note that some CHP sites enter into long term contracts for natural gas to "lock in" a price. These systems could forecast the price of electricity generated from their systems for the term of the contract.

four on a scale of zero to ten, where zero is "not at all influential" and ten is "very influential." Therefore, respondents cited improving their business image as less influential in the company's decision to use cogeneration than reducing utility bills and improving electric reliability.

2.3.2 Benefits to the Grid and Utility Companies

By reducing load and congestion on the transmission and distribution system, **operating losses can be reduced**. Researchers note that line losses average around 9.5% (WGA 2006). Also, generating electricity at the point of use can **defer additional transmission and distribution capacity**, and thus avoid additional investment. The *Distributed Generation Interconnection Manual* discusses "the potential for DG as a peaking resource to defer or avoid T&D capital investments" (PUCT 2002). Finally, transmission and distribution systems benefit from CHP installations through provision of **ancillary services,** such as voltage support, contingency reserves, and reactive power support.

The addition of CHP capacity to the grid **improves the overall system reliability**. Having a mix of generating technologies and fuel sources, along with a mix of utility scale and smaller-scale distributed generation increases the reliability of the system. With a portion of Texas operating under a restructured market, CHP provides support to this competitive electricity market structure.

Utilities or power generating companies also benefit. Added capacity at the point of use can **defer additional generation capacity** and can **reduce peak power requirements**. Distributed generation also **allows for modularity** of the total generation capacity— installed capacity can be increased in small increments, rather than with one large investment. CHP units' **fast start capability** can also aid in quickly meeting peak power requirements. Also, **installation of a CHP unit requires less time** than the installation of a traditional power plant. Regulated utilities that own a CHP system can treat the system like other power plants, and can earn a return on the investment. If the utility company has some ownership in the CHP units, they may also see **benefits from the sale of steam or chilled water** produced from the CHP unit. If a utility-owned CHP unit is located at or near customer sites and provides benefits to the customer, the utility could see **increased customer satisfaction**. Utility respondents to the project team's interview cited **thermal reliability** as a benefit of CHP in terms of a CHP system's ability to keep thermal cooling units in operation.

Natural gas utilities can also benefit. Because the majority of units in Texas currently operate on natural gas, many additional CHP units would likely use natural gas, thus increasing its demand in Texas.

The interviews with industry stakeholders concerning CHP in Texas included comments about possible benefits to utilities if additional CHP capacity were added to the grid. Respondents mentioned that CHP helps support the grid and can provide voltage support, thus avoiding system upgrades if the CHP was utility-owned. Another benefit would be the possibility of a utility purchasing excess power from a CHP unit at a cheaper rate than from other options. In addition, the nodal market program was discussed. In 2003, the PUCT ordered ERCOT to design a nodal wholesale market.[12] Once the transition has been made from a zonal to a nodal market, end users could pay more for energy in a congested area. Therefore, CHP could alleviate some of the congestion.

[12] ERCOT website. Available at www.ercot.com.

2.3.3 Benefits to Ratepayers and Society in General

Environmental and economic benefits are two categories of benefits from CHP that can accrue to ratepayers and society in general.

Environmental Benefits

Environmental benefits of CHP include decreases in water and land use, reductions in air emissions, and more efficient fuel use. Generating electricity with a CHP unit rather than a large coal-fired power plant greatly **reduces the demand on water**, primarily because the heat sink for a CHP unit is the thermal energy (steam, hot water, etc.) that is used in some form on-site or nearby, compared to the heat sink for a large coal fired power plant which is the evaporation of water. The Department of Energy and the Environmental Protection Agency estimate that the use of small and medium-sized natural gas-fueled CHP reduces water use by 90%, compared to the average power plant's water use in Texas (Bullock 2008).

Because CHP systems are generally located at the point of use, overall **land use for power generation is reduced,** because the system is included as a part of the footprint of the commercial or industrial facility. Land use for rights-of-way for transmission and distribution lines is also reduced, as well as public opposition to additional transmission lines.

A CHP unit can **reduce air emissions** if the unit uses a fuel that is as clean or cleaner than large scale generation, and thus the installation can improve the air quality. The Gulf Coast CHP Application Center also notes that CHP generated electricity produces less NOx than a traditional utility power plant (Gulf Coast CHP 2008b). The Department of Energy and the Environmental Protection Agency estimate that the use of small and medium sized natural gas-fueled CHP reduces NOx emissions by 84%, CO_2 emissions by 51%, and SOx emissions by 106%, compared to the average power plant emissions in Texas (TX CHPI 2007). However, to the extent that air emission standards differ by region, as they do for NOx, the location of a CHP facility may result in permitting difficulties. In addition, CHP systems can reduce or avoid the installation of backup diesel generators, thus reducing the air emissions from the diesel generators. Interview respondents also cited environmental benefits, including a reduction in greenhouse gas emissions.

Lastly, **CHP units efficiently use fuel**. The Texas Combined Heat and Power Initiative found that the installation of 5 GW of CHP in Texas could save the equivalent of 34 million barrels of oil each year (TX CHPI 2007). Also, some fuels used to generate electricity and heat in a CHP unit could otherwise enter the environment. For example, animal feeding lots result in methane emissions. By adding anaerobic digesters on-site, these emissions could be reduced or eliminated. Interview respondents also mentioned the use of waste for CHP, thus reducing total waste streams.

Economic Benefits

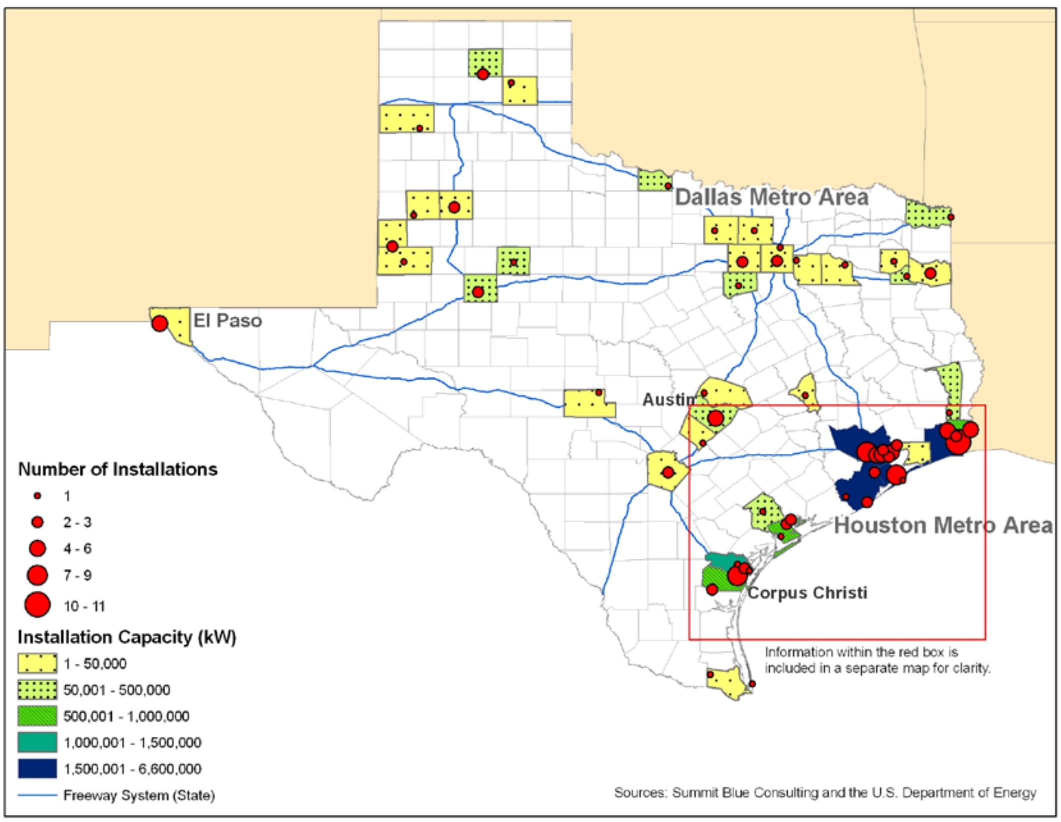
An increase in CHP installations could **build the CHP industry in Texas** and could **add jobs**. An increase in the CHP industry in Texas could make Texas businesses more competitive in global markets, as businesses in Texas currently supply and service turbo machinery, engines and heat recovery parts. An increase in CHP in Texas would aid these businesses. CHP could also benefit the natural gas industry in Texas, because most CHP units currently use natural gas as their primary fuel. Use of Texas biomass in CHP facilities might also provide value to agriculture and forestry businesses that generate waste.

3 EXISTING CHP INSTALLATIONS

Texas leads the nation in the use of CHP, with an estimated 135 facilities currently operating CHP systems capable of generating 17,333 MW of power. These facilities were identified primarily from a database of existing CHP installations compiled under contract to the U.S. Department of Energy.[13] The database was supplemented and verified with data from several other sources, including other federal and state government databases and Texas air permit applications (see Appendix B-1).

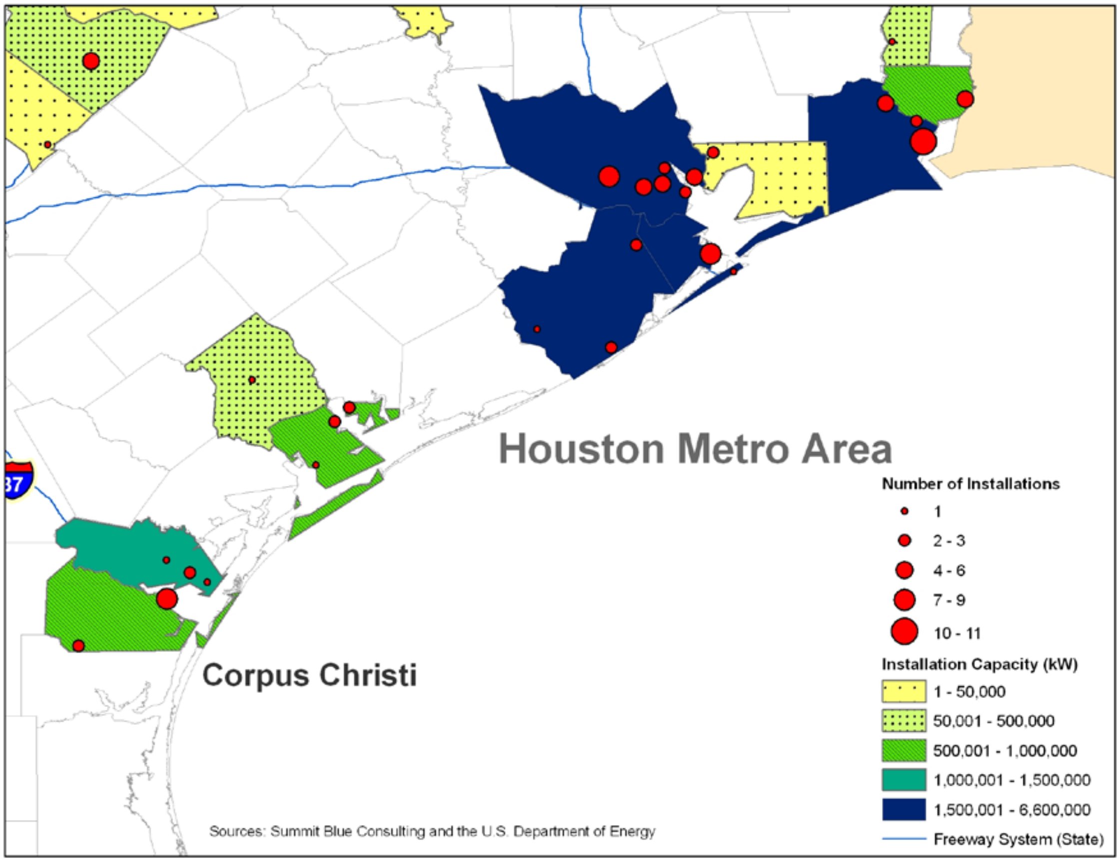
Additional information about the identified CHP facilities was gained through a survey of 32 existing facilities (see Appendices A-1 and B-2 for the survey and sampling methodology). This information was used to update the database by removing more facilities that are no longer functioning CHP units and by adjusting the values for generating capacity where newly acquired information differed from that in the original database. The resulting list of facilities and their associated generating capacities represents *the most accurate and up-to-date compilation of data on currently operating CHP installations in Texas.* These facilities are shown by number of installations and total capacity on a statewide basis in Figure 3-1 and along the Gulf Coast in Figure 3-2.

Figure 3-1. Map of Existing CHP Installations in Texas



[13] The original database was compiled by Energy and Environmental Analysis (EEA) Inc., which is under contract to the U.S. DOE. Prior to use by Summit Blue, the database was updated by Tommy John, Vice President of Regulatory Affairs of the Texas CHP Initiative, to add new projects and remove duplicate entries and facilities known to be either shut down or no longer providing thermal energy.

Figure 3-2. Map of Existing CHP Installations along the Gulf Coast of Texas



3.1 Updating the CHP Installations Database

The current profile of existing CHP facilities in Texas (illustrated in the maps above and presented in Section 3.2) reflects a net decrease of 13 facilities and approximately 1,200 MW of capacity from what was contained in the original database provided to the research team. The current CHP facility profile reflects the *research activities* and *findings* described below. Appendix B-1 contains a more detailed explanation of the how the study team identified facilities using CHP.

The method used to update the CHP installations database can be broken into four discrete steps:

1. Review of the existing CHP facility database;
2. Supplemental research to identify additional CHP facilities;
3. Identification of invalid facility listings; and
4. Updating of capacity values for existing facilities.

These steps were followed, as discussed below, to generate the most accurate and up-to-date estimate of the number of CHP facilities operating in Texas and their associated generating capacity.

Step 1: Review of the existing CHP facility database

The original database of existing CHP facilities compiled for the U.S. Department of Energy (DOE) contained 148 facilities with 18,570 MW of total capacity.[14] The capacity values generally reflect the operating capacity, although in some cases the only available data was nameplate capacity (Hampson 2008).

Step 2: Supplemental research to identify additional CHP facilities

Research into federal Form EIA-860 data (EIA 2006) and several state databases, coupled with a detailed review of Texas Commission on Environmental Quality (TCEQ) permit applications, identified four additional facilities not contained in the original DOE database. These four facilities, with 72.1 MW of total capacity, were tentatively added to the original database and included in the sample used for the facility survey effort (see Appendix B-1 for the methods used to identify additional facilities).

Step 3: Identification of invalid facility listings

The survey effort indicated that more than a dozen previously identified facilities are not unique CHP facilities currently in operation. None of the four facilities tentatively added to the original database in Step 2 were found to be unique and currently in operation. Of these four facilities, one 45 MW facility is no longer operating as cogeneration; a 7.5 MW facility was a duplication of another facility already in the database under a different name; and two facilities with a combined 19.6 MW of capacity will not begin operating until 2009. Thus, the final, updated database does not reflect the addition of any new facilities. Furthermore, following the survey component of this study, 13 facilities were removed from the original database for a new total of 135 facilities employing CHP. These 13 facilities were removed for the following reasons:

- Five of the facilities removed from the original database, representing 214 MW, are not currently operating as cogeneration facilities and do not plan to restart operations.
- Six facilities, with a total capacity of 322 MW, were duplicate entries, under different names, of other facilities in the database. This is not surprising due to frequent changes in the name and ownership of many of the facilities.
- Two of the facilities in the original database, representing 90 MW, have been shut down.

As a result of the changes describe above, the updated database contains 135 facilities, down from the 148 originally provided to the project team.

Step 4: Updating of capacity values for existing facilities

The estimated generation capacity of the 135 existing CHP facilities is 17,333 MW. This figure reflects adjustments made to some of the original capacity values, as informed by data collected during the survey

[14] The original database was compiled by Energy and Environmental Analysis (EEA) Inc., which is under contract to the U.S. DOE. Prior to use by Summit Blue, the database was updated by Tommy John, Vice President of Regulatory Affairs of the Texas CHP Initiative, to add new projects and remove duplicate entries and facilities known to be either shut down or no longer providing thermal energy.

effort. Prior to the survey, the same 135 facilities represented 17,944 MW of capacity, for a net decrease of 611 MW due to adjustments in capacity values.

In all but six cases, the capacity values from the original data sources were used.[15] In general, the original DOE database reflected the operational capacity of the facility rather than the nameplate capacity. Since the survey was designed to capture the nameplate capacity, the survey data was only used to update the capacity value in the following cases:

- *The facility survey indicated an explicit change in capacity.* One facility had just installed 75 MW of new capacity from CHP within the past year; another facility was bringing online an additional 16 MW in November 2008; and a third facility had just removed a 12 MW turbine from the 1960s.[16]

- *The capacity reported in the survey was lower than the capacity given in the original database.* The project team sought to maintain consistency by reporting operating capacity, rather than nameplate capacity, when operating capacity data was available. (The DOE database contained primarily operating capacity values except in cases where the only available information was nameplate data.) It was assumed that when a capacity value was reported to be lower than the figure in the original database, this lower value was likely to be closer to the true operating capacity.[17, 18]

As noted above, the updated database of facilities and their associated generating capacities represents the most accurate and up-to-date compilation of data on currently operating CHP installations in Texas. However, the methods employed in identifying existing CHP installations and their generating capacities suggest that the 17.3 GW of capacity from 135 facilities may be an over-estimation of the actual CHP installations in Texas.

Many of the facilities identified as duplicates or non-operational were flagged in advance (due to expectations that their status had changed) and explicitly included in the original survey sample that

[15] There were often small differences in capacity between the original database figures and what was reported by the survey respondents. This was due to differences in whether the data was reported as nameplate capacity or maximum actual output and on whether the respondents provided approximate values during the survey.

[16] The facility that removed the 12 MW turbine was planning to replace it with a new 30 MW turbine in 2010. This addition was not included in the tally of existing CHP capacity.

[17] Three of the facilities reporting lower capacity than what was in the original DOE database had *nameplate* capacities from the EIA data that matched the capacity values in the original DOE database. This suggests that the capacity values in the original database for these particular facilities were nameplate capacities, rather than operational capacities. This approach was further verified through a conversation with the interviewee at one of these facilities, who suggested that the capacity reported to EIA was probably the hydrogen-cooled capacity, rather than the more typical ambient-cooled capacity, which was the number he reported in the survey. A fourth facility reported a capacity of 4.3 MW, versus the 4.5 MW figure that was in the DOE database and the 5.0 MW nameplate capacity reported to EIA. This small difference of approximately 4% between the DOE and survey data was deemed too small to be of material importance in the analysis, but for consistency the 4.3 MW figure reported in the survey was used in the final analysis.

[18] In cases where the capacity reported in the survey was *higher* than the capacity given in the original database, the values from the original database were used since the higher reported values were likely nameplate capacities rather than operating capacities. This assumption is supported by the fact that the survey included a question asking if there were any changes in the plant's capacity in recent years. If an explicit change was, in fact, acknowledged by the respondent, then the new capacity value would be reflected, as discussed above.

included 30 facilities (see the sampling methodology in Appendix B-2). It would not be appropriate to extrapolate the findings (i.e., the net reduction of 13 facilities and more than 1,200 MW) to the entire population of the database based on a sample that, by intention, was not completely random. Several facilities that were *not flagged* also were subsequently determined to be duplicates, non-operational, or operating at lower capacities. Since the majority of facilities in the updated database were not contacted through surveys, there is a reasonable expectation that additional duplicate or non-operational facilities remain in the database.

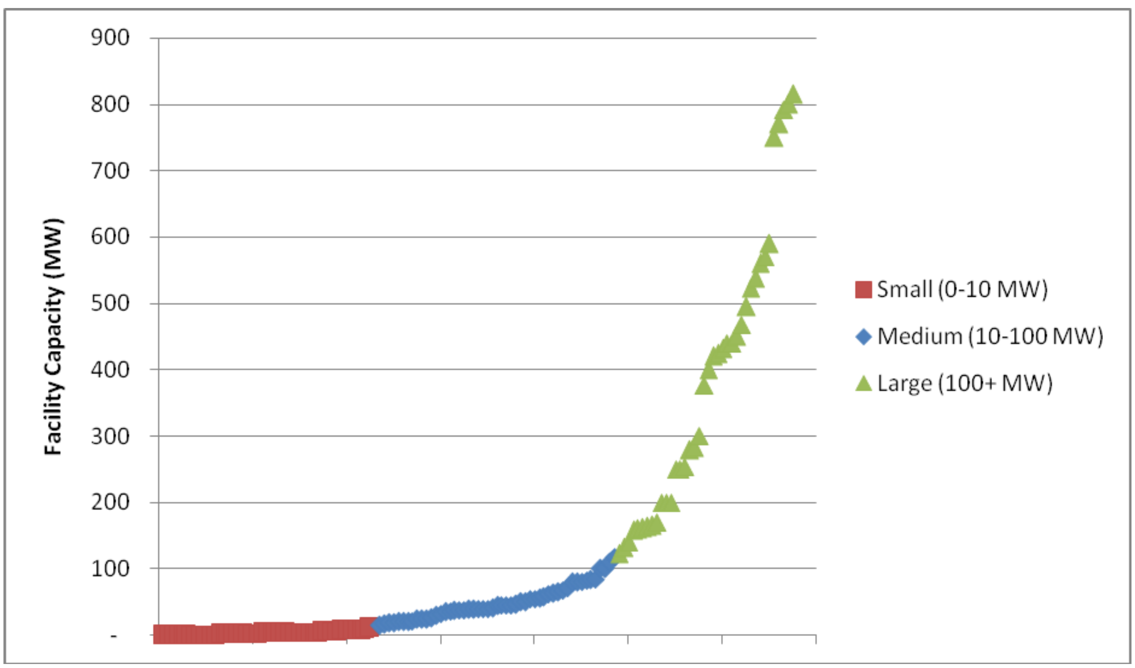
3.2 Characteristics of Texas CHP Facilities

An assessment of the updated CHP facility database revealed several patterns and common characteristics among the CHP facilities in Texas. An overview of existing CHP installations is presented and illustrated in the remainder of this chapter, organized by size, technology, fuel, and other attributes.

Size

The 135 facilities in the updated database represent 17.3 GW of CHP capacity. About a third of these facilities have nameplate capacity under 10 MW (designated "small" facilities), and about a third have capacities over 100 MW ("large" facilities), including more than a dozen facilities with more than 400 MW of generating capacity (Figure 3-3).

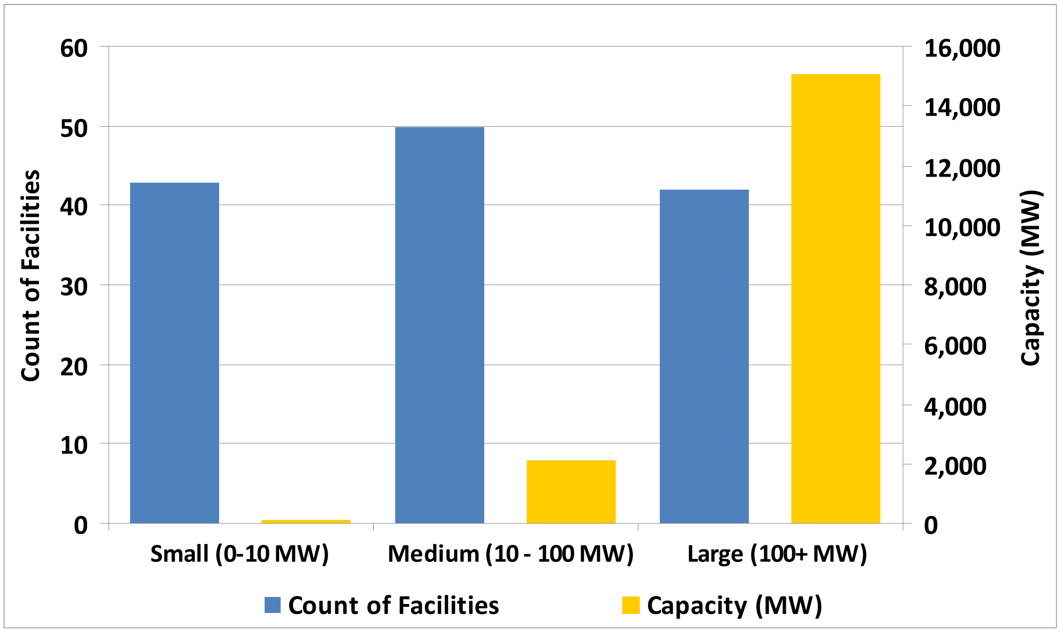
Figure 3-3. All CHP Facilities in Texas Shown by Capacity (MW)



Source: Summit Blue survey of CHP facilities and U.S. DOE

Although the three size groups each account for roughly the same number of facilities, the smaller facilities contribute less than one percent of total capacity and the large facilities contribute over 85% of total capacity (Figure 3-4).

Figure 3-4. Number and Capacity of CHP Facilities by Size Category

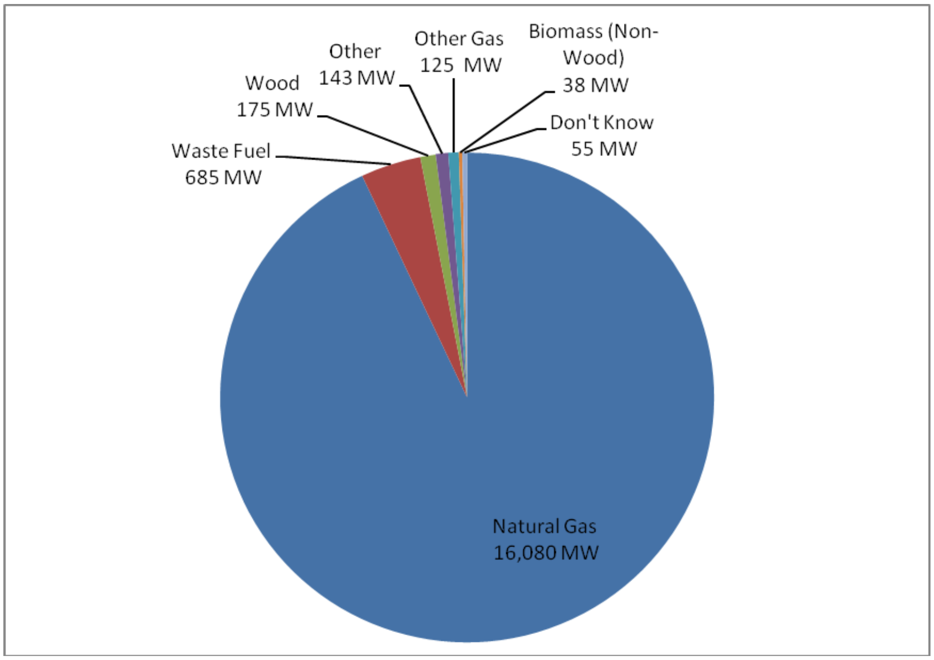


Source: Summit Blue survey of CHP facilities and U.S. DOE

Fuel Type

The vast majority of CHP facilities in Texas (79%) are fueled by natural gas, and these facilities account for over 90% of all CHP capacity in the state. Wood and other biomass fuels are used at nine relatively small facilities, and their contribution to statewide capacity is only one percent. Another eight facilities use waste fuel, accounting for 4% of capacity (Figure 3-5).

Figure 3-5. Capacity of CHP Facilities by Fuel Type

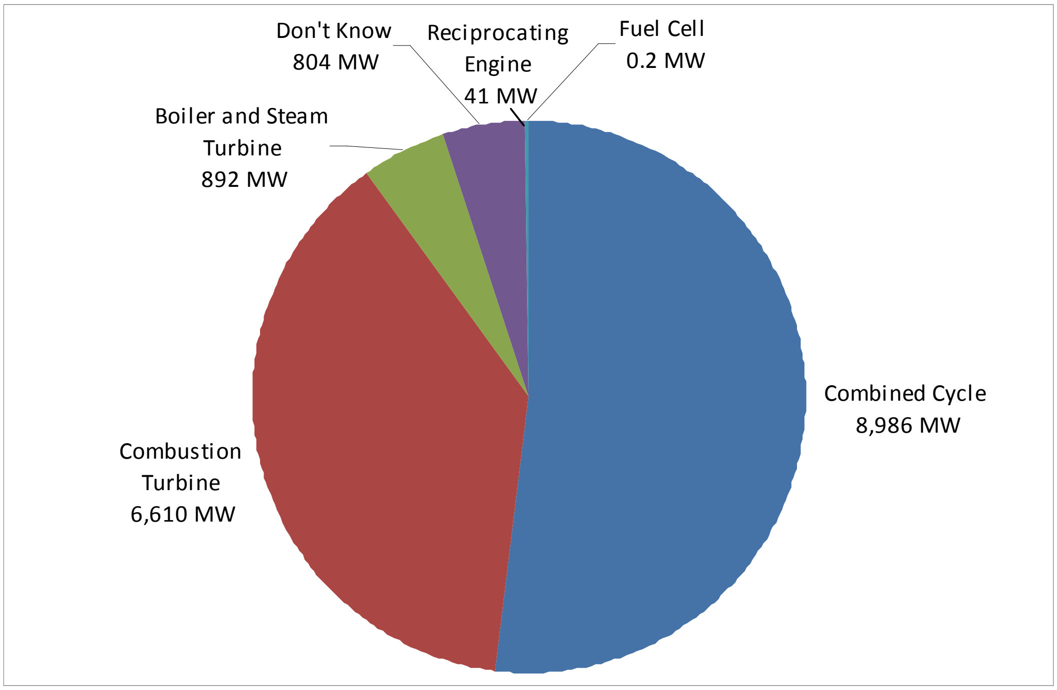


Source: Summit Blue survey of CHP facilities and U.S. DOE

Technology Type

In terms of installed capacity, combined cycle units and combustion turbines dominate the Texas CHP landscape, with over 90% of capacity provided by these two technologies. Steam turbines provide just 5% of capacity, but they account for more than 20% of the installations. No other technologies provide a significant amount of power, although 16 reciprocating engines are used for CHP systems, as well as one fuel cell (Figure 3-6).

Figure 3-6. Capacity of CHP Facilities by Technology Type

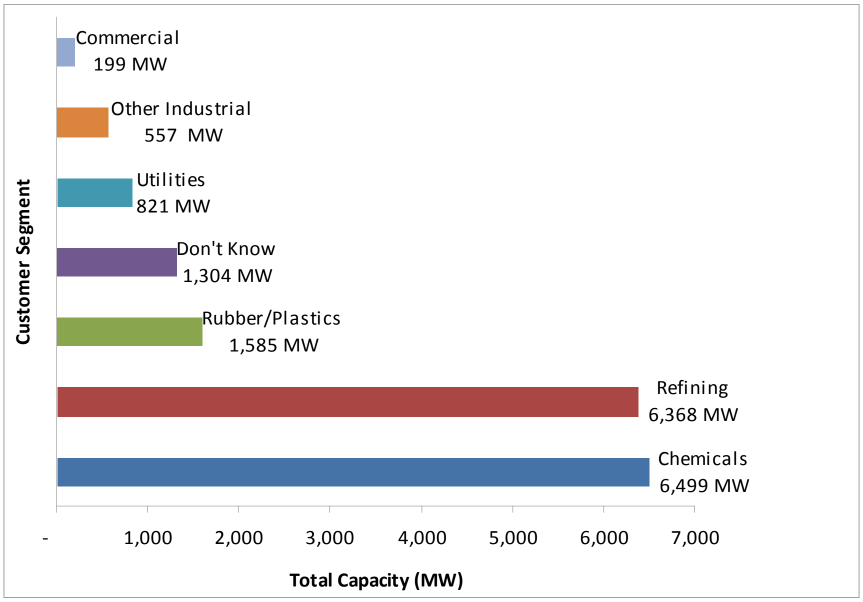


Source: Summit Blue survey of CHP facilities and U.S. DOE

Customer Segment

Chemical and refining facilities operate CHP systems accounting for roughly three-quarters of the installed capacity from CHP in the state, but there are a diverse number of customer segments incorporating CHP. Aside from these two customer segments, 58 other facilities use CHP, including 18 commercial buildings accounting for 199 MW of capacity (Figure 3-7).

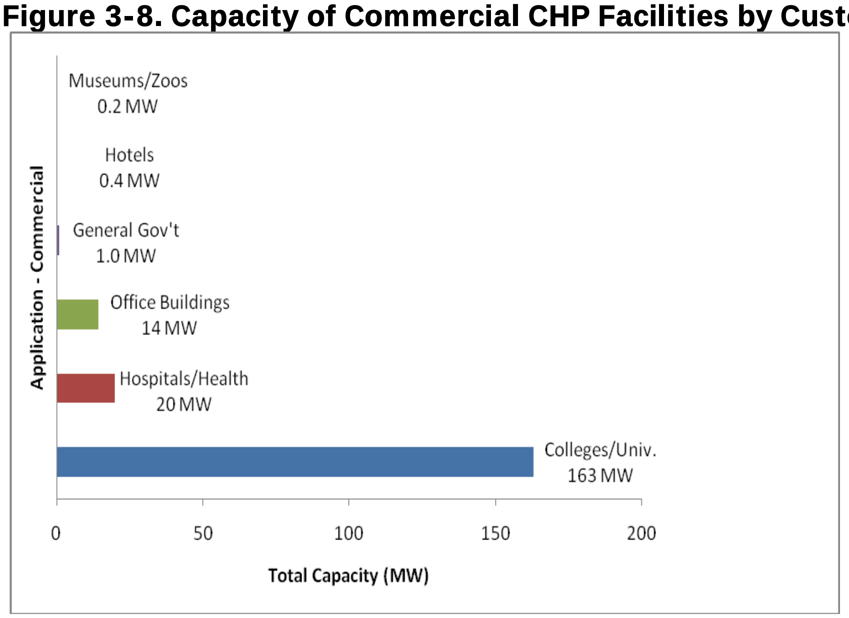
Figure 3-7. Capacity of CHP Facilities by Customer Segment



Source: Summit Blue survey of CHP facilities and U.S. DOE

Of the 199 MW of commercial CHP facility capacity in Texas, 82% is installed at colleges and universities. Another 10% of total commercial capacity is installed at hospitals or healthcare facilities, 7% is installed in general office buildings, and less than one percent of total commercial capacity is intalled at government establishments, hotels, museums, and zoos (Figure 3-8).

Figure 3-8. Capacity of Commercial CHP Facilities by Customer Segment

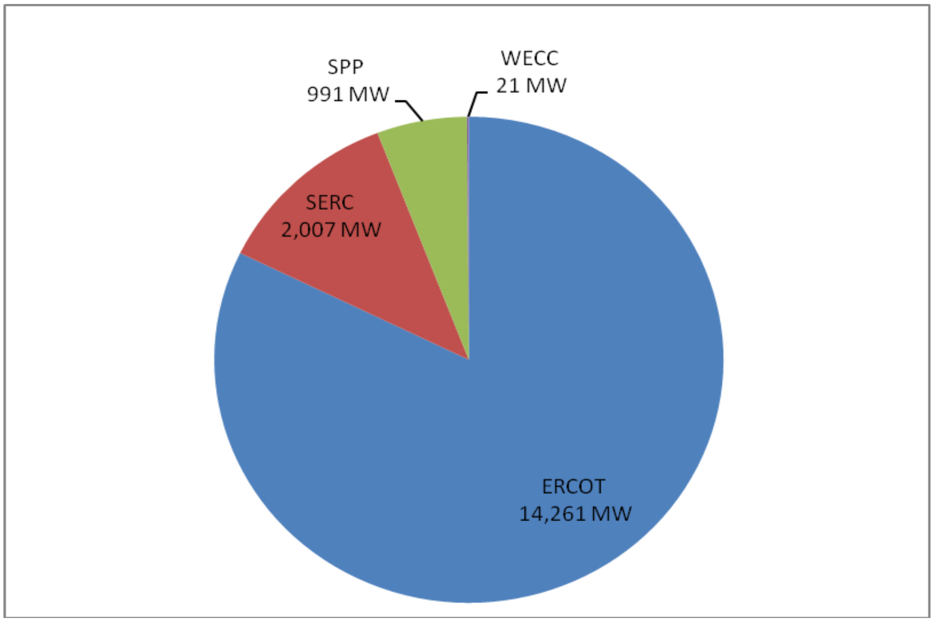


Source: Summit Blue survey of CHP facilities and U.S. DOE

NERC Region

The vast majority (82%) of CHP capacity in Texas is located in ERCOT. However, this leaves more than 3,000 MW of capacity in the other NERC regions in the state, with most installed in SERC (Figure 3-9).

Figure 3-9. Capacity of CHP Facilities by NERC Region

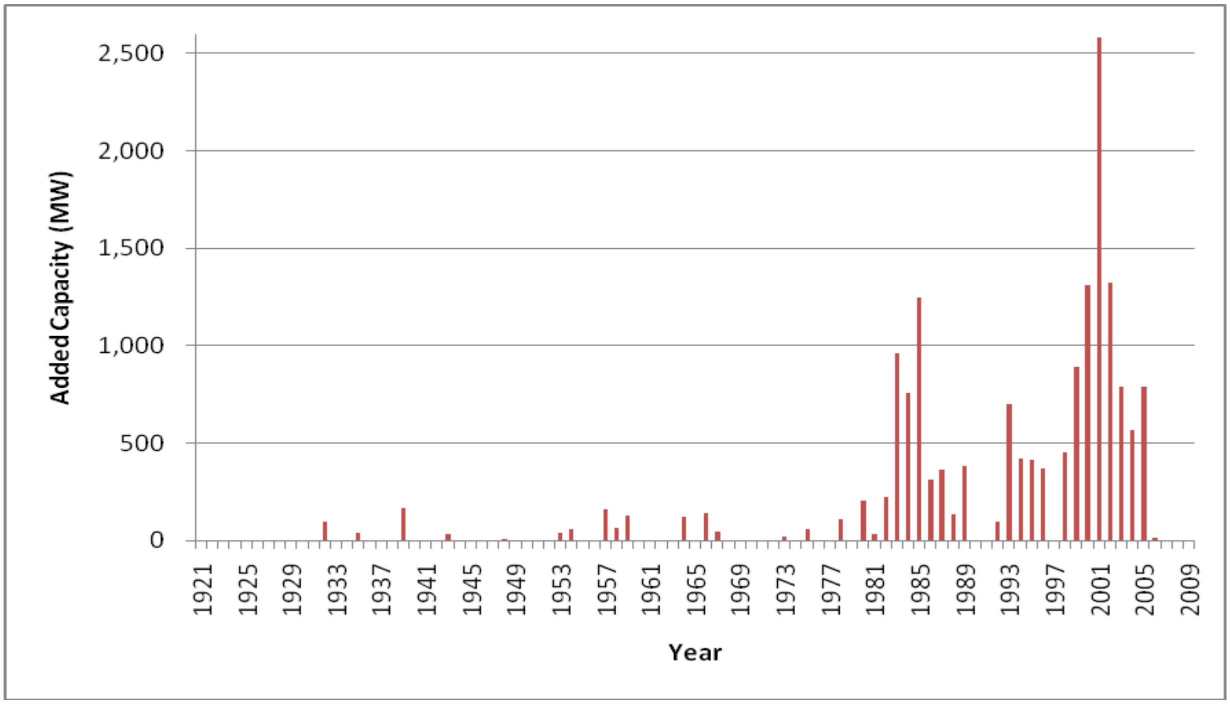


Source: Summit Blue survey of CHP facilities and U.S. DOE

Year of Operation

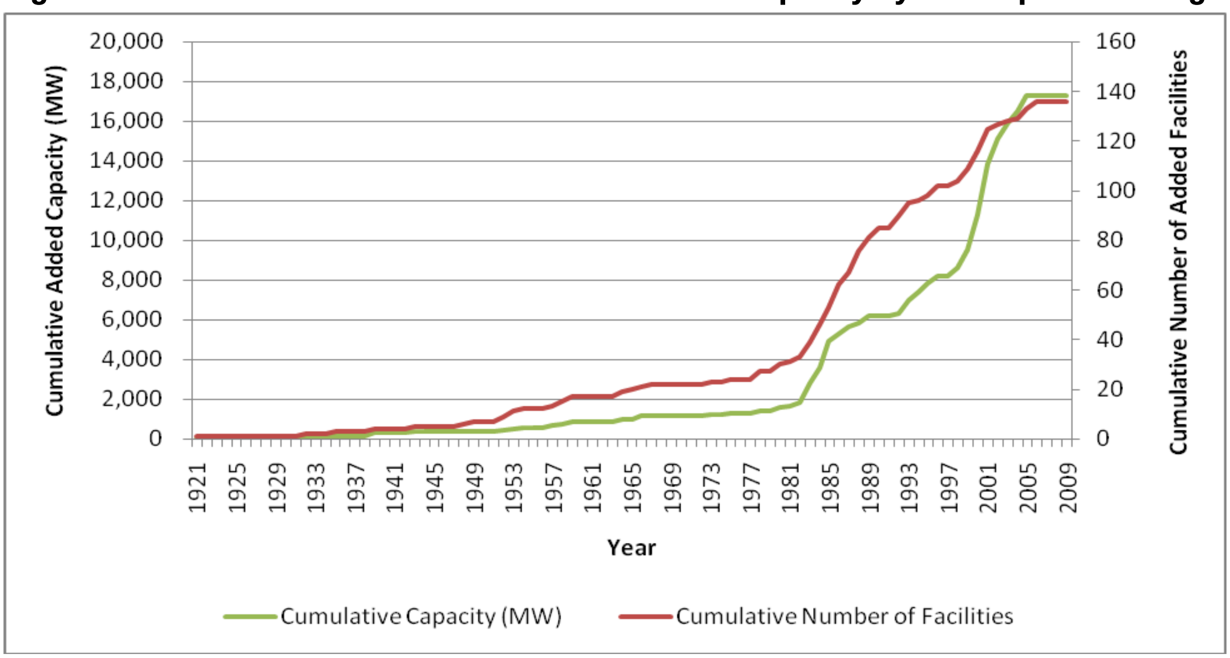
The earliest CHP facility began operating in 1921, although Texas did not see a significant increase in CHP capacity until the early 1980s. More than half of the existing CHP capacity in Texas began operating in 1998 or later. The past two years have seen a significant decline in added capacity, with no facilities beginning operations in 2007 or 2008 and only 19.6 MW (representing two facilities, not included in these results) scheduled to begin operations in 2009. Figure 3-10 shows the incremental CHP capacity added in Texas each year (based on currently operating facilities), while Figure 3-11 displays the cumulative additions of CHP facilities and capacity over time.

Figure 3-10. Annually Added CHP Capacity by Installation Year



Source: Summit Blue survey of CHP facilities and U.S. DOE

Figure 3-11. Cumulative Added CHP Facilities and Capacity by Year Operation Began



Source: Summit Blue survey of CHP facilities and U.S. DOE

4 TECHNICAL AND ECONOMIC POTENTIAL FOR CHP

This section presents the statewide technical and economic potential for CHP in Texas in 2023 (over a 15-year time horizon) and describes the approach used to develop these estimates. The technical potential estimates were developed by characterizing the statewide sectors well suited to CHP, and then sizing CHP systems in several size categories to each of these sectors. The economic potential estimates were then developed based on cost assumptions and a required benefit-cost ratio of greater than 1.0 from the customer perspective.

Today there are 135 CHP facilities in Texas with a combined capacity of more than 17,300 MW (see Chapter 3). Analysis of the potential for CHP suggests that by 2023 there could be an additional 13,400 MW of economical CHP opportunities, for a total of more than 30,000 MW. All but about 2% of the economic potential for new CHP capacity is accounted for by the industrial sector. The economic potential for new CHP from commercial facilities, while relatively small at 350 MW of additional capacity, represents nearly double the 215 MW of existing commercial-facility CHP capacity in the state.[19] These figures imply that existing CHP installations in Texas represent about 56% of the economic potential. Existing installations in the industrial sector represent 57% of the estimated potential, while the commercial sector has achieved penetration of approximately 38% of the estimated potential.

It is difficult to compare the penetration rate of economic potential between states, since economic potential depends on individual study assumptions regarding electricity prices, fuel prices, required payback periods and other factors. More reliable comparisons can be made, however, between estimates of technical potential. The estimated technical potential for CHP in Texas is approximately 16,900 MW, most of which is at mid-size to large industrial facilities that tend to have favorable economics. Thus, the state's existing 17,300 MW of installed capacity represents approximately 51% of technical potential. By comparison, California had achieved less than 25% of its estimated technical potential as of 2005 (ERPI 2005) and New York had achieved less than 40% as of 2002 (NYSERDA 2002).

4.1 Methodology for Estimating CHP Potential

This subsection briefly describes the methodology for estimating CHP potential in Texas in 2023. A more detailed description is provided in Appendix C-1. The 15-year time horizon was considered to allow Texas to develop policies to foster CHP and for market penetration to reach higher levels. The approach used the following steps:

Site and Technology Assessment	*Price Forecasting & Technology Application*	*Potential Estimation*
1. Identify Candidate CHP Host Population	4. Forecast Energy Prices	6. Estimate Technical Potential
2. Estimate Candidate Site Energy Load	5. Size CHP Systems	7. Estimate Economic Potential
3. Characterize CHP Technology		8. Conduct Key Parameter Sensitivities

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[19] For purposes of penetration rates as a share of estimated potential, the 1,304 MW of capacity not positively identified as either commercial or industrial (see Figure 3-7) was assigned proportionally to the two sectors. Thus, the 199 MW of commercial CHP capacity cited in Figure 3-7 becomes 215 MW with the addition of 16 MW allocated from the unknown category.

4.1.1 Identify Candidate CHP Host Population

The first step in the estimation process was to determine what sectors to consider as potential CHP hosts. Because the economics of CHP are typically only compelling if a system can be used efficiently throughout the year, only sites with consistent year-round heat loads were considered. These heat loads include hot water for restrooms, laundry, car washing, and kitchen; swimming pool and hot tub heating; and steam and other process heat. For the selected sectors, the statewide population and size distribution of buildings was determined. For most sectors, the U.S. Census Bureau County Business Patterns was used to obtain data; for select sectors, the study team conducted additional research to obtain this data. The sectors considered are stated in Table 4-1.

Table 4-1. CHP Candidate Commercial and Industrial Sectors

Industrial	Commercial
Apparel Manufacturing	Colleges and Universities
Beverage and Tobacco Product Manufacturing	Dormitory/Fraternity/Sorority
Chemical Manufacturing	Elementary/Middle School
Computer and Electronic Product Manufacturing	High School
Dry Mill Ethanol Plant	Hospital/Inpatient Health
Electrical Equipment, Appliance, and Component Manufacturing	Hotel
Fabricated Metal Product Manufacturing	Laundry and Car Wash Services
Food Manufacturing	Nursing Home/Assisted Living
Furniture and Related Product Manufacturing	Other Classroom Education
Leather and Allied Product Manufacturing	Prison
Machinery Manufacturing	Recreation
Miscellaneous Manufacturing	
Nonmetallic Mineral Product Manufacturing	
Paper Manufacturing	
Petroleum and Coal Products Manufacturing	
Plastics and Rubber Products Manufacturing	
Primary Metal Manufacturing	
Printing and Related Support Activities	
Textile Mills	
Textile Product Mills	
Transportation Equipment Manufacturing	
Waste Water Treatment Facility	
Wood Product Manufacturing	

For this analysis, only the application of waste heat to thermal loads, i.e., hot water, steam, and other process heat was considered. Consideration of thermally activated cooling as an application for waste heat was beyond the scope of the study, although possible impacts are discussed in Section 4.2.3.

4.1.2 Estimate Candidate Site Energy Load

For each candidate prototype CHP site (i.e., a particular business type in a particular size category), electricity and CHP-appropriate thermal loads were determined from the United States Energy Information Agency (EIA) Commercial Buildings Energy Consumption Survey and Manufacturers Energy Consumption Survey, as well as from sector-specific sources where available.

4.1.3 Characterize CHP Technology

Four CHP technologies were considered for candidate hosts: reciprocating engines, gas turbines, fuel cells, and microturbines. Of the four technologies, only microturbines have no current presence in Texas. However, microturbines do have potential niche applications such as small candidate sites for which reciprocating engines are not feasible.[20] Two of the most prevalent CHP technologies in Texas, steam turbines and combined cycle plants, were not considered, because of the assumption that these systems are relatively large (10s of MW to 100s of MW) and already exist at appropriate sites.[21] Each of the four technologies was considered in several size categories, representing the range of technologies that are commercially available.

4.1.4 Forecast Energy Prices

The EIA's Annual Energy Outlook (AEO) 2008 was used to estimate representative electricity and natural gas costs for commercial and industrial customers over the lifetime of their potential CHP systems (EIA 2008). Average forecasted costs (in real dollars) from 2009 to 2030 were used. The Electric Reliability Council of Texas provides historical electricity clearing prices, but not price forecasts, which were more appropriate than historical prices for this analysis. For this analysis, it was assumed that all candidate sites would be able to sell excess electricity at wholesale prices.[22] Wholesale electricity prices from the AEO were used as a proxy for electricity sales prices that CHP owners would receive for such exports.

Natural gas prices used in the analysis ranged from $6.08/MMBtu for industrial customers to as high as $9.99 for commercial customers not likely to receive high volume discount rates. Electricity purchase prices were assumed to be 8 cents/kWh for industrial customers to as high as 9.9 cents/kWh for commercial customers, and electricity sales on the wholesale market were assumed to be between 6.8 and 7.4 cents/kWh. As stated above, all prices are the average of forecasted prices as presented in 2008 dollars. Additional detail is provided in Appendix C-1.

4.1.5 Size CHP Systems

The Distributed Generation Technical and Economic Potential Model (DG-TEP), which had been previously developed by Summit Blue, was modified for this project and applied to the site population, energy consumption, CHP technology, and energy cost data compiled for this analysis. For each sector/size-category pair (e.g., hotels, 200 to 499 rooms), each of the four CHP technologies was sized to produce heat equivalent to the base thermal load of the site.

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[20] For example, microturbines may be appropriate if emissions restrictions prohibit reciprocating engines or if a site is not structurally capable of housing a reciprocating engine because of vibrations (*e.g.*, for roof-top applications).

[21] This assumption is supported by a comparison of the existing CHP database to the candidate site CHP count, as well as by interviews with industry experts who noted that the economics of large scale (i.e., many 10s of MW) CHP systems are fairly straightforward. Thus, a CHP potential analysis is unlikely to identify additional potential projects of these types. Results of the analysis, discussed in Section 4.2, further support this contention, as more than 90% of the technical potential (which is largely independent of technology type) of sites larger than 10 MW was found to be economic, even considering only the four technologies employed in the analysis.

[22] This is typically the case for CHP sites in Texas because much of the state operates under a competitive electricity market.

For each system at each sector/size category pair, energy and economic parameters were computed. The electrical efficiency and electric-to-thermal ratio, along with estimates of the usable percentage of potential thermal and electrical output (due to daily and seasonal variation in load below the assumed baseload level), were used to estimate the fuel consumption, electric and thermal load offsets, and electric export quantities. Finally, the study team used energy prices and CHP capital cost, operation and maintenance cost, and equipment lifetime to estimate two key economic metrics for each candidate sector/size-category/CHP-technology combination: the simple payback period and the net present value benefit to cost ratio.[23] While these economic metrics were not used to size CHP systems, they were used in the technical and economic potential estimates that follow.

4.1.6 Estimate Technical Potential

Technical potential is defined here as the electrical capacity of CHP systems that are technically possible. The technical potential for CHP was determined by assigning portions of the CHP potential to the competing CHP technologies for each sector/size category pair (e.g., hotels, 200 to 499 rooms). For sites where more than one CHP technology could be adopted, the simple payback periods of competing technologies were used to determine what portion of candidate host sites would be assigned to each of the competing technologies: the lower the payback period, the larger the share of sites any particular technology received.[24] Dividing the share of CHP potential among competing technologies reflects real-world adoption patterns, where factors outside of the consideration in this model result in a range of technology adoptions; the technologies with the most compelling economics tend to dominate the market, however.

This approach to dividing technical potential amongst competing technologies presents the counterintuitive result that the technical potential *changes* under different scenario assumptions. For example, gas turbines have an electric-to-thermal (E/T) ratio of approximately 0.65 and reciprocating engines have an E/T ratio of approximately 1.05. This means that, for a given output of thermal energy, reciprocating engines produce almost twice as much electricity as gas turbines. If systems are sized to the thermal load of the site, and if Scenario A favors gas turbines and Scenario B favors reciprocating engines, then Scenario A will result in a smaller technical potential in terms of electrical capacity relative to Scenario B. Note that the *thermal* output capacity of the technical potential in all scenarios stays constant.

The EIA ERCOT annual load growth forecast of 1.1% for the years 2009 to 2030 was used to extrapolate the results from current data to the 2023 estimation year potential results. This 15-year time horizon was considered to allow Texas to develop CHP policies and for market penetration to reach higher levels.

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[23] This is the Participant Test benefit/cost ratio, as defined in the *California Standard Practice Manual: Economic Analysis of Demand-Side Programs and Projects*, (CPUC 2001).

[24] For a particular candidate site (e.g., Hotels, 200 to 499 rooms), competing technologies received a score of

$$\left(\frac{1}{PaybackPeriod}\right)^2$$

and the number of candidate sites was assigned proportional to these scores, adding up to the statewide number of candidate sites. This is similar to the approach used in Elliot, R. Neal, et al., *Potential for Energy Efficiency, Demand Response, and Onsite Renewable Energy to Meet Texas's Growing Electricity Needs*, American Council for an Energy Efficient Economy, ACEEE Report Number E073, March 2007.

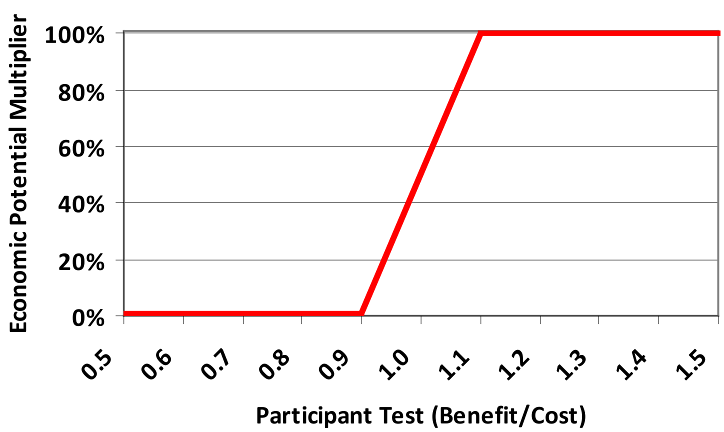
4.1.7 Estimate Economic Potential

A benefit/cost ratio from the operator perspective was used to determine whether a particular system was economic. *Benefits* are the sum of fuel and energy savings, revenue from electricity sales, and subsidies received for the CHP system. *Costs* are the sum of capital, operation and maintenance, and fuel costs for the CHP system. All benefits and costs are calculated over a 10- to 20-year period (depending on the expected lifetime of the equipment) beginning in 2009, with annual values discounted to 2008 dollars at a 6.4% real discount rate.

Any system with a benefit/cost ratio greater than one is considered economic. However, a modification to this approach was made in order to account for the aggregate nature of the facility data used in the model and to avoid rejecting a whole category of facilities for falling just short of the economic threshold. Thus, any system with a benefit/cost ratio less than 0.9 was assigned no economic potential; and system with a benefit/cost ratio greater than 1.1 was assigned 100% economic potential (i.e., 100% of technical potential was economic); and any system with a benefit/cost ration between 0.9 and 1.1 was assigned an economic potential that varied linearly from 0% (for a benefit cost ratio of 0.9) to 100% (for a benefit cost ratio of 1.1). This is illustrated in Figure 4-1.

Note that economic *potential* simply gauges whether or not a project meets a specific economic criteria. This is different than *market* potential, which considers additional factors, such as perceived risk, competing technologies and practices, and penetration rates. Market potential was not addressed in this analysis.

Figure 4-1. Percentage of Technical Potential that is Economic as a Function of Benefit / Cost Ratio



4.1.8 Conduct Key Parameter Sensitivities

Several scenarios were considered to examine the sensitivity of results to variations in key parameter assumptions. The parameters that varied were natural gas prices, electricity prices, capital cost, $/kW CHP subsidies, and the assumed discount rate. Table 4-2 states the scenarios considered and parameter adjustment values for each scenario.

Table 4-2. Sensitivity Analysis Scenarios

Scenario	Difference from Base Case	Description
Base Case		*See above and Appendix C-1*
Low Gas Cost	-25%	decrease from base case gas cost
High Gas Cost	+50%	increase from base case gas cost
Low Electricity Cost & Market Price	-15%	decrease from base case values
High Electricity Cost & Market Price	+50%	increase from base case values
Low Capital Cost	-20%	decrease from base case capital cost
High Capital Cost	+20%	increase from base case capital cost
Low Subsidy	$100	$/kW decrease from base case capital cost
High Subsidy	$500	$/kW decrease from base case capital cost
Low Discount Rate	-2%	Decrease from base case discount rate of 6.4%
High Discount Rate	+2%	Increase from base case discount rate of 6.4%

4.2 Estimates of Technical and Economic Potential

The analysis described in this section concludes that nearly 17 GW of additional CHP capacity is technically feasible by 2023 in the base case, both from existing sites and from anticipated load growth over the next 15 years. This technical potential is roughly equal to the existing CHP in Texas, implying that the capacity for CHP in Texas has the potential to double by 2023. Of this technical potential, more than 13 GW, or 80%, is economic. Economic potential is significantly less in the high gas and low electricity price sensitivities.

4.2.1 Base Case Results

Figure 4-2 and Table 4-3 show the technical and economic potential in the base case, disaggregated by CHP system size and by commercial/industrial distinction. Of the roughly 17 GW of technical potential in 2023,[25] 89% (15 GW) is from the industrial sector and 11% (2 GW) is from the commercial sector. Eighty percent of the technical potential is economic (13 GW). Nearly all (98%) technical potential for systems larger than 10 MW is economic, while 86% of technical potential for systems between one MW and 10 MW is economic, and only 25% of technical potential for systems less than one MW is economic. This difference is reflective of the economies of scale with larger systems.

[25] The 16.9 GW of technical CHP potential is slightly higher than the value of 14 GW found in a recent study of the potential for energy efficiency and distributed renewable energy to meet Texas' future electricity needs (ACEEE 2007).

Figure 4-2. Base Case Technical and Economic Potential in 2023

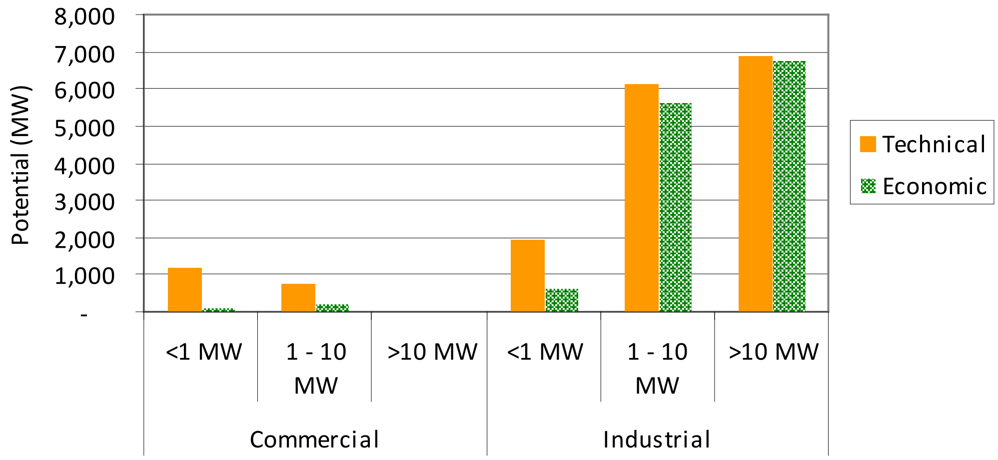
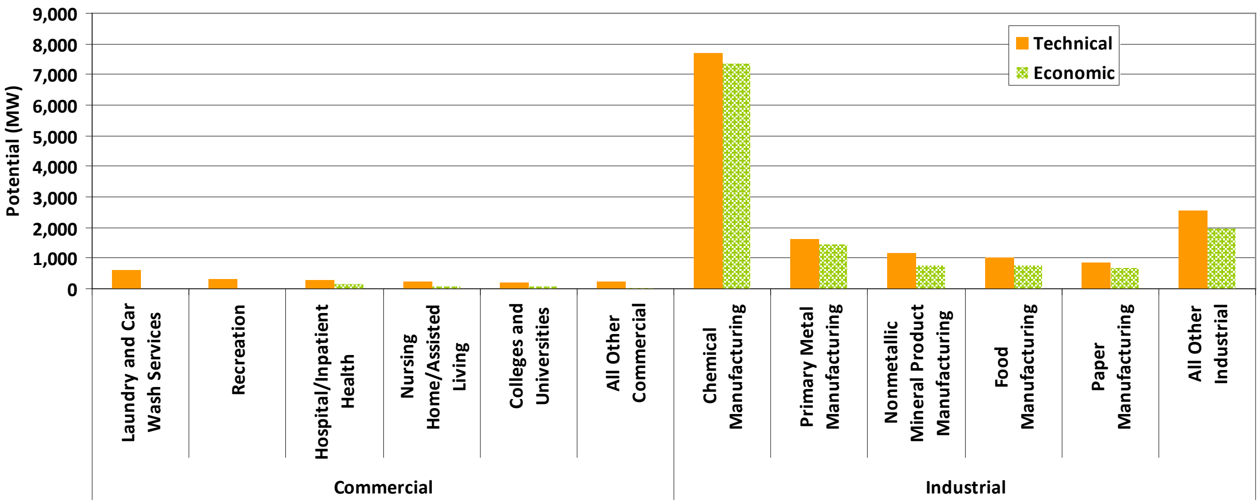


Table 4-3. Base Case Technical and Economic Potential in 2023

		Technical	Economic	% Economic
Commercial	**<1 MW**	1,172	110	9%
	1 - 10 MW	752	240	32%
	>10 MW	0	0	n/a
Total Commercial		***1,924***	***350***	***18%***
Industrial	**<1 MW**	1,959	668	34%
	1 - 10 MW	6,102	5,630	92%
	>10 MW	6,874	6,759	98%
Total Industrial		***14,935***	***13,057***	***87%***
Commercial and Industrial	**<1 MW**	3,131	778	25%
	1 - 10 MW	6,855	5,870	86%
	>10 MW	6,874	6,759	98%
Total Industrial and Commercial		***16,859***	***13,407***	***80%***

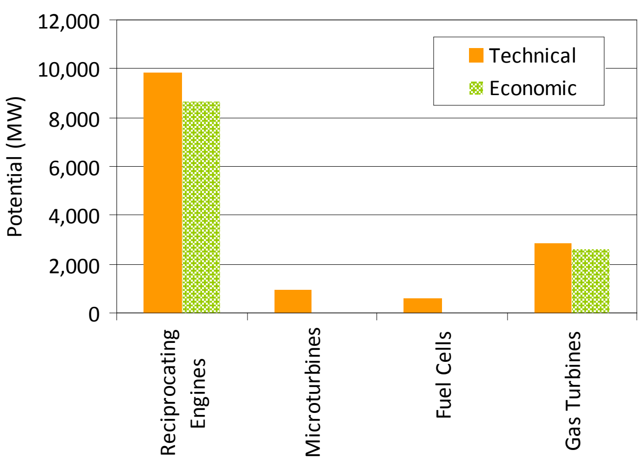
A small number of sectors dominate the potential estimates. In the industrial sectors, 52% of all technical potential is in the chemical manufacturing sector, followed by primary metal manufacturing (11%), nonmetallic mineral product manufacturing (8%), food manufacturing (7%), and paper manufacturing (6%). In the commercial sector, 32% of all technical potential is in laundry and car washes, followed by recreation (18%), hospital/inpatient health (14%), nursing home/assisted living (13%), and colleges and universities (11%). Figure 4-3 shows these results graphically.

Figure 4-3. Base Case Potential by Sector



Reciprocating engines are the dominant technology, and account for 69% of all technical potential in the base case. Another 20% of this technical potential is from gas turbines. Fuel cells and microturbines account for 11% of the technical potential. In the base case, most of the reciprocating engine and gas turbine systems are economic, where as virtually none of the microturbine or fuel cell systems are economic.[26] These results are shown graphically in Figure 4-4.

Figure 4-4. Base Case Potential by Technology Type

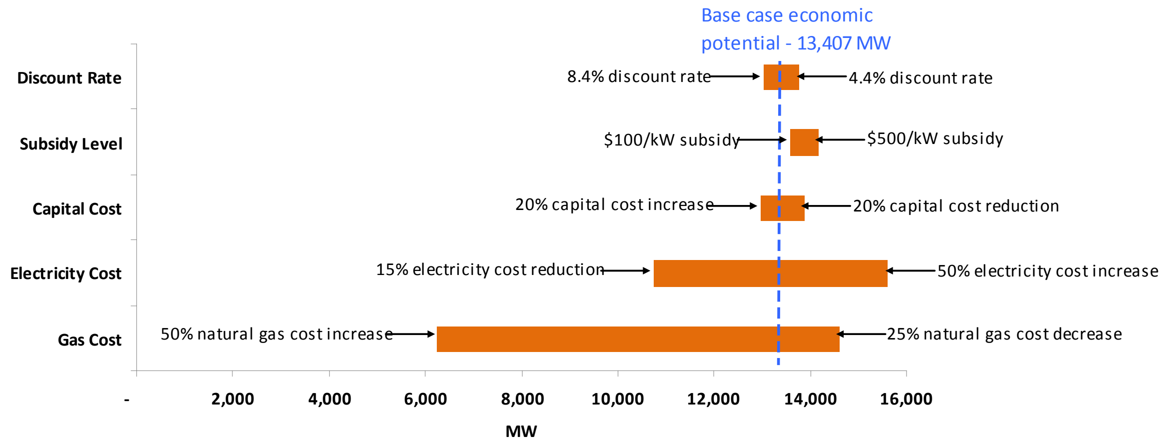


[26] In this case, assigning some of the technical potential to uneconomic technologies does not understate the economic potential; microturbines and fuel cells are assigned some technical potential primarily in smaller sized systems. In reality, some of these candidates would not be able to house reciprocating engines, the competing, economic technology because emissions restrictions or structural limitations (i.e., reciprocating engine vibration might be unacceptable). In those cases, there would be technical potential for these alternative technologies (microturbines and fuel cells), but not much economic potential.

4.2.2 Results from Sensitivity Analysis

Economic potential is most sensitive to gas costs, followed by electricity prices. Economic potential decreases dramatically in the high gas cost sensitivity to only 46% of the base case value, illustrating the significance of natural gas price uncertainty on exposure to risk for a long term investment such as CHP. Similarly, the next most significant impact on results is the low electricity cost sensitivity, which reduces the economic potential by 20%. Results from the other sensitivities illustrate that the model results are fairly consistent with changes in capital cost, subsidies, and discount rate. High level results for economic potential of all the scenarios are presented in Figure 4-5. More detailed results for each scenario are presented in Appendix C-2.

Figure 4-5. Economic Potential under Various Sensitivity Cases



Source: Summit Blue Consulting

Sensitivity parameters are not independent of one another. A plausible future scenario is that both gas costs and electricity prices will be high, since electricity prices are largely driven by marginal fuel costs for natural gas, and future regulation of carbon emissions could raise fuel costs above current projections. Under this high/high cost scenario, economic potential is estimated at nearly 14,700 MW, or nearly 10% above the base case.

One significant finding from the capital cost sensitivities and capital subsidy sensitivities is that large CHP systems (greater than 10 MW) are almost always economic (98% of all technical potential in this size range is economic in all of the capital cost and subsidy sensitivities). Similarly, most technical potential between one and 10 MW is economic in all cases (ranging from 81% for the high capital cost sensitivity to 89% in the high subsidy sensitivity). However, *the economic potential of small systems of less than one MW is highly sensitive to capital cost,* as illustrated in the following examples:

- In the base case, 21% of the technical potential from small facilities is economic;
- But when capital costs are high, this figure drops to only 13% (i.e., the economic potential drops by more than one-third); and
- And when high subsidies are considered, the economic potential increases to a 38% of the technical potential (Table 4-4).

Furthermore, small systems under one MW and commercial facilities of all sizes become significantly more economical with lower capital costs. Relative to the base case, the economic potential of small systems rises by 62% with a $500/kW subsidy (from 778 MW to 1,264 MW). Similarly, the economic potential of commercial facilities of all sizes is increased by 51% (from 350 MW to 528 MW) under this high subsidy scenario. These figures are not large relative to the potential from mid-sized and large industrial facilities, but they represent a significant increase in capacity from a segment of the customer population that today represents only about 2% of installed CHP capacity.

These findings suggest that if CHP is to be encouraged, subsidies would best be targeted at the smaller – typically commercial – sites. This finding is supported by the majority of interviews conducted for this study, which generally suggest that, in large facilities, CHP is much more likely to enjoy favorable economics.

Table 4-4. Percent of Technical Potential that is Economic in Sensitivities that Affect Capital Costs

	<1 MW	1 - 10 MW	>10 MW	Total
Base Case	21%	84%	98%	78%
Low Capital Cost Sensitivity	30%	88%	98%	82%
High Capital Cost Sensitivity	13%	81%	98%	75%
Low Subsidy Sensitivity	24%	85%	98%	79%
High Subsidy Sensitivity	38%	89%	98%	83%

4.2.3 Topics for Additional Consideration

Several simplifying assumptions used in this analysis are worth discussion, and might warrant development of a more detailed analysis if more precision is desired.

Thermally Activated Cooling

Combined heating, cooling, and power applications (e.g., winter and summer space conditioning in office buildings and retail space) would increase both the number of potential host sites and the size of potential systems at host sites. Combined cooling and power applications (such as refrigerated warehouses and data centers) would further add to the potential.[27] While thermally activated cooling applications would

[27] Elliot, R. Neal, et al., Potential for Energy Efficiency, Demand Response, and Onsite Renewable Energy to Meet Texas's Growing Electricity Needs, American Council for an Energy Efficient Economy, ACEEE Report Number E073, March 2007: including thermally activated cooling applications increased the technical potential 51%, relative to technical potential from only traditional heating CHP applications (from 9,681 MW to 14,366 MW). This

increase the technical potential for CHP, it is not expected to increase the economic potential, as thermally activated cooling has generally not proved cost- or energy-efficient (relative to combined cycle plants from the grid) in Texas. In the commercial sector, the cooling season is simply too short for space conditioning to be a viable application, and even for consistent cooling loads, the grid may be more efficient than CHP systems at providing an equivalent amount of electricity and cooling (the grid via an electrically driven compression chiller and the CHP system via an absorption or adsorption chiller).

Regional Differentiation

This analysis did not account for regional differences in energy costs and in building populations across the state. Populations of buildings, particularly industrial buildings, will vary by region. To the extent that this is correlated with differences in energy prices in the state, a more precise model would be possible. However, the deregulated electricity market in Texas has resulted in customers paying many different rates for electricity in a given region, which would be difficult to model.

New Construction vs. Existing Buildings

The technology cost information used in the DG-TEP model is the average system cost information for a range of sites, including new construction and existing buildings. However, CHP costs for new construction would most likely be less than those for existing buildings; it costs less to accommodate a system in the planning stages of a site than to alter the site after it has been built. Additionally, the likelihood of a system being adopted at a new site is greater than that at an existing site, because the new site can be designed to accommodate CHP from the start, whereas developing a CHP system at an existing site may be discouraged by the added cost and complexity of reworking thermal systems and site configuration. However, recent releases of smaller, packaged CHP units allow for easier integration into existing facilities.

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suggests that there might be an additional 8.7 MW of technical potential unaddressed in our analysis. However, it is unlikely that a significant share of this technical potential would be economic.

5 INVESTMENT ENVIRONMENT FOR CHP

Private companies and municipal governments in Texas have invested in CHP to a degree beyond what has occurred anywhere else in the country. More than 17,300 MW of CHP capacity is in operation throughout the state, accounting for nearly 20% of the electricity generating capacity in Texas and roughly 23% of all CHP capacity nationally.[28] One reason for this large-scale investment in CHP is the prevalence of large industrial facilities, such as chemical manufacturing and petroleum refining that have both large electrical loads and a need for thermal energy.

The passage of the federal Public Utility Regulatory Policies Act (PURPA) in 1978 created a market for non-utility electric power producers by requiring electric utilities to buy power from these producers at their "avoided cost," which was the cost the electric utility would incur were it to generate or purchase from another source. PURPA enhanced the economics of CHP by granting qualifying facilities the option to sell power to the local utility company. This enabled companies to develop onsite cogeneration capability large enough to serve their thermal loads, even if this resulted in surplus generating capacity. As a result, installed CHP capacity grew from roughly 2,000 MW in 1982 to more than 6,000 MW by 1987. Slow, but steady, growth in the industry followed through the late 1990s before CHP capacity jumped from about 9,000 MW to more than 17,000 MW between 1998 and 2005. Investment in CHP began slowing as early as 2002 and there has been little change in capacity since 2005.

One possible reason for the recent decline in CHP investment is that the Texas restructured market eliminated the requirement that the host utility purchase excess power generated by a CHP facility. In the ERCOT region, a CHP facility has the opportunity to sell into the ERCOT electricity and ancillary service markets, but the prices can be highly variable. This introduces an uncertainty into the economics of building the facilities because the CHP operator must sell into a market with a volatile price or find purchasers that agree to long-term contracts with greater pricing certainty. The PUC also changed the avoided cost calculation used to price the CHP power in the non-ERCOT areas in 2004, which made the economics of CHP facilities less attractive. Another likely reason for the decline in investment is the sharp rise in natural gas prices, and gas price volatility, that began in 2000 and that has increased the risks for investment in CHP. More than half of the survey respondents cited high gas prices as a barrier to further investment.

Various regulatory issues and business considerations contribute to the current environment for CHP investments in Texas. The remainder of this chapter discusses the regulatory landscape surrounding CHP, efforts by government and industry to promote CHP, and the barriers faced by companies considering investment in CHP operations.

5.1 Regulatory Landscape

A company's decision to invest in CHP likely will be driven by a combination of factors, including the desire for reduced energy costs, the added reliability of power supply, and other non-economic benefits provided by efficient, onsite generation (see Chapter 2). Beyond these business-related issues, the

[28] This study identified roughly 17,300 MW of CHP installations in Texas (see Chapter 3), and the state has approximately 100,000 MW of summer capability (EIA 2007a). Texas' share of U.S. CHP capacity was derived from data provided in EIA 2007b.

regulatory environment in which the facility will operate can also be critical driver of investment decisions. Regulatory issues encompass both the regulatory *requirements* that must be met (e.g., rules for air permitting, interconnection rules, and wholesale power transactions) as well as regulatory *promotion of CHP*, which could include policies such as the provision of financial incentives for investment or mandates for the state to achieve a minimum level of CHP capacity (HB 2178, 2007).

There is no single regulatory policy governing CHP, but many individual regulations affect CHP projects indirectly and, in some cases, explicitly. For example, deregulation of the electric industry introducing a competitive market in much of ERCOT only indirectly affects CHP by affecting the ability of CHP (and other non-utility generation) facilities to sell surplus power; and the rules for interconnection of distributed generation apply to CHP facilities despite the fact that "CHP" is not explicitly addressed. Conversely, the air permitting regulations that apply to electric generators include an *explicit* reference to an emissions credit given to CHP facilities (TCEQ 2007).

Restructuring of the Texas Electricity Market

Competition in the retail electric industry was introduced for most of Texas in 2002.[29] Under the new rules, there are no longer vertically integrated utilities performing generation, transmission, delivery, and billing functions (Power to Choose 2008). The utilities were "unbundled" into three entities:

1. Power Generation Companies, which own and operate power plants, generating most of the electricity consumed in the state;

2. Retail electric providers (also known as "REPs"), which purchase electricity from the power generation companies or other sources and sell it to customers. REPs are the only entities authorized to sell power to the end users, and REPs administer customer service and billing functions as well; and

3. Transmission and Distribution Service Providers (TDSPs), which are responsible for the actual delivery of electricity to customers. These are the regulated utilities that previously performed all electricity related functions. The TDSPs work through the REPs and only interface with the end users in the case of power outages.

The attractiveness of CHP may vary depending on whether a customer is in the restructured portion of ERCOT or whether they are served by an entity not subject to all of the restructuring rules, such as a municipal utility, electric cooperative, or a regulated non-ERCOT utility. In the restructured market, a facility with CHP does not have assurance that it can sell surplus power at a fixed price, and smaller facilities in particular may have little leverage with REP to market this surplus. On the other hand, a CHP facility can sell into the energy and capacity markets operated by ERCOT and, in times of extreme price volatility, self-generators can sometimes benefit from high market prices. In the service territories that are not subject to competition, CHP facilities enjoy a regulatory guarantee to sell surplus power at avoided cost, but they may encounter greater difficulties interconnecting with the electric grid of a utility that also owns generation that would compete with the new CHP capacity.

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[29] Not all areas in Texas are open to competition, including the areas served by Entergy Gulf States, Southwestern Public Service Company, El Paso Electric Company, and AEP SWEPCO. Furthermore, electric cooperatives and city-owned utilities are not required to provide customers with a choice of electric provider.

Air Permitting

The Texas Clean Air Act, contained in Chapter 382 of the Texas Health and Safety Code, requires that any stationary source that emits air contaminants obtain an air permit. Therefore, virtually all CHP projects must obtain a permit from the Texas Commission on Environmental Quality (TCEQ).[30] The four main air permit options for CHP facilities are as follows (Linville 2008; TCEQ 2007):

1. **Standard Permit for Electric Generating Units –** This permit applies to electric generating units installed or modified after June 1, 2001. It offers relatively quick and low-cost permitting, especially for units under one MW. The standard permit rule also contains provisions that allow CHP facilities to more easily meet nitrogen oxide (NOx) emissions requirements (see below).

2. **Permit by Rule** applies to emergency generators, engines and turbines, and other combustion devices that do not generate electricity. This permit is also relatively inexpensive and quick to obtain, but it has had limited use for the CHP project since introduction of the standard permit.

3. **New Source Review Permit** applies to all sources that do not qualify for other permit options for reasons such as exceeding emissions limits or being classified as major stationary sources under the federal Prevention of Significant Deterioration regulations.

4. **A boiler permit** may also be required for projects that are operating with a boiler/steam turbine configuration.

Emissions limitations under the Standard Permit account for regional differences, requiring lower emissions rates in areas of the state that have experienced significant air quality issues. Other factors contributing to allowable emissions rates are the capacity of the unit (stricter limits above 10 MW), the age of unit (stricter limits after January 1, 2005), and the hours of operation (stricter limits above 300 hours per year).

The standard permit enables CHP facilities to more easily meet NOx emissions limits by offering credit for the heat recovered from the exhaust of the combustion unit. The emissions limits are designated in terms of pounds of NOx per MWh generated, and credit is offered at a rate of one MWh for each 3.4 million BTUs of heat recovered. The result is to reduce the calculated emissions rate for purposes of compliance with the regulation. In order to receive credit, the owner or operator must: 1) provide documentation on the generating unit and CHP operations, and 2) recover heat equal to at least 20% of the total energy output of the CHP unit.

The result of the emissions credit is to level the playing field for CHP by effectively regulating NOx emissions based on the total energy output rather than solely on the electricity output. This removes what would otherwise be a disadvantage for CHP relative to facilities that only generate electricity. The issue has been raised by some parties that CHP units should not be regulated as electric generating units,

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[30] If the CHP project is added to an existing facility that is already authorized, it may not require further authorization. It would only require a permit if there are additional emissions associated with the CHP. Adding CHP to an existing turbine with no supplemental firing (duct burners) likely would have no increase in emissions and would therefore not be a source of emissions requiring a permit. The original authorization for the turbine may need to be reviewed to ensure the impacts do not significantly change and require review because of the lower stack temperature.

especially the smaller units that generate primarily for onsite use and that cannot economically incorporate the sophisticated emissions controls that larger generating stations often employ (TX CHIP 2007).

Interconnection

For most of the history of the electric industry in Texas, vertically integrated utilities owned generation sources as well as the transmission and distribution systems into which the generators connected. The issue of interconnection by non-utility-owned generators grew in significance after the passage of PURPA in 1978 and it became an essential component of the competitive wholesale market after deregulation in Texas in 1995. In order for competition to work, power generation companies needed easy access to the transmission lines owned by the TDSPs in order to deliver electricity to customers.

Prior to deregulation, there was relatively little regulatory guidance regarding utilities' acceptance of interconnection requests, and interconnection was perceived as a significant barrier to a robust wholesale market for power. This barrier applied to distributed generation sources as well, including CHP, especially for smaller facilities that did not possess the experience or expertise in the electric industry.

The interconnection process that a CHP unit must use depends on the size of the plant. If the unit is less than or equal to 10 MW, the unit may interconnect as a distributed generation unit. For units greater than or equal to 10 MW, the unit must submit a request to interconnect to the grid to ERCOT. The timeline for an interconnection study can range from 52 to 440 days. The fees required for interconnection include a Security Screening Study fee of $1,000 to $5,000 and a Full Interconnection Study fee of $15/MW and a $15,000 or $30,000 deposit (ERCOT 2004). Utilities outside of ERCOT are subject to FERC regulations that establish interconnection procedures, and CHP units have the same right to interconnect.

For units less than or equal to 10 MW, the unit may interconnect as a distributed generation unit. In 1999 the PUCT adopted news rules governing the interconnection and parallel operation of distributed generation (PUCT 1999) that largely alleviated the problems encountered previously. The rules were intended "to clearly state the terms and conditions that govern the connection and operation of small power generation and to establish technical requirements to promote the safe and reliable operation of distributed generation resources." Three years later, the Commission published the *Distributed Generation Interconnection Manual* to provide further guidance on the "inclusion of distributed generation into the Texas electric system" [and] "to encourage the use of distributed resources." The intent was to simplify the interconnection process, including the required hardware and the contractual relationships between the utilities and the parties seeking interconnection. The *Manual's* guidance on the engineering analysis for interconnection requests serves "to ensure that TDU interconnection analyses of the impacts of distributed generation are conducted in a clear, unbiased and consistent manner, irrespective of the TDU, the DG technology, or the applicant" (PUCT 2002). Over the period from 2002 to 2007, small distributed generation in Texas increased from 220 MW to 409 MW, according to utility reports filed at the PUCT (PUCT 2008c). The passage of HB 3693, regarding net metering, may have some affect on interconnection of small units (see below).

Three specific advantages offered to CHP by the distributed generation interconnection rules are the following:

1. *Ease of interconnection*: For smaller units, the rules and interconnection manual help streamline the process and provide comparable application complexity for project complexity.
2. *Low costs*: Interconnection study fees range from $0-$5,000 and vary by TDU, size and characteristics, amount of energy exported to the grid, connection to a radial or networked system, and pre-certification.

3. *Short timeline*: TDU approves or rejects applications within four to six weeks. Time may be longer depending on complexity of pre-interconnection studies.

P.U.C. SUBST. R. 25.11(1) requires that the T&D utility designate a single contact to aid in all matters relating to the interconnection process, which is described in Table 5-1 for distributed generation resources.

Table 5-1. Distributed Generation Interconnection Procedures for Texas

Step 1	Filing of an application by the DG applicant with the TDU
Step 2	TDU review of the application
Step 3	Response specifying the requirements for further study, if needed, and the technical requirements to interconnect
Step 4	Approval of an agreement between the DG applicant and the TDU
Step 5	Connection, testing and operation of the DG project

Source: PUCT 2002

5.2 Promotion of CHP

Various governmental entities and industry groups have promoted CHP through regulatory support, advocacy, and direct technical assistance. Some of these efforts are discussed below.

CHP Inclusion in the Energy Efficiency Goal

Since 2002, the regulated TDSPs have been directed by the PUCT to meet an energy efficiency goal of a 10% reduction in the growth of electricity demand. The TDSPs were authorized to provide financial incentives for qualifying energy efficiency measures. In 2008, the PUCT implemented the rules that reflected an increase in the goal to 20%. These amendments also specifically allowed for incentives to be provided for CHP technologies. Specifically, a new rule states that standard offer and market transformation programs "may permit the use of renewable DSM and *combined heat and power technologies*, involving installations of ten megawatts or less" (PUCT 2008a).

CHP Resource Portfolio Standard Legislation

House Bill 2178 was introduced by Rep. Deshotel in February 2007. This bill was "relating to the legislature's goal for electric generation capacity using combined heat and power technology." This bill was not enacted.

The legislation aimed to amend the Utilities Code by adding a section with four main provisions: (1) defining "combined heat and power technology;" (2) setting a goal of 21,000 MW of installed CHP capacity by January 1, 2016; (3) establishing a CHP credits trading program in order to assist the utilities in meeting the CHP goal; and (4) adopting rules to administer the section including setting the requirement for each REP, municipal utility, and electric cooperative and specifying reasonable performance standards for CHP installations (HB 2178, 2007).

The Gulf Coast Combined Heat and Power Application Center

The Gulf Coast Combined Heat and Power Application Center was established and funded by the U.S. DOE to promote the use of CHP in three Gulf Coast states, including Texas. It is located within the Houston Advanced Research Center (HARC). The Center is an information clearinghouse that provides technology reviews, case studies, and project development advice with the objectives of reducing the perceived risk of CHP to users and fostering CHP as a viable technical and economic option for customers. Their mission is "to help the DOE double the nation's CHP capacity from an estimated 46 GW to 92 GW by 2010 by being a champion for CHP in Louisiana, Oklahoma, and Texas." However, federal funding for the Center has declined in recent years.

The Texas Combined Heat and Power Initiative

The Texas Combined Heat and Power Initiative (TX CHPI) is a non-profit organization supporting CHP in the state. Their mission is to "champion combined heat and power as the most effective, economical, and environmentally-sensible energy option for Texas." TX CHPI's main objective is to provide education and resources to those interested in CHP.

5.3 Barriers to CHP

The benefits of CHP to customers, distribution utilities, and the environment are well documented and were discussed in Chapter 2. Despite the benefits, however, investment in CHP has slowed considerably in recent years and a variety of economic and other factors could prevent significant expansion of CHP capacity in the state for the foreseeable future. The barriers to increased adoption of CHP in Texas are addressed in the remainder of this chapter. This discussion is based on numerous sources including the following:

- Surveys of 32 Texas commercial and industrial customers operating, or who have recently operated, facilities using CHP (see Appendix A-1);
- Interviews with more than a dozen Texas utilities, industry associations, and other stakeholders who are involved in CHP development, interconnection, and policy (see Appendix A-2); and
- Research studies, policy papers, and articles by a variety of organizations and individuals on status of and prospects for CHP in Texas and the United States.[31]

Some of these barriers are universal in nature and apply generally to Texas, as well as to other states, regardless of the status of electric restructuring, the makeup of the customer base, or other factors specific to any single jurisdiction. Other barriers, and the policy options for overcoming them, are a product of the investment and regulatory environment in Texas discussed earlier in this chapter. For example, the competitive market that exists in much of the state affects the economics of CHP in ways that are not applicable in jurisdictions where vertically integrated utilities are fully regulated. Likewise, some recently enacted policies in Texas, such as the streamlined air permitting process and the interconnection guidelines for distributed generators, have at least partially removed barriers that might exist to a larger degree in other states.

The following discussion of barriers to CHP in Texas is organized into the following categories:

1. Economic barriers;
2. Regulatory barriers; and

[31] Unless otherwise noted, information on each of the barriers identified in the remainder of this chapter was obtained from one or more of the following sources: Houston Advanced Research Center (Bullock and Weingarden 2006), Texas CHP Initiative (TX CHPI 2008a), and Western Governors Association (WGA 2006).

3. Business/operational barriers.

Many of the issues cross over between these arbitrary categories, but this organization provides a useful framework for discussion. A summary of the barriers is provided in Table 5-2.

Table 5-2. Summary of Barriers to CHP Development

Economic Barriers

- High capital costs
- High operating costs
- Rise and volatility of natural gas prices

Regulatory Barriers

- Grid interconnection
- Permitting
- Wholesale market rules

Customer and Stakeholder Barriers

- Limited on-site space and suitable loads
- Lack of management support
- Lack of technical expertise
- Conflicts between stakeholder goals

5.3.1 Economic Barriers

Expansion of the market for CHP depends on the ability of customers to achieve a reasonable return on their investment. The potential benefits provided by CHP, such as independence from grid power, may lessen the economic threshold relative to other investments that a company makes. However, CHP is generally considered to be a long-term investment with a payback greater than the three years that CHP project developers typically use as a threshold for an acceptable return on investment (WGA 2006). As such, the factors contributing to a project's return on investment can pose significant barriers. Some of these factors are discussed below.

High Capital Costs

Most CHP facilities are small relative to generating stations owned by utilities or participating in the ERCOT wholesale power market. The median generating capacity of Texas CHP facilities is less than 40 MW, which does not afford CHP investments the same economies of scale enjoyed by large utility-scale power generation. As a result, the installed cost of the system can often be a barrier to facilities interested in installing CHP (EPRI 2005). Limited access to low-cost financing is an additional barrier to CHP development since most traditional financial institutions consider distributed generation projects as high-risk investments (HARC 2006).

High Operating Costs

Despite the energy and economic efficiencies of CHP, operating costs are often high relative to retail electricity prices, especially for facilities that are not ideally suited for CHP. For a facility that cannot take advantage of cogeneration efficiencies for 24 hours per day or 12 months per year, the economics of the CHP investment diminish in rough proportion to degree to which operations are not optimized. The issue of high operating costs can be illustrated through a discussion of what constitutes an ideal facility and how exceptions to this ideal can raise costs considerably. For purposes of illustration, a facility ideally suited for CHP would exhibit the following characteristics:

- **Round-the clock (24/7) operation and low seasonal variation in loads,** which allow capital costs to be spread over a greater number of operating hours and a greater amount of energy output. An industrial facility with significant thermal and electrical needs and continuous, non-variable operation would be an ideal facility. In contrast, a relatively poor candidate for CHP would be a typical office building that has high electrical needs in the summer for air conditioning, but little need for thermal energy, and high thermal needs in the winter for space heating, but low electrical demands relative to the summer. Some facilities are able to circumvent this dilemma by using thermally activated absorption chillers for space cooling, thus creating a more constant thermal load throughout the year. However, this is generally applicable only for new construction or when major HVAC renovations are occurring. Furthermore, the efficiency of CHP providing for thermally activated cooling is not as attractive as when true thermal needs are met.

- **Coincident electrical and thermal loads** that utilize both the full power generation capability of the system and the thermal output. If loads peak at different times of day, then the CHP units may have to be run at less than maximum capacity, which reduces the generating efficiency, as well as the energy output over which fixed capital costs can be spread. The alternative is that surplus generation be sold on the wholesale market (or to a REP via a bilateral power purchase contract), which generally offers lower prices than the price of the retail power that facilities avoid through onsite generating. Under either of these alternatives, the economic attractiveness of an investment in CHP is reduced when electrical and thermal loads are not coincident.

- **High power reliability needs** that would require investment in backup generation in the absence of CHP. The cost savings from avoiding the need to purchase and maintain an emergency power supply can help to make the CHP investment more attractive. Absent the need for backup power, the investment must demonstrate sufficient returns based on the net savings from avoided power purchases and any sales of surplus power.

Rise and Volatility of Natural Gas Prices

The cost of natural gas accounts for the vast majority of operating costs in gas-fired CHP systems, which account for more than 70% of CHP facilities in Texas. Over the past five years, the price of natural gas has consistently held at two to three times what it was prior to 2003. As a result, operating costs have increased dramatically since the time that most of the existing CHP capacity was installed. Not surprisingly, high natural gas prices were cited in many reports as a barrier to CHP installation and use (US DOE 2007, Brooks 2006).

Moreover, the volatility of natural gas prices creates added uncertainty regarding the economics of operating a CHP unit. Businesses generally prefer to make investments in which the costs are known and the risks relatively low. To the extent that CHP investments must be financed externally, this uncertainty can add to project risk and increase the cost of raising capital. Adding to the problem for smaller facilities is that typical rate structures seen in the Texas wholesale gas markets do not provide favorable pricing for low-volume customers (TX CHPI 2008a). This has been an issue nationwide, as a U.S. Department of Energy report notes that charging retail rates for natural gas that is used for wholesale applications can economically impede a CHP project (US DOE 2007).

5.3.2 Regulatory Barriers

The regulatory landscape described above includes both requirements that CHP projects must meet as well as guidance to utilities for fostering developing of new CHP capacity. Some of these regulations effectively create barriers to investment in CHP, even while they serve important public policy objectives, such as lowering the cost of electricity and ensuring clean air. Some of the barriers identified in the CHP literature and through surveys and interviews are discussed below.

Grid Interconnection

As a means of fostering the nascent competitive wholesale power market in the state, the PUCT adopted new rules governing the interconnection of large generating units in 1996 and governing parallel operation of distributed generation in 1999. The new rules served to facilitate interconnection of CHP projects as well. Despite these efforts, an independent group advocating clean energy options found that Texas has "poor interconnection standards that leave in place many needless barriers to interconnection" and that a "significant number of systems will experience delays and high fees for interconnection, and a sizable percentage may be blocked because of rules" (NNEC 2008).[32] The report did not provide detail on any specific problem areas.

These criticisms may be overstated, but not entirely unfounded, based on a review of the surveys and interviews conducted by the project team for this CHP study. Representatives from roughly one-quarter of the facilities responding to the CHP facility survey conducted for this study indicated that "difficulty in working with the local utility" would be a significant barrier to the companies' installing new cogeneration capacity. One party responding to the PUCT's 2008 request for comments regarding CHP contends that electric utilities that have not opted into retail competition "discourage CHP in ways that are similar to the treatment of cogeneration prior to the enactment of PURPA" (TX CHPI 2008b). Utilities may also be concerned about grid stability and safety and could use these concerns to delay interconnection or add costs to CHP projects (HARC 2006).

In the non-ERCOT areas, which are under the jurisdiction of the Federal Energy Regulatory Commission for interstate transmission, the lack of adequate transmission facilities serves as a barrier. The PUC may exercise jurisdiction if the transmission and distribution systems interfere with delivery of electricity to customers in Texas or the utility is not meeting its obligation to serve. Some of the non-ERCOT utilities still view the existence of CHP as competition for sales of its own power.

Despite the claims of difficulties with interconnection of CHP systems, little concrete evidence was uncovered in the course of this study. Interviews did not indicate that interconnection was a significant barrier and comments on CHP filed with the PUCT suggest that industrial customers believe that "barriers to the development of CHP were largely removed with the passage and subsequent implementation of PURPA" (TIEC 2008).

[32] In *Freeing the Grid*, a report by the Network for New Energy Choices, 43 states and the District of Columbia were graded on their net metering and interconnection policies. Texas received a "D" for interconnection, ranking it 15th out of the 44 jurisdictions covered in the report.

Permitting

The process of obtaining all of the necessary permits to operate a CHP facility can inhibit greater application of the technology. There may be state, local, and federal compliance requirements and permits regarding utility and environmental regulations and fire, zoning, and building codes (HARC 2006). It can be particularly difficult to meet permit requirements for air emissions in Clean Air Act non-attainment areas, given that emissions limits for CHP systems of all sizes are equivalent to what can be achieved by a large-scale utility unit with expensive, state-of-the-art pollution control equipment (TX CHPI 2008a). More than 40% of survey respondents indicated that permitting issues would be a barrier to their expanded development of CHP, although less than 20% indicated having problems in completing the permitting process.

Wholesale market rules

Wholesale market rules may also be a barrier for some facilities interested in CHP. One aspect of this is that facilities cannot use CHP systems to sell electricity to a nearby facility without using a REP and paying wheeling charges. Direct sales could be advantageous, because they would allow multi-party CHP investment in systems that have greater economies of scale.

Another aspect of the wholesale market that may not favor CHP is that REPs may be less interested in CHP facilities, because there the energy requirement for the facility are likely to be low, as well as more variable than for a typical customer. One of the industry interviewees explained that, from the perspective of REPs, "Purchasing for the load requirements in excess of the cogeneration capacity is very difficult and leads to a great deal of uncertainty. In addition, interviews suggested that in the restructured market there is relatively little demand for and interest in surplus power from cogenerators. REPs may not be interested in marketing surplus power if the supply is variable and relatively small. One party commenting on the PUCT's request for comments on CHP noted that small facilities may pay relatively high natural gas prices, since they do not have access to wholesale markets (TX CHPI 2008b). However, gas marketers may be able to secure competitive prices, especially for all but the smallest facilities.

5.3.3 Customer and Stakeholder Barriers

Many of the barriers to CHP are issues with the customers themselves, not necessarily with the underlying economics or regulatory environment. Some of the barriers encountered by customers and other stakeholders are as follows:

Limited On-Site Space and Suitable Loads

Adding CHP systems to current buildings or operations may require additional space on-site. If the required space is unavailable, the CHP project will not be viable. In addition, lack of suitable loads on-site for using the heat and power can be a barrier. This barrier can be overcome by selling the power to the grid or selling the heat to a nearby business.

Lack of Management Support

Research has found that, in general, senior management does not view energy matters as a high priority compared to other business matters (EPRI 2005). Generally, if power production is not the facility's core business activity, they are less likely to give CHP attention, as it may distract from other core operations. One industry interviewee for this study commented that, even if the facility managers advocate for CHP, "the problem is getting the business folks to understand the advantages and finding the money for the capital expenditures." In addition, installing a CHP system at a facility requires a long-term commitment that can make it difficult to relocate and that depends on maintaining the thermal load for which the system was designed.

Lack of Technical Expertise

Technical expertise on CHP systems can be limited in many facilities, especially smaller facilities. Expertise on items such as fuel supply options, thermal sales, use of thermal energy on-site, and wholesale power contracts can aid in a facility interested in installing CHP. Businesses whose core activity is not power production are also less likely to have knowledge about CHP opportunities and benefits. Interviews conducted for this study suggest that while customers are often aware of the opportunities offered by CHP, they do not always have the expertise to conduct a proper assessment of the economics. One utility representative contends that customers too often use "rules of thumb" efficiency values that can be misleading. In his review of eight prospective municipal CHP projects, only one used what he deemed to be an appropriate set of assumptions and data.

Conflicts between Stakeholder Goals

Many conflicts exist between different stakeholder groups that may be affected by CHP installations. For example, for new construction, building developers are incentivized for lowest cost construction (Bullock 2008). Building developers often do not consider lifetime costs and benefits during construction. Electric utility shareholders are often in conflict with the general public interest. Shareholders are interested in increasing electric utility sales and revenue, thus discouraging distributed generation. However, the efficiency of CHP provides many benefits to the general public. In addition, a perceived conflict between economic and environmental policies exists—many believe that today's environmental policies cannot also be economic (WGA 2006).

Researchers that have studied barriers to CHP state that vertically integrated electric utilities have a general bias against distributed generation (Bullock 2008, WGA 2006, TX CHPI 2007). Because most of these utilities' revenue is directly related to their sales, they have an incentive to increase their volume of sales—the more electricity they sell, the more revenue they generate. Therefore, energy efficiency or distributed generation, both of which reduced the volume of electricity bought by the customers, will reduce the utilities' revenue. Utilities may also be unaware of the benefits of CHP and may view distributed generation as causing technical and safety issues on their system (Brooks 2006). Some utilities doubt market economics, making integration with CHP difficult (WGA 2006). The bias affects the customers through interconnection, utility surcharges, and prices paid for generation. For example:

- Utilities often add surcharges to customers' bills to recover stranded costs, often known as exit fees that would otherwise be recovered through electric sales. Another method to recover costs are standby charges, charges placed on the customer bill for maintaining capacity and distribution to the customer for the times when they require electric service from the utility. These surcharges often are placed on the customer's bill as a flat, monthly rate (CBO 2003, US DOE 2007, Brooks 2006).

- Some utilities pay for electricity generated by distributed generation units through different methods including paying for the electricity with a wholesale rate and providing net metering. These payments may under- or over-value the energy. Several federal government assessments contend that these rates often do not capture the true value of the DG/CHP generated electricity. Payments often not included are locational marginal price payments, capacity payments, and credits for reduction in line losses (CBO 2003, US DOE 2007).

6 POLICY OPTIONS TO FOSTER ADOPTION OF CHP

While Texas has a high level of CHP capacity, both in absolute and relative terms, there has been a decline in the development of new CHP facilities in the past several years. A number of factors are important in the decision whether to pursue CHP, including natural gas and electricity prices, capital costs, and market structure. To the extent that the policy of the State of Texas is to foster CHP, this chapter suggests ways to address some of the barriers to its development.

Specific policy options that can lower the identified barriers and foster adoption of CHP are presented in Table 6-1 and are discussed below. These policy options were identified through an extensive review of policy papers and research studies on CHP in Texas and across the country.[33] The appropriateness of the policies for the Texas market was determined by reviewing the barriers to adoption of CHP discussed in Chapter 5 and by studying the responses to the CHP facility surveys (Appendix A-1) and the industry, utility, and stakeholder interviews (Appendix A-2) that were conducted for this study.

Table 6-1. Policy Options to Foster Adoption of CHP in Texas

Improving the Economics of CHP

E1. Provide direct financial incentives for each kW of CHP capacity.

E2. Offer a state-funded investment tax credit (ITC) against the Franchise Tax based on the capital investment.

E3. Offer property tax abatement for facilities that incorporate CHP capacity.

E4. Provide low-cost financing for CHP projects.

E5. Offer a state-funded production tax credit (PTC) against the Franchise Tax based on the energy generated from the facility.

E6. Provide funding to encourage electricity generation from agricultural wastes used for CHP.

Supporting Customer Adoption of CHP

C1. Provide education and outreach services to increase customer awareness of CHP opportunities and benefits.

C2. Provide technical assistance to aid customers interested in CHP.

Lowering Regulatory Barriers

R1. Facilitate interconnection of CHP systems, especially in regions without competition.

R2. Modify wholesale market rules to facilitate CHP among small customers and neighboring facilities.

R3. Modify air permitting rules to encourage greater CHP development.

Promoting Statewide Development of CHP

S1. Establish statewide CHP goals to be met through requirements placed on utilities and other market players.

S2. Establish a statewide CHP Resource Portfolio Standard.

S3. Modify state standards and planning procedures to foster adoption of CHP in publicly owned buildings and critical public infrastructure.

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[33] Unless otherwise noted, the policy options discussed in this Chapter were identified from one or more of the following sources: Houston Advanced Research Center (Bullock and Weingarden 2006), Texas CHP Initiative (TX CHPI 2008a), and Western Governors Association (WGA 2006).

6.1 Identification of Policy Options

Specific policy options are discussed below, organized into four unique categories aimed at overcoming barriers identified in Chapter 5. These policy options are intended to achieve the following objectives:

1. Improve the **Economics** of CHP
2. Lower **Regulatory** Barriers
3. Support **Customer** Adoption of CHP
4. Promote **Statewide** Development of CHP

The policy options are denoted with the letters **E, R, C, and S** denoting the policy category in which the option most closely fits: **E**conomic, **R**egulatory, **C**ustomer, and **S**tatewide, respectively.

6.1.1 Improve the Economics of CHP

Economic barriers were shown to be a significant drag on adoption of CHP in Texas. Consequently, policies to improve the financial returns from CHP investments may have an impact on the amount of new CHP capacity brought online in the coming years. In fact, more than 90% of survey respondents indicated that financial incentives would promote expanded use of CHP in the state.

Six specific economic policy options are discussed below; the first four address the barriers associated with *high capital costs*:

E1. Provide direct financial incentives for each kW of CHP capacity. Direct financial incentives would function in a manner similar to the current energy efficiency incentives, which are paid according to the peak load avoided through verifiable installation of a qualified measure. These incentives could be funded through utility rates or an expanded system benefits charge paid by customers taking electric delivery. The state of New York offers $600 per kW for qualifying projects that demonstrate reduction in summer on-peak demand (NYSERDA 2008b).[34] In the California Self-Generator Incentive Program (SGIP), incentive levels for cogeneration technologies varied by technology and changed over time. Beginning in 2006, the rebates ranged from $600 per kW for internal combustion engines and gas turbines over one MW to $2,500 per kW for fuel cells operating on natural gas (Summit Blue 2006). As noted above in Section 4.2.2, the economic potential in Texas of small systems under one MW and commercial facilities of all sizes is estimated to increase by more than 50% with a subsidy of $500/kW.

An alternative to a specific incentive program for CHP would be an expansion of the energy efficiency program to provide broader support for CHP. One simple change would be to modify the existing requirements for utility programs to *require* utilities to offer incentives for CHP rather than merely *permitting* them to include CHP (PUCT 2008a). However, this could siphon a

[34] Qualifying projects must use reciprocating engines or gas turbine-based CHP systems with a 60% annual fuel conversion efficiency. They must use at least 75% of the generated electricity on-site and have a NOx emission rate of less than 1.6 lbs/MWh.

significant amount of funds from energy efficiency. A single five megawatt CHP project could consume incentive funds equivalent to hundreds of energy efficiency projects, the result of which could be a decline in the market infrastructure (e.g., active energy efficiency service providers, or EESPs) that the state has been fostering for much of this decade.

E2. Offer a state-funded investment tax credit (ITC) against the Franchise Tax based on the capital investment. Tax credits are used by taxing authorities to reduce tax liabilities. Texas does not have an income tax, but could use credits subject to minimum operating thresholds, such as the use of waste heat. The credits could be used to offset the Texas margin tax liability. Unlike incentives in the energy efficiency program, which are funded by ratepayers, tax credits are effectively funded by all state taxpayers. The ITC could work in a similar manner to the Business Energy Tax Credit currently offered by the federal government for investment in solar power, CHP, and other renewable and efficient generation sources. The federal credit is for 10% of expenditures for CHP systems up to 50 MW that exceed 60% efficiency and that use at least 20% of the total energy in the form of thermal energy and at least 20% in the form of mechanical or electrical power (H.R. 1424 2008; DSIRE 2008).

E3. Offer property tax abatement for facilities that incorporate CHP capacity. The property tax abatement would provide an ongoing incentive that is effectively funded by taxpayers at the county level. The concept could be modeled after Harris County's new Green Building Tax Abatement program, which offers a reduction in property taxes of up to 10% per year for ten years for new buildings that receive Leadership in Energy and Environmental Design® certification. The level of tax abatement depends on the level of LEED certification and is capped at the incremental cost of qualifying for the certification. For CHP, the tax abatement could vary according to the efficiency of the unit, its emissions characteristics, or other criteria.

In Chapter 11, Subchapter B, Texas Tax Code, solar and wind generation are exempted from property appraisals if the power is predominantly self-used. The exemption could be extended to CHP facilities. Local tax authorities were authorized to create economic investment districts and to abate local taxes on qualified investment in § 313.021of the Texas Property Code. This section expired on December 31, 2007, but the Legislature could consider reinstituting it and expanding the types of qualified investment to include CHP facilities. These types of tax incentives encourage investment in Texas, as well as the creation of jobs.

E4. Provide low-cost financing for CHP projects, such as through the existing LoanSTAR revolving loan program. The program was initiated by the Texas Energy Office in 1988 to help finance energy efficiency retrofits and upgrades for state buildings, schools, and non-profit hospitals. In its first ten years, nearly 200 projects totaling over $240 million were funded (SECO 2008). By creating a new fund or modifying the guidelines for LoanSTAR, financing could be made available to facilities lacking capital for CHP projects or for which the high cost of project financing is a barrier to investment. In order to accommodate significant investment in CHP, the size of the fund and the allowable payback period would need to be increased.

In addition to the above policy options addressing capital costs, two more alternatives may be considered that can also improve the economics of CHP.

E5. Offer a state-funded production tax credit (PTC) against the Franchise Tax based on the energy generated from the facility. Incentives provided by a PTC would be proportional to the kWh generated by the facility and could be subject to minimum efficiency thresholds and use of both thermal and electrical energy. The federal government offers a PTC for renewable electricity production, but not for CHP. The credit is two cents per kWh for wind, geothermal, and closedloop biomass, and one cent per kWh for other eligible generation, for up to ten years of operation (DSIRE 2008). Some existing energy efficiency incentives in Texas are paid according to kWh saved, as opposed to reductions in demand, so there is precedent for this approach. Unlike the energy efficiency incentives, a PTC would effectively be paid for by taxpayers in much the same way as an investment tax credit. An important difference is that a PTC would continue to provide financial benefits beyond the time of the initial investment.[35]

E6. Provide funding to encourage electricity generation from agricultural wastes used for CHP. The existing House Bill 1090 relates "to the establishment of a program by the Department of Agriculture to make grants to encourage the construction of facilities that generate electricity with certain types of agricultural residues, waste, debris, or crops and the state's goal for generating renewable energy." The program could be modified to encourage the use of CHP, whenever possible, and provide for additional funds for those facilities that produce electricity and usable heat. The United States Congress has ordered the U.S. Department of Energy to establish a grant program for electricity generation from waste energy. The Energy Independence and Security Act of 2007 provides that CHP would qualify for a 1.0 cent per kilowatt-hour incentives to be paid for the first three years of production (H.R. 6 2007).

6.1.2 Lower Regulatory Barriers

A variety of regulatory barriers to adoption of CHP were discussed in Chapter 5, including wholesale market rules that may inhibit some CHP development and air emissions rules that do not fully capture the benefits of CHP. Several policy options to address these barriers are presented below.

R1. Facilitate interconnection of CHP systems, especially in regions without competition. The state recognized the need to facilitate interconnection of small generators when it established guidelines for interconnection of distributed generation in 2002. However, some barriers remain and utilities do not have incentive to encourage CHP development, especially in parts of the state that have not been deregulated. One method of ensuring that utilities do not discourage CHP is to decouple revenues from T&D throughput. Decoupling is most often cited as a mechanism to remove financial disincentives to energy efficiency, but it can apply as well to CHP. Utilities could be encouraged to facilitate CHP if they were able to benefit financially from any T&D system benefits accruing from CHP. This point was emphasized by one of the utility interviewees for this study, who noted that, while TDSPs in the restructured market do not have a big financial stake in deployment of CHP, the T&D benefits could be significant.

R2. Modify wholesale market rules to facilitate CHP among small customers and neighboring facilities. Several purported barriers to CHP investment could be addressed through modification of wholesale market rules for electricity to better enable participation by small generators and to improve the economics of the projects. For example, regulatory or financial incentives for REPs to work with small CHP generators could alleviate the difficulty that some facilities may have in attracting a partner to sell surplus power into the wholesale market. More than 60% of survey respondents identified "easier integration into the ERCOT market" as a policy that would

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[35] The continuing financial benefit provided by a PTC is an important attribute of this policy approach, according to one utility interviewee: "Initial tax breaks or incentives up front will not be enough. Ongoing, long-term incentives are needed." It was further suggested that a good mechanism to provide the incentive would be to include it in the price of the avoided power, but this approach could not work in a restructured market.

effectively encourage more CHP in Texas. One survey respondent commented that the administrative requirements to participate in ERCOT were very burdensome even for large cogenerators, suggesting that it may be particularly difficult for smaller operators to handle those requirements.

Also, small facilities may be able to benefit from greater economies of scale if they are able to build larger CHP units and directly share the power generation with a neighboring facility. However, current market rules and state law prohibit direct sales of electricity from one customer to another, even if the sites are in close proximity and there is already a sharing of thermal energy. The costs of using a REP to wheel the surplus power on the grid can erode the often modest economic benefits of a sharing agreement. A representative of one of the organizations interviewed for this study explained, "It is now possible to share the steam, but not over very great distances. If nearby facilities could share electricity, it would be *very* attractive, because the companies could share the capital costs." Thus, the economics of CHP for small facilities could be improved if direct sales of generation from CHP were allowed between customers.

R3. Modify air permitting rules to encourage greater CHP development. CHP units are currently regulated as electric generators, despite the fact that much of their output is for thermal, not electrical, uses. The result is that permissible emissions rates (as low as 0.14 pounds per MWh) may be stricter than what some units can achieve, particularly smaller units that do not have the room or cannot afford to install the most advanced pollution control devices. For comparison, New York State's CHP incentive program is applicable to units with NOx emissions rates as high as 1.6 pounds per MWh (NYSERDA 2008a).

Emissions limitations under the Standard Permit vary according to region, size, age, and hours of operation, as discussed in Chapter 5. A greater variation in the permissible rates based on size might be appropriate given the expense of selective catalytic reduction (SCR) controls and the efficiency benefits of CHP that are not fully recognized. The Standard Permit's credit for the recovery of waste heat assumes 100% conversion efficiency of fuel to heat in the alternative configuration that would be used in the absence of CHP. A more generous credit may be appropriate, depending on the alternative technology.

The CHP technology itself may warrant regulatory treatment separate from that given to standard generating units that do not offer the efficiency benefits of CHP. Without CHP, a facility likely would burn natural gas or another fuel to meet its thermal loads, while purchasing electricity from the grid for its power needs. The net result would likely be greater overall emissions than under the CHP configuration that may not be economically feasible due to the current emissions rules. Emissions rates for CHP units could be set at levels higher than those for generating resources such that total emissions from a CHP unit would be equal to or less than what could be expected from onsite thermal production plus generation from the grid.[36]

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[36] The Texas CHP Initiative has argued that the current emissions regime is "counter-productive because it inhibits cleaner CHP relative to less efficient…central station power plants…. [The] Initiative believes that CHP systems are a technology class unto themselves and require a unique permit level that takes into account the unique features and benefits of these systems" (TX CHPI 2007).

6.1.3 Support Customer Adoption of CHP

For most electric customers, power generation is unrelated to their core business. Consequently, they are often unaware of the potential benefits of CHP and do not generally possess the technical knowledge to adequately assess the opportunities. In these respects, policies to educate customers about CHP and to provide technical assistance in the assessment, development, and operation of CHP systems could increase investment in CHP throughout the state. Most interviewees agree that large industrial facilities have staff that are highly knowledgeable about CHP and are often able to perform the technical and financial assessments needed to review CHP opportunities. However, the level of awareness among smaller facilities, especially commercial customers, is relatively low, and many lack sufficient technical expertise.

C1. Provide education and outreach services to increase customer awareness of CHP opportunities and benefits. It has been well documented that customer education on CHP opportunities is lacking, particularly among smaller industrial and commercial customers. Nearly half of the survey respondents (46%) indicated that education and outreach would help to increase the amount of CHP capacity in the state. In addition, several of the interviewees recommended more education for smaller customers to make them more aware of opportunities and to provide a "cookie-cutter process" for dealing with regulations and permits.

The state is already home to the Gulf Coast Combined Heat and Power Application Center, which promotes the use of CHP in Texas. The Center could provide an effective, existing platform for the state to offer educational opportunities to targeted customer segments (e.g., hospitals).

C2. Provide technical assistance to aid customers interested in CHP in evaluating the opportunities, developing the systems, and operating the facilities. More than one-third of the survey respondents cited technical assistance as beneficial for expanded CHP development, including seven out of 17 facilities with generating capacity under 100 MW. Several utility personnel interviewed for the study indicated that many customers who are knowledgeable about CHP are nevertheless not prepared to conduct a sufficiently rigorous technical and economic analysis. The result could be investment in CHP at facilities that are not well-suited for the application, which can lead to highly uneconomic operation.

A useful tool for customers, according to several interviews, would be an online model that can solicit input on facility characteristics and be used to screen opportunities. The Gulf Coast CHP Application Center could play a role in the delivery of technical assistance supported by the state, as well as the utilities, which routinely meet with customers to review plans for CHP installations. At least one of the Texas utilities helps companies to analyze their CHP project plans using an economic model that assesses financial payback and other issues. Another opportunity for technical assistance is in training facility managers in how to operate CHP systems. Interviews conducted for this study suggested that some critical facility personnel are not well trained in operation of existing backup power systems. CHP systems would likely be more complex and require additional training.

An important question in shaping the delivery mechanism for technical assistance is the degree to which the state would support individual projects. New York State's Technical Assistance program shares up to half the cost of a comprehensive study to "investigate the site-specific technical and economic feasibility of installing CHP," up to a maximum of $500,000 over five years. In the six years since the program began in 2000, NYSERDA has supported approximately 100 small projects that, when fully built, will have a capacity of 100 MW (NYSERDA 2008b).

6.1.4 Promote Statewide Development of CHP

The policies discussed above address specific barriers to adoption of CHP and can encourage greater investment in cogeneration throughout the state. Specific goals and directives for utilities and industry can complement these policies by ensuring that CHP will be pursued. Essentially, the state would set CHP targets and/or require consideration of CHP in public facility planning, and the policies aimed at overcoming barriers would create an environment more conducive to economical development of CHP systems.

S1. Establish statewide CHP goals to be met through requirements placed on TDSPs and other market participants. These CHP goals could be analogous to the existing energy efficiency goals, which most of the state's investor-owned utilities are directed to achieve through administration of incentive programs. In the case of CHP, financial incentives such as those discussed above, could be administered by the utilities. In fact, rule changes in 2008 allow utilities to offer incentives to CHP projects under ten MW. In order to be most effective, the goals would be mandatory and the enabling regulations would include penalties for under-compliance.

S2. Establish a statewide CHP Resource Portfolio Standard, which would function like the state's existing Renewable Portfolio Standard. Under an RPS for CHP capacity, the state's electricity providers (i.e., REPs, municipally owned utilities, and electric cooperatives), rather than the T&D utilities, would be responsible for either: 1) owning or purchasing capacity using CHP technologies, or 2) acquiring tradable CHP credits in sufficient amounts to meet the requirements of the regulations. According to one interviewee, a portfolio standard for CHP would be the single, most effective way to achieve more CHP, because it forces people to consider cogeneration. Other policy changes would simply help make it easier to reach the established goals.

S3. Modify state standards and planning procedures to foster adoption of CHP in publicly owned buildings and critical public infrastructure. Critical public infrastructure, such as hospitals, are required to provide emergency backup generation powered by liquid fuels stored onsite (Bullock and Weingarden 2006). The liquid fuel requirement may unnecessarily reduce the cost-effectiveness of CHP, which typically use natural gas and would, therefore, be a redundant backup system. A CHP system could serve as the emergency backup power were it not for the liquid fuel requirement. A strong case can be made that natural gas is a comparable or even superior fuel for use in extended emergency situations, such as those caused by recent hurricanes.

A related policy option would be to require that planning for all public infrastructure (publicly owned buildings, public or private emergency facilities, water and wastewater treatment plants) include CHP feasibility studies. Facilities requiring emergency backup power are often good candidates for CHP, since they tend to have 24-hour-per-day, 365-day-per-year operation and often have onsite generation even if they do not employ CHP technology. In addition to the possible efficiency and economic benefits offered by CHP, these systems could displace the need (and associated cost) for traditional backup power, making them more economical than at facilities that do not require emergency generation (Jackson, 2006). These facilities could also provide additional flexibility to the electric utilities' emergency operations plans under P.U.C. SUBST. R. 25.53.

6.2 Summary of Policy Options

The policy options available to foster adoption of CHP run the gamut from financial incentives to regulatory mandates. Within each category of policy options discussed above, the various alternatives offer unique advantages and drawbacks that make some relatively attractive and others relatively complicated or expensive. Tables 6-2 through 6-5 present the advantages and drawbacks of specific policies and address the degree to which Texas has begun to pursue these avenues.

Table 6-2. Economic Policy Options

Policy	Advantages	Drawbacks	Actions taken in Texas
Addressing high capital costs:			
E1. Direct financial incentives	• Incentive linked to installed MW • Ease of administration	• Cost to ratepayers • Incentive not linked to output • Energy efficiency incentives could be wiped out if CHP draws from same source of money • Does not provide long-term support • Incentive not linked to output	Energy efficiency incentives could serve as model
E2. Investment tax credit against the Franchise Tax	• Costs spread across entire state • Incentive linked to value of investment • Ease of administration	• Delay in customer receiving incentive • Cost to all taxpayers • Incentive not linked to capacity or output	Not known
E3. Property tax abatement	• Costs borne in the area where investment is made • Customer tax burden does not rise (CHP may result in increased property value)	• Delay in customer receiving incentive • Cost limited to local taxpayers • Incentive only loosely linked to capacity, and not to output •	Harris County LEED program could serve as model
E4. Low-cost financing	• Little or no cost to ratepayers or taxpayers • Greater reach to more and larger projects	• Little change to underlying economics of CHP investment	LoanSTAR for energy efficiency could be expanded to include CHP
Addressing other economic issues:			
E5. Production tax credit against the Franchise Tax	• Incentive linked to output	• Delay in customer receiving incentive • Cost to all taxpayers • Incentive must be long term	Not known
E6. Promote lower natural gas rates for CHP systems	• Long term reduction in operating costs • Little or no cost to taxpayers and ratepayers	• May be difficult to establish rules	

Source: Summit Blue Consulting

Table 6-3. Policy Options to Lower Regulatory Barriers

Policy	Advantages	Drawbacks	Actions taken in Texas
R1. Facilitate interconnection of CHP systems	• T&D benefits could be significant, especially with nodal market rules	• May require significant changes in rules governing T&D operation	DG interconnection rules simplified process for small generators
R2. Modify wholesale market rules to facilitate small customer participation	• May allow more participation by commercial customers and smaller facilities	• Utilities may oppose some rule changes	Not known
R3. Modify air permit rules to promote CHP	• Reduced aggregate emissions relative to separate electricity and thermal production • Thermal heat recovery valued more appropriately	• Some CHP could increase emissions in non-attainment areas	Standard permit already credits CHP based on thermal output

Source: Summit Blue Consulting

Table 6-4. Policy Options to Support Customer Adoption of CHP

Policy	Advantages	Drawbacks	Actions taken in Texas
C1. Provide education and outreach to increase customer awareness of CHP	• More sites will be considered for installation of CHP technology • Promotes more participation by commercial customers and smaller facilities	• May not lead directly to an increase in CHP capacity	Gulf Coast CHP Application Center based in Houston; some informal education provided by utilities
C2. Provide technical assistance to customers considering CHP investments	• Can move customers from awareness to adoption of CHP • Helps avoid CHP investments at facilities not well-suited to the technology	• Can be expensive and does not guarantee new CHP capacity	

Source: Summit Blue Consulting

Table 6-5. Policy Options for Direct Statewide Promotion of CHP

Policy	Advantages	Drawbacks	Actions taken in Texas
S1. Establish statewide CHP goals to be met by T&D utilities	• Sets a specific, known target for energy generated from CHP • Assigns responsibility for achieving targets • Can be modeled on existing energy efficiency program	• Goals at some TDUs may not be met if local market determines CHP is not cost-effective • New regulatory tracking system required	Goals have been in place for energy efficiency since 2002, and CHP can now be counted toward achievement
S2. Establish statewide CHP goals to be met by Retail Electric Providers	• Sets a specific, known target for CHP capacity • Assigns responsibility for achieving targets • Market determines value of CHP credits • Can be modeled on existing Renewable Portfolio Standard	• Requires CHP investment regardless of cost (unless ceilings included) • New regulatory tracking system required • Cost of credits could be high	A renewable portfolio standard has been in place since 1999 and could be used as a model for CHP
S3. Modify state standards and planning procedures to foster adoption of CHP in publicly owned buildings and critical public infrastructure	• Provides needed emergency power and heat • Ensures emergency operation for longer periods • Target market well-suited to CHP • These facilities generally accept longer payback times	• Current state and local building codes may need to be changed • Certifications by various agencies need to be reviewed • Target market facilities are generally relatively small	Funds provided from Homeland Security without qualification of facility type

Source: Summit Blue Consulting

6.3 Recommended Policy Approach

The benefits of CHP are summarized in Chapter 2. A persuasive argument can be made the citizens and ratepayers in Texas will be better off economically and in terms of environmental quality if more CHP system were in operation. There is no precise set of policy options that will most effectively and economically achieve greater adoption of CHP. However, there is a broad policy approach encompassing several key principles that state policymakers can follow to select a desirable and beneficial mix of policies. These principles are as follows:

1. **Consider at least one concrete action to improve the economics of CHP.** Economics is the primary barrier to investment in CHP, and more than 90% of CHP facilities surveyed believe that financial incentives would promote greater use of CHP. While many other barriers exist, removal of these impediments will not increase CHP development if companies cannot expect a reasonable return on investment with a modest level of risk. The economic barriers can be lowered by offering one or more financial incentives (Policy Options E1, E2, E3, E5, and E6) to improve the returns, combined with a method of helping companies to finance their investments (E4). If incentives are provided, they should be offered primarily to smaller systems, mostly at commercial customer sites, since these are less likely to be economic from the perspective of the operator and their economic potential can be significantly increased through financial incentives (see Section 4.2.2). Providing incentives to large facilities may be unnecessary to spur investment and could quickly exhaust limited incentive funds.

   It should be noted that some stakeholders do not believe that economic incentives are necessary, or even a good idea. Several sources of information, including the interviews conducted for this study, raise the point that direct subsidies may not always promote the best projects. In comments to the PUCT, an industrial coalition expressed support for removing structural and technical barriers to CHP, but "would not support subsidies or mandates that would have the effect of furthering uneconomic projects" (TIEC 2008). Most parties weighing in on the issue of how to promote CHP agree that financial incentives would promote investment, but one interviewee posed an important question, "Who will pick up the cost, and is it fair?" While there may be merit to the argument that incentives are not warranted, if the state's objective is to advance CHP to realize its broad benefits to operators, ratepayers, and citizens alike, then incentives may be needed to encourage investment in CHP projects that might not otherwise be pursued.

2. **Assess policy options to reduce as many of the identified barriers as possible.** Even if the economics of a prospective CHP project appear favorable, many non-economic barriers can deter companies from making the investment. The more that barriers that can be lowered, even if not completely eliminated, the greater the likelihood that the market will pursue the financial and other benefits offered by CHP. Not all stakeholders agree that there are significant barriers to CHP other than economics. Responding to the PUCT's request for comments on CHP in Texas, one industry coalition contended that they could not identify any barriers (TIEC 2008). Moreover, a power generation company that operates CHP plants suggested that "the biggest barrier to the development of large scale CHP projects is commercial, rather than regulatory" (Calpine 2008). Despite these contentions, there is sufficient evidence to suggest that reducing non-economic barriers (Policy Options R1, R2, and R3) will contribute to greater investment in CHP.

3. **Support customers in identifying and assessing CHP opportunities.** Many customers, especially those at smaller and mid-size facilities, are not aware of opportunities for CHP or do not possess the in-house expertise to evaluate the potential benefits. Nearly half of all customers surveyed believe that education and/or technical assistance would lead to more CHP investment. Education and outreach regarding CHP should be expanded (Policy Option C1) and technical assistance (C2) could be offered by supporting or administering targeted programs through existing organizations using their established delivery mechanisms.

4. **Consider policy options to directly drive investment in CHP.** An incentive program modeled after the state's energy efficiency goals (Policy Option S1) or a program modeled after the renewable portfolio standard (S2) could provide the mandate and direction needed to spur development of new CHP capacity. These two approaches would each provide financial incentives for investment but, importantly, they would also ensure that specific entities are responsible for making this investment happen.

   Fostering CHP in publicly owned buildings and critical public infrastructure (S3) is a less ambitious, but direct, driver of CHP investment that could also be pursued. It also serves the goal of maintaining operations during and after a catastrophic event like a hurricane or an outage due to generation resource shortages or transmission failures.[37] In addition, since these facilities would be built in areas that are closer to demand, they would be more likely to relieve transmission congestion, which in the nodal market can reduce transmission investment and decrease costs to consumers.

Adopting the policy approach described above would provide the state with an excellent opportunity to achieve a large share of the economic potential for CHP that was presented in Chapter 4. This approach includes targeted policies that allow the free market to work where the economics of CHP are already good (e.g., at large industrial facilities) while providing financial incentives where the marginal economics may be preventing CHP investments that could otherwise provide significant system and environmental benefits. The ultimate impact of efforts in Texas to foster greater adoption of CHP may be influenced by the extent to which the policies are pursued and the level of funding afforded them.

[37] A recent Oak Ridge National Laboratory report cites the effective role that CHP can have in disaster response, noting that "CHP and distributed energy can help communities respond to natural disasters and prolonged energy emergencies [and] have proven to be extremely valuable in the continuity of critical health services…" (ORNL 2008).

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APPENDICES

APPENDIX A-1:

TEXAS CHP FACILITY SURVEY

TEXAS CHP FACILITY SURVEY

Note: The terms "cogeneration" and "combined heat and power," or "CHP" may be used interchangeably.

I. Facility and Contact Information

Don't Know = 888 Refused = 999

1. **Record contact info**
   a. Name: ____________________________________
   b. Title: _____________________________________
   c. Phone: ____________________________________
   d. Email: ____________________________________
2. **Confirm facility location/industry type fields from database**
   a. Company name: _____________________________
   b. Facility name: _______________________________
      i. Has the facility name or ownership changed in the past several years? ____
      ii. What was the old name or owner? ____
   c. City ____
   d. Industry type: _____________________________
   e. *[Clarifications]* ____

II. Current Status of CHP Installations

3. **First of all, is the facility still in operation as combined heat and power?**
   a. YES/NO
   b. If NO,

i. When did you stop operating the facility for cogeneration? ___________ (year)

ii. Is it still operating for non-electrical loads (i.e., is it operating for heat/steam only)? YES / NO

iii. Why did you stop operating the facility as a cogeneration plant? _______________________

iv. Do you have plans to restart it in the future? Explain. _________________________________

4. We have some information on your cogeneration plant from a CHP database kept by the U.S. Department of Energy. We'd like to confirm or update some of this information, starting with the electric capacity of your CHP operations.

Question/topic	**Response**	
a. Nameplate Capacity (MW) a1. Data type?		
a1. Capacity data type?	1. Nameplate 2. Measured maximum output	3. Respondent's best estimate 4. Other: a1a) ______________
a2. Any changes? Explain.		
b. Steam production (mmBtu/hr) at capacity		
c. Year operation began		
d. Prime mover (type of equipment)	1. Boiler & steam turbine 2. Combustion turbine 3. Combined cycle 4. Reciprocating engine	5. Microturbine 6. Fuel cell 7. Other 7a) ____________
e. Primary fuel	1. Natural gas 2. Coal 3. Distillate fuel oil 4. Residual fuel oil 5. Wood	6. Biomass (non-wood) a) Source: ______________ 7. Landfill gas 8. Waste fuel 9. Other 9a) _______________
f. Utility name (distribution utility)	1. Oncor (TXU ED) 2. CenterPoint 3. AEP 4. Entergy	5. Texas- New Mexico Power 6. Xcel 7. Other 7a)______________________
g. Sales to utility (Y/N)	1=YES / 2= NO If YES, i) Max MW _______ ii) Annual MWh _______	
h. [Enter comments here]		

III. Operation of the CHP Facility

5. **How often is the plant used for combined heat and power?**

   a. SEASONALLY:

      i. All year round

      ii. Seasonally (i.e., only part of the year)

      iii. Other

b. WEEKLY:
   i. 7 days per week
   ii. Specific days only (e.g., weekdays)
   iii. Other

c. DAILY:
   i. 24 hours per day
   ii. During certain hours of the day (e.g., 6am to 6pm)
   iii. Other

d. Do operating hours depend on *production schedules/facility needs*?
   i. YES ➔ d2) *Explain*__________________________
   ii. NO

e. Do operating hours depend on *the price of fuel and electricity*?
   i. YES ➔ e2) *Explain*__________________________
   ii. NO

f. *[Comments/explanation on plant operation]*

6. What is the steam being used for? *[select all that apply]*

a. Industrial process
b. Space heating
c. Space cooling (e.g., through an absorption chiller)
d. Water heating
e. Other ____

7. **When the plant is operating in cogeneration mode, is it normally (with limited exceptions) at maximum electrical output?**

   a. Yes

   b. No ➔

      B1) Why not? (e.g., can't utilized all of the waste heat) ___________________

      B2) On average, at what percent of capacity does the plant operate? _______%

8. **Is the plant capable of operating during grid outages? And are you allowed to operate during outages?**
   a. Capable
   b. Allowed
   c. Both capable and allowed

9. **Does the plant provide any ancillary services to the local utility, such as black starts, spinning reserves, or automatic generator control (AGC)?**

   a. Yes ➔ *Explain* ____
   b. No

10. **Does your company operate any other cogeneration facilities in Texas?**

    a) ***Note modifications to data for facilities currently in database:***

    b) For facilities NOT currently in the database

1 Facility Name	2 MW	3 Prime Mover	4 Fuel	5 Year Operation Began	6 Utility Name	7 Sales to Utility?

IV. Air Permitting Process

11. In what year did the facility receive an air permit for the CHP plant? ___________

12. What type of permit did you receive?

a. "Standard" Permit - i.e., Air Quality Standard Permit for Electric Generating Units (only available on/after June 1, 2001)

b. Permit by Rule (PBR)

c. New Source Review Permit

d. Other - *specify*:____

13. *[If applied for the Standard Permit per Question 12]*
Did you receive the CHP credit that effectively relaxed your emissions requirements?

a. Yes

b. No - Why not? ____

c. Did not know about CHP credit

14. Did you encounter any problems in completing the permitting process?

a. Yes (Explain ____)

b. No

IV. Motivations, Barriers, and Policies for Expansion of CHP Capacity

15. Please indicate on a scale of 0 to 10, where 0 is "not at all influential" and 10 is "very influential," how much each of the following factors influenced your company's decision to develop and use cogeneration. *(Can also answer with regard to <u>continued use</u> of cogeneration.)*

Factor	Rating (0 – 10)
a. Reduced utility bills	
b. Self-generation capability to improve electric reliability	
c. Improve our business image— green marketing	
d. Provide technical demonstration	
e. Other major factors? ______________________________	

16. On a scale of 0 to 10, where 0 means "Not at all likely to install and 10 means "Very likely to install," how likely is it that your organization will install additional

cogeneration capacity either __at this facility__ or __elsewhere in Texas__ in the next five years? _______ (0 – 10)

17. [If Question 16 > 0]
Do you have any specific plans?

a. YES ➔ *[Probe for 1) how many MWs and 2) details of the plans.]*

b. NO

18. Which, if any, of the following would be a significant barrier to your organization installing new or expanded cogeneration capacity? *[Choose all that apply]*

a. No additional loads to be served

b. No more space/room for additional equipment

c. Difficulty with the current system

d. High natural gas prices (or uncertain prices)

e. Equipment is expensive (or uncertain equipment/construction costs)

f. Limited availability of capital

g. Commercial or technical complexity

h. Difficulty in air permitting and/or other regulations?

i. Difficulty in working with the local utility

j. Other (specify :_________________________)

19. For those barriers you have previously mentioned, which barrier would be:

a. The most significant? ____ *[Enter letter from above]*
b. The next most significant? ____ *[Enter letter from above]*

20. *[For <u>each</u> of the two barriers in Question 19 (or for the single barrier in Question 18)]*

i. In what way is *[Barrier a or b]* a barrier to new cogen capacity?

ii. How might this barrier be overcome through changes in state policies?

21. Which of the following government policies, if any, do you think would promote expanded use of CHP in the state? *[Choose all that apply]*

a. Financial incentives
b. Technical assistance
c. Education and outreach
d. Easier integration into the ERCOT market
e. Simpler permitting process
f. Less stringent air emissions regulations
g. None of the above

22. For the items that you just mentioned, do you have any specific ideas regarding how state policies could be used to promote CHP? Explain.

23. Is there anything that you would like to see the state government do to facilitate the development and expansion of combined heat and power in Texas? Explain.

24. What advice would you have for a business like yours that was considering an investment in cogeneration?

25. Is there anything else you'd like to add before we wrap up?

Thank you for your cooperation!

26. Would you like to be contacted when our report to the Commission is made public?
1= YES /2= NO [We will send an email]

APPENDIX A-2:

TEXAS CHP STAKEHOLDER INTERVIEW GUIDE- INDUSTRY ASSOCIATIONS

Texas CHP Stakeholder Interview Guide- Industry Associations

Interviewer: ___________________________________

Date: _______________________

I. Contact Information

1. Record and/or confirm contact info

a. Name: _____________________________________

b. Organization: ______________________________

c. Title: ______________________________________

d. Phone: _____________________________________

e. Email: _____________________________________

1b. Role of interviewer at organization or with respect to CHP

II. Question for Industry Associations

2. **Are you familiar with any** [facility type – eg, hopsitals] **using cogeneration in Texas? What types of cogeneration operations do they have (e.g., how large, what type of equipment/fuels, what is the steam used for)?**

III. New CHP facilities and Industry Knowledge/Education

3. **Do you know of any CHP plants currently under development or being considered at [facility type]?** *[Ask for as much detail as possible including facility/company name, size (MW), technology, fuel, and location.]* **How about any that are planning to reduce cogen capacity?**

4. **How knowledgeable do you think [the industry] is regarding the opportunities for CHP and the potential benefits?**

5. **Are you doing anything to help educate [facility type] or have there been any education efforts that you know of? What could be done to help [facility type] to learn about the opportunities and investigate the potential at their facilities?**

IV. Motivations, Barriers, and Policies for Expansion of CHP Capacity

- **What are some of the main benefits of cogeneration among [facility type]?** *[Prompt if necessary from below]* **How do these benefits affect the decision to invest in CHP?**

- reduced utility bills
- self-generation capability to improve electric reliability
- green marketing
- technical demonstration

6. What are some of the most significant barriers to [facility type]s developing cogeneration capability? *[Prompt if necessary from below]* **In what way do these barriers inhibit development of cogeneration capacity?**

- Distraction from core business
- Lack of information about opportunities, benefits, and costs
- Insufficient loads to be served
- No space/room for equipment
- Investment is substantial/ equipment is expensive
- Difficulty in air permitting and/or other regulations?

7. How are the barriers different for existing facilities as opposed to new facilities that are not fully designed and built? To what extent are the opportunities for CHP greater in new facilities?

8. How might these barriers be overcome through changes in state policies? In other words, what government policies do you think would best facilitate the development and expansion of combined heat and power in Texas?
[Prompt from list below after open-ended response. Address EACH item.]

1. Financial incentives
2. Technical assistance
3. Education and outreach
4. Easier integration into the ERCOT market
5. Simpler permitting process
6. Less stringent air emissions regulations to capture the full benefits of CHP
7. Create a Resource Portfolio Standard for CHP (minimum CHP levels in state)
8. Allow electricity from CHP to be used directly by adjacent facilities (for better economics and/or emergency power)

9. In what ways is the use of cogeneration unique in Texas, as opposed to the rest of the country? Are there differences in facility type, corporate culture, state regulations, etc. that suggest that a different approach is needed in Texas?

10. What advice would you have for a business that was considering an investment in cogeneration?

11. Can you suggest some good sources of information on CHP, including how CHP is being used, technologies and costs, and policies to promote CHP?

12. Is there anything else that you would like to add related to this study?

13a. May be cite you by name if we refer to any of your comments? How about the name of your organization?

13b. May we list you by name as one of the people that we interviewed? How about the name of your organization?

13. **Interviewer Comments Only**
[Summarize the key points of the interview in a few sentences or bullets. If a reader sees nothing else but this item, what is the essential gist of the interviewee's responses?]

APPENDIX B-1:

METHODOLOGY FOR IDENTIFYING CHP INSTALLATIONS

METHODOLOGY FOR IDENTIFYING CHP INSTALLATIONS

In order to develop the most complete database of CHP facilities located within Texas, data from four different organizations were compared and combined:

- The U.S. Department of Energy (DOE);
- Energy Information Administration (EIA);
- Public Utility Commission of Texas (PUCT); and
- Texas Commission on Environmental Quality (TCEQ).

An extensive database compiled under contract to the U.S. DOE provided the bulk of information about Texas CHP installations.[38] This database contained fields such as Operator Name, Facility Name, City, Capacity, and several other facility characteristics. However, it was unclear whether or not all CHP facilities in Texas were included in the database. Thus, other databases were matched to the DOE database with the primary goal of identifying existing CHP facilities in Texas that were not already listed.

EIA

The 2006 EIA-860 Annual Electric Generator Report (EIA 2008) was the first database examined through the following steps:

- A list of electrical generators with cogeneration capabilities in Texas was obtained by filtering the EIA-860 Existing Generators File (GenY06) to only include generators in Texas that answered "Yes" to the question "Cogeneration Function?"
- PLNTCODE and UTILCODE numbers from EIA were assigned to DOE database facilities with an Operator or Facility Name that matched the UTILNAME or PLNTNAME in EIA.
- Because names were not always exact matches, some judgment was exercised and unit capacity was often used as a secondary matching criteria.

Of the approximately 150 facilities provided in the DOE database, about 90 were found in the EIA-860 data. The EIA-860 database was then reduced to facilities listed by EIA but not listed by in the DOE database. Two facilities were found that matched this criterion. Through the surveys, it was learned that one of these two facilities identified with the EIA-860 report was no longer operating as a cogeneration

[38] The original database was compiled by Energy and Environmental Analysis (EEA) Inc., which is under contract to the U.S. DOE. Prior to use by Summit Blue, the database was updated by Tommy John, Vice President of Regulatory Affairs of the Texas CHP Initiative, to add new projects and remove duplicate entries and facilities known to be either shut down or no longer providing thermal energy.

facility and the other facility was a duplicate of a facility already in the database under a different name. Thus, no facilities were added from the EIA-860 data to the final database.

PUCT

Because the 2006 EIA-860 information was last updated on January 1, 2007 and only generators with a nameplate rating of one megawatt or more are required to submit information to EIA, other databases were referenced, including the PUCT's databases of Power Generation Companies and Self Generators (PUCT 2008b). Since no information about generation type was provided in the PUCT databases, the names of the facilities were searched for the terms "CHP" and "cogen." This search identified several facilities, but all of these facilities were already included in the DOE database. Thus, no facilities were added from the PUCT database.

TCEQ

The TCEQ air permit website was the final source consulted (TCEQ 2008a). TCEQ offers several classes of air permits for which electrical generating units can apply, including:

- Permit-By-Rule (PBR) for Stationary Engines and Turbines: A PBR may be claimed when a facility is too large to apply for a De Minimis permit and small enough that the emissions of the unit do not trigger the need for a new source review permit. There are over one hundred different PBRs that a facility can claim. Through communications with the TCEQ, it was determined that the PBR applicable to CHP facilities was Rule 106.512 for Stationary Engines and Turbines. As of 2001, PBR 106.512 cannot be used if the turbine or engine generates electricity.

- Standard Air Permit for Electric Generating Units: This standard air permit is designed to streamline the permitting process for facilities that are electric generating units. Facilities with CHP fall under the category of Standard permits for Electric Generating Units.

    - It should be noted that the Standard air permit also allows for a credit of one MWh for each 3.4 million British Thermal Units of heat recovered if the facility properly documents the use of CHP and recovers at least 20 percent of the total energy output as heat from the CHP unit (TCEQ 2007).

- New Source Review (NSR) air permits: NSR permits are available for facilities that do not qualify for PBR or Standard air permits (TCEQ 2008b).

The TCEQ website offered two primary methods for searching these air permit documents:

- Air Permits Remote Document Server: A searchable server by keywords that provided a list of documents by Subject, Author, and Size with the option of opening, saving, or seeing the document properties (TCEQ 2008c).

- Complete Air New Source Review (NSR) Permit Applications in Each TCEQ Region—New Source Review Air Permits: Provided ASCII data for NSR, Standard, and PBR permit types by Program Area, Permit Number, Permit Type, Permit Status, Company Name, Date Technical Review Finished, Project Status, Project Name, Physical Location, and others. However, information about the use of CHP was not included.

Searching for the term "cogeneration" in the Air Permits Remote Document Server returned 1,874 documents, which had no consistent naming scheme. Extensive manual searching within the documents would have been required to find additional facilities from these results.

Instead, a combination of the two search methods was ultimately used to locate facilities. The NSR Applications search method was employed to download ASCII data that identified specific permit numbers for potential CHP facilities. These specific permit numbers were then searched for in the Air Permits Remote Document Server. Searching by permit number typically provided about two to ten documents without a consistent naming scheme. Documents labeled as "Technical Review" or "TRV" commonly provided the most pertinent information. Once the TRV was downloaded, it was searched for the key terms "CHP," "cogen," and "combined heat and power." If the facility included information about CHP capabilities in the TRV, the facility name was matched with the facilities in the DOE database.

The NSR Applications search method returned over four thousand results for PBR 106.512 air permit documents related to initial projects (as opposed to documents about name changes, ownership changes, etc.). There were still a significant number of documents after narrowing these search results down to permits that were complete or pending; issued or void; and received in 2008. After reviewing over a dozen of these results, it was clear that additional review of PBR documents would not be a time-effective search method. None of the documents included the terms "CHP" or "cogen," and most of the permits applied for within the past month did not have significant information online yet.

In contrast, about one hundred documents were returned in the ASCII results for Standard permits. Five of these were identified as CHP facilities and two were not already included in the DOE database. Both of these facilities had their permits issued in 2008. Through interviews, it was learned that neither facility is currently operating, but both will begin operations within the next couple of years. These facilities were not included in the final database.

According to an engineer at TCEQ, there is currently no easy way of searching for NSR permits. Thus, all completed permit documents from 2008 were downloaded from the Air Permits Remote Document Server. The project names in these three thousand documents were searched for the terms "CHP," "cogen," and "combined," with only one positive result: the Helios Plaza Energy Trading Center CHP by BP, which had already been added to the database from the Standard permit search results.

Summary

In total, reviewing databases from EIA, PUCT, and TCEQ identified no additional facilities. Two facilities were identified in the TCEQ database as under construction, but these were not included in the final database. The review of these three databases helped validate the majority of the facilities listed in the DOE database and affirmed the DOE database as a valuable resource for identification of CHP facilities in Texas.

APPENDIX B-2:

METHODOLOGY FOR SELECTING CHP FACILITY SURVEY SAMPLE

METHODOLOGY FOR SELECTING CHP FACILITY SURVEY SAMPLE

This appendix describes the sample of 30 combined heat and power (CHP) facilities in Texas that was proposed for the direct survey component of the CHP study. The data reported in this appendix does not reflect updates made after the interview process and is not representative of the final database.

The priority in developing the sample was to select those facilities that could best contribute to the objectives of the study. This suggests that the ideal sample would have the following characteristics:

1) Be representative of the population of CHP facilities in the state;

2) Allow for identification of facilities whose operating status or characteristics have changed from the latest data acquired by the project team; and

3) Elicit respondent comments to identify policies likely to overcome barriers to expansion of CHP capacity, especially by the types of facilities in Texas that have the greatest potential for use of CHP.

To this end, the sample was developed in part through random sampling and in part through intentional selection of specific facilities or facility types from those compiled from initial research into a facility database. For example, several facilities were selected because the project team found information suggesting that the facility listing may be a duplicate of another facility in the database or that the facility may no longer be operating. Others were selected because they represent customer segments of particular interest for expansion of CHP in the state (e.g., hospitals). The remainder of the sample was determined by random selection.

Following this approach, 30 facilities were chosen for the sample from the database of CHP facilities in Texas as identified by Summit Blue. Facilities in the database were broken down into three size categories based on electric generation capacity (megawatts), and ten facilities were chosen from each size category. The remaining facilities in each size category serve as "alternates" in the event that a survey cannot be completed with all facilities in the sample. The "Small" category corresponds to facilities with less than 10,000 kW of capacity, the "Medium" category corresponds to 10,000-99,999 kW of capacity, and the "Large" category corresponds to greater than 100,000 kW of capacity.

The 30 facilities selected for the proposed sample is shown in **Table B-2, 1**.

Table B-2, 6. Thirty CHP facilities selected for survey sample.

#	Size Category	Operator Name	Facility Name	City	Capacity (kW)	Customer Segment
1	Small	Hospital Corporation Of America/ Thermo	Vista Hills Medical Center	El Paso	180	Hospitals/ Healthcare
2	Small	Lone Star Energy/ Enserch/ TXU	Univ. Of Texas Health Science Center	Dallas	4,600	Colleges/ Univ.
3	Small	R.E. Thomason Hospital	Thomason Hospital Central Plant	El Paso	2,400	Hospitals/ Healthcare
4	Small	Moody Gardens	Moody Gardens	Galveston	200	Museums/ Zoos
5	Small	CSI Texas Holdings, Inc. / DBA Corrugated Services Inc.	Paper Recycling	Forney	4,000	Solid Waste Facilities
6	Small	Austin Energy	Domain Industrial Park	Austin	4,500	Misc. Manf.
7	Small	Valero Refining Co	Valero Refinery Corpus Christi West	Corpus Christi	7,500	Refining
8	Small	BP America Production Company	Helios Plaza Energy Trading Center	Houston	4,600	Office Buildings
9	Small	Rio Grande Valley Sugar Growers	Rio Grande Valley Sugar Growers	Santa Rosa	5,000	Food Processing
10	Small	Freeport Mcmoran	Freeport Mcmoran	Pecos	5,200	Refining
11	Medium	CCPC Chemical, Inc. / Occidental	CCPC Chemical, Inc.	Corpus Christi	37,880	Chemicals
12	Medium	Arlington Landfill	Village Creek Municipal WWTP	Fort Worth	10,600	Wastewater Treatment
13	Medium	BASF Corp	NROC Cogeneration Facility	Port Arthur	83,200	Chemicals
14	Medium	NewPage Corporation	MeadWestvaco Evadale	Evadale	57,700	Pulp and Paper
15	Medium	Targa Midstream Services Limited Partnership	Mont Belvieu Fractionator /	Mont Belvieu	15,000	Refining
16	Medium	Celanese Engineering Resin Inc	Celanese Engineering Resin		56,800	Chemicals
17	Medium	Westvaco / Temple-Inland Forest Products Corporation	Evandale Pulp & Paperboard	Evadale	48,200	Pulp and Paper
18	Medium	Equistar Chemicals LP	Corpus Christi Plant	Corpus Christi	45,176	Refining
19	Medium	TXU Generation Co LP	TXU Sweetwater Generating Plant	Sweetwater	45,000	Utilities
20	Medium	Wichita Falls Energy Company	Vetrotex / Certainteed Corporation	Wichita Falls	80,000	Stone/Clay/Gla ss
21	Large	Calpine - Channel Energy Center	Channel Energy Center	Houston	560,000	Refining
22	Large	Sabine Cogen LP	Sabine Cogen	Orange	100,000	Chemicals
23	Large	South Houston Green Power LP	Power Station 3	Texas City	117,900	Refining
24	Large	Union Carbide Corporation	Seadrift Cogeneration	Seadrift	110,000	Chemicals
25	Large	LG&E Power Inc./Gregory Power Partners	Reynolds Metals Sherwin Alumina Plant	Gregory	400,000	Chemicals
26	Large	Formosa Plastics Corporation, Usa	Point Comfort Project	Point Comfort	537,400	Chemicals
27	Large	Air Liquide America Corp	Bayou Cogeneration Plant	Pasadena	300,000	Chemicals
28	Large	South Houston Green Power LP / Green Power 2 / Cinergy	BP Texas City Refinery	Texas City	570,000	Refining
29	Large	SRW Cogeneration LP	SRW Cogeneration	Orange	360,000	Chemicals
30	Large	AES Corporation	AES Deepwater Inc	Pasadena	143,000	Chemicals

Note: This table does not reflect updates made after the interview process and is not representative of information in the final database.

There are several things to note about the rationale for choosing these facilities. First, the size category break-down was chosen because:

- a scatter plot of the facilities' capacities revealed natural divisions at these points (see Figure B-2, 1);
- this categorization roughly equally allocates facilities across three size categories, with 49 in Small, 60 in Medium, and 42 in Large; and
- a change to the TCEQ standard air permit in 2001 affected the air permitting process for units under 10,000 kW.[39,40]

Figure B-2, 1. All CHP facilities in Texas by capacity and size category.[41]

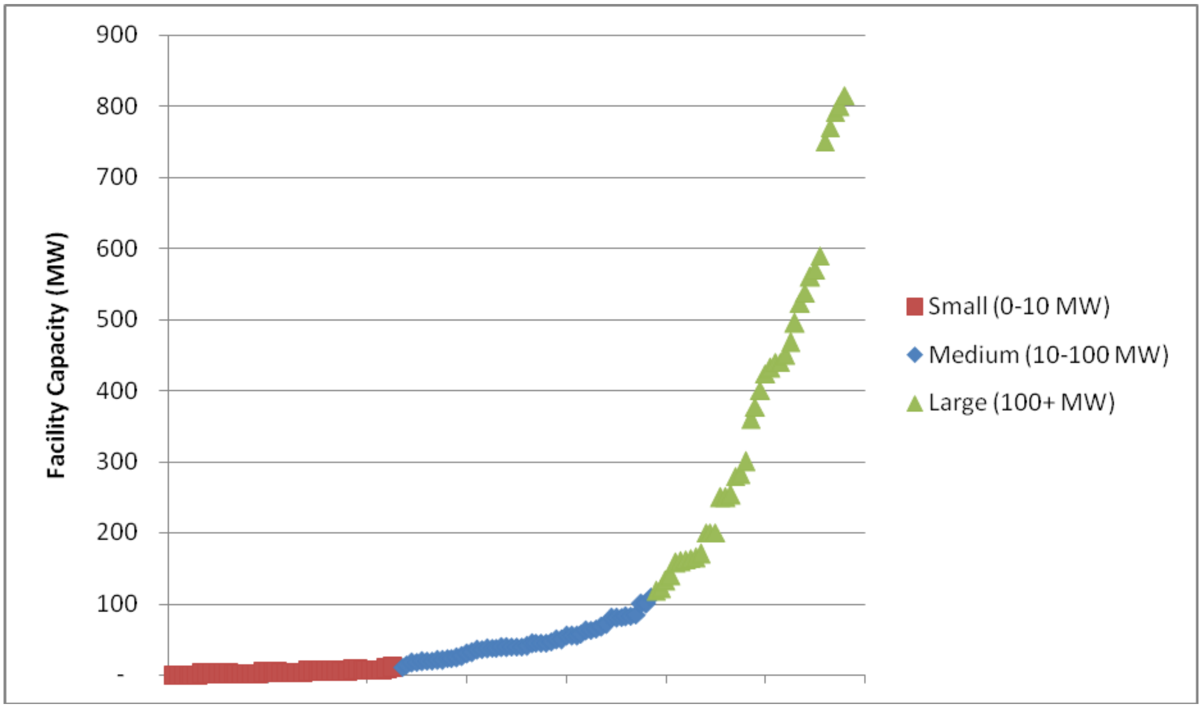
[39] Prior to June 2001, the standard air permit only applied to electric generating units under 10,000 kW. As of June 2001, the requirements for Standard Air Permit qualification changed in order to:

- Streamline the permitting process and allow more electric generating units to apply through the standard process by removing the 10,000 kW size limit; and
- Increase the emission limits required to qualify for a Standard Air Permit, particularly for small electric generating units which were previously regulated by much looser emission limits.

Since the majority of facilities in the database went into operation pre-2001, 10,000 kW serves as a good breakpoint for helping to differentiate how the change in the standard permit affected new capacity.

[40] Texas Commission on Environmental Quality, "Air Quality Standard Permit for Electric Generating Units," June 2001, http://www.tceq.state.tx.us/assets/public/permitting/air/NewSourceReview/Combustion/segu_final.pdf, (accessed October 9, 2008).

[41] This figure does not reflect updates made after the interview process and is not representative of the final database.



Initially, the ten facilities in each size category were chosen at random. However, in order to achieve secondary goals of filling information gaps in the CHP facility database and providing information for policy making, the sample was modified to include facilities that either began operating after 2000 (and which may have therefore been eligible for the Standard Permit) or that were flagged because they had one of the following characteristics:

1. Highlighted in the original Houston Advanced Research Center (HARC) database as a potential duplicate of another facility or a potential electricity-only facility;
2. Identified by the project team as a possible new facility (i.e., not in the existing database), with some uncertainty about whether the facility was actually a duplicate of a previously identified facility;
3. Identified by Summit Blue as a new facility and was missing facility characteristics like application or technology type; or
4. Listed as either Hospital/Healthcare or Educational facilities, which are customer segments that may have particularly high potential for CHP installations.

The randomly generated sample included one post-2000 facility in the Small category, zero in the Medium category, and one in the Large category.[42] Thus, from the randomly generated list of facilities, the next three Small facilities that went into operation post-2000 replaced the last three of the sample's pre-2001 facilities, which then became the first alternate facilities. Similarly, three post-2000 facilities were included in the Medium sample and two more post-2000 facilities were included in the Large sample. More emphasis was intentionally given to the Small post-2000 facilities in an effort to explore

[42] The percentage of post-2000 facilities in each size category was approximately 10% in Small, 8% in Medium, and 29% in Large.

the claim that the 2001 change in air permit standards has made it more difficult for smaller cogeneration plants to meet the stricter and more costly emissions standards.[43] A similar approach was used to incorporate flagged facilities and Hospitals/Educational facilities into the database. With the intention of surveying at least three Hospital/Educational facilities, several of the facilities that were not included in the sample were elevated in the sample list to be the first few alternate facilities. Table B-2, 2 gives an overview of the final sample and reason for including each facility. It should be noted that, although most of the facilities in the final sample were hand-picked rather than selected at random, the randomization process still determined which facilities of each category would be surveyed first and the order in which most facilities would be considered as alternates.

Table B-2, 2. Number of facilities randomly and non-randomly chosen to be in the sample by reason and size category.

	Small	**Medium**	**Large**	**Total**
Randomly Chosen Facilities	1	0	7	**8**
Post-2000 Facilities	4	3	3	**10**
Flagged - New Facilities	2	2	0	**4**
Flagged - Possible Duplicates	0	5	0	**5**
Flagged - Other	2	2	1	**5**
Education/Hospital Customer Segments	3	0	0	**3**

Note: Number of facilities in each category does not add to ten due to overlaps in categories.

A comparison of characteristics between the survey sample and the entire population of CHP facilities in Texas affirms that the survey sample is a representative selection of the entire population:

- **Size:** The survey sample represents a wide variety of facility sizes by capacity. However, the average capacity of the sample facilities in each size category is very similar to the average capacity of the population of all facilities in each category (see Figure B-2, 2).
- **Primary fuel:** 92% of all CHP facilities in Texas use natural gas as their primary fuel. Similarly, 89% of the facilities in the survey sample use natural gas as their primary fuel. In both cases, about 5% of the facilities use waste fuel as their primary fuel and the remaining facilities use a scattered variety of fuels.
- **Technology type:** The population and survey sample are similar with respect to the type of technology, or prime mover, used for generation at the facility. Combined-cycle turbines are the leading technology, with combustion turbines as the clear second (see Figure B-2, 3).

[43] "Twice the Power at Double the Efficiency: Providing Secure Energy in Texas with CHP," Prepared by the Texas Combined Heat and Power Initiative, February 2007, page 9.

- **Customer Segment:** By far, chemicals and refining are the two customer segments with the greatest number of CHP facilities. This is true for both the entire population and the survey sample (see Figure B-2, 4).

The project team began the survey effort with the sample list and approach described above. This approach combined random selection/prioritization with hand-selection of facilities and facility types. In this way, the survey responses provided the most useful information for meeting the objectives of this study.

Figure B-2, 2. Distribution of facilities in each size category by capacity and comparison of average facility size for the survey sample and the entire population.

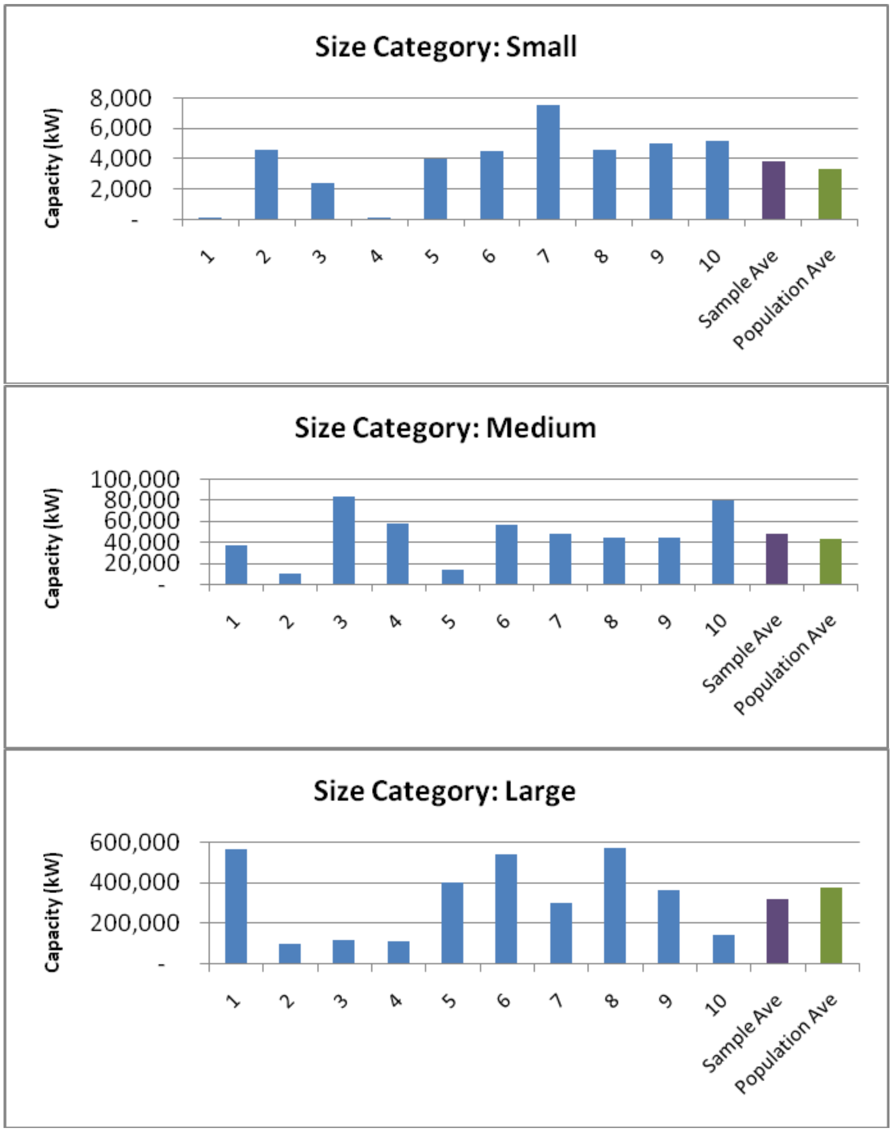


Figure B-2, 3. Percentages of all CHP facilities in Texas for each technology type compared to percentages of survey sample for each technology type.

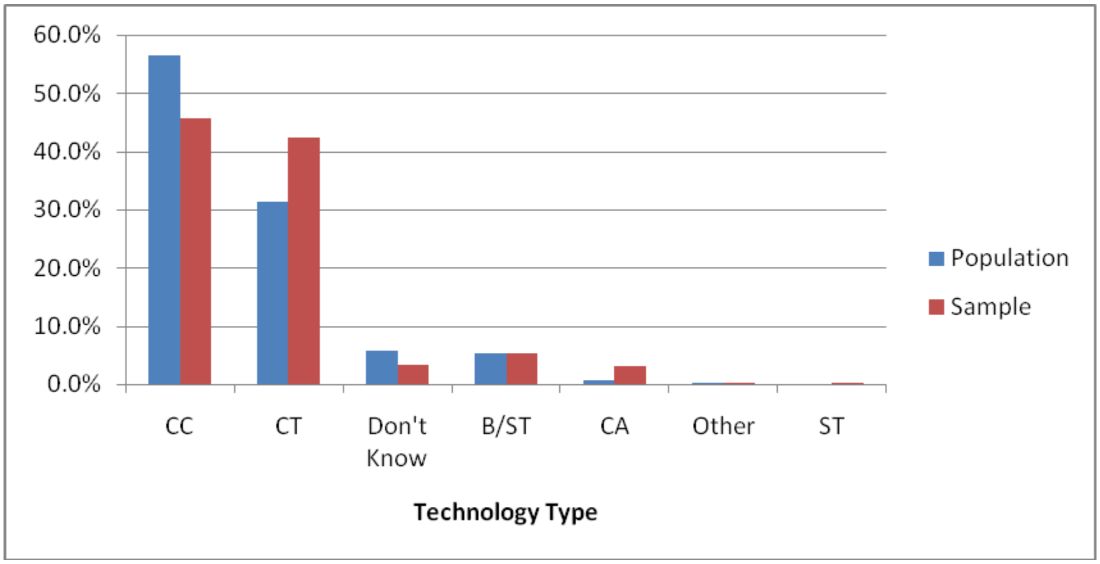
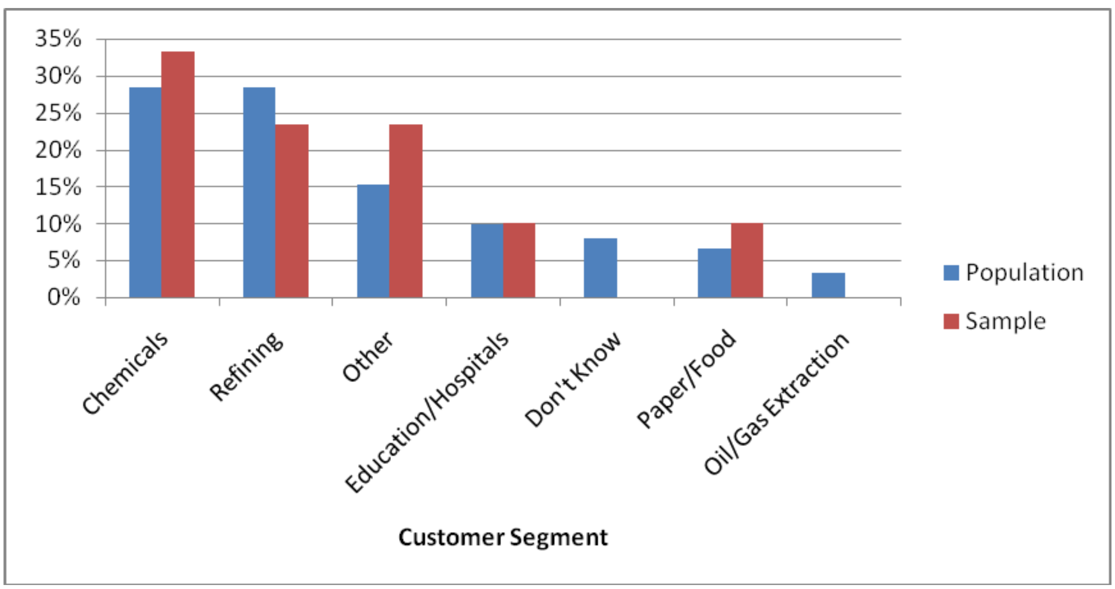


Figure B-2, 4. Percentages of all CHP facilities in Texas for each customer segment compared to percentages of survey sample for each customer segment type.



APPENDIX C-1:

DETAILED METHODOLOGY FOR ESTIMATING CHP POTENTIAL

DETAILED METHODOLOGY FOR ESTIMATING CHP POTENTIAL

This appendix describes the methodology for estimating CHP potential in Texas. The key components of the estimation are:

1. Identify Candidate CHP Host Population

2. Estimate Candidate Site Energy Load

3. Characterize CHP Technology

4. Forecast Energy Prices

5. Size CHP Systems

6. Estimate Technical Potential

7. Estimate Economic Potential

8. Conduct Key Parameter Sensitivities

Identify Candidate CHP Host Population

We started by identifying commercial and industrial sectors with consistent annual thermal loads for which a CHP system could be efficiently utilized on a year-round basis; all thermal loads other than space conditioning and commercial cooking were considered appropriate for CHP. The sectors were selected from the categorization (arranged by NAICS code) used in the United States Census Bureau's County Business Patterns (CBP)[44] database of buildings. All industrial sectors were considered, because the majority of their heat loads are for process hot water, steam, or air. For commercial sectors, we selected the following categories:

[44] Prisons and jails were also considered, although they cannot be distinguished from other municipal facilities in the database. A separate analysis was conducted to determine the population and size distribution of these sites.

- *Non-University Schools* – These sectors were selected because of their year-round restroom hot water (restroom, cleaning, laundry) and possibly swimming pool loads. The sectors considered were:
    - Dormitory/Fraternity/Sorority
    - Elementary/Middle School
    - High School
    - Other Classroom Education

- *Colleges and Universities* – Similar to the non-university schools selection rationale, colleges and universities have year round hot water loads and may have additional heating loads for laboratories and recreation centers.

- *Institutional and Commercial Residences* – These sites have consistent heat loads to provide hot water to residents for bathroom and laundry applications, as well for cleaning and often for recreation. The sectors considered were:
    - Dormitory/Fraternity/Sorority
    - Hospital/Inpatient Health
    - Hotel
    - Nursing Home/Assisted Living
    - Prison

- *Commercial sites with process hot water loads* – Laundry services (both professional and laundromats) and car washes were considered.

- *Recreation* – The gym and swimming pool subsectors of the recreation sector were considered, because of their consistent heat loads for showers, laundry, swimming pools, and hot tubs.

This approach to sector selection is based on prior experience with potential estimates and is consistent with other CHP studies included in Neal *et al*. (2007). The complete list of sectors that we considered are shown in Table C-1, 1.

Table C-1, 1. CHP Candidate Commercial and Industrial Sectors

Industrial	Commercial
Apparel Manufacturing	Colleges and Universities
Beverage and Tobacco Product Manufacturing	Dormitory/Fraternity/Sorority
Chemical Manufacturing	Elementary/Middle School
Computer and Electronic Product Manufacturing	High School
Dry Mill Ethanol Plant	Hospital/Inpatient Health
Electrical Equipment, Appliance, and Component Manufacturing	Hotel
Fabricated Metal Product Manufacturing	Laundry and Car Wash Services
Food Manufacturing	Nursing Home/Assisted Living
Furniture and Related Product Manufacturing	Other Classroom Education
Leather and Allied Product Manufacturing	Prison
Machinery Manufacturing	Recreation
Miscellaneous Manufacturing	
Nonmetallic Mineral Product Manufacturing	
Paper Manufacturing	
Petroleum and Coal Products Manufacturing	
Plastics and Rubber Products Manufacturing	
Primary Metal Manufacturing	
Printing and Related Support Activities	
Textile Mills	
Textile Product Mills	
Transportation Equipment Manufacturing	
Waste Water Treatment Facility	
Wood Product Manufacturing	

For this analysis, we only considered the application of waste heat to thermal loads, i.e., hot water, steam, and other process heat. Consideration of thermally activated cooling as an application for waste heat was beyond the scope of our study. The impacts of this omission are discussed in Chapter 4.

For the identified sectors, we used the United States Census Bureau's County Business Patterns (CBP) database[45] to determine the Texas populations (by count of business sites) and size distributions (by number of employees). We also collected this data for the other states in the U.S. Energy Information Agency's (EIA) South region, as this was the granularity of sectoral energy load data we had available for most industrial sectors. CBP data categorizes sites within each sector by the number of employees at the site. For select sectors, additional resources were used to obtain more detailed counts and size distributions than were available from CBP: these sectors were prisons/jails, universities/colleges, wastewater treatment facilities, hotels, and ethanol production plants. The population of current CHP hosts, as identified from existing data sources (see Appendix B-1 for methods) was then subtracted from the list of candidate sites for the purposes of potential estimation.

Estimate Candidate Site Energy Load

[45] United States Census Bureau, County Business Patterns, 2006 Edition, http://www.census.gov/epcd/cbp/index.html.

Electric and thermal loads were estimated from the count of business sites and size distributions identified above and results of the EIA's Commercial Buildings Energy Consumption Survey[46] (CBECS) for Texas and the EIA's Manufacturing Energy Consumption Survey[47] (MECS) for the South region. Total annual electric kWh and natural gas therms (a proxy for thermal load) by sector were divided by the total number of employees in the sector to determine kWh/employee and therm/employee values. These values were then applied to all CBP size categories in order to estimate site electricity and natural gas loads. Sector specific CHP studies were used in place of CBECS data where available, namely for the prisons/jails, universities/colleges, wastewater treatment facilities, hotels, and ethanol production plants sectors.

Only a fraction of natural gas load at a given site would be applied to year-round loads, such as hot water, steam, and process heat. For commercial buildings, the California End Use Survey[48] (CEUS) study was used to estimate the portion of total annual load that year-round loads account for. For industrial sites, we assumed that all thermal natural gas loads[49] were appropriate for CHP. For the sectors identified, we estimate 87,500 GWh of annual electricity consumption and 8.5 billion therms of natural gas loads that CHP systems could be matched to. Figure C-1, 1 and Figure C-1, 2 show the sectors with the largest electricity and applicable thermal loads.

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[46] [EIA] United States Energy Information Agency, Commercial Buildings Energy Consumption Survey, 2003 Edition, http://www.eia.doe.gov/emeu/cbecs/.

[47] [EIA] United States Energy Information Agency, Manufacturing Energy Consumption Survey, 2002 Edition, http://www.eia.doe.gov/emeu/mecs/contents.html.

[48] Itron, Inc., California Commercial End-Use Survey, California Energy Commission, CEC-400-2006-005, March 2006.

[49] This does not include gas loads in MECS for non-energy processes.

Figure C-1, 1. Annual Electricity Consumption (GWh) of Largest CHP Candidate Sectors

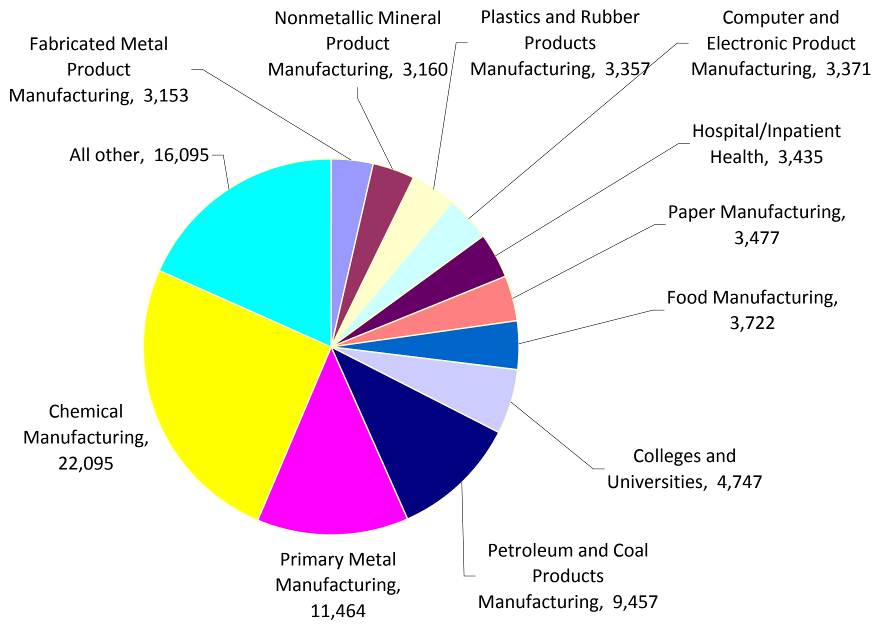
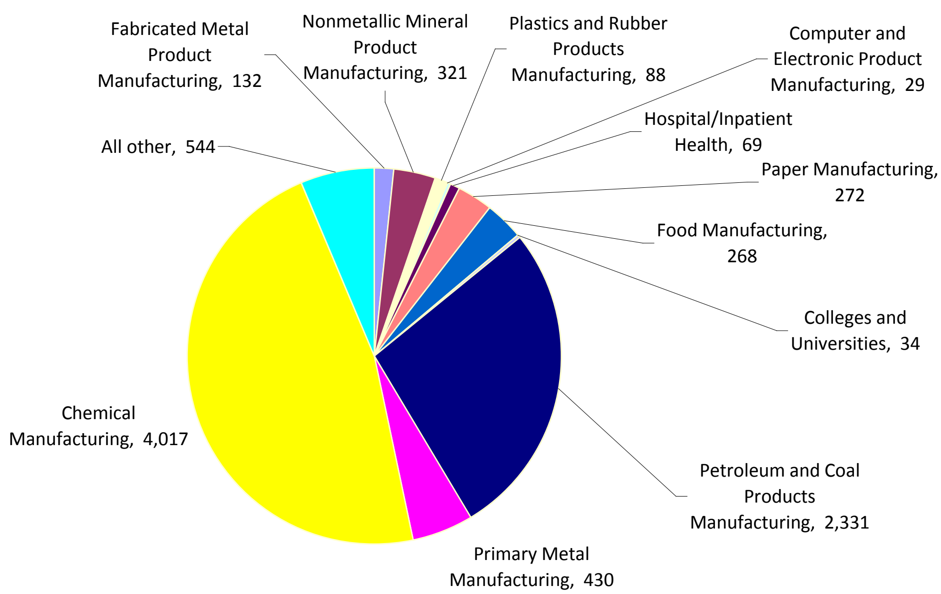


Figure C-1, 2. Annual CHP Appropriate Natural Gas Load (million therms) of Largest CHP Candidate Sectors



Characterize CHP Technology

Four CHP technologies were considered for candidate hosts: reciprocating engines, gas turbines, fuel cells, and microturbines. Of the four technologies, only microturbines have no current presence in Texas. However, microturbines do have potential niches, such as small candidate sites for which reciprocating engines are not feasible.[50] The two most prevalent CHP technologies in Texas, steam turbines, and combined cycle plants, were not considered, because of the assumption that these systems are relatively large (10s of MW to 100s of MW) and already exist at appropriate sites. This assumption is supported by a comparison of the existing CHP database to the candidate site CHP count, as well as by interviews with industry experts who noted that the economics of large scale (i.e., many tens of MW) CHP systems are fairly straightforward – a CHP potential analysis is unlikely to identify additional potential projects of these types. Each of the four technologies considered was considered in several size categories, representing the range of technologies that are commercially available.

We developed representative cost and performance data for these technologies from National Renewable Energy Research Laboratory[51,52] publications, and prior Summit Blue research. The resulting cost and performance characteristics used in our model are stated in Table C-1, 2. In this table, *E/T* is the unit-less ratio of electric energy output to thermal energy output and *Availability* is the portion of time that the CHP system is dispatchable, i.e., not inoperable due to a forced or unforced outage.

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[50] For example if emissions restrictions prohibit reciprocating engines or a site is not structurally capable of housing a reciprocating engine (e.g. roof-top applications) because of vibrations.

[51] National Renewable Energy Laboratory, Power Technologies Energy Data Book: Fourth Edition, NREL/TP-620-39728, August 2006.

[52] Gas Research Institute, Gas Fired Distributed Energy Resource Technology Characterizations, National Renewable Energy Laboratory, NREL/TP-620-34783, November 2003.

Table C-1, 2. CHP Technology Cost and Performance Characteristics

Technology Type	Minimum Capacity (MW)	Maximum Capacity (MW)	Capital Cost ($/kW)	O&M Cost ($/kWh)	Heat Rate (Btu/kWh)	E/T	Lifetime (years)	Availability
Fuel Cell	0.1	0.5	$5,748	$0.036	8,743	1.38	10	0.80
Fuel Cell	0.5	1	$5,346	$0.034	8,346	1.96	10	0.80
Fuel Cell	1	2.5	$5,193	$0.029	8,022	2.33	10	0.80
Fuel Cell	2.5	5	$5,132	$0.019	8,022	2.52	10	0.80
Gas Turbine	0.5	1	$5,030	$0.008	13,035	0.65	20	0.89
Gas Turbine	1	2.5	$2,669	$0.008	12,936	0.63	20	0.89
Gas Turbine	2.5	5	$1,725	$0.007	12,738	0.65	20	0.89
Gas Turbine	5	10	$1,312	$0.0071	12,367	0.77	20	0.89
Gas Turbine	10	50	$1,002	$0.0050	10,142	1.03	20	0.89
Microturbine	0.1	0.5	$2,681	$0.022	12,867	0.72	10	0.89
Microturbine	0.5	1	$2,672	$0.015	10,946	0.76	10	0.89
Reciprocating Engine	0.1	0.5	$1,576	$0.017	10,903	1.03	20	0.95
Reciprocating Engine	0.5	1	$1,326	$0.016	10,642	1.06	20	0.95
Reciprocating Engine	1	2.5	$1,176	$0.013	9,859	1.08	20	0.95
Reciprocating Engine	2.5	5	$1,125	$0.008	8,758	1.08	20	0.95
Reciprocating Engine Source: National Renewable Energy Laboratory and Gas Research Institute	5	10	$1,100	$0.0078	8,758	1.09	20	0.95

Forecast Energy Prices

We used the EIA's Annual Energy Outlook 2008[53] to develop electricity and natural gas price forecasts.[54] We assumed customers would calculate avoided energy costs using retail prices and calculate revenues from resale at wholesale prices. The ERCOT region electric power projections were used to forecast electricity prices; separate rates for commercial and industrial customers were determined, as were wholesale rates that were used to estimate the resale price of CHP generated electricity in excess of host site demand.[55] The West South Central regional forecast[56] was used for natural gas prices (again, separate rates for commercial and industrial customers). In all cases, the average cost from 2009 to 2030 (in 2008$) was used.

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[53] [EIA] United States Energy Information Agency, Annual Energy Outlook 2008 http://www.eia.doe.gov/oiaf/aeo/.

[54] ERCOT does provide *historic* market price data on their website but does not provide price forecasts. For this reason, the EIA forecasts for ERCOT for the West South Central region were used.

[55] Sites with relatively large thermal loads may have excess electrical capacity if a CHP system is sized to the thermal load. The deregulated electricity market in Texas allows for this electricity can be sold, either through ERCOT or through a bilateral contract.

[56] The ERCOT specific forecast did not include natural gas prices.

We made some adjustments to energy costs to reflect sales volume or coincidence of peak load. Commercial customers often receive a reduced natural gas rate when they add CHP to their site, because of the higher volume of natural gas consumption and more consistent year-round consumption. Therefore, a commercial CHP natural gas rate was assumed to be 90% of the EIA commercial rate. The lower, industrial natural gas rate was applied to the larger commercial sites; no reduced rate for CHP sites was applied to industrial customers, because they already receive lower rates for their high volume, consistent gas loads. Table C-1, 3 states the natural gas prices used in the CHP potential model. Commercial electricity rates for sites with 24 hour operations were assumed to be 10% less than the EIA average commercial rate, and commercial electricity sale (i.e., export) prices at business hours were assumed to be 10% greater than the EIA forecasted wholesale price to account for coincidence with peak load and peak prices. Table C-1, 4 states the electricity prices used in the CHP potential model.

Table C-1, 3. Natural Gas Rates

Rate Group	Fuel Cost (2008$/MMBtu)	Notes
Commercial - Regular Use	$9.99	EIA, commercial rate
Commercial – CHP	$8.99	90% of commercial rate
Industrial - Regular Use	$6.08	EIA, industrial rate
Industrial – CHP	$6.08	EIA, industrial rate

Table C-1, 4. Electricity Rates

Rate Group	Purchase Price ($/kWh)	Notes	Sale Price ($/kWh)	Notes
Commercial - Business Hours	$0.099	EIA	$0.074	export at high demand hours, therefore 110% of wholesale price
Commercial - All Hours	$0.089	90% of average commercial price	$0.068	EIA, ERCOT region
Industrial - All Hours	$0.080	EIA	$0.068	EIA, ERCOT region

Size CHP Systems

The Distributed Generation Technical and Economic Potential Model (DG-TEP), which had been previously developed by Summit Blue, was modified for this project and applied to the site population, energy consumption, CHP technology, and energy cost data compiled for this analysis. For each sector/size-category pair (e.g., hotels, 200 to 499 rooms), each of the four CHP technologies were sized to the base thermal load of the site.

For each system at each sector/size category pair, energy and economic parameters were computed. The electrical efficiency and E/T ratio, along with estimates of the usable percentage of potential thermal and electrical output (due to daily and seasonal variation in load below the assumed baseload level), were used to estimate the fuel consumption, electric and thermal load offsets, and electric export quantities. Finally, we used energy prices and CHP capital cost, operation and maintenance cost, and equipment lifetime to estimate two key economic metrics for each candidate sector/size-category/CHP-technology combination: the simple payback period and the net present value benefit to cost ratio.[57]

Estimate Technical Potential

Technical potential is defined here as the electrical capacity of CHP systems that are technically possible. The technical potential for CHP was determined by assigning portions of the CHP potential to the competing CHP technologies for each sector/size category pair (e.g., hotels, 200 to 499 rooms). For sites where more than one CHP technology could be adopted, the simple payback periods of competing technologies were used to determine what portion of candidate host sites would be assigned to each of the competing technologies: the lower the payback period, the larger the share of sites any particular technology received.[58] Dividing the share of CHP potential among competing technologies reflects real-world adoption patterns, where factors outside of the consideration in this model result in a range of technology adoptions; the technologies with the most compelling economics tend to dominate the market, however.

This approach to dividing technical potential amongst competing technologies presents the counterintuitive result that the technical potential *changes* under different scenario assumptions. For example, gas turbines have an E/T ratio of approximately 0.65 and reciprocating engines have and E/T ratio of approximately 1.05. This means that, for a given output of thermal energy, reciprocating engines produce almost twice as much electricity as gas turbines. If systems are sized to the thermal load of the site, and if Scenario A favors gas turbines and Scenario B favors reciprocating engines, then Scenario A will result in a smaller technical potential (the electrical capacity) than Scenario B. Note that the *thermal* output capacity of the technical potential in all scenarios stays constant.

The EIA ERCOT annual load growth forecast for the years 2009 to 2030 (1.1%) was used to extrapolate the results from current data to the 2023 estimation year potential results. This 15-year time horizon was considered to allow Texas to develop desirable policies and for market penetration to reach high levels.

Estimate Economic Potential

The benefit/cost ratio was used to determine whether a particular system was economic. *Benefits* are the sum of fuel and energy savings, revenue from electricity sales, and subsidies received for the CHP system. *Costs* are the sum of capital, operation and maintenance, and fuel costs for the CHP system. All

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[57] The participant test benefic cost ratio, as defined in the *California Standard Practice Manual: Economic Analysis of Demand-Side Programs and Projects*, (CPUC 2001) was used:

$$B/C = \frac{NPV(Benefits)}{NPV(Costs)}$$

where *Benefits* is the sum of fuel and energy savings, revenue from electricity sales, and subsidies received for the CHP system. Costs are the sum of capital, operation and maintenance, and fuel costs for the CHP system.

[58] For a particular candidate site (e.g. Hotels, 200 to 499 rooms), competing technologies received a score of

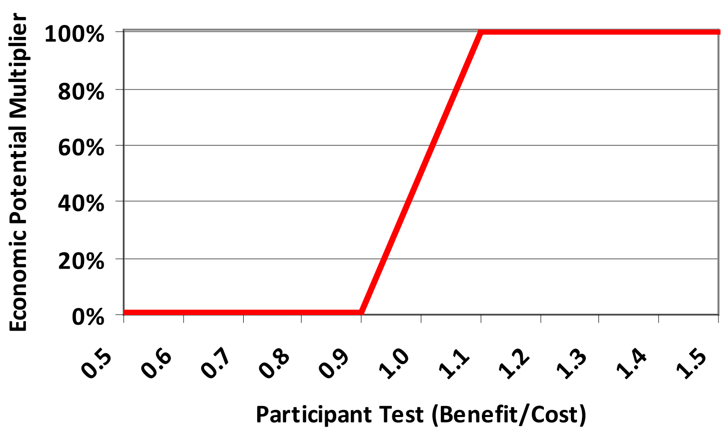
$$\left(\frac{1}{PaybackPeriod}\right)^2$$

and the number of candidate sites was assigned proportional to these scores, adding up to the statewide number of candidate sites.

benefits and costs are calculated over a 10- to 20-year period (depending on the expected lifetime of the equipment) beginning in 2009, with annual values discounted to 2008 dollars at a 6.4% real discount rate.

Any system with a benefit/cost ratio greater than one is considered economic. However, a modification to this approach was made in order to account for the aggregate nature of the facility data used in the model and to avoid rejecting a whole category of facilities for falling just short of the economic threshold. Thus, any system with a benefit/cost ratio less than 0.9 was assigned no economic potential; and system with a benefit/cost ratio greater than 1.1 was assigned 100% economic potential (i.e., 100% of technical potential was economic); and any system with a benefit/cost ration between 0.9 and 1.1 was assigned an economic potential that varied linearly from 0% (for a benefit cost ratio of 0.9) to 100% (for a benefit cost ratio of 1.1). This is illustrated in Figure C-1, 3. Note that economic *potential* simply gauges whether or not a project meets a specific economic criteria. This is different than *market* potential, which considers additional factors, such as perceived risk, competing technologies and practices, and penetration rates. Market potential was not addressed in this analysis.

Figure C-1, 3. Percentage of Technical Potential that is Economic as a Function of Benefit / Cost Ratio



As with the technical potential, the economic potential was extrapolated to 2023 by assuming the average annual load ERCOT load growth.

Opportunity Fuels

CHP can benefit from available fuels or fuel precursors that are typically not used as such. This analysis only considered such "opportunity fuels" for waste water treatment facilities, where methane can be produced on-site from anaerobic decomposition of the waste water. Other opportunity fuels include agricultural waste (including animal manure, crop residue, and animal offal), food processing waste, landfill gas, municipal solid waste, wood, and wood waste, as well as industrial waste products, such as textile waste and tire derived fuels. These fuels could also be used to fire CHP systems, providing a carbon neutral fuel source and potentially lower fuel cost than natural gas. Extra costs are incurred, however, in the collection, processing, and possibly transporting of these fuels.

Some opportunity fuels are already located at candidate CHP sites, such as food processing waste, paper mill wood waste, and agricultural sites that include greenhouses or food processing plants. Other fuels could be collected locally to fuel a central CHP plant. Opportunity fuels do not represent additional technical potential for CHP, but could improve the economic case for some of the technical potential identified in this analysis.

A recent study by the Houston Advanced Research Center[59] concluded that there are roughly 419 MW of net CHP electrical capacity that could be supported by agricultural waste produced in Texas. Another study, shown in Table C-1, 5, by Resource Dynamics Corporation[60] estimates 5,511 MW of opportunity derived CHP in Texas, although these estimates are approximately an order of magnitude larger than the biomass estimates in the HARC study and the wastewater treatment plant estimates developed as part of this analysis.

Table C-1, 5. Resource Dynamics Corporation Estimate of Opportunity Fuel CHP Potential in Texas

Source	Potential Capacity (MW)
Waste Water Treatment Plants	152
Cow and Pig Waste	362
Biomass Gas	3,610
Landfill Gas	174
Wellhead Gas	546
Wood (Forest Residue and Harvested Wood)	229
Urban Wood Waste	438
Total	5,511

Conduct Key Parameter Sensitivities

Several scenarios were considered to examine the sensitivity of results to variations in key parameter assumptions. The parameters that varied were natural gas prices, electricity prices, capital cost, $/kW CHP subsidies, and the assumed discount rate. Table C-1, 6 states the scenarios considered and parameter adjustment values for each scenario.

Table C-1, 6. Sensitivity Analysis Scenarios

Scenario	Difference from Base Case	Description
Low Gas Cost	-25%	decrease from base case gas cost
High Gas Cost	+50%	increase from base case gas cost

[59] Bullock, Daniel, Sarah Weingarden, and Lianne Lami., *Combined Heat and Power Potential using Texas Agricultural Wastes*, Houston Advanced Research Center January 2008.

[60] Resource Dynamics Corporation, *Combined Heat and Power Market Potential for Opportunity Fuels: Task 1 and 2*, United States Department of Energy Distributed Energy Program Report, December 2004.

Low Electricity Cost & Market Price	-15%	decrease from base case values
High Electricity Cost & Market Price	+50%	increase from base case values
Low Capital Cost	-20%	decrease from base case capital cost
High Capital Cost	+20%	increase from base case capital cost
Low Subsidy	$100	$/kW decrease from base case capital cost
High Subsidy	$500	$/kW decrease from base case capital cost
Low Discount Rate	-2%	Decrease from base case discount rate of 6.4%
High Discount Rate	+2%	Increase from base case discount rate of 6.4%

APPENDIX C-2:
DETAILED POTENTIAL RESULTS FOR ALL SCENARIOS

DETAILED POTENTIAL RESULTS FOR ALL SCENARIOS

This appendix presents the sector technical and economic CHP potential results for all scenarios, as shown in Table C-2, 1 through Table C-2, 12.

Table C-2, 1. Base Case Results

	Technical Potential				*Economic Potential*			
	<1 MW	**1 - 10 MW**	**>10 MW**	***Total***	**<1 MW**	**1 - 10 MW**	**>10 MW**	***Total***
Commercial								
Hotel	107	27		***134***	1	23		***23***
Prison	25	1		***27***	0	0		***1***
Colleges and Universities	46	172		***217***		72		***72***
Dormitory/Fraternity/Sorority	10			***10***	3			***3***
Elementary/Middle School	39	3		***42***				
High School	1			***1***				
Hospital/Inpatient Health	126	138		***264***	38	119		***156***
Nursing Home/Assisted Living	245	7		***252***	68	7		***75***
Other Classroom Education	26			***26***				
Laundry and Car Wash Services	309	305		***614***		1		***1***
Recreation	237	99		***337***		19		***19***
Commercial Total	***1,172***	***752***		***1,924***	***110***	***240***		***350***
Industrial								
Waste Water Treatment Facility	7	12		***18***	7	12		***18***
Dry Mill Ethanol Plant		43	268	***311***		43	268	***311***
Food Manufacturing	225	579	203	***1,007***	27	527	203	***756***
Beverage and Tobacco Product Manufacturing	17	101		***118***	3	99		***103***
Textile Mills	13	49		***62***	5	49		***54***
Textile Product Mills	64	20		***84***	15	20		***35***
Apparel Manufacturing	21	25		***46***	8	19		***27***
Leather and Allied Product Manufacturing	3	7		***10***	1	7		***8***
Wood Product Manufacturing	53	40		***92***	29	34		***63***
Paper Manufacturing	167	606	95	***868***	38	561	95	***693***
Printing and Related Support Activities	42	16		***58***	18	16		***34***
Petroleum and Coal Products Manufacturing		663		***663***		608		***608***
Chemical Manufacturing		2,389	5,306	***7,695***		2,176	5,192	***7,368***
Plastics and Rubber Products Manufacturing	216	83		***299***	111	78		***188***
Nonmetallic Mineral Product Manufacturing	412	773		***1,185***	74	712		***786***
Primary Metal Manufacturing	211	489	906	***1,606***	103	469	906	***1,478***
Fabricated Metal Product Manufacturing	228	71		***299***	92	71		***163***
Machinery Manufacturing	91	12		***103***	45	12		***57***
Computer and Electronic Product Manufacturing	45	62		***107***	22	59		***81***
Electrical Equipment, Appliance, and Component Manufacturing	39	17		***56***	19	12		***31***
Transportation Equipment Manufacturing	55	38	96	***188***	28	38	96	***162***
Furniture and Related Product Manufacturing	20	5		***25***	10	5		***14***
Miscellaneous Manufacturing	31	3		***34***	15	3		***17***
Industrial Total	***1,959***	***6,102***	***6,874***	***14,935***	***668***	***5,630***	***6,759***	***13,057***
Commercial and Industrial Total	***3,131***	***6,855***	***6,874***	***16,859***	***778***	***5,870***	***6,759***	***13,407***

Table C-2, 2. Low Gas Cost Sensitivity - 75% of Base Case

	Technical Potential				Economic Potential			
	<1 MW	1 - 10 MW	>10 MW	*Total*	<1 MW	1 - 10 MW	>10 MW	*Total*
Commercial								
Hotel	106	24		***130***	56	24		***80***
Prison	25	4		***29***	14	3		***17***
Colleges and Universities	48	168		***215***	6	128		***134***
Dormitory/Fraternity/Sorority	10			***10***	9			***9***
Elementary/Middle School	39	3		***41***				
High School	1			***1***				
Hospital/Inpatient Health	129	138		***266***	104	117		***221***
Nursing Home/Assisted Living	240	7		***247***	208	7		***215***
Other Classroom Education	26			***26***				
Laundry and Car Wash Services	421	21		***442***		10		***10***
Recreation	239	37		***276***	4	34		***38***
Commercial Total	***1,282***	***401***		***1,683***	***400***	***323***		***723***
Industrial								
Waste Water Treatment Facility	7	12		***18***	7	12		***18***
Dry Mill Ethanol Plant		41	268	***309***		41	268	***309***
Food Manufacturing	210	581	201	***992***	123	556	201	***880***
Beverage and Tobacco Product Manufacturing	17	98		***115***	10	98		***108***
Textile Mills	12	49		***61***	11	49		***60***
Textile Product Mills	63	20		***83***	48	20		***68***
Apparel Manufacturing	20	27		***47***	13	27		***40***
Leather and Allied Product Manufacturing	3	7		***10***	2	7		***9***
Wood Product Manufacturing	54	40		***94***	43	37		***80***
Paper Manufacturing	173	594	95	***862***	134	558	95	***787***
Printing and Related Support Activities	41	16		***58***	35	16		***52***
Petroleum and Coal Products Manufacturing		643		***643***		612		***612***
Chemical Manufacturing		2,334	5,279	***7,613***		2,189	5,126	***7,315***
Plastics and Rubber Products Manufacturing	217	84		***300***	182	78		***260***
Nonmetallic Mineral Product Manufacturing	437	752		***1,189***	316	716		***1,032***
Primary Metal Manufacturing	214	482	900	***1,596***	173	461	900	***1,533***
Fabricated Metal Product Manufacturing	236	71		***306***	179	71		***249***
Machinery Manufacturing	91	11		***102***	77	11		***88***
Computer and Electronic Product Manufacturing	45	61		***106***	38	59		***97***
Electrical Equipment, Appliance, and Component Manufacturing	39	19		***57***	29	19		***47***
Transportation Equipment Manufacturing	56	48	82	***186***	44	48	82	***173***
Furniture and Related Product Manufacturing	20	5		***25***	17	5		***22***
Miscellaneous Manufacturing	31	3		***34***	27	3		***29***
Industrial Total	***1,986***	***5,996***	***6,824***	***14,806***	***1,508***	***5,691***	***6,672***	***13,870***
Commercial and Industrial Total	***3,268***	***6,396***	***6,824***	***16,489***	***1,908***	***6,014***	***6,672***	***14,594***

Table C-2, 3. High Gas Cost Sensitivity - 150 % of Base Case

	Technical Potential				Economic Potential			
	<1 MW	1 - 10 MW	>10 MW	*Total*	<1 MW	1 - 10 MW	>10 MW	*Total*
Commercial								
Hotel	104	36		***140***		18		***18***
Prison	26	9		***35***				
Colleges and Universities	40	225		***265***		16		***16***
Dormitory/Fraternity/Sorority	10			***10***				
Elementary/Middle School	42	2		***43***				
High School	1			***1***				
Hospital/Inpatient Health	117	244		***362***		1		***1***
Nursing Home/Assisted Living	235	36		***272***		4		***4***
Other Classroom Education	24	5		***29***				
Laundry and Car Wash Services	373	156	13	***542***				
Recreation	204	131		***335***				
Commercial Total	***1,178***	***843***	***13***	***2,035***		***40***		***40***
Industrial								
Waste Water Treatment Facility	7	12		***18***	7	12		***18***
Dry Mill Ethanol Plant		43	268	***311***		18	190	***208***
Food Manufacturing	177	865	235	***1,277***		236	118	***354***
Beverage and Tobacco Product Manufacturing	24	129		***153***		51		***51***
Textile Mills	12	58		***70***		39		***39***
Textile Product Mills	52	53		***104***		13		***13***
Apparel Manufacturing	28	37		***65***		5		***5***
Leather and Allied Product Manufacturing	3	11		***15***		3		***3***
Wood Product Manufacturing	78	53		***131***		6		***6***
Paper Manufacturing	96	837	159	***1,092***		370	50	***421***
Printing and Related Support Activities	42	23		***65***		3		***3***
Petroleum and Coal Products Manufacturing		723		***723***		236		***236***
Chemical Manufacturing		2,631	5,697	***8,328***		930	2,065	***2,996***
Plastics and Rubber Products Manufacturing	163	217		***380***		80		***80***
Nonmetallic Mineral Product Manufacturing	613	836		***1,450***		391		***391***
Primary Metal Manufacturing	130	704	930	***1,765***		458	717	***1,175***
Fabricated Metal Product Manufacturing	337	103		***440***		10		***10***
Machinery Manufacturing	75	50		***125***		12		***12***
Computer and Electronic Product Manufacturing	36	88		***124***		63		***63***
Electrical Equipment, Appliance, and Component Manufacturing	56	28		***84***				
Transportation Equipment Manufacturing	76	41	109	***226***		5	104	***109***
Furniture and Related Product Manufacturing	23	5		***28***		1		***1***
Miscellaneous Manufacturing	38	3		***40***		1		***1***
Industrial Total	***2,067***	***7,549***	***7,397***	***17,012***	***7***	***2,942***	***3,245***	***6,194***
Commercial and Industrial Total	***3,245***	***8,392***	***7,410***	***19,047***	***7***	***2,982***	***3,245***	***6,234***

Table C-2, 4. Low Electricity Cost Sensitivity - 85% of Base Case

	Technical Potential				Economic Potential			
	<1 MW	1 - 10 MW	>10 MW	*Total*	<1 MW	1 - 10 MW	>10 MW	*Total*
Commercial								
Hotel	102	44		***146***		25		***25***
Prison	27	13		***40***				
Colleges and Universities	16	243		***258***		30		***30***
Dormitory/Fraternity/Sorority	10			***10***				
Elementary/Middle School	47	3		***50***				
High School	1			***1***				
Hospital/Inpatient Health	88	204		***291***		47		***47***
Nursing Home/Assisted Living	231	38		***269***		7		***7***
Other Classroom Education	18	19		***37***				
Laundry and Car Wash Services	358	237	13	***608***				
Recreation	199	152	18	***370***		1		***1***
Commercial Total	***1,097***	***952***	***32***	***2,081***		***110***		***110***
Industrial								
Waste Water Treatment Facility	7	12		***18***	7	12		***18***
Dry Mill Ethanol Plant		43	268	***311***		36	245	***282***
Food Manufacturing	237	566	203	***1,007***		391	188	***580***
Beverage and Tobacco Product Manufacturing	20	97		***117***		71		***71***
Textile Mills	13	52		***64***		46		***46***
Textile Product Mills	54	37		***91***		20		***20***
Apparel Manufacturing	26	22		***49***	0	7		***7***
Leather and Allied Product Manufacturing	3	7		***10***		5		***5***
Wood Product Manufacturing	57	40		***97***	2	19		***21***
Paper Manufacturing	93	751	110	***954***		561	87	***647***
Printing and Related Support Activities	43	16		***60***		10		***10***
Petroleum and Coal Products Manufacturing		717		***717***		530		***530***
Chemical Manufacturing		2,545	5,462	***8,007***		1,954	4,041	***5,995***
Plastics and Rubber Products Manufacturing	196	122		***317***	6	79		***85***
Nonmetallic Mineral Product Manufacturing	574	811		***1,385***		711		***711***
Primary Metal Manufacturing	170	568	906	***1,644***	3	461	906	***1,370***
Fabricated Metal Product Manufacturing	255	69		***324***		36		***36***
Machinery Manufacturing	85	24		***109***	2	12		***14***
Computer and Electronic Product Manufacturing	42	69		***111***	1	59		***60***
Electrical Equipment, Appliance, and Component Manufacturing	45	17		***61***	1	1		***2***
Transportation Equipment Manufacturing	59	38	96	***193***	2	20	96	***118***
Furniture and Related Product Manufacturing	21	5		***25***	0	3		***3***
Miscellaneous Manufacturing	32	3		***35***	1	2		***2***
Industrial Total	***2,032***	***6,631***	***7,045***	***15,708***	***26***	***5,045***	***5,563***	***10,634***
Commercial and Industrial Total	***3,129***	***7,583***	***7,077***	***17,789***	***26***	***5,155***	***5,563***	***10,744***

Table C-2, 5. High Electricity Cost Sensitivity - 150 % of Base Case

	Technical Potential				*Economic Potential*			
	<1 MW	**1 - 10 MW**	**>10 MW**	***Total***	**<1 MW**	**1 - 10 MW**	**>10 MW**	***Total***
Commercial								
Hotel	105	24		***129***	91	24		***115***
Prison	25	4		***29***	22	4		***26***
Colleges and Universities	48	168		***216***	36	152		***187***
Dormitory/Fraternity/Sorority	10			***10***	9			***9***
Elementary/Middle School	39	3		***41***	17	3		***20***
High School	1			***1***	0			***0***
Hospital/Inpatient Health	128	139		***268***	125	128		***253***
Nursing Home/Assisted Living	239	7		***246***	217	7		***224***
Other Classroom Education	26			***26***	5			***5***
Laundry and Car Wash Services	422	26		***448***	102	19		***121***
Recreation	240	39		***279***	168	35		***202***
Commercial Total	***1,282***	***409***		***1,691***	***792***	***371***		***1,163***
Industrial								
Waste Water Treatment Facility	7	12		***18***	7	12		***18***
Dry Mill Ethanol Plant		41	271	***312***		41	271	***312***
Food Manufacturing	206	585	201	***992***	186	573	201	***961***
Beverage and Tobacco Product Manufacturing	17	98		***115***	16	98		***115***
Textile Mills	12	49		***61***	11	49		***60***
Textile Product Mills	64	20		***84***	60	20		***80***
Apparel Manufacturing	20	27		***47***	20	27		***47***
Leather and Allied Product Manufacturing	3	7		***10***	3	7		***10***
Wood Product Manufacturing	55	40		***95***	53	40		***93***
Paper Manufacturing	174	594	95	***862***	172	584	95	***851***
Printing and Related Support Activities	41	16		***57***	37	16		***54***
Petroleum and Coal Products Manufacturing		643		***643***		617		***617***
Chemical Manufacturing		2,329	5,300	***7,629***		2,219	5,175	***7,394***
Plastics and Rubber Products Manufacturing	216	86		***302***	208	79		***288***
Nonmetallic Mineral Product Manufacturing	449	751		***1,200***	416	735		***1,151***
Primary Metal Manufacturing	213	483	900	***1,596***	213	474	900	***1,587***
Fabricated Metal Product Manufacturing	240	72		***312***	231	72		***303***
Machinery Manufacturing	90	13		***103***	85	11		***96***
Computer and Electronic Product Manufacturing	44	61		***105***	42	60		***102***
Electrical Equipment, Appliance, and Component Manufacturing	40	19		***58***	39	19		***57***
Transportation Equipment Manufacturing	57	48	82	***187***	55	48	82	***185***
Furniture and Related Product Manufacturing	20	5		***24***	19	5		***23***
Miscellaneous Manufacturing	31	3		***33***	29	3		***32***
Industrial Total	***1,997***	***6,000***	***6,849***	***14,846***	***1,902***	***5,809***	***6,724***	***14,435***
Commercial and Industrial Total	***3,279***	***6,409***	***6,849***	***16,537***	***2,694***	***6,179***	***6,724***	***15,598***

Table C-2, 6. Low Capital Cost Sensitivity - 80% of Base Case

	Technical Potential				*Economic Potential*			
	<1 MW	1 - 10 MW	>10 MW	*Total*	<1 MW	1 - 10 MW	>10 MW	*Total*
Commercial								
Hotel	107	26		***133***	2	23		***25***
Prison	25	1		***27***	1	0		***1***
Colleges and Universities	46	172		***217***		99		***99***
Dormitory/Fraternity/Sorority	10			***10***	4			***4***
Elementary/Middle School	39	3		***42***				
High School	1			***1***				
Hospital/Inpatient Health	126	138		***264***	52	119		***171***
Nursing Home/Assisted Living	245	7		***252***	100	7		***107***
Other Classroom Education	26			***26***				
Laundry and Car Wash Services	325	258		***583***		8		***8***
Recreation	240	79		***319***		29		***29***
Commercial Total	***1,191***	***684***		***1,875***	***160***	***285***		***445***
Industrial								
Waste Water Treatment Facility	7	12		***18***	7	12		***18***
Dry Mill Ethanol Plant		43	268	***311***		43	268	***311***
Food Manufacturing	223	579	203	***1,005***	58	559	203	***820***
Beverage and Tobacco Product Manufacturing	17	101		***118***	6	101		***107***
Textile Mills	13	49		***62***	7	49		***56***
Textile Product Mills	64	20		***84***	23	20		***43***
Apparel Manufacturing	21	25		***46***	10	22		***32***
Leather and Allied Product Manufacturing	3	7		***10***	1	7		***8***
Wood Product Manufacturing	53	40		***92***	35	35		***70***
Paper Manufacturing	167	606	95	***868***	54	575	95	***724***
Printing and Related Support Activities	42	16		***58***	25	16		***41***
Petroleum and Coal Products Manufacturing		663		***663***		619		***619***
Chemical Manufacturing		2,389	5,306	***7,695***		2,217	5,192	***7,409***
Plastics and Rubber Products Manufacturing	216	83		***299***	141	79		***220***
Nonmetallic Mineral Product Manufacturing	412	773		***1,185***	113	728		***842***
Primary Metal Manufacturing	211	489	906	***1,606***	128	471	906	***1,505***
Fabricated Metal Product Manufacturing	228	71		***299***	119	71		***189***
Machinery Manufacturing	91	12		***103***	58	12		***70***
Computer and Electronic Product Manufacturing	45	62		***107***	28	60		***88***
Electrical Equipment, Appliance, and Component Manufacturing	39	17		***56***	23	15		***39***
Transportation Equipment Manufacturing	55	38	96	***188***	35	38	96	***169***
Furniture and Related Product Manufacturing	20	5		***25***	13	5		***17***
Miscellaneous Manufacturing	31	3		***34***	20	3		***22***
Industrial Total	***1,956***	***6,102***	***6,874***	***14,932***	***904***	***5,756***	***6,759***	***13,419***
Commercial and Industrial Total	***3,147***	***6,786***	***6,874***	***16,807***	***1,063***	***6,041***	***6,759***	***13,863***

Table C-2, 7. High Capital Cost Sensitivity - 120% of Base Case

	Technical Potential				*Economic Potential*			
	<1 MW	1 - 10 MW	>10 MW	*Total*	<1 MW	1 - 10 MW	>10 MW	*Total*
Commercial								
Hotel	106	29		***135***		22		***22***
Prison	25	1		***27***				
Colleges and Universities	46	172		***217***		53		***53***
Dormitory/Fraternity/Sorority	10			***10***	1			***1***
Elementary/Middle School	39	3		***42***				
High School	1			***1***				
Hospital/Inpatient Health	126	138		***264***	26	107		***133***
Nursing Home/Assisted Living	245	7		***252***	39	7		***46***
Other Classroom Education	26			***26***				
Laundry and Car Wash Services	298	338		***636***				
Recreation	232	122		***354***		11		***11***
Commercial Total	***1,155***	***810***		***1,965***	***66***	***199***		***265***
Industrial								
Waste Water Treatment Facility	7	12		***18***	7	12		***18***
Dry Mill Ethanol Plant		43	268	***311***		43	268	***311***
Food Manufacturing	228	579	203	***1,010***		486	203	***688***
Beverage and Tobacco Product Manufacturing	17	101		***118***	1	93		***94***
Textile Mills	13	49		***62***	3	48		***51***
Textile Product Mills	65	20		***85***	8	20		***28***
Apparel Manufacturing	21	25		***46***	6	16		***22***
Leather and Allied Product Manufacturing	3	7		***10***	0	7		***7***
Wood Product Manufacturing	53	40		***92***	23	33		***56***
Paper Manufacturing	167	606	95	***868***	22	548	95	***665***
Printing and Related Support Activities	42	16		***58***	11	16		***28***
Petroleum and Coal Products Manufacturing		663		***663***		598		***598***
Chemical Manufacturing		2,389	5,306	***7,695***		2,139	5,192	***7,331***
Plastics and Rubber Products Manufacturing	216	83		***299***	83	76		***159***
Nonmetallic Mineral Product Manufacturing	412	773		***1,185***	37	697		***734***
Primary Metal Manufacturing	211	489	906	***1,606***	79	456	906	***1,441***
Fabricated Metal Product Manufacturing	228	71		***299***	68	69		***136***
Machinery Manufacturing	91	12		***103***	32	12		***45***
Computer and Electronic Product Manufacturing	45	62		***107***	16	58		***74***
Electrical Equipment, Appliance, and Component Manufacturing	39	17		***56***	15	10		***25***
Transportation Equipment Manufacturing	55	38	96	***188***	22	36	96	***154***
Furniture and Related Product Manufacturing	20	5		***25***	7	5		***11***
Miscellaneous Manufacturing	31	3		***34***	11	3		***13***
Industrial Total	***1,962***	***6,102***	***6,874***	***14,938***	***450***	***5,479***	***6,759***	***12,688***
Commercial and Industrial Total	***3,117***	***6,912***	***6,874***	***16,903***	***516***	***5,678***	***6,759***	***12,954***

Table C-2, 8. Low Subsidy Sensitivity - $/100 kW

	Technical Potential				Economic Potential			
	<1 MW	1 - 10 MW	>10 MW	*Total*	<1 MW	1 - 10 MW	>10 MW	*Total*
Commercial								
Hotel	107	27		***134***	1	23		***24***
Prison	25	1		***27***	1	0		***1***
Colleges and Universities	46	172		***217***		83		***83***
Dormitory/Fraternity/Sorority	10			***10***	3			***3***
Elementary/Middle School	39	3		***42***				
High School	1			***1***				
Hospital/Inpatient Health	126	138		***264***	42	119		***161***
Nursing Home/Assisted Living	245	7		***252***	79	7		***86***
Other Classroom Education	26			***26***				
Laundry and Car Wash Services	309	305		***614***		4		***4***
Recreation	237	99		***337***		23		***23***
Commercial Total	***1,172***	***752***		***1,924***	***126***	***259***		***385***
Industrial								
Waste Water Treatment Facility	7	12		***18***	7	12		***18***
Dry Mill Ethanol Plant		43	268	***311***		43	268	***311***
Food Manufacturing	225	579	203	***1,007***	35	543	203	***780***
Beverage and Tobacco Product Manufacturing	17	101		***118***	4	100		***104***
Textile Mills	13	49		***62***	5	49		***54***
Textile Product Mills	64	20		***84***	18	20		***38***
Apparel Manufacturing	21	25		***46***	9	20		***28***
Leather and Allied Product Manufacturing	3	7		***10***	1	7		***8***
Wood Product Manufacturing	53	40		***92***	31	34		***65***
Paper Manufacturing	167	606	95	***868***	44	565	95	***703***
Printing and Related Support Activities	42	16		***58***	20	16		***36***
Petroleum and Coal Products Manufacturing		663		***663***		611		***611***
Chemical Manufacturing		2,389	5,306	***7,695***		2,188	5,192	***7,380***
Plastics and Rubber Products Manufacturing	216	83		***299***	121	78		***199***
Nonmetallic Mineral Product Manufacturing	412	773		***1,185***	89	717		***806***
Primary Metal Manufacturing	211	489	906	***1,606***	111	471	906	***1,489***
Fabricated Metal Product Manufacturing	228	71		***299***	101	71		***172***
Machinery Manufacturing	91	12		***103***	49	12		***61***
Computer and Electronic Product Manufacturing	45	62		***107***	24	59		***84***
Electrical Equipment, Appliance, and Component Manufacturing	39	17		***56***	21	13		***34***
Transportation Equipment Manufacturing	55	38	96	***188***	30	38	96	***164***
Furniture and Related Product Manufacturing	20	5		***25***	11	5		***15***
Miscellaneous Manufacturing	31	3		***34***	16	3		***19***
Industrial Total	***1,959***	***6,102***	***6,874***	***14,935***	***747***	***5,674***	***6,759***	***13,181***
Commercial and Industrial Total	***3,131***	***6,855***	***6,874***	***16,859***	***873***	***5,933***	***6,759***	***13,565***

Table C-2, 9. High Subsidy Sensitivity - $/500 kW

	Technical Potential				Economic Potential			
	<1 MW	1 - 10 MW	>10 MW	*Total*	<1 MW	1 - 10 MW	>10 MW	*Total*
Commercial								
Hotel	107	27		***134***	5	23		***28***
Prison	25	1		***27***	2	0		***2***
Colleges and Universities	46	172		***217***	5	129		***134***
Dormitory/Fraternity/Sorority	10			***10***	5			***5***
Elementary/Middle School	39	3		***42***		1		***1***
High School	1			***1***				
Hospital/Inpatient Health	126	138		***264***	61	119		***180***
Nursing Home/Assisted Living	245	7		***252***	120	7		***127***
Other Classroom Education	26			***26***				
Laundry and Car Wash Services	309	305		***614***		16		***16***
Recreation	237	99		***337***	1	34		***35***
Commercial Total	***1,172***	***752***		***1,924***	***198***	***330***		***528***
Industrial								
Waste Water Treatment Facility	7	12		***18***	7	12		***18***
Dry Mill Ethanol Plant		43	268	***311***		43	268	***311***
Food Manufacturing	225	579	203	***1,007***	69	562	203	***834***
Beverage and Tobacco Product Manufacturing	17	101		***118***	7	101		***107***
Textile Mills	13	49		***62***	8	49		***57***
Textile Product Mills	64	20		***84***	28	20		***48***
Apparel Manufacturing	21	25		***46***	11	24		***35***
Leather and Allied Product Manufacturing	3	7		***10***	1	7		***8***
Wood Product Manufacturing	53	40		***92***	40	35		***75***
Paper Manufacturing	167	606	95	***868***	69	580	95	***743***
Printing and Related Support Activities	42	16		***58***	28	16		***44***
Petroleum and Coal Products Manufacturing		663		***663***		623		***623***
Chemical Manufacturing		2,389	5,306	***7,695***		2,233	5,192	***7,425***
Plastics and Rubber Products Manufacturing	216	83		***299***	161	79		***240***
Nonmetallic Mineral Product Manufacturing	412	773		***1,185***	149	737		***886***
Primary Metal Manufacturing	211	489	906	***1,606***	147	471	906	***1,524***
Fabricated Metal Product Manufacturing	228	71		***299***	138	71		***208***
Machinery Manufacturing	91	12		***103***	66	12		***79***
Computer and Electronic Product Manufacturing	45	62		***107***	33	60		***93***
Electrical Equipment, Appliance, and Component Manufacturing	39	17		***56***	27	17		***44***
Transportation Equipment Manufacturing	55	38	96	***188***	40	38	96	***173***
Furniture and Related Product Manufacturing	20	5		***25***	15	5		***19***
Miscellaneous Manufacturing	31	3		***34***	22	3		***25***
Industrial Total	***1,959***	***6,102***	***6,874***	***14,935***	***1,066***	***5,798***	***6,759***	***13,623***
Commercial and Industrial Total	***3,131***	***6,855***	***6,874***	***16,859***	***1,264***	***6,128***	***6,759***	***14,151***

Table C-2, 10. Low Discount Rate Sensitivity – 4.4% Discount Rate

	Technical Potential				*Economic Potential*			
	<1 MW	1 - 10 MW	>10 MW	*Total*	<1 MW	1 - 10 MW	>10 MW	*Total*
Commercial								
Hotel	107	27		***134***	1	23		***24***
Prison	25	1		***27***	1	0		***1***
Colleges and Universities	46	172		***217***		93		***93***
Dormitory/Fraternity/Sorority	10			***10***	4			***4***
Elementary/Middle School	39	3		***42***				
High School	1			***1***				
Hospital/Inpatient Health	126	138		***264***	49	119		***168***
Nursing Home/Assisted Living	245	7		***252***	92	7		***99***
Other Classroom Education	26			***26***				
Laundry and Car Wash Services	309	305		***614***		6		***6***
Recreation	237	99		***337***		27		***27***
Commercial Total	***1,172***	***752***		***1,924***	***147***	***274***		***421***
Industrial								
Waste Water Treatment Facility	7	12		***18***	7	12		***18***
Dry Mill Ethanol Plant		43	268	***311***		43	268	***311***
Food Manufacturing	225	579	203	***1,007***	49	557	203	***809***
Beverage and Tobacco Product Manufacturing	17	101		***118***	5	101		***106***
Textile Mills	13	49		***62***	6	49		***55***
Textile Product Mills	64	20		***84***	21	20		***41***
Apparel Manufacturing	21	25		***46***	9	21		***30***
Leather and Allied Product Manufacturing	3	7		***10***	1	7		***8***
Wood Product Manufacturing	53	40		***92***	34	34		***68***
Paper Manufacturing	167	606	95	***868***	50	572	95	***717***
Printing and Related Support Activities	42	16		***58***	23	16		***39***
Petroleum and Coal Products Manufacturing		663		***663***		616		***616***
Chemical Manufacturing		2,389	5,306	***7,695***		2,207	5,192	***7,399***
Plastics and Rubber Products Manufacturing	216	83		***299***	133	79		***213***
Nonmetallic Mineral Product Manufacturing	412	773		***1,185***	104	725		***829***
Primary Metal Manufacturing	211	489	906	***1,606***	122	471	906	***1,499***
Fabricated Metal Product Manufacturing	228	71		***299***	112	71		***183***
Machinery Manufacturing	91	12		***103***	55	12		***67***
Computer and Electronic Product Manufacturing	45	62		***107***	27	60		***87***
Electrical Equipment, Appliance, and Component Manufacturing	39	17		***56***	22	14		***37***
Transportation Equipment Manufacturing	55	38	96	***188***	33	38	96	***167***
Furniture and Related Product Manufacturing	20	5		***25***	12	5		***17***
Miscellaneous Manufacturing	31	3		***34***	18	3		***21***
Industrial Total	***1,959***	***6,102***	***6,874***	***14,935***	***846***	***5,733***	***6,759***	***13,338***
Commercial and Industrial Total	***3,131***	***6,855***	***6,874***	***16,859***	***993***	***6,007***	***6,759***	***13,759***

Table C-2, 11. High Discount Rate Sensitivity – 8.4%

	Technical Potential				*Economic Potential*			
	<1 MW	1 - 10 MW	>10 MW	*Total*	<1 MW	1 - 10 MW	>10 MW	*Total*
Commercial								
Hotel	107	27		***134***	0	22		***22***
Prison	25	1		***27***	0	0		***0***
Colleges and Universities	46	172		***217***		54		***54***
Dormitory/Fraternity/Sorority	10			***10***	2			***2***
Elementary/Middle School	39	3		***42***				
High School	1			***1***				
Hospital/Inpatient Health	126	138		***264***	28	110		***138***
Nursing Home/Assisted Living	245	7		***252***	44	7		***51***
Other Classroom Education	26			***26***				
Laundry and Car Wash Services	309	305		***614***				
Recreation	237	99		***337***		12		***12***
Commercial Total	***1,172***	***752***		***1,924***	***73***	***206***		***279***
Industrial								
Waste Water Treatment Facility	7	12		***18***	7	12		***18***
Dry Mill Ethanol Plant		43	268	***311***		43	268	***311***
Food Manufacturing	225	579	203	***1,007***	4	493	203	***699***
Beverage and Tobacco Product Manufacturing	17	101		***118***	1	94		***96***
Textile Mills	13	49		***62***	3	48		***51***
Textile Product Mills	64	20		***84***	9	20		***29***
Apparel Manufacturing	21	25		***46***	6	16		***23***
Leather and Allied Product Manufacturing	3	7		***10***	0	7		***7***
Wood Product Manufacturing	53	40		***92***	24	33		***57***
Paper Manufacturing	167	606	95	***868***	25	550	95	***670***
Printing and Related Support Activities	42	16		***58***	12	16		***29***
Petroleum and Coal Products Manufacturing		663		***663***		600		***600***
Chemical Manufacturing		2,389	5,306	***7,695***		2,145	5,192	***7,337***
Plastics and Rubber Products Manufacturing	216	83		***299***	87	76		***164***
Nonmetallic Mineral Product Manufacturing	412	773		***1,185***	44	699		***743***
Primary Metal Manufacturing	211	489	906	***1,606***	83	458	906	***1,448***
Fabricated Metal Product Manufacturing	228	71		***299***	72	70		***142***
Machinery Manufacturing	91	12		***103***	35	12		***47***
Computer and Electronic Product Manufacturing	45	62		***107***	17	58		***75***
Electrical Equipment, Appliance, and Component Manufacturing	39	17		***56***	16	10		***26***
Transportation Equipment Manufacturing	55	38	96	***188***	23	37	96	***155***
Furniture and Related Product Manufacturing	20	5		***25***	7	5		***12***
Miscellaneous Manufacturing	31	3		***34***	11	3		***14***
Industrial Total	***1,959***	***6,102***	***6,874***	***14,935***	***486***	***5,506***	***6,759***	***12,752***
Commercial and Industrial Total	***3,131***	***6,855***	***6,874***	***16,859***	***560***	***5,712***	***6,759***	***13,031***

Table C-2, 12. High Gas Cost / High Electricity Cost and Market Price Sensitivity - 150% of Base Case

	Technical Potential				*Economic Potential*			
	<1 MW	**1 - 10 MW**	**>10 MW**	***Total***	**<1 MW**	**1 - 10 MW**	**>10 MW**	***Total***
Commercial								
Hotel	109	24		***133***	36	24		***60***
Prison	24	4		***28***	8	2		***10***
Colleges and Universities	46	173		***219***	8	138		***146***
Dormitory/Fraternity/Sorority	10			***10***	7			***7***
Elementary/Middle School	39	3		***42***		1		***1***
High School	1			***1***				
Hospital/Inpatient Health	125	142		***267***	94	121		***215***
Nursing Home/Assisted Living	244	7		***251***	166	7		***173***
Other Classroom Education	26			***26***				
Laundry and Car Wash Services	414	23		***437***		15		***15***
Recreation	235	37		***272***	7	34		***41***
Commercial Total	***1,274***	***413***		***1,686***	***325***	***342***		***667***
Industrial								
Waste Water Treatment Facility	7	12		***18***	7	12		***18***
Dry Mill Ethanol Plant		41	271	***312***		40	271	***312***
Food Manufacturing	211	587	203	***1,001***	128	567	203	***898***
Beverage and Tobacco Product Manufacturing	18	101		***118***	12	101		***112***
Textile Mills	12	49		***61***	11	49		***59***
Textile Product Mills	63	20		***83***	48	20		***68***
Apparel Manufacturing	20	26		***46***	16	26		***42***
Leather and Allied Product Manufacturing	3	7		***10***	2	7		***9***
Wood Product Manufacturing	54	40		***94***	46	37		***84***
Paper Manufacturing	169	607	95	***871***	126	577	95	***798***
Printing and Related Support Activities	42	16		***58***	36	16		***52***
Petroleum and Coal Products Manufacturing		656		***656***		617		***617***
Chemical Manufacturing		2,382	5,288	***7,670***		2,218	5,122	***7,340***
Plastics and Rubber Products Manufacturing	215	87		***302***	190	80		***270***
Nonmetallic Mineral Product Manufacturing	432	768		***1,200***	279	738		***1,017***
Primary Metal Manufacturing	211	492	906	***1,609***	185	473	906	***1,565***
Fabricated Metal Product Manufacturing	234	72		***306***	195	72		***267***
Machinery Manufacturing	90	14		***104***	79	12		***92***
Computer and Electronic Product Manufacturing	44	63		***108***	39	61		***100***
Electrical Equipment, Appliance, and Component Manufacturing	40	17		***57***	33	17		***50***
Transportation Equipment Manufacturing	56	48	82	***186***	47	48	82	***177***
Furniture and Related Product Manufacturing	20	5		***25***	18	5		***22***
Miscellaneous Manufacturing	31	3		***34***	27	3		***30***
Industrial Total	***1,973***	***6,113***	***6,845***	***14,931***	***1,524***	***5,797***	***6,679***	***14,000***
Commercial and Industrial Total	***3,247***	***6,525***	***6,845***	***16,617***	***1,850***	***6,139***	***6,679***	***14,668***