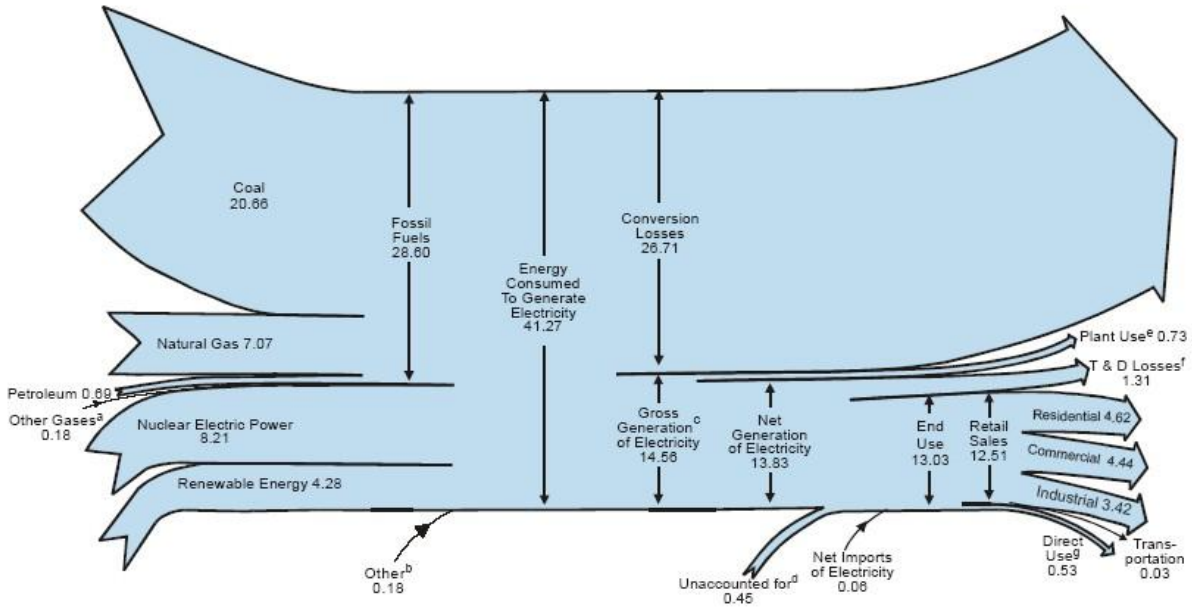
Distributed Electricity Generation Using Combined Heat and Power (CHP)

Introduction

In Texas today, electricity generation is provided predominantly by large (> 500 MW), remotely-located power plants – the so called "central station utility model." The model relies on long transmission lines to connect these power plants to load centers requiring electricity. The model allows for economies of scale in construction, fuel procurement, and operations and maintenance, which historically has resulted in low electricity prices. However, the remote location of central station power plants necessitates that heat, which is a normal output of the power generating process, be discarded unused into the environment. As a result, the central station model results in the loss of about 66% of the energy existing in the raw fuel (See Figure 1).

Figure 1. Electricity Flow, 2006
(Quadrillion Btu)
Energy Information Administration / Annual Energy Review 2006 221

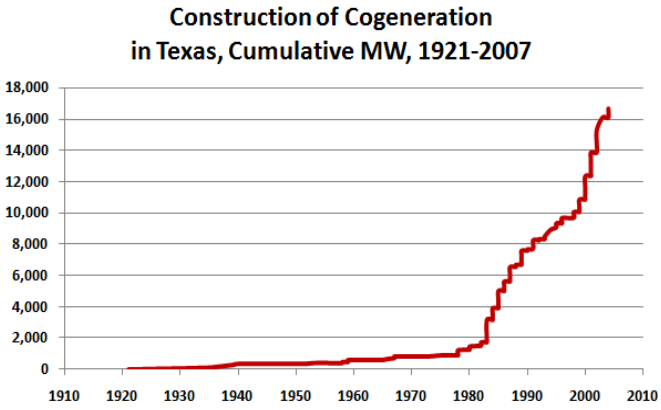


Combined Heat and Power (CHP) refers to a type of distributed generation where naturally occurring thermal energy is captured and used productively for heating and cooling needs. To allow this, CHP systems must be located nearby a facility with a suitable thermal (heating or cooling) load. CHP can be used any place that heating or cooling is needed. The systems can be very large to serve a petrochemical

complex, or small to match the heat load of a building, hospital, university campus, or school. In most cases, CHP uses conventional power generating equipment, but that equipment is sized consistent with the scale of the host facility's energy needs. The primary goal of CHP is to meet the energy needs of a specific host building or facility, rather than to provide electricity to the wholesale market. By using the thermal energy available from the power generating process, CHP plants can have overall energy efficiency between 60-90%, which is at least double the efficiency attained using the central station model. As a result, CHP systems provide impressive environmental benefits and enhance the wise utilization of our energy resources. Because CHP systems are located at the point of energy use, they do not require additional transmission and distribution infrastructure to support broad implementation. Due to the ability to "island" the CHP system during grid outages, CHP systems improve the security of energy supplies of their site hosts. For many adopters, CHP will reduce their overall energy costs. A number of CHP equipment suppliers operate in Texas today, providing thousands of jobs in the process.

Potential for CHP Development

Texas has a long and successful history of CHP implementation. Between 1980 and 2005, more than 16,000 MW of CHP electrical generating capacity has been built in Texas, which represents roughly 20% of the total generating capacity in Texas. The vast majority of CHP in Texas is operating at industrial sites along the Gulf Coast. Because these host facilities have large energy needs, these CHP plants are also extremely large. Today, only a small fraction of the existing CHP capacity is provided by plants with a capacity of less than 100 MW. The historical rate of adoption shows that sophisticated energy managers running the region's chemical plants and petroleum refineries have found CHP to be cost-effective and beneficial to their facilities.



Even with that great success story, CHP still represents a substantial opportunity to bring clean, cost-effective generating resources online in the state. An estimated 20 GW of additional potential is believed to exist in Texas at:

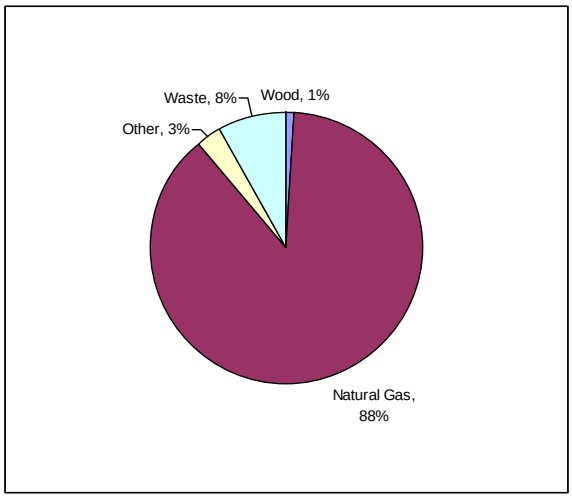
- Industrial plant sites
- Commercial buildings
- Institutional facilities and campuses
- Agricultural operations

While many of the larger opportunities for CHP have been developed, a tremendous opportunity exists for small to medium sized CHP facilities. Project opportunities also include the recovery of wasted heat at industrial plants. In addition, the commercial and institutional facility market is virtually untapped for CHP projects. An estimated 9 GW of new CHP could be developed at Texas universities and schools, food processing plants, hotels, office buildings, data centers, refrigerated warehouses, and wastewater treatment facilities. A number of recent and developing projects in the commercial sector illustrate the types of projects possible in the state. These projects include:

- Thermal Energy Cooperative – Houston, Texas
- BP Rodeo and Helios Plaza – Houston, Texas
- Methodist Hospital – Houston, Texas
- The Domain – Austin, Texas
- Dell Children's Hospital – Austin, Texas

CHP Fuels

About 90% of all CHP systems in Texas are fueled with natural gas. The breakdown of existing CHP systems by fuel type is shown in the figure. As prices for all forms of energy are expected to continue rising, the high energy efficiency of CHP systems increases the economic value of natural gas. CHP stimulates demand for natural gas, which benefits the Texas natural gas industry and the state.



A small fraction of CHP in Texas is powered by renewable fuels such as wood wastes and landfill gas, although the potential exists for much more. Renewable fuels can be converted in biogas through the use of anaerobic digesters or gasification, or simply combusted to generate high pressure steam. Untapped sources of biomass fuel include urban wood waste, land clearing wastes, agriculture wastes, forestry wastes, and wastes from lumber mills and paper mills. A recent study by HARC concluded that up to 1.0 GW of CHP could be fueled with Texas agricultural wastes alone.

Benefits of CHP

CHP can fulfill a vital need in the state's economy for highly efficient, highly reliable sources of clean energy. The technologies can be dispatched at will, so they can provide firm capacity during summer peak conditions. The following three benefits represent important reasons for adopting CHP.

ECONOMIC BENEFITS

CHP dramatically reduces fuel consumption, which can result in an energy cost savings for Texas businesses working to compete in global markets. Added electricity reliability can create a competitive advantage for Texas manufacturers. In addition, CHP plants can provide operational flexibility to the host facility. By providing several options to meet energy supply needs, adopters can better manage energy costs under changing conditions and prices.

The development of CHP can also provide economic benefits to communities across the state. Installation of CHP systems creates high paying jobs for Texans who design, construct, manufacture, and operate them. Because of the CHP potential in Texas and our leadership in the energy industry, our businesses are already leaders in the supply of equipment and services for CHP systems. There are numerous facilities in Texas that supply and service turbo machinery, engines, and heat recovery systems. In addition, Texas has a large number of consultants, engineers, and developers with experience in CHP. CHP also benefits the natural gas industry because it provides a way for natural gas to be competitive as a base load power resource.

ENHANCED POWER RELIABILITY

CHP systems provide an on-site power source capable of keeping critical facilities operating during grid outages. Whether power outages are brought by an event such as a hurricane, tornado, or ice storm, or from a systemic or grid operating condition resulting in a black out, CHP plants can be “islanded” from the grid and continue running. Because they rely on secure natural gas supplies, CHP systems have been documented to continue operations during natural disasters like Hurricanes Katrina and Rita. CHP plants offer an excellent solution to ensure power continuity to the state’s critical infrastructure including hospitals, schools, airports, military bases, and other critical government offices. In addition, CHP plants can improve the power quality during grid imbalances, when minor events can cause major consequences to emissions controls, lost production, and loss of life. CHP plants help ensure that computers and other sensitive equipment are not affected by momentary voltage sags, surges, and harmonics.

ENVIRONMENTAL BENEFITS

CHP conserves fuel and represents an important energy conservation technique. CHP has been documented to reduce toxic air emissions, water consumption, and greenhouse gas emissions. The United States DOE and EPA compared the environmental benefits from a mix of small to medium sized natural gas CHP applications (anticipated to be typical of many commercial and small industrial applications) to the average emission produced from Texas power plants and concluded the following:

- Mercury emissions are reduced by 100%
- Sulfur oxides are reduced by 100%
- Water use is reduced by 90%

- NOx emissions are reduced by 84%
- Carbon dioxide emissions are reduced by 51%

Combined Heat & Power Technologies

The existing CHP plants in Texas use conventional natural gas combustion turbines for over 90% of the capacity, with the balance of the plants using steam turbines and reciprocating engines. CHP technologies expected for new projects, including small projects in the commercial and institutional sector, would also utilize conventional power equipment, albeit sized consistent with the needs of building and facilities that they would serve. "Packaged" CHP systems are becoming more readily available to serve many applications with shorter design and construction times at lower costs. Most technologies are readily available in the marketplace at competitive prices. In many cases, equipment manufacturers have well established operations and offer maintenance programs. The primary CHP technologies include natural gas combustion turbines, steam turbines, natural gas reciprocating engines, and fuel cells. Heat recovery units, absorption chillers, and thermal energy storage systems are also common components in CHP plants.

Implementation Barriers

CHP technologies have seen excellent adoption rates in the industrial sector, but the uptake has been uneven and the pace of adoption has slowed recently. In addition, Texas industrial facility managers have not aggressively pursued small to medium sized CHP projects at medium and large-scale industrial sites, nor have many commercial and institutional facility managers implemented projects. The reasons for the untapped potential is that significant barriers exist that inhibit the development of many CHP projects. The following barriers illustrate important barriers to CHP, but are not the only obstacles.

Electric Utilities Have a Historic Bias Against Distributed Generation

Decades of rate of return regulation in the electric utility industry institutionalized a bias toward large capital projects capable of generating large returns on investments. Small projects including many CHP projects, especially those not requiring significant capacity on the transmission and distribution infrastructure, were less attractive to utility decision makers, due to their lower capital costs and higher incremental development costs. Non-utility CHP developers were seen as competition within the utility's monopoly service territory, which led some utilities to adopt punitive "standby" or "cogen killer" rates. While deregulation of ERCOT has helped, some transmission and distribution service providers (TDSP) oppose CHP because their revenues are adversely impacted by projects that decrease their energy deliveries. Outside of ERCOT, traditional regulated utilities having a monopoly in their service territories remain staunchly opposed to CHP.

Energy Production is Not the Core Business of Facility Owners & Operators

The development of small projects at individual facilities is hindered by a lack of knowledge of the benefits of CHP projects. Facility managers and owners often do not have the capital, the skill set, or the risk profile to invest in CHP projects. Management often requires a financial return unsuited for a long term capital asset like the power equipment used in CHP projects. The requirement to enter into long-term contracts of up to 20 years to secure third party financing can be a barrier for companies wishing to outsource project development.

Building Developers Are Incentivized for Lowest Cost

Building developers are often not the long term owners of the buildings they construct, nor are they often tenants. As a result, they are rarely interested in the operating cost benefit or energy security enhancement that can arise from CHP. Competition in the building market is based upon cost per square foot metrics, which tend to penalize developers that add non-standard value enhancing features like CHP. While the LEED system is having a positive impact, a general lack of awareness and understanding of the benefits of on-site CHP systems by building owners and tenants results in a failure to set high standards for energy performance sufficiently early in the building design process.

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Daniel Bullock joined the Houston Advanced Research Center (HARC) in July 2002, where he is a Senior Research Scientist and Program Manager. Dan focuses on development and commercialization of distributed generation technologies. He has over fifteen years R&D experience encompassing a broad range of work including technology development, public policy analysis, and business development. Bullock is Director of the U.S. Department of Energy-funded Gulf Coast Combined Heat and Power (CHP) Regional Application Center and HARC's Center for Fuel Cell Research and Applications. Bullock holds a bachelor's degree in physics from Pennsylvania State University, a master's degree in engineering from UT Austin and a Master in Public Affairs from the LBJ School of Public Affairs at UT Austin.