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Clean Heat and Power Market Assessment for the Glass Industry in North Carolina

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Executive Summary

In the beginning of 2008, the Southeast CHP Regional Application Center commenced work pertaining to Clean Heat and Power (CHP) and the Industries of the Future as designated by the United States Department of Energy (DOE). This report describes the North Carolina glass industry and its potential for fostering CHP development.

Clean heat and power (CHP) is an effective way to increase energy efficiency and reduce polluting emissions. CHP applications may reduce consumer costs and provide reliable heat and power to a facility. Favorable scenarios for CHP applications exist near well matched thermal and electrical loads. If a facility uses substantial amounts of both heat and electricity, there is a possibility of implementing CHP.

The state of North Carolina is fourth for glass manufacturing in the United States. With 88 glass related facilities and a total value of shipments of $1.7 billion dollars in 2002, the North Carolina glass industry is the largest of any state in the southeast. Approximately 14% of operating costs are associated with energy usage in the glass industry. The fact that the glass industry is regarded as a high-heat, energy-intensive industry has made it a prime candidate for a CHP market assessment.

Energy costs account for approximately 14% of total operating costs in the US glass industry for an approximate national industry electricity bill of almost 700 million dollars annually. Power disruptions, fluctuations in power quality and increasing energy prices can all have a negative impact on operational efficiency and energy costs. CHP systems can be utilized to supplement electricity needs while also capturing waste heat for other facility uses.

Although the limited use of steam and discontinuous production of waste heat inhibits traditional CHP installations, the glass industry still is able to present favorable CHP installation opportunities. Opportunities for CHP installations exist in bottom cycle applications where waste heat from stack gases is captured and employed for the production of steam and power. Specialized installations include use of an air bottoming cycle or an organic Rankine cycle designed around the exhaust of a melting furnace to capture otherwise wasted thermal energy and produce electricity to meet a portion of the facility demand.

Since CHP reduces energy costs by using energy resources more efficiently, the energy-intensive nature of the North Carolina glass industry offers significant potential for CHP capacity. This assessment attempts to evaluate the current CHP efforts in the industry as well as determine opportunities for CHP in unexplored areas that may serve to lower costs and/or increase energy efficiency for the glass industry in the state of North Carolina.

What is Clean Heat and Power?

Conventional electricity production, as it exists today in the United States, is only about 33% efficient[1]. The waste of approximately two-thirds of internal energy from a fuel is generally accounted for by thermal losses resulting from the thermodynamic cycle used in standard electricity production and losses in the transmission and distribution system. Clean heat and power (CHP) systems capture and utilize these heat losses by applying thermal energy to existing needs.

CHP is an integrated energy system located at or near a facility to provide at least a portion of the electrical or mechanical load while recycling the waste heat from the power application to provide heating, process steam, cooling, and/or dehumidification or the production of electrical power[1].

There are two main types of CHP systems. The first is known as a topping cycle system, which requires a prime mover to generate electricity before recycling the waste heat. The second system, known as a bottoming cycle system, is the reverse of the topping cycle system. Waste heat from a process is recycled to generate electricity.

Common thermal loads for CHP applications can be cooling, heating, humidity control systems, steam production, and hot water production. CHP can also utilize opportunity fuels such as LFG, biomass, and digester gas[2,3].

Benefits of Clean Heat and Power

By capturing waste heat, CHP systems, if effectively integrated, can reach up to or greater than 80% efficiency[4]. An illustrative example of CHP system efficiency can be seen in Figure 1: CHP Efficiency. Additionally CHP includes the added benefit of power availability and reliability. CHP also alleviates grid overcrowding and costs associated with distribution[5]. If a utility outage occurs, a CHP system can maintain operation and lessen the effect of the outage on a facility[6]. Certain facilities have a requirement for constant, uninterruptable steam and power. An example of such a facility is the Bristol-Myers Squibb facility in Wallingford Connecticut. The requirement for a closely monitored working environment led Bristol-Myers to install a CHP system which provides 4.8 Megawatts (MW) of generating capacity[7].

One report estimates that power interruptions cost industries $80 billion dollars annually in the United States. The commercial and industrial sectors incur the largest costs associated with power outages. It was also shown that “momentary interruptions,” those lasting less than five minutes were more expensive than “sustained interruptions[8].” CHP installations can reduce the effects of power outages in an industrial manufacturing setting such as the glass industry. When interconnected with the utility grid, during an outage, power can be obtained from the CHP system without costly interruption.

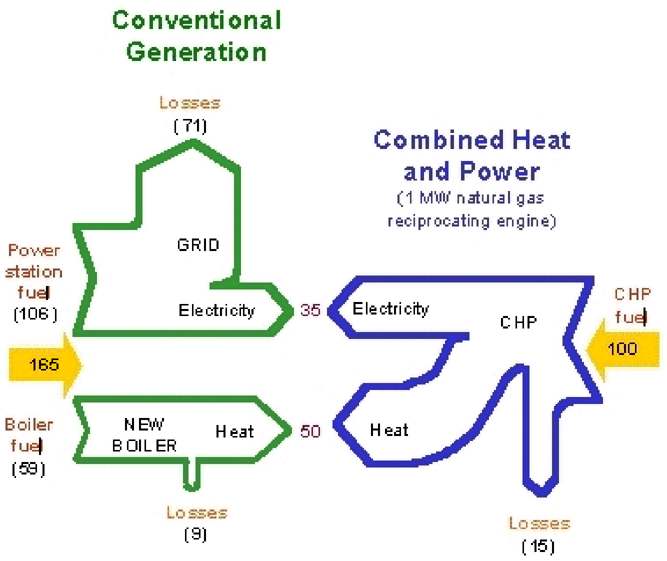


Figure 1: CHP Efficiency

A CHP system also includes the benefits of reduced emissions due to increased system efficiency. If the potential for CHP in the United States was met, approximately 130GW, the carbon equivalent emissions would shrink by 70 million metric tons[6].

CHP in the North Carolina Glass Industry

Based on estimated values for energy consumption and waste heat streams[9] for the glass industry and the number of glass manufactures in North Carolina, there exists an estimated 15 MW of generation potential from waste heat in the North Carolina glass industry. This estimated value of CHP potential is a high level approximation based on average values for glass producing facilities. If 15 MW of generation potential could be realized, energy savings of 131.4 GWh per year may be possible. With an estimate of 15 MW of potential generation, a Market Analysis serves as a logical first step to investigate the potential integration of CHP technology into the glass industry. The glass industry is an important part of the North Carolinian economy, and as such, may offer an opportunity to increase productivity and economic efficiency through CHP implementation.

Glass Industry Profile: North Carolina

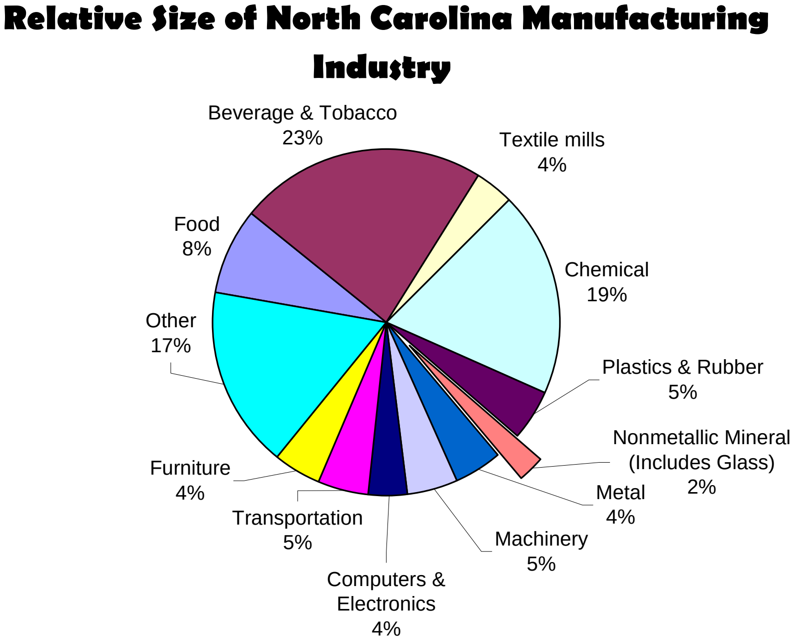
North Carolina ranks fourth in the United States and first in the southeast for value of shipments related to the glass industry[13]. For this reason, the glass industry in North Carolina was chosen for a CHP market analysis. However, glass manufacturing in North Carolina makes up less than two percent of all North Carolina manufacturing industry. Table 1 outlines data obtained by the U.S. Census Bureau[10] related to the size of the North Carolina Glass Industry. Figure 2 compares the glass industry to other manufacturing sectors in North Carolina.

Table 1: Glass Industry Statistics – NC

North Carolina Glass Industry Statistics for the Year 2002

Type	Establishments	Value of Shipments ($Millions)	Annual Payroll ($Millions)	Paid Employees
Flat Glass	2	W	W	500-999
Pressed and Blown Glass	8	W	W	2500-4999
Container	3	W	W	500-999
Glass Products from Manufactured Glass	75	$686	$136	4,329
Total	88	$1,702	$313	8,814

W* - Data Withheld



Relative Size of North Carolina Manufacturing Industry

Figure 2: Manufacturing Comparison based on Industry Value Added[*]

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[*] Value added is recommended by the U.S. Census Bureau as the best economic comparison between industries

Figure 3 compares the Industries of the Future within North Carolina by the total value added. The glass industry is the third largest "Industry of the Future" in North Carolina as designated by the U.S. Department of Energy (DOE).

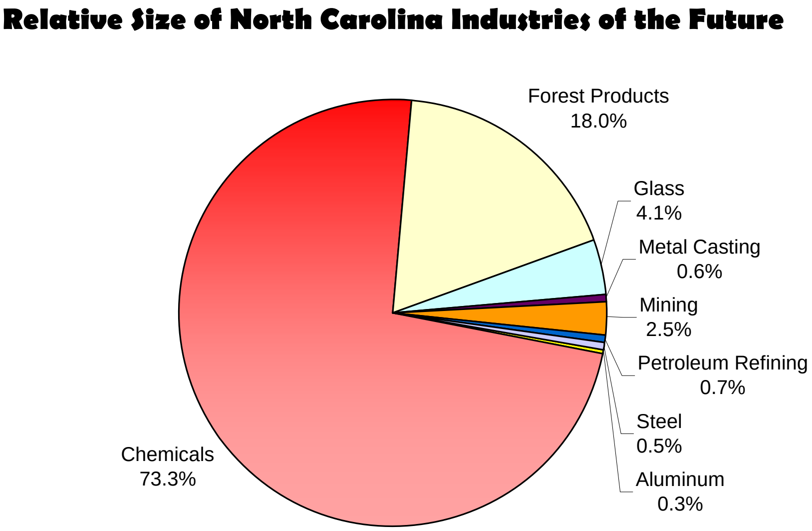

Figure 3: Industries of the Future in NC Comparison based on Industry Value Added *

The 2002 Economic Census divides the glass manufacturing industry in North Carolina into four categories: flat glass, container glass, pressed and blown glassware, and products from manufactured glass. Products from manufactured glass contribute 75 manufacturers to the overall 88. The glass manufacturing industry may also be divided into more specific classifications: container glass, fiberglass, flat glass, and specialty glass[11]. Major glass manufactures in North Carolina include two flat glass facilities and five container glass facilities. There are also a number of specialty glass facilities including operations where purchased glass is modified to meet the end consumer's needs. Figure 4 illustrates the location of glass related facilities in North Carolina[12]. Appendix B lists several glass manufacturers in North Carolina.

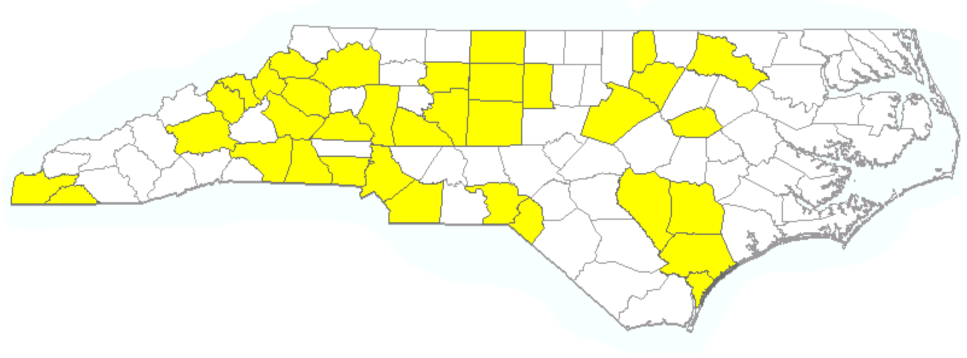

Figure 4: Glass Industry Facilities Locations – Designated by Highlighted Counties

The Energy Information Administration conducts a survey for the glass industry related to various energy aspects. Information is published on a national basis, and may serve as an indicator of energy usage by the glass industry in general. In 1998 the United States glass industry consumed 293 trillion BTU's, of which 159 trillion BTU's were attributed to natural gas as shown by Figure 5. Electricity and electrical losses make up the majority of remaining energy consumed[13].

Energy Consumption by Fuel – 1998 (NAICS 3272)
(Trillion Btu)

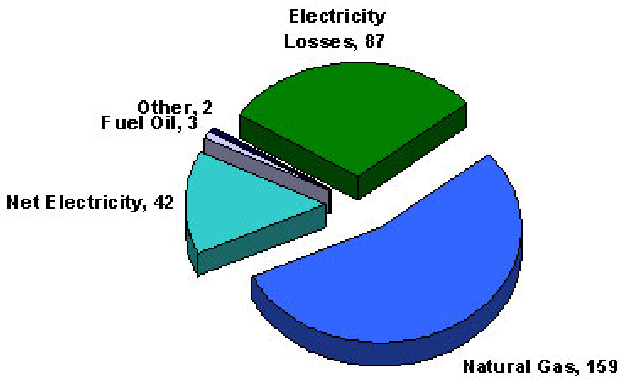

Figure 5: Total Energy Consumed
293 trillion BTU (with electrical losses*)[13]

Glass Industry Divisions

Container Glass

According to the North Carolina Department of Environment and Natural Resources 1998 Market Assessment on Glass, approximately 560,000 tons of glass container products were produced in 1997[14]. The production of glass container product consumes the greatest amount of energy of all the glass market sectors. Container glass includes bottles, jars, packaging materials, and research glassware[11]. Major container glass producers in North Carolina include:

- Kimble Glass Inc.
- Owens-Illinois
- Saint-Gobian

Flat Glass

Flat glass, also sometimes referred to as float glass, is used for windows, mirrors, and tabletops, as well as windshields and other automotive glass products. Flat glass utilizes large furnaces to melt silica sand or cullet, much larger than those of the other glass manufacturing processes[11]. Major flat glass producers in North Carolina include:

- Cardinal
- Pilkington

Fiberglass

Fiberglass manufacturing is divided into two categories: glass wool insulation, and textile fibers[15]. It should be noted that the US Census considers glass wool insulation as part of the wool manufacturing industry; however, the Department of Energy considers glass wool insulation as a potential market sector for the implementation of CHP technologies in its *Industries of the Future* outline. Major fiberglass producers in North Carolina include:

- Corning Inc.
- Hexcel-Schwebel
- PPG

Specialty Glass

Specialty glass is glass is essentially a miscellaneous catchall for glass products that do not fall into one of the three aforementioned glass product groupings. Specialty glass includes medical glass products, laboratory equipment, hand-pressed and blown glassware products, cookware, lighting, television glass, and glass product utilized in optical communication. Some sources estimate that this category includes as many as 60,000 different glass products, most with very small volumes of production[11]. Because of the wide variety of products and small volumes of production, the manufacturing technologies utilized in this sector of the glass industry vary from company to company. Cogeneration technologies utilized in specialty glass companies will need to be more specifically tailored from organization to organization.

Glass Manufacture

While the manufacturing process utilized in the glass industry differs based on the product created, there are several key process components found in most glass plants. These include batching, melting/refining, forming, finishing and post-processing.

Batching consists of selecting raw materials and preparing them for melting. Organic materials present in the batch result in increased emissions in the form of flue gas which results in added cleanup costs[11].

The melting and refining process typically employs a glass furnace that is heated by electricity, combustion, or both. Wasted thermal energy can be recovered through use of a regenerator or recuperator, and can increase overall system efficiency by up to 65%[16]. Glass production also utilizes a preheating process. Instead of using a separate burner, the exhaust heat can be utilized through a heat recovery system to produce this preheat.

Forming is the process by which the glass is shaped. During forming the melted and refined glass is moved from the forehearth to various forming apparatuses at either a constant rate (for flat glass or fiberglass) or in smaller sections known as gobs.

Finishing, also referred to as post-processing, involves elements such as annealing, tempering, laminating, polishing, coating, or fiberization.

To further develop and understand the implementation of CHP into the glass industry a review of current CHP technologies follows. The following sections outline prime movers currently used in CHP installations

CHP Technologies

CHP Equipment Selection

Selection of a system's CHP equipment is often dependent on the particular needs of a facility. Many CHP applications differ with respect to thermal loads, the electrical needs of the facility, and location requirements.

Generally, it is preferable to size the system based on thermal loads. Thermal loads are comparatively dynamic and greatly influence the size and type of heat recovery equipment required. Thermal requirements also vary in the type of thermal energy required[17].

In some cases, the facility may not be able to utilize all of the electricity produced by the CHP system. Systems designed and engineered with the intention to sell energy back to the local utility differ from systems using all energy produced "inside the fence." Thermal energy may also be exported from the facility, influencing the size and configuration of prime mover technology.

Emissions, noise control, and aesthetics are examples of siting requirements which may influence the selection of prime mover, recovery, exhaust treatment, and other equipment. These factors must all be considered when assessing a potential CHP application.

Reciprocating Engines

The most common type of prime mover used in CHP system installations is the reciprocating engine[18]. These engines use either spark ignition or compression to ignite a fuel and produce mechanical work. This work is then converted into electrical energy via a generator[19]. These engines can be sized to handle small fractional loads or large base load electrical requirements. Diesel and natural gas engines are both popular choices, but stringent emissions standards have reduced the use of diesel-fired engines to back up power systems that generally operate less than 200 hours per year[20].

Natural gas engines have become a more widely accepted technology with respect to emissions standards. Lean burn technology, as well as exhaust treatment methods, make natural gas engines preferable in many situations. For a cost and performance analysis, refer to Table 2: Analysis of Reciprocating Engine Cost and Performance.

Recoverable heat can be obtained from four sources from a reciprocating engine. These sources of heat are exhaust gas, engine jacket cooling water, lube oil cooling water, and turbocharger cooling. The available heat may be used to create low pressure steam and hot water. In certain cases the exhaust gas is used in a drying process. Generally, the heat obtained from a reciprocating engine may be used in low temperature loads, space heating, hot water supplies, or thermally activated technologies[19].

Microturbine Options

Microturbines utilize a flow of compressed air combusted with a fuel and then expanded through a turbine to create a rotation that turns an electrical generator. The combustor design makes it possible to use lower BTU content fuel. For a cost and performance analysis, refer to Table 3.

The benefit of microturbines is further enhanced by the reduction of emissions and higher temperature waste heat. While reciprocating engines produce NO_x emissions in the range of two to six lbs/MWh without treatment, emission levels from microturbines are less than one half (.5) lbs/MWh[21].

Table 2: Analysis of Reciprocating Engine Cost and Performance

Reciprocating Engines (300kW)		
Fuel Energy		
Available as Electricity	30%	
Available as Recoverable Heat	50%	
Output Temperature		
Exhaust	850	°F
Coolant	150-250	°F
Installed Cost	$1,200	per kW
Maintenance	$0.012	per kWh
After treatment Cost	$50	per kW

Statistics taken from "Potential for Energy Efficiency and Renewable Energy to Meet Florida's Growing Energy Demands." Elliott et al. June 2007, AEEE. Data also taken from "Clean Heat and Power Resource Guide." Midwest CHP Application Center, Sept, 2003.

Microturbines utilize a recuperator to preheat the inlet air, reducing the amount of fuel needed in combustion. This lowers the amount of heat available to the second heat exchanger which captures thermal energy from the microturbine exhaust stream. The utilization of recovered heat from a microturbine is similar to a reciprocating engine. The recovered heat is generally used for space heating, water heating, and thermally activated technologies[21].

Gas Turbine Options:

Because of clean and efficient power production, gas turbines have become a popular choice in the power generation market[22]. Efficiencies for gas turbines can range from 21% to 40% when used only for power production. When waste heat is utilized, efficiencies of nearly 90% can be obtained[22].

Gas turbines operate by using a high-temperature, high-pressure flow of air which expands while moving through turbine blades. This expansion causes the turbine blades to rotate producing shaft work which is converted into electrical energy by a generator. Various heat recovery options are available depending on the thermal load. Heat in the turbine exhaust may be recovered by a heat exchanger and used in the production of hot water. The gas turbine may also be configured in such a way to utilize the exhaust heat for the production of steam. This steam is used to drive a steam turbine producing additional electrical energy. This configuration is known as "combined cycle" and steam may be extracted during the process to provide energy to a thermal load. The waste heat can also be used to drive an absorption chiller to provide cooling and dehumidification.

Table 3: Analysis of Microturbine Cost and Performance

Microturbines (250kW)		
Fuel Energy		
Available as Electricity	28.8%	
Available as Recoverable Heat	30.6%	
Output Temperature		
Exhaust	500	°F
Installed Cost	$2,000	per kW
Maintenance	$0.016	per kWh
After treatment Cost	$500	per kW

Statistics taken from "Potential for Energy Efficiency and Renewable Energy to Meet Florida's Growing Energy Demands." Elliott et al. June 2007, AEEE. Data also taken from "Clean Heat and Power Resource Guide." Midwest CHP Application Center, Sept, 2003.

Gas turbines are regarded as one of the cleanest power production technologies currently available for large scale power production. By applying after-treatment and lean-burn technology, large turbines often produce less than 10 parts per million of NOx, and have significantly smaller carbon dioxide emissions than any other commercially available fossil fuel fired technology[1].

Table 4: Analysis of Gas Turbine Cost and Performance

Gas Turbines (1MW)		
Fuel Energy		
Available as Electricity	21.9%	
Available as Recoverable Heat	42.9%	
Output Temperature		
Exhaust	950	°F
HRSG Exhaust	280	°F
Installed Cost	$1,900	per kW
Maintenance	$0.010	per kWh
After treatment Cost	$300	per kW

Statistics taken from "Potential for Energy Efficiency and Renewable Energy to Meet Florida's Growing Energy Demands." Elliott et al. June 2007, AEEE. Data also taken from "A Brief Characterization of Gas Turbines in Clean Heat and Power Applications." EPA, 2002.

Potential Applications for CHP in the Glass Industry

The glass industry is characterized by its intensive use of energy. The Glass Manufacturing Energy Council reported that 14% of the total operating costs for the glass industry are attributed to energy consumption[15]. Table 5 displays energy costs as a percentage of operating costs for selected Industries of the Future designated by the Department of Energy.

Natural gas contributes up to 80% of the energy consumed in the glass industry[23]. While this situation may initially appear as a favorable scenario for CHP, the glass manufacturing process hinders conventional CHP applications. Steam is not a heavily employed working fluid in the glass industry[15]. Therefore, CHP installations which utilize waste heat to generate steam for thermal loads are generally unsuitable. However, scenarios exist where waste heat is utilized in alternative fashion.

Table 5: Energy Costs

Energy Costs for Selected Industry	
Industry	**Percentage of Operating Cost**
Glass[9]	14%
Aluminum[24]	33%
Chemical[25]	85%
Mining[26]	17%
Steel[27]	15%

Of all the key process components of glass manufacturing, the melting and refining process offers the greatest opportunity to utilize CHP technologies. Combustion-heated furnaces offer a major opportunity to employ CHP technologies to recover waste heat. As much as 67% of the heat generated by these furnaces is exhausted as waste heat[11].

Peaking and Back Up/ Stand By Generation

A large production industry, such as glass manufacturing, may be concerned with shaving peak loads to reduce energy costs. Interest may also be found in back up and stand by generation to lessen or completely eliminate the negative effects of a utility outage.

A CHP system may be sized to meet production critical loads. These loads include both electrical and thermal. The CHP system would be utilized during the event of a utility outage or a planned facility outage. Research indicates that the mechanical operations of batch processing consume approximately 4% to 5% of overall energy consumption for a glass manufacturing facility in the form of purchased electricity[15]. Heating, ventilation, and air conditioning (HVAC) accounts for 4% of the total energy purchased for glass manufacturing[15]. However, no clear definition of the percentage of HVAC from purchased fuels or purchased electricity could be found. Assuming that the total energy requirement for flat glass is approximately 2,800 kWh/ton, 80 kWh/ton and 112 kWh/ton accounts for batching and HVAC requirements respectively[15]. These assumed values equate to 106 MWh a day for flat glass plant with a 550[15] ton per day production average. Consumption for critical electrical loads of this size may warrant the installation of CHP for backup and standby applications in the glass industry.

A CHP system designed for back up operation must have the ability to start independent of the grid. The system must not rely on the signal of the grid for operation as well. Critical loads must be recognized, and the CHP system sized appropriately[28].

While conventional natural gas fired systems may be appropriate for back up generation, high fuel costs prohibit continuous use as a load shedding operation. Alternate systems such as the air bottoming cycle and the organic Rankine cycle should be considered for continuous operation.

Air Bottoming Cycle

The air bottoming cycle (ABC) uses compressed, high temperature air as a working fluid. Expansion of this fluid through a turbine drives an electrical generator to produce electricity. Mechanical work is also derived from the turbine. Exhaust from the turbine can be used for drying of raw materials, or to preheat combustion air. A system of this nature can create electricity from waste heat at efficiencies approaching 26%[6].

The ABC has potential to be installed in a glass manufacturing facility due to the exhaust temperatures of the furnace. Temperatures of exhaust directly from the furnace can reach 2800°F. After the exhaust is transported through a regenerative system, temperatures are reduced to approximately 1200°F[29]. In the study conducted by Korobitsyn, exhaust from a regenerative system at 500°C produced 430 kW of power. A model of a recuperative furnace with exhaust temperatures at 900°C produced approximately 1 MW of power[6]. A process flow diagram of the ABC is shown in Figure 6.

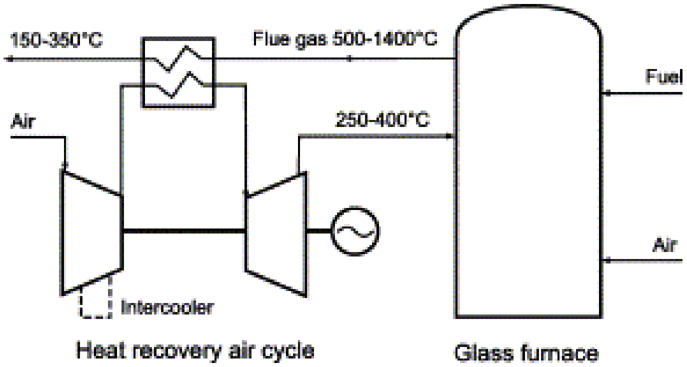

Figure 6: “HERAC behind a glass furnace” Korobitsyn, Mikhail. "[6]

While a CHP scenario such as this seems promising, no ABC systems have been reported in the glass industry, and the technology is not commercially available[15].

Organic Rankine Cycle

Instead of using a conventional working fluid such as steam, the Organic Rankine Cycle (ORC) utilizes an organic working fluid. This allows for greater energy conversion efficiency when flue gas exit temperatures are below 1000°F. The ORC offers benefits such as less corrosion of turbine blades and more compact equipment due to the nature of the organic working fluid. The ORC uses flue gas through a heat exchanger to vaporize and superheat the working fluid. The fluid is then expanded in a turbine, condensed, and recycled. The turbine drives both an electrical generator and pumping equipment for the process. When compared to a typical steam Rankine cycle for a regenerative glass furnace process, the ORC generates 36% to 47% more power[30]. For a flue gas flow rate of approximately 63,000 lb/hr and an exhaust temperature of 761°F, the ORC analysis yielded 275 kW of power[30]. An example of an ORC is shown in Figure 7.

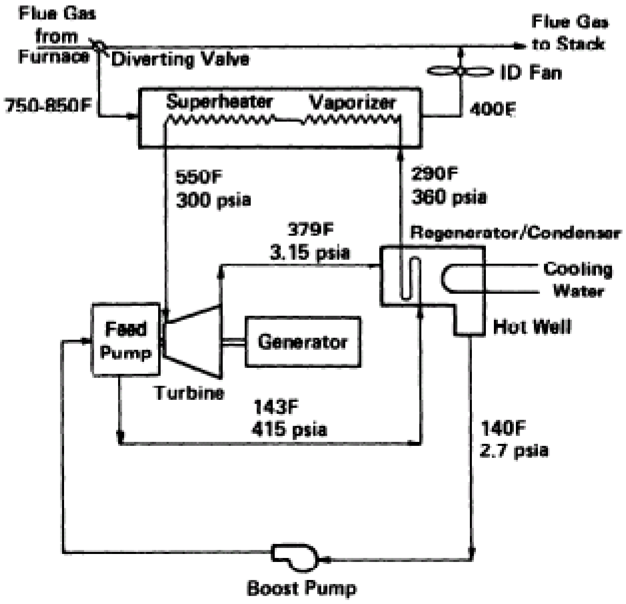

Figure 7: "Process diagram for organic Rankine cycle heat recovery system using toluene as working fluid."[30]

Barriers to CHP Development

Several barriers prohibit the timely and efficient design, installation, and operation of CHP facilities. These barriers include air quality regulations, interconnection issues, the prohibition of third party sales of electricity, and utility rates. These barriers are not specific to CHP, but apply to most distributed generation projects. CHP does have a number of specific glass industry related barriers. These include the discontinuous use and production of heat due to batch processing, extensive fouling from flue gas contaminants, and with-holding of proprietary information in the industry.

Air Quality Regulations

There are six criteria pollutants that the EPA utilizes as indicators of air quality. These pollutants include ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, particulate matter, and lead. For a detailed look at these various pollutants, please refer to the EPA's website Green Book at: http://www.epa.gov/oar/oaqps/greenbk/o3co.html

Hazardous Air Pollutants (HAP) adversely affects human health and the environment, resulting in cancer, reproductive defects, birth defects, etc. Currently, there exist 188 pollutants that the EPA defines as HAPs. Nine of these pollutants are related to CHP technologies including benzene, formaldehyde, naphthalene, and toluene. For a comprehensive list of HAPs please visit the EPA's website at http://www.epa.gov/ttn/atw/188polls.html

The installation of a CHP system may require the EPA to issue a New Source Review (NSR) regulation. The restrictions created by a NSR are dependent upon whether or not the proposed CHP installation will exceed pollution thresholds. These thresholds are set at different levels depending on attainment status. If a specific region is a non-attainment area, the thresholds are lower than if the region is located in an attainment area. If the CHP system exceeds pollution thresholds it is considered a major source. If the CHP system falls short of the thresholds, it is considered a minor source[31]. The best available control technology is required by a NSR. However, the requirements are based on fuel input rather than system output. Input criteria do not recognize the efficiency of CHP[32].

Often, heat recovery from a CHP system is not given the appropriate emissions credit. Although offsite utility power generation and onsite thermal energy generation are now combined, the displacement of these sources is not taken into account. Unfortunately, the decrease of emissions for the production of thermal energy is not accounted for in a CHP system. Smaller sources such as CHP do not receive the "netting" treatment that larger sources do. Netting enables a facility to decrease one source of emissions while increasing another. Additional limitations arise from the prohibitive unit costs of after treatment technology generally applied to larger installations. Standards for emissions limits from large installations are unsuitable for smaller CHP units, however these limits are erroneously applied to mass produced generation equipment, voiding the cost savings yielded from mass production. The savings from mass production are lost because of the high cost per unit of treatment technology. Improper emissions requirements often lend to the difficulty of a CHP installation and therefore should be carefully reviewed before the consideration of a CHP operation[31].

Interconnection

When a facility installs onsite generation, there are typically three ways which that system may be configured in relation to the utility grid: isolated operation, isolated operation with utility backup, and parallel operation with utility system[33]. Installation of a system with utility backup or parallel operation may yield interconnection issues which pose a barrier to smooth and timely installation. Additional costs and lengthy installation schedules may result as an effect of interconnection boundaries. These barriers may be classified by two categories: technical barriers and regulatory barriers[34].

Technical barriers arise from the utility's requirement that CHP technology systems be grid compatible[34]. Utilities are generally concerned with issues of safety, power quality, equipment protection, and system control[33]. Typically, technical issues are addressed with thorough engineering analysis and costly equipment. However, this is often unnecessary due to the already present safety devices included in the customer's generation system[34]. Comparable to expensive emissions equipment inappropriate for the small scale of CHP, mass production cost savings are reduced via the required equipment and analysis appropriate for a large scale installation where cost per unit is considerably less.

Regulatory interconnection issues also hinder the successful installation of CHP systems. Many states lack consistent polices, if policies even exist at all[35]. North Carolina has adopted standards for residential systems up to 25kW and commercial systems up to 100kW. According to these standards, the owner of a commercial system must have a minimum of a $300,000 commercial insurance policy[36]. Insurance and inconsistencies in regulations create a difficult problem for all interested parties when investigating final monetary costs and time requirements related to a CHP installation. As with technical interconnection barriers and air quality regulations, inconsistent regulations related to interconnection reduces the cost savings of mass manufacture.

Prohibition of Third Party Sales

CHP, along with many other distributed generation projects, face a persistent barrier that arises from policy and regulation regarding the third party sales of electricity. It is suggested that the ban on third party sales is the largest hindrance to distributed generation projects[37]. North Carolina General Statute, chapter 62, article six, prohibits the third party sale of electricity in North Carolina. Without a legal framework for third party sales, cost savings are difficult to obtain for interested parties due to the “case by case” basis of power purchase agreements between customers and utilities[38].

Utility Rates

Many CHP applications utilize the local utility as a source of backup power in the system design. But relying on the utility for backup power creates a large hurdle for CHP applications in North Carolina.

North Carolina rate structures outline certain charges that pertain to owning and operating private power production equipment. Charges known as “back stand” charges or “standby rates” are charges that the consumer must pay in compensation for the utility’s generating capacity. These rates apply to consumers that generate their own power, but still require electrical service from the utility intermittently. Periods of predetermined downtime of the consumer’s generation equipment, additional supplemental energy supply from the utility, and the use of the utility as backup power during unforeseen system downtime create the need for standby power[33]. Sometimes the standby rate can be a large enough expense to negate any financial benefit from a CHP system in effect hindering a peak shaving application in North Carolina[39].

The three major utilities that serve North Carolina all have rate structures and riders that address standby charges. For example, Duke Energy’s Parallel Generation (Schedule PG) applies to generating facilities with a generating capacity of less than 80 megawatts. The standby capacity is determined in one of two ways. Either the generating capacity given by the nameplate of the customers facility is used to calculated standby kW, or at the option of the customer, the standby capacity is based on the maximum demand from the previous twelve month billing period. A charge of $1.03 per kW of standby capacity is applied to the customer's bill. Table 6 and Table 7 Duke Energy billing schedules related to standby service.

Negative effects of standby charges have been seen by CHP applications in North Carolina. In a recent letter to Senator Janet Cowell from Raymond Dubose, director for Energy Services at the University of North Carolina Chapel Hill, Mr. Dubois states that Duke Energy's charge of $1,030 per megawatt of generation at the Chapel Hill CHP Facility is a large financial burden on the energy department. With a generating capacity of 28 MW operating over a twelve month period, the CHP facility pays in excess of $345,000 a year in standby charges.

With the current low costs of electricity in North Carolina and rising fuel prices coupled with high standby rates, the economic return on a CHP system generally remains unappealing when compared to current proven technologies already in place in North Carolina glass installations. While standby charges are still present in other states where CHP has been successful, the high cost of electricity as compared to the cost of fuels, otherwise known as "spark spread" have overcome the expense created by standby charges.

Glass Industry Specific Obstacles

Batch Processing

In the best possible scenario, CHP is utilized efficiently where there is a constant supply of thermal energy and a constant load for that thermal energy. However, many manufacturing processes in the glass industry are batch processing. In this mode of processing, heat is generated in a cycle. Since the heat is only available during a cycle, the waste heat must be applied to a source that is also utilized during the cycle.

Batch processing can be improved through the use of a regenerative glass furnace which utilizes regenerative heat exchangers. These heat exchangers incorporate a thermal energy storage checker which acts to preheat combustion air for the next batch process. CHP proposals have been made which diverts the flue gas stream after it has left the regenerator to a heat recovery system. The heat recovery system uses a heat exchanger and a working fluid to drive a turbine. The turbine drives an electrical generator[30].

Fouling From Flue Gas

The flue gas constituents of greatest concern are sodium sulfate salts. These salts can form a sticky eutectic when contacted with water. The eutectic forms a layer on the surface of the heat exchanger, reducing the overall system efficiency[30]. Sodium Sulfates also exhibit corrosive properties which are of concern in both regenerators and secondary heat exchangers. Sulfur trioxide, hydrochloride, and hydrofluoric acid are also present in typical flue gas and are corrosive in vapor form[29].

The corrosive nature of condensable flue gas constituents limits the allowable temperature drop of the exhaust gas. Therefore, the amount of thermal energy which may be extracted is also limited. Due to the fouling and corrosive nature of certain compounds in flue gas, the minimum temperature of exhaust gas should be limited to 400°F [30].

Table 6: Duke Energy Schedule G (NC) General Service

Duke Energy Schedule G(NC) General Service	
Basic Facilities Charge	$10.88
Demand Charge	
First 30 kW of Billing Demand per Month	No Charge
Over 30 kW of Billing Demand per Month	$3.48 per kW
Energy Charge	
First 125kWh per Kw Billing Demand per Month	
First 3,000 kWh per month	9.9095¢ per kWh
Next 87,000 kWh per month	5.336¢ per kWh
Over 90,000 kWh per month	3.9782¢ per kWh
Next 275kWh per kW Billing Demand per Month	
First 6,000 kWh per month	5.4639¢ per kWh
Next 134,000 kWh per month	5.3425¢ per kWh
Over 140,000 kWh per month	4.9521¢ per kWh
Over 400kWh per kW Billing Demand per Month	
For all kWh per Month	4.7148¢ per kWh

Table 7: Duke Energy Schedule PG Parallel Generation

Duke Energy Schedule PG Parallel Generation		
	Interconnected To	
	Transmission System	Distribution System
Customer Charge per Month:	$58.40	$58.40
On-Peak Demand Charge per On-Peak Month	$14.26 per kW	$16.94 per kW
Energy Charge		
General Service		
On-Peak	3.4299 ¢ per kWh	3.5293 ¢ per kWh
Off-peak	3.2311 ¢ per kWh	3.3084 ¢ per kWh
Standby Charge per month	$1.03 per kW	$1.03 per kW

Additives such as magnesium oxide and carbon have been proven to lower and neutralize sulfur trioxide in the exhaust. Control of excess air has also have been proved at lowering sulfur trioxide concentrations.

Use of higher quality fuels with lower sulfur content is another option. However, higher quality fuels are often more expensive. Electrical preheat may be a viable solution. The preheat lowers combustion temperatures in the furnace. There are no combustion products directly associated with electrical preheat and therefore could reduce fouling and contamination. The electrical energy produced from a CHP application may be use in the preheat process. A feasibility study would need to be completed to determine the overall improvement when using exhaust gas to generate electricity to heat process inputs, instead of using the exhaust heat directly.

Proprietary Information

As the Southeast CHP Application Center conducted the market assessment for CHP in the glass industry, issues of proprietary information were encountered. While several glass producers and glass related operations facilities were contacted to collect information concerning production rates, facility size, and energy and waste heat usage, very little information was received due to the proprietary nature of the data requested. A lack of information and industry cooperation presents itself as a barrier to the successful implementation of CHP in the glass industry. The situation created by limited access to proprietary information continues to inhibit the development of CHP in an industrial setting. Partnership between industry, government agencies, and research institutions in early discussion and development of CHP is a necessary link for achieving the goals of reduced grid reliance, reduced pollution emissions, and an overall safer, cleaner, electricity market in North Carolina and the United States.

Overcoming Barriers

Although solutions to glass industry specific barriers have been previously mentioned, broader, across-the-board, barriers to CHP and distributed generation as a whole require more in depth discussion for answers to the barriers which pose difficulties to the success of CHP.

Air Quality Regulations - Output Based Regulation

Obtaining permits for a CHP installation can be surrounded by stringent, inappropriate emissions standards. However, relief can be found in using output-based emissions regulations. Instead of traditional "fuel-input" emissions based regulations, output-based regulations focus on the amount of emissions relative to the useful output of a process [40].

Output-based regulations reduce fuel consumption by fostering new ways to use energy such as CHP. An output-based approach also lends to the use of new energy conversion technologies and opportunity and renewable fuels. By decreasing the fuel consumption for the same productive output, emissions totals are also decreased. By regulating emissions based on the productive output of the system, different types of technologies may be evaluated on a comparable basis[40].

States such as Connecticut, Massachusetts, and Indiana have already adopted output-based regulations. Output-based regulations are gaining attention and allowing developers to introduce pollution preventing techniques such as CHP without air quality regulation hindrance. Output-based regulations should be used as a tool to overcome the current regulations which do not account for the efficiency of CHP systems.

Air Quality Regulations - Carbon Trading

A potential revenue stream for a CHP installation is participation in a greenhouse gas emissions allowance trading system. The Chicago Climate Exchange serves an "Offset Provider" or an "Offset Aggregator" to buy and sell exchange allowances and exchange offsets in a rules based market system. Sources whose emissions are less than a set value, also known as a "Cap," may sell exchange offsets. Sources which produce more emissions than the "Cap" must buy exchange allowances to comply with regulation.

Energy offsets are traded in the form of a Carbon Financial Instrument (CFI). The tradable unit for a CFI is 100 metric tons of CO_2. CFI's are issued at a rate of .4 metric tons of CO_2 per megawatt hour. This is a default rate of carbon production of a typical gas combined cycle power plant. This rate may be modified where an "alternative emission displacement rate" is appropriate[41]. For more information on Emissions trading, please visit the Chicago Climate Exchange homepage at http://www.chicagoclimatex.com/ and the EPA's "Cap and Trade" website at http://www.epa.gov/airmarkets/cap-trade/index.html.

Interconnection – Adopting Standards

Interconnection issues can create technical and regulatory barriers for CHP installations. However, in February 2008, the EPA reported that 31 States have set policies in place for distributed generation, including North Carolina. The recently-adopted North Carolina Renewable Energy Portfolio requires that interconnection standards be established by the North Carolina Utilities Commission for installations under 10 MW[36]. Currently, North Carolina has interconnection standards for residential systems up to 25 kW. Standards for systems up to 100 kW also exist for non residential use[42].

Utilities, manufacturers, independent power producers, and end users all benefit from standardized interconnection procedures. Utility duties and responsibilities are more clearly defined. Manufacturers can more efficiently mass produce equipment with clear standards instead of having to tailor equipment produced for different interconnection procedures. Independent power producers benefit from lower interconnection costs and shorter interconnection periods. The end user benefits from lower product costs[43].

Prohibition of Third Party Sales – Modify Existing Policy

Access to the grid is crucial for CHP growth. It is important that clear established policies and procedures exists so that interested parties can plan and develop new projects with clear cost savings estimates. Grid access polices would allow CHP projects an equal opportunity to compete with centralized generation[38]. Unbundling of utilities is also related to "open-access" policies. However, costs associated with transmission capacity charges may negatively affect a generating facility.

Utility Rates

Several methods may be used to overcome unfavorable utility rates concerning the installation and operation of a CHP system. The CHP system owner/operator may take certain measure to reduce the negative impacts of standby utility rates. Changes may also be needed for utility policy concerning the application of certain rates related to a CHP or distributed generation project.

A CHP owner/operator may invest in multiple generating units as insurance against system outages. Then standby rates and insurance are purchased for only one of the units. Owners/operators may also identify non-critical loads that may be shed in the event of an outage. Load shedding would decrease demand and lessen penalties applied by the utility in the event of an outage[33].

Removal of standby charges and exit fees would be a best case scenario for advocates of CHP. Although this event is unlikely, certain steps may be taken by the utility commission to address prohibitive rate and fee practices. Increased testing and analysis should be placed on standby rates. This analysis may prove that exit rates and standby charges are unnecessary. Other rates are subject to a rigorous evaluation and standby rates and exit fees should be no exception. Public interest should also be considered when deciding standby rates. Environmental and economic issues that affect a community at large may outweigh utility profit and the goal of utility service should include society's long term interests[44].

Exploring Implementation of CHP

CHP technologies offer a potential opportunity to increase productivity and economic efficiency within the glass manufacturing process. There are numerous government, trade, and support organizations for the implementation of CHP equipment.

The Southeast CHP Application Center was established in August 2004 for the DOE. The Center promotes the development and deployment of integrated systems that provide on-site electrical generation and utilize the heat from the generation equipment to provide cooling and/or heating for the building. It provides the following services for CHP systems in the Southeastern United States

- Application Assistance
- Technology Information
- Educational Support

The DOE through a contract with the Mississippi Development Authority - Energy Division (MDA-ED) funds the Southeast CHP Application Center. It is co-located at the Micro-CHP and Bio-Fuels Center at Mississippi State University and the NC+CHP Application Program at North Carolina State University. Contact information, along with CHP evaluation tools, publications, and other CHP related material may be accessed at the Southeast CHP Application Center website at http://www.chpcenterse.org/home.html.

The Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) offers *Quick Plant Energy Profiler (Quick PEP)* software on its website to help plants determine how energy is currently being used and where opportunity exists to save cost and energy. The Department of Energy also sponsors *Industrial Assessment Centers (IACs)* which provide no-cost energy assessments for small and medium sized manufacturing facilities.

The United States CHP Association offers links under the resources section of its website including CHP software tools, CHP manufacturing company links, and national case studies for current CHP projects and technologies.

Appendix A includes a list of CHP technology manufacturers in the United States. Appendix C contains a list of organizations which offer support for those interested in utilizing CHP equipment, including contact information for the EERE and USCHPA.

Conclusions

Under the direction of the United States DOE, the Southeast CHP Application Center has set out to develop market assessments for CHP with respect to specific industries within the southeastern states. Resulting from the fact that North Carolina had the largest dollar value of shipments for the glass industry in the southeast United States in the year 2002; a market assessment was completed for the glass industry in North Carolina.

The North Carolina glass industry is a large, energy intensive, multi-billion dollar business that accounts for the employment of nearly 10,000 North Carolinians. North Carolina is home to several flat, fiber, container, and specialty glass operations.

Energy costs account for approximately 14% of the total operating cost in the glass industry. At a national level, the glass industry consumes nearly 160 trillion BTU's of natural gas on an annual basis. Although the limited use of steam and discontinuous production of waste heat inhibits traditional CHP installations, the glass industry still is able to present favorable CHP installation opportunities. Opportunities for CHP installations exist in bottom cycle applications where waste heat from stack gases is captured and employed for the production of steam and power. Specialized installations include use of an air bottoming cycle or an organic Rankine cycle designed around the exhaust of a melting furnace to capture otherwise wasted thermal energy and produce electricity to meet a portion of the facility demand.

Conventional barriers inhibit the installation of CHP in the glass industry as well as distributed generation on a broad spectrum. Improper environmental regulations, prohibitive interconnection procedures, escalated standby utility rates, and the lack of third party sales for electricity all present themselves as barriers for CHP installation. The glass industry also faces more specific barriers such as inconsistent or thermal cycles and fouling issues related to flue gas flow. Difficulty in obtaining local industry data such as energy usage, production rates, and waste heat utilization manifests a barrier in the creation of a market assessment as well as CHP development in general.

Industry-specific barriers may be resolved internally with effective engineering practices. However, barriers that affect CHP and distributed generation projects as a whole should be addressed through policy reformation and modification on a federal, state, and local level. Regulators, officials, and industry and utility representatives must work together to create sound, consistent policies and regulations that give CHP equal or favorable treatment in the world of power generation.

While CHP may provide a cost-saving, energy-efficient option for glass manufactures, change is slow to come due to the capital and energy-intensive nature of the industry. Modifications and equipment updates generally coincide with planned outages[45]. CHP implementation, as discussed within this report, is a cost-based decision that will more than likely coincide with a major shutdown for component and equipment replacement. Engineering and economic analysis will determine if a project using CHP technologies would be profitable to complete during and outage. While costs associated with exhaust gas heat recovery projects are viewed as relatively high by the glass industry, rising fuel costs may cast a more appealing light on such proposals[45] and subsequently create a large market for CHP applications.

Appendix A: Manufacturers Combined Heat and Power

Capstone Turbine Corporation
21211 Nordhoff Street
Chatsworth, CA 91311
818-734-5300
1-866-4-CAPSTONE
http://microturbine.com/index.asp

Elliott Energy Systems, Inc.
2901 S.E. Monroe Street
Stuart, FL 34997
Tel: +1 772 219 9449
Fax: +1 772 219 9448

T. L. Johnson & Assoc.
Tim L. Johnson
7 Farmingdale Lane
Newark, DE 19711
Tel: +1 302-292-6940
Fax: +1 302-292-6940
Email: tljohnsonassoc@aol.com
Market: Delaware, Maryland, New Jersey, Virginia, Washington DC & Pennsylvania

Ingersoll Rand
Customer Service, Sales, Literature:
877-IR-POWER (477-6937)
http://energy.ingersollrand.com/index_en.aspx

Gas Turbines

Kawasaki Gas Turbines - Americas
8829 North Sam Houston Parkway West
Houston, TX 77064
Tel: 281.970.3255
Fax: 281.970.6465

Eastern Regional Office
Kawasaki Gas Turbines – Americas
176 Woodland Ave.
Summit, NJ 07901
Tel: 908.277.6611
kgtaeast@kmc-usa.com
http://www.kawasakigasturbines.com/home/

Solar Turbines Incorporated
Turbomachinery Sales/Service
10691 S.W. 88th Street
Suite 109
Miami, FL 33176
Tel: (+1) 305-279-6270
Fax: (+1) 305-595-2575

Vericor Power Systems
3625 Brookside Parkway, Suite 500
Alpharetta, Georgia 30022 U.S.A.

Reciprocating Engines

Aircogen
New England Sales Office
80 Front Street, Suite 23, Scituate, MA 02066

Caterpillar INC.
CAROLINA CAT
9000 STATESVILLE RD
CHARLOTTE 28269-7680
http://www.carolinacat.com/

Cummins Inc.
3700 Jeff Adams Drive
Charlotte, NC 28206
Phone: 704-596-7690
Fax: 704-596-3038
Toll Free: 800-958-9972
http://www.cummins.com/

Appendix B: Manufacturers Glass Industry in NC

Container Glass

Terresheimer Glass
114 Wamsutta Mill Rd
Morganton, NC 28655
Tel: 828.433.5000

Owens Illinois, Inc.
Owens Brockway Glass Containers
9698 Old US Highway 52
Lexington, NC 27295
Tel: 336.764.2900

Saint-Gobain Containers
2200 Firestone Parkway
Wilson, North Carolina 27893
Tel: 252.291.1500
620 Facet Road
Henderson, NC 27537
Tel: 252.430.3635
www.sgcontainers.com

Flat Glass

Pilkington North America, Inc.
Laurinburg Float Plant
13121 S. Rocky Ford Rd.
Laurinburg, NC 28352
Tel: 910.276.5630
www.pilkington.com

Custom Glass Products of NC
1475 Harrison Rd
Salisbury, NC 28145
Tel: 704.633.4946
www.cgpglass.com

Fiberglass

Corning, Inc.
Optical Fibers Divison
310 N College RdWilmington, NC
28405
(910)784-7200
www.corning.com

PPG Industries, Inc.
Fiber Glass Products Division
473 New Jersey Church Rd
Lexington, NC 27292
Tel:336.357.8151
940 Washburn Switch Rd
Shelby, NC 28150
(704)434-2261
www.ppg.com

Specialty Glass

Prism Research Glass
6004 Triangle Dr
Raleigh, NC 27617
Tel:800.771.6773
www.prismresearchglass.com

Public Scientific Glass
4317 Rock Hill Rd
Pfafftown, NC 27040
Tel:336.924.2183

Pieper Glass
2778 Halls Chapel Rd
Burnsville, NC 28714
Tel: 828.675.1113
www.pieperglass.com

Appendix C: CHP Trade & Support Organization

Affiliated Engineers
North Carolina Office
1414 Raleigh Road, Suite 305
Chapel Hill, NC 27517
Contact: Patty Wilson
pwilson@aeieng.com

American Council for an Energy Efficient Economy
1001 Connecticut Ave, NW Suite 801
Washington, DC 20036
Tel: 202-42-8873
Email: info@aceee.org
http://aceee.org/

Consumer Energy Council of America
2000 L Street NW, Suite 802
Washington DC, 20036
Tel: 202.659.0404
Email: outreach@cecarf.org
http://www.deforum.org/

Energy Efficiency and Renewable Energy, Department of Energy
1000 Independence Ave., SW
Washington DC, 20585
Tel: 877.337.3463
http://www.eere.energy.gov/

Energy and Environmental Analysis, Inc., an ICF International Company
1655 North Fort Myer Drive
Arlington, VA 22209
Tel: 703.528.1900
Email: inquiries@eea-inc.com
http://www.eea-inc.com/

EPA CHP Partnership
1200 Pennsylvania Ave, NW
Washington DC 20460
Tel: 703.373.8108
Email: chp@epa.gov

Gas Technology Institute
1700 South Mount Prospect Rd
Des Plaines, IL 60018
Tel: 847.768.0500
http://www.gastechnology.org/

International District Energy Association
24 Lyman Street, Suite 230
Westborough, MA 01581
Tel: 508.336.9339
Email: idea@districtenergy.org

United States Clean Heat & Power Association
6436 Quincy Place
Falls Church, VA 22042
Contact: Jessica Bridges
Tel: 703.231.4443
jbridges@uschpa.org

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