COMBINED HEAT AND POWER

Effective Energy Solutions for a Sustainable Future

December 1, 2008

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Energy Efficiency and Renewable Energy

COMBINED HEAT AND POWER

Effective Energy Solutions for a Sustainable Future

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Executive Summary

CHP is a proven and effective energy option, deployable in the near term, that can help address current and future U.S. energy needs.

Combined Heat and Power (CHP) solutions represent a proven and effective near-term energy option to help the United States enhance energy efficiency, ensure environmental quality, promote economic growth, and foster a robust energy infrastructure. Using CHP today, the United States already avoids more than 1.9 Quadrillion British thermal units (Quads) of fuel consumption and 248 million metric tons of carbon dioxide (CO_2) emissions annually compared to traditional separate production of electricity and thermal energy. This CO_2 reduction is the equivalent of removing more than 45 million cars from the road. In addition, CHP is one of the few options in the portfolio of energy alternatives that combines environmental effectiveness with economic viability and improved competitiveness.

This report describes in detail the four key areas where CHP has proven its effectiveness and holds promise for the future—as an:

- *Environmental Solution:* Significantly reducing CO_2 emissions through greater energy efficiency
- *Competitive Business Solution:* Increasing efficiency, reducing business costs, and creating green-collar jobs
- *Local Energy Solution:* Deployable throughout the US
- *Infrastructure Modernization Solution:* Relieving grid congestion and improving energy security

As an efficiency technology, CHP lowers demand on the electricity delivery system, frequently reduces reliance on traditional energy supplies, makes businesses more competitive by lowering their costs, reduces greenhouse gas and criteria pollutant emissions, and refocuses infrastructure investments towards a next-generation energy system. Already used by many large industrial, commercial, and institutional facilities, CHP is a proven and effective energy resource, deployable in the near term, that can help address current and future US energy needs. Incorporating commercially available technology, CHP can provide an immediate solution to pressing energy problems.

CHP is one of the most promising options in the US energy efficiency portfolio. It is not a single technology but a group of technologies that can use a variety of fuels to provide reliable electricity, mechanical power, or thermal energy at a factory, university campus, hospital, or commercial building—wherever the power is needed. CHP's efficiency comes from recovering the heat that would normally be wasted while generating power to supply the heating or cooling needs of the user. By capturing and utilizing waste heat, CHP requires less fuel than equivalent separate heat and power systems to produce the same amount of energy services. Because CHP is located at or near the point of use, it also eliminates the losses that normally occur in the transmission and distribution of electricity from a power plant to the user.

CHP, or cogeneration, has been around in one form or another for more than 100 years; it is proven, not speculative. Despite this proven track record, CHP remains underutilized and is one of the most compelling sources of energy efficiency that could, with even modest investments, move the Nation strongly toward greater energy security and a cleaner environment. Indeed, ramping up CHP to account for 20 percent of US electricity capacity—several European countries have already exceeded this level—would be equivalent to the CO_2 savings of taking 154 million cars off the road.

2030 CHP – Proposition: 20% of US Capacity	**240,900** MW
Reduced Annual Energy Consumption with CHP	**5.3** Quads
Total Annual CO_2 Reduction	**848** MMT
Total Annual Carbon Reduction	**231** MMT
Number of Car Equivalents Taken Off Road	**154** million

The generating capacity of the more than 3,300 US CHP sites now stands at 85 gigawatts (GW)—almost 9 percent of total US capacity.[1] In 2006 CHP produced 506 billion Kilowatt Hour (kWh) of electricity—more than 12 percent of total US power generation for that year.

If the United States adopted high-deployment policies to achieve 20 percent of generation capacity from CHP by 2030, it could save an estimated 5.3 quadrillion Btu (Quads) of fuel annually, the equivalent of nearly half the total energy currently consumed by US households.[2] Cumulatively through 2030, such policies could also generate $234 billion in new investments[3] and create nearly 1 million new highly-skilled, technical jobs[4] throughout the United States. CO_2 emissions could be reduced by more than 800 million metric tons (MMT) per year, the equivalent of taking more than half of the current passenger vehicles in the US off the road.[5] In this 20 percent scenario, over 60 percent of the projected increase in CO_2 emissions between now and 2030 could be avoided.

While the benefits of added CHP capacity are promising, current market conditions and technical barriers continue to impede full realization of CHP's potential. Challenges include unfamiliarity with CHP, technology limitations, utility business practices, regulatory ambiguity, environmental permitting approaches that do not acknowledge and reward the energy efficiency and emissions benefits, uneven tax treatment, and interconnection requirements, processes, and enforcement. Addressing these challenges will require a holistic approach involving policy, regulatory, and technical solutions. Improving the fuel efficiency and fuel flexibility of CHP and developing optimized, integrated packaged systems can also lower costs and expand the application of cost-effective CHP.

Increasing worldwide energy demand, rising energy prices, and concerns about climate change are driving interest in energy efficiency and renewable energy. There is growing recognition that energy efficiency must be part of any realistic strategy to ease short-term US energy prices and stabilize the long-term energy future. Energy efficiency and renewable energy are key components of a portfolio of promising supply- and demand-side resources that can provide the Nation with clean, affordable energy and support continued economic prosperity. CHP is first and foremost an energy efficiency resource.

The cost-effectiveness and near-term viability of CHP development establishes this exciting technology as a leader among other clean energy technologies such as wind, solar, clean coal, biofuels, and nuclear power. As the United States continues to transform the way it produces, transports, and uses energy, it should capitalize on the vast and valuable benefits of CHP. A strategic approach is needed to encourage CHP where it can be applied today and address the challenges discouraging its deployment. A history of success here and abroad proves that a balanced set of policies, incentives, and technology investments can bring sustained CHP growth and realize its enormous potential.

[1] CHP Installation Database developed by Energy and Environmental Analysis, Inc. for Oak Ridge National Laboratory and U.S. Department of Energy, 2007. www.eea-inc.com

[2] Based on Energy Information Administration AEO 2008 figure of 11.58 QBtu consumed in the residential sector in 2005.

[3] Based on assumed cost of $1,500 per kilowatt-hour installed cost.

[4] Based on four jobs created for every $1 million in capital investment.

[5] Based on Bureau of Transportation Statistics figure of 251 million registered passenger vehicles in 2006.

CHP: A Key Part of Our Energy Future

Much like wind power, solar energy, plug-in hybrid vehicles, compact fluorescent light bulbs, and biofuels, CHP should be a key component of a well-rounded energy portfolio. CHP offers several distinct advantages over many other electricity and thermal energy generating technologies with regard to performance, availability, and cost.

CHP provides efficient, clean, reliable, affordable energy – today and for the future.

CHP positively impacts the health of local economies and supports national policy goals in a number of ways. Specifically, CHP can:

- **Enhance our energy security** *by reducing our national energy requirements and help businesses weather energy price volatility and supply disruptions*
- **Advance our climate change and environmental goals** *by reducing emissions of* CO_2 *and other pollutants*
- **Improve business competitiveness** *by increasing energy efficiency and managing costs*
- **Increase resiliency of our energy infrastructure** *by limiting congestion and offsetting transmission losses*
- **Diversify energy supply** *by enabling further integration of domestically produced and renewable fuels*
- **Improve energy efficiency** *by capturing heat that is normally wasted*

The energy lost in the United States from wasted heat in the utility sector is greater than the total energy use of Japan.

What Is Combined Heat and Power?

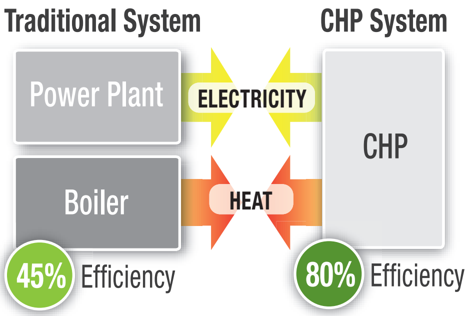
CHP, also known as cogeneration, is the concurrent production of electricity or mechanical power and useful thermal energy (heating and/or cooling) from a single source of energy. CHP is a type of distributed generation, which, unlike central station generation, is located at or near the point of consumption. Instead of purchasing electricity from a local utility and then burning fuel in a furnace or boiler to produce thermal energy, consumers use CHP to provide these energy services in one energy-efficient step. As a result, CHP improves efficiency and reduces greenhouse gas (GHG) emissions. For optimal efficiency, CHP systems typically are designed and sized to meet the users' thermal baseload demand.

While the traditional method of producing separate heat and power has a typical combined efficiency of 45%, CHP systems can operate as high as 80% efficiency.

CHP is not a single technology but a suite of technologies that can use a variety of fuels to generate electricity or power at the point of use, allowing the heat that would normally be lost in the power generation process to be recovered to provide needed heating and/or cooling. This allows for much greater improvement in overall fuel efficiency, resulting in lower costs and CO_2 emissions. CHP's potential for energy savings is vast.

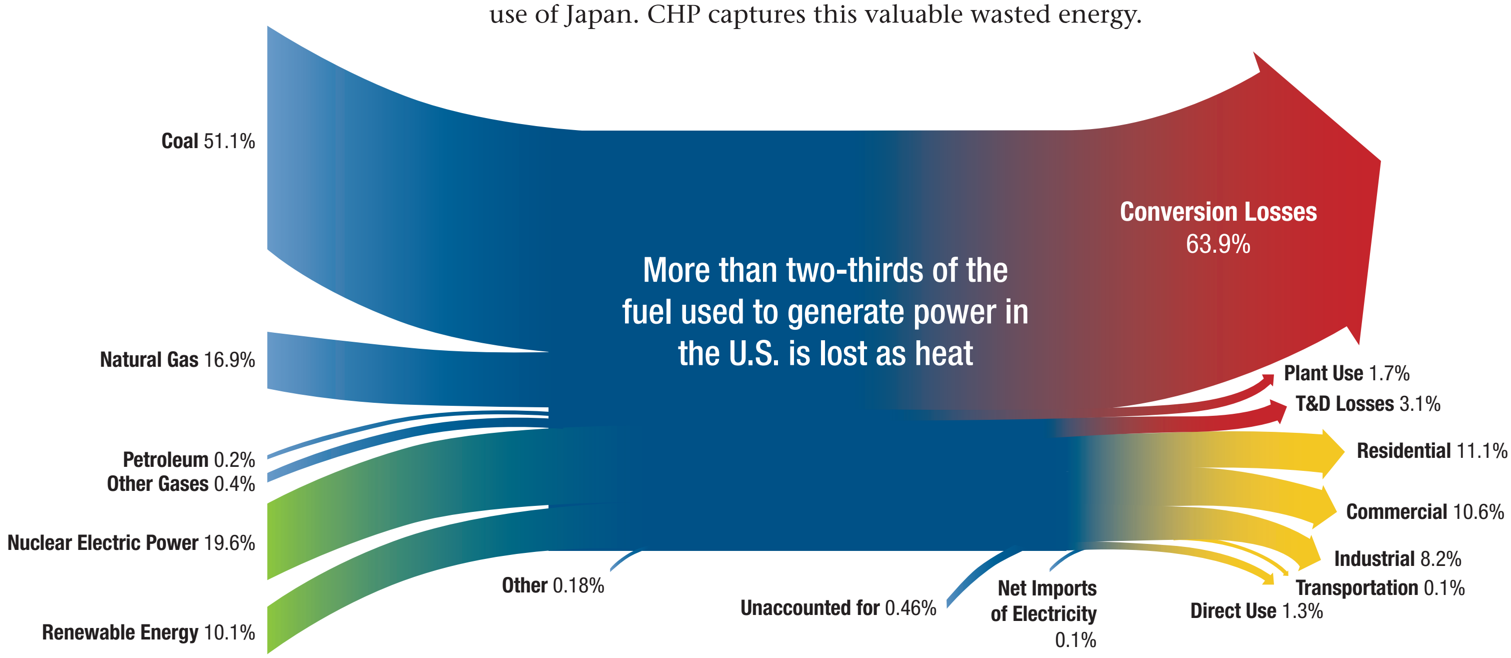
CHP technology can be deployed quickly, cost-effectively, and with few geographic limitations. CHP can use a variety of fuels, both fossil- and renewable-based. It has been employed for many years, mostly in industrial, large commercial, and institutional applications.

CHP Process Flow Diagram



CHP may not be widely recognized outside industrial, commercial, institutional, and utility circles, but it has quietly been providing highly efficient electricity and process heat to some of the most vital industries, largest employers, urban centers, and campuses in the United States. While the traditional method of separately producing usable heat and power has a typical combined efficiency of 45 percent, CHP systems can operate at efficiency levels as high as 80 percent.

The great majority of US electric generation does not make use of the waste heat. As a result, the average efficiency of utility generation has remained at roughly 34 percent since the 1960s. The energy lost in the United States from wasted heat in the power generation sector is greater than the total energy use of Japan. CHP captures this valuable wasted energy.



Source: DOE Energy Information Administration Annual Energy Review 2007

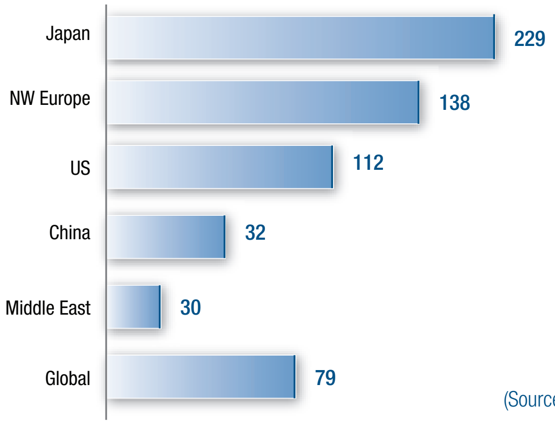
Current US Energy Situation and How CHP Can Help

Changing energy markets and climate change policies are driving greater interest in energy efficiency and clean energy technologies. In recent years, the United States has seen record or near-record high prices in electricity, coal, natural gas, and petroleum. Consumers, especially energy-intensive businesses, industries, and institutions are feeling the pinch of these prices. Businesses can not afford to absorb these higher costs and are passing them on to consumers. The increased costs of goods and services are negatively affecting the US and world economies. US businesses and industry have struggled to maintain profitability in an environment where uncertainty of supply, uncertainty of availability, and risk are now the norm. Most analysts believe this pattern will hold for an extended period and that cheap energy is a thing of the past.

CHP is a realistic, near-term option for energy efficiency improvements and significant CO_2 reductions that simultaneously spurs business investment and job creation.

In addition to the economic concerns resulting from the current energy situation, there is a global drive to limit emissions of CO_2, primarily from the burning of fossil fuels, to curb climate change. The United States, while accounting for just 5 percent of the world's population, consumes nearly 25 percent of the world's energy. This disproportionate fuel demand is a reflection of the country's poor energy productivity—the lowest of any developed economy in the world.[6]

Energy Productivity (Billion Real $ GDP/QBTU)



(Source: McKinsey & Company)

The United States has experienced and overcome energy crises in the past. However, the current energy situation will not lend itself to remedy through simple supply-side measures and short-term conservation as in the 1970s, when increased petroleum supplies quickly reduced consumer price pressures. There are several differences today that require more comprehensive solutions.

The following issues are shaping the US energy landscape:

- Growing energy demand
- Constraints on traditional energy supply and delivery
- Global competition
- Climate change concerns
- Need for infrastructure modernization
- Security concerns

[6] "Energy productivity" refers to the amount of economic output produced per amount of total economy-wide fuel input.

CHP offers flexibility in fuel selection and can take advantage of both fossil fuels and locally-sourced and renewable fuels.

Growing Energy Demand

When energy markets stabilized after the 1970s, Americans began to abandon the efficiency and conservation methods that had been implemented to help them cope with the era's market tumult. Americans today live in larger homes, drive larger cars, have more conditioned space, and use more electronic equipment. While technological improvements and efficiency have improved productivity per unit of energy consumed, this trend is being outpaced by these other factors. CHP reduces growing energy demand by promoting the efficient use of our finite natural resources.

Constraints on Traditional Energy Supply

In the United States, domestic oil production peaked in 1972 and natural gas production peaked in 1973.[7] Globally, oil production may be approaching its peak today.[8] Both domestic and foreign oil are becoming more expensive to obtain, as quality (sour crudes) lessens and supplies become more difficult to extract.

While North American production and consumption of natural gas are largely in balance, small fluctuations in supply or demand can bring high price volatility. While natural gas can be imported in the form of liquefied natural gas (LNG), this requires significant additional infrastructure investment and faces notable environmental obstacles. Domestically, new gas shale formations hold promise to boost natural gas production by 5-10 percent and moderate prices.[9]

While domestic coal is relatively plentiful, environmental concerns limit its use. Moreover, the cost of building traditional coal-fired power plants has been escalating, driven by pollution control requirements, high construction levels globally, tightness in the equipment and engineering markets, and high prices for raw materials. Overall, capital costs for coal power plants have risen 78 percent since 2000.[10] General Electric gives estimates of $2,000–$3,000 per kW for new conventional coal-fired plants, and Duke Energy is proposing to spend $1.83 billion to build an 800-MW plant in North Carolina, or $2,300/kW.[11] At $2,500 per kW installed, the delivered price of electricity to consumers would be roughly 10 to 12 cents per kWh, more than 60 percent above current average industrial electricity prices.[12]

Advanced clean coal technologies will be even more expensive. The use of carbon capture and sequestration and advanced approaches to coal combustion will significantly add to these costs. As an example, Tenaska Energy is seeking $3.5 billion for its proposed 630MW integrated gasification combined cycle (IGCC) coal plant in Taylorville, IL. This translates to $5,555/kW.[13]

CHP systems offer flexibility in fuel selection and can take advantage of both fossil fuels and locally-sourced and renewable fuels such as landfill gas, biomass, or digester gas. Bio-methane sources are particularly well-suited to CHP systems and help supplement traditional natural gas supplies with a renewable resource. This flexibility will be an ever more important advantage in an environment where thermal energy is required and fossil-fuel price and availability is volatile or uncertain.

[7] Elliott. 2006. *America's Energy Straitjacket*. ACEEE.

[8] Deffeyes. 2001. *Hubbert's Peak: The Impending Oil Shortage.*

[9] ICF International. 2008. *Availability, Economics, and Production Potential of North American Unconventional Natural Gas Supplies.*

[10] IHS/CERA 2008. *Power Capital Costs Index.*

[11] New York Times. July 10, 2007.

[12] Casten. June 5, 2008. "*Coal is no longer cheap—so what comes next?*" Grist.

[13] Argus Air Daily. November 12, 2008.

Global Competition

Today's energy market is global. There is competition for energy supplies from growing economies such as China, India, Brazil, and others. Domestic manufacturers are struggling to maintain competitiveness against countries with lower labor, raw material, and energy costs. In the past, natural gas and refined petroleum products were produced domestically for American consumers, but now these products are frequently imported from overseas, with prices driven up by increased demand in other energy-hungry countries. This energy straitjacket involves all fossil fuels—petroleum, natural gas, and coal.

Domestically produced equipment, materials, skilled labor, engineering expertise, services, and fuel are all utilized in the operation and installation of CHP systems, resulting in job creation. Using these systems domestically will allow the US to come one step closer to achieving true energy security and independence. Also, US leadership in the development of these technologies and skills will allow a thriving home-grown industry to export these innovations globally.

Energy efficiency, including CHP, is the least expensive and most rapidly deployable energy resource available today. Efficiency will pave the road to a sustainable energy future.

Climate Change Concerns

Most scientists agree that the increase in global temperatures or warming in recent decades has been caused primarily by human activities that have increased the amount of CO_2 and other greenhouse gases in the atmosphere.[14] The largest man-made source of CO_2 is the combustion of fossil fuels. Many states and regions of the United States are following the lead of other countries that are implementing policies to avoid or reduce carbon emissions. Many people believe the United States is on a path to adopt policies to limit CO_2 and other greenhouse gas (GHG) emissions.

CHP reduces the carbon footprint of separately generated heat and power. Furthermore, it is one of the most cost-effective methods of reducing CO_2 emissions.[15]

Need for Infrastructure Modernization

While US energy demand continues to increase, investment in energy-delivery infrastructure has not kept pace. In many parts of the country, especially near urban and economic centers, both natural gas and electricity T&D systems are operating at capacity. Energy-related infrastructures are aging.[16] Even small disturbances such as a heat wave, cold snap, or storm can cause major bottlenecks in energy deliveries. The movement toward a distributed energy paradigm can play an important role in solving energy delivery constraints while deferring or avoiding costly investments in infrastructure. CHP located at or near the site, can reduce capacity requirements or overloading on transmission lines, transformers, and distribution feeders. This could enable current infrastructure to serve new or growing loads, reducing or deferring infrastructure reinforcement.

[14] The National Academies. 2008. *Understanding and responding to Climate Change.*

[15] International Energy Administration. March 2008. *Combined Heat and Power—Evaluating the Benefits of Greater Global Investment.*

[16] Average Age of US coal-fired power plants is 40 years. Form EIA-860 Database, Annual Electric Generator Report.

47 percent of boiler capacity is at least 40 years old and 76 percent is at least 30 years old. Energy and Environmental Analysis, Inc. 2005. *Characterization of the U.S. Industrial and Commercial Boiler Population.*

Testimony before the U.S. House Committee on Transportation and Infrastructure. April 26, 2006. *The U.S. Rail Capacity Shortage.*

Building the US Energy Future with Energy Efficiency and CHP

Many may hope for a silver bullet in the form of groundbreaking technology or massive discovery of new fossil fuel reserves, but the US energy situation must be approached with a comprehensive, sophisticated strategy. The Nation will need solutions that alleviate its short-term energy price and constraint situation. Solutions it can count on for longer term energy stability must be developed. This strategy must include both supply- and demand-side solutions and must hold promise for clean, affordable energy and economic prosperity.

Energy efficiency should be the cornerstone of a sustainable energy portfolio. It is the least expensive and most rapidly deployable energy resource available today. Increasing efficiency extends existing energy resources and infrastructure while the United States develops future alternative energy technologies. Efficiency will pave the road to a sustainable energy future.

CHP is first and foremost an energy efficiency resource. It allows users to produce needed electricity, heat, and mechanical energy while using as little fuel as possible. As an efficiency technology, CHP can lower overall energy demand, reduce reliance on traditional energy supplies, make businesses more competitive, cut GHG emissions, and reduce the need for infrastructure improvements. Because of its inherent efficiency, performance, and reliability, CHP is an effective near-term solution that can address the Nation's current and future energy needs.

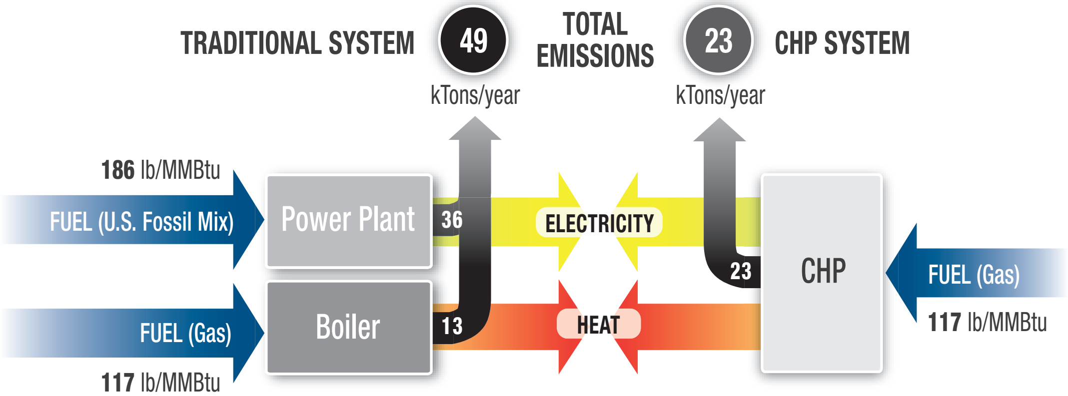
Environmental Solution

Gas Turbine providing heating, cooling and power to a university campus and hospital.

CHP offers significant environmental benefits compared to separately purchased electricity and onsite-generated thermal energy. By capturing and utilizing heat that would otherwise be wasted, CHP is more efficient than traditional separate electricity generation and heat production, thereby using less fuel and emitting lower levels of greenhouse gases (GHGs) such as CO_2 and pollutants such as NO_x.

CHP in the United States today avoids more than 1.9 Quadrillion Btu of fuel consumption and 248 million metric tons of CO_2 emissions compared to traditional separate production of electricity and heat. This CO_2 reduction is the equivalent of removing more than 45 million cars from the road.

Increased Efficiency Results in Reduced Carbon Emissions



Example of the CO_2 savings potential of CHP based on a 5 MW gas turbine CHP system with 75% overall efficiency operating at 8,500 hours per year providing steam and power on-site compared to separate heat and power comprised of an 80% efficient on-site natural gas boiler and average fossil based electricity generation with 7% T&D losses.

Source: ICF International

Compared to average fossil-based electric-supply generation, the existing base of CHP results in:

Based on comparing the annual fuel use and CO_2 emissions of existing CHP with separate heat and power comprised of on-site thermal energy supplied by the same fuel type and average fossil based electricity generation for 2006 (AEO 2008) with 7% T&D losses.

2006 Existing CHP - 9% of U.S. Capacity	**85** GW
Reduced Annual Energy Consumption With CHP	**1.9** Quads
Total Annual CO_2 Reduction	**248** MMT
Carbon Saved	**68** MMT
Number of Car Equivalents Taken Off Road	**45** million

Source: Based on *Annual Energy Outlook 2008* (AEO 2008), U.S. Energy Information Administration and eGRID, EPA.

If in the future, the United States received 20 percent of its electricity capacity from CHP, this would be equivalent to removing more than 154 million cars (or more than half of the US vehicle fleet) from the road. Achieving that environmental impact would be a huge accomplishment, and few other technologies or practices can be implemented as economically or quickly as CHP.

Based on extrapolating existing CHP performance by fuel type to proposed 2030 capacity and comparing with separate heat and power comprised of on-site thermal energy supplied by the same fuel type and average fossil based electricity generation for 2030 (AEO 2008) with 7 % T&D losses.

2030 CHP – 20% of U.S. Capacity	**240.9** GW
Reduced Annual Energy Consumption With CHP	**5.3** Quads
Total Annual CO_2 Reduction	**848** MMT
Carbon Saved	**231** MMT
Number of Car Equivalents Taken Off Road	**154** million

Source: Based on *Annual Energy Outlook 2008* (AEO 2008), U.S. Energy Information Administration and eGRID, EPA.

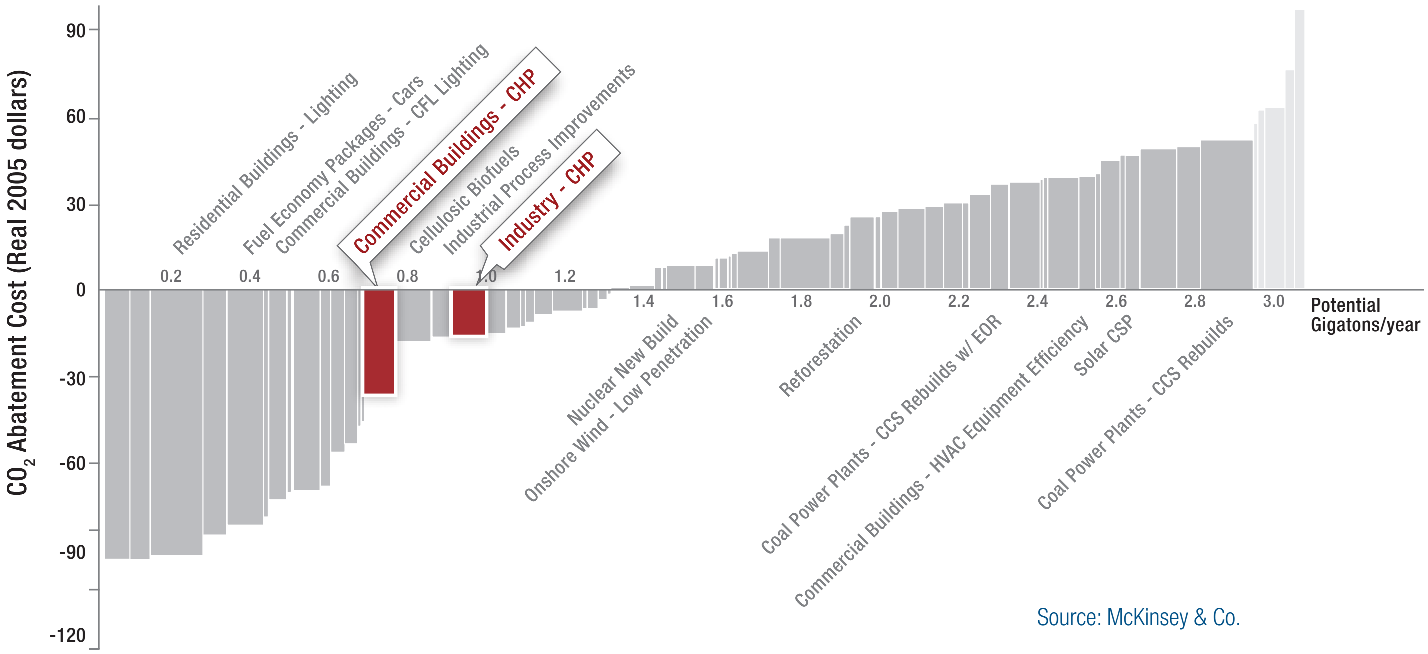
Cost-Effectively Reducing CO_2 Emissions

CHP is a comprehensive, effective, and economically sound strategy for minimizing GHG emissions. In the United States, the electric power sector produces the largest portion of CO_2 emissions. Data from the US Energy Information Administration's (EIA) Annual Energy Outlook 2008 (AEO 2008) shows that in 2006, 23 percent of US CO_2 emissions were attributable to coal-fired utility generation. This share is projected to grow to 27 percent in 2030.

CHP systems are usually installed only when they make economic sense. A 2007 study by McKinsey & Company on reducing US GHG emissions shows that under proper market conditions, CHP can deliver CO_2 reductions at a negative marginal cost for both the commercial and industrial sectors.[17] This means that investing in CHP generates positive economic returns over the technology's life cycle. The McKinsey study further shows that based on the current price and performance of various technologies, investing in CHP has an economic advantage over many other environmentally-friendly technologies.

[17] McKinsey and Company. 2007. *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?*

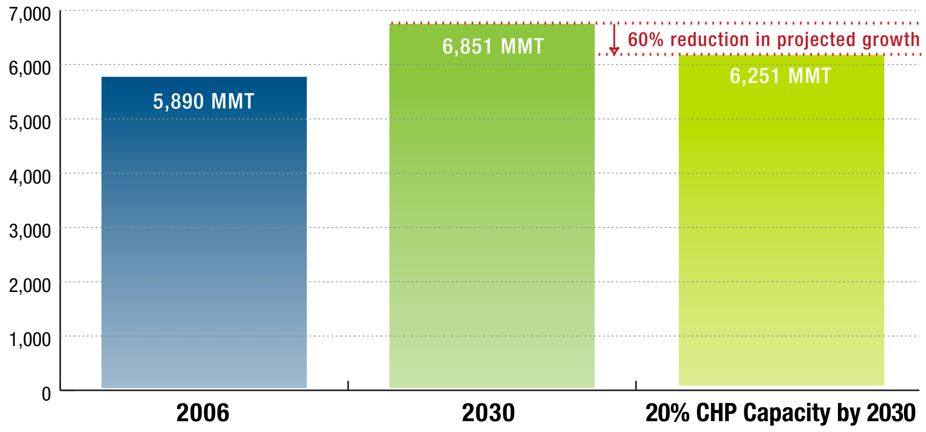
Cost of CO_2 Reduction Technologies



Source: McKinsey & Co.

The figure above shows a range of CO_2 abatement practices and technologies, ranging from efficiency standards for consumer products to carbon capture and storage for coal-fired power plants. Among the most cost-effective (with negative real costs) are energy efficiency technologies, including commercial and industrial CHP.

US Carbon Dioxide Emissions 2006 and 2030 (MMT)



Source: DOE EIA AEO 2008 and internal analysis

According to AEO 2008, total annual US CO_2 emissions in 2006 were 5,890 million metric tons (MMT). In 2030, these emissions are projected to rise to 6,851 MMT. If in 2030 CHP were used to provide 20 percent of electricity generating capacity, over 60 percent of the expected increase in CO_2 emissions could be avoided.

SC Johnson Cleans Up With CHP

Cleaning products maker SC Johnson installed a 6.4-MW CHP in Racine, WI, to reduce energy costs and CO_2 emissions. Two industrial turbines burn a combination of natural gas and methane from a nearby landfill to provide all the facility's baseload electricity and make 40,000 pounds of process steam per hour.

Benefits

- Reduces plant CO_2 emissions by 52,000 tons per year, the equivalent of taking 5,200 cars off the road.
- Avoids methane energy from being wasted and flared at the landfill.
- Supplants the facility's need for natural gas.

Coal is the primary fuel for 52 percent of the electricity produced in the United States, and will grow to 57 percent by 2030 under business as usual. Natural gas accounted for 16 percent of electricity produced and is projected to be 11 percent in 2030.[18] Faster deployment of CHP and other efficient technologies is needed to reverse these trends.

Other Pollution, Land and Water Use Issues

In addition to the large reductions in GHG emissions it can deliver, CHP can significantly cut mercury, NO_x, and SO_x emissions. CHP located near or at the point of use must meet all local criteria pollutant standards, which can be quite stringent in urban and highly populated areas. As an example, electricity generation from coal is the largest emitter of mercury, a toxic heavy metal. The great majority—93 percent—of existing CHP systems do not use coal as fuel and therefore emit no mercury.

CHP systems are typically located at existing industrial or commercial facilities. Therefore, no new green space is required for their construction. There is usually no impact to local wildlife from existing or new installations of CHP systems. Siting at or near the customer may defer the construction of new distribution and/or transmission lines.[19]

In the United States, 89 percent of the energy produced in power plants is generated by thermoelectric systems. These thermally driven, water-cooled central station power generators use an enormous amount of water for cooling. While most of this water is withdrawn from rivers, groundwater, and other sources and returned, a small amount is consumed through evaporation in cooling towers and from cooling tower blowdown. The National Renewable Energy Laboratory (NREL) estimates that almost half a gallon of water is evaporated at central station thermoelectric plants for every kWh of electricity consumed at the point of use.[20] This issue is particularly important in western states and the Colorado River basin, where water supplies are limited. CHP recovers and recycles thermal energy and generally does not use condensers or cooling towers, therefore, its water consumption is much lower.

[18] AEO 2008.

[19] Con Edison. 2005. *Energy Infrastructure Master Plans—Hudson Yards and Lower Manhattan.*

Con Edison. 2005. *System Reliability Assurance Study.*

[20] National Renewable Energy Laboratory. 2003. *Consumptive Water Use for U.S. Power Production.* NREL/TP-550-33905.

Competitive Business Solution

CHP is a proven, reliable, cost-effective way of providing energy services for the manufacturing, commercial, and institutional sectors. Where a renewable or waste fuel is available onsite, a facility may be able to independently supply itself with heat and power, making it less vulnerable to rate increases or volatility in fuel price and availability. CHP improves energy efficiency and reduces the energy cost per unit of product. The cost savings can help make the difference between staying in business and shutting down.

During natural or manmade disasters, CHP is capable of keeping critical facilities running when local or regional electric grids fail. As Hurricanes Katrina and Rita dramatically showed, the petrochemical and refinery sector is vulnerable to grid disruptions. For an industrial manufacturing facility, a 1-hour outage can cost a company over $50,000 in losses.[21] For high-value data-driven operations, losses can be staggering. For example, a 1-hour outage at the First National Bank of Omaha's credit card processing facilities can cost the company as much as $6 million in lost revenues.[22] Consequently, the bank installed a fuel cell-based CHP system that is integrated with Omaha's downtown district energy system.

As a direct result of efficiency improvements from installation of a CHP plant, an Ethan Allen furniture factory in Vermont was able to reduce its energy cost by 10 percent and continue operating in the United States, saving 550 jobs.

Energy Efficiency and CHP Provide Economic Benefits for the Nation

Various studies have shown that CHP, employed as part of a comprehensive energy efficiency and renewable energy strategy, can have significant, positive economic impacts including the creation of "green-collar" jobs. Texas, one of the fastest growing states in the country, faces the triple challenges of surging demand for electricity, increasing energy costs, and continuing environmental problems, all of which imperil its economic health.

A recent study has shown that energy efficiency including customer-sited CHP, onsite renewables, and demand-response[23] can meet the growth in Texas' electricity needs without the need for new central station power plants.[24] This strategy also limits consumer energy costs, creates new jobs, and offers significant emissions reductions, thus addressing the environmental and energy cost challenges while contributing to the growth of the state's economy.

The suite of policies recommended in the study would result in net cumulative consumer energy savings of $37.4 billion by 2023, and annual SO_x and NO_x emissions reductions of 31,400 and 23,400 tons, respectively. At the same time, the policies would create more than 38,000 new jobs. Many of the new jobs would be associated with the manufacture and installation of energy efficiency and renewable energy measures, and would contribute more than $1.6 billion in new net wages to the Texas economy by 2023.

[21] Sentech, Inc. 2006. *Update of Business Downtime Costs.*

[22] Business Week. October 9, 2000 *Commentary: Oil: A Modest Proposal for the U.S.*

[23] "Demand-response" refers to mechanisms that call for reducing customer energy use during peak demand or utility system emergency.

[24] Laitner, et al. 2007. *The Economic Benefits of an Energy-Efficiency and Onsite Renewable Energy Strategy to Meet Growing Electricity Needs in Texas.* ACEEE.

Entenmann's Keeps on Baking

The CHP system at the Entenmann's bakery in Bayshore, NY, consists of four natural gas-burning reciprocating engines producing 5.1 MW of electric power. During normal operations the system is used for baseload power and meets all the electricity needs of the site, with any excess power sold back to the local utility. Bayshore was heavily affected by the August 2003 blackout, with power remaining out for a long time. While other facilities in the area had to shut down, the bakery stayed fully operational. Since the CHP system was able to serve all the energy needs of the facility independent of the grid, operations "didn't miss a beat" and no product was lost, according to a company official.

Reliability was the primary reason for installing the system due to the substantial losses that are associated with power outages at food processing facilities. The system is highly valued by site managers, has proved itself to be extremely beneficial in maintaining operations, and has performed exactly as designed. In management's view, the decision to install the system has been completely justified, and they would "definitely" recommend a CHP system to others.

The benefits of increased energy efficiency from technologies such as CHP extend to fuel markets as well. Several 2003 studies showed how reducing natural gas consumption with efficiency and CHP lowers pressure on natural gas wholesale prices.[25/26] These studies showed that reducing natural gas consumption by 5–6 percent can result in a 20 percent reduction in commodity price.

In the United States, where labor, raw material, and fuel costs are high, improving energy efficiency can mean the difference between remaining in business, moving offshore, or closing altogether. Unless the country acts now to improve its energy efficiency, the energy productivity gap between the United States and the rest of the world will continue to grow. Energy efficiency improves the financial competitiveness of a company just as much as other more "conventional" measures to eliminate waste and increase output in production.

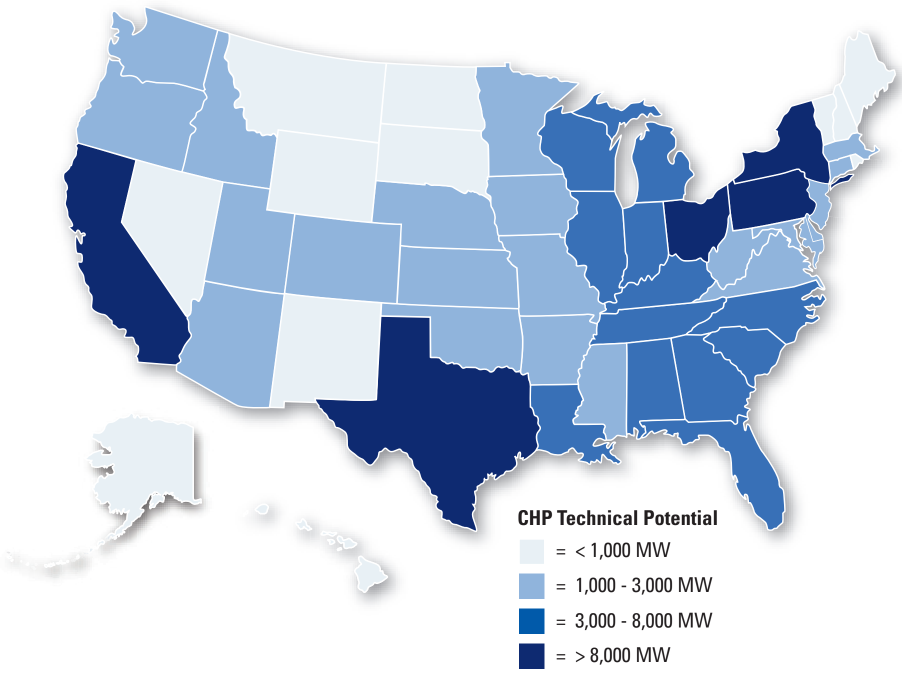
[25] EEA, Inc. 2003. *Natural Gas Impacts of Increased CHP.*

[26] Elliott, et al. 2003. *Natural Gas Price Effects of Energy Efficiency and Renewable Energy Practices and Policies.* ACEEE.

Local Energy Solution

While the largest concentrations of existing installed CHP capacity are in a handful of states—California, Louisiana, New York, and Texas—CHP is deployable throughout the Nation. Distributed energy is often locally owned and controlled, so energy consumers and communities become direct stakeholders in their own energy supply. In some areas that are worried about their energy supply, CHP may be a way to attract new business in the face of transmission constraints or electricity shortages.

Remaining Technical CHP Potential



CHP Is Applicable Throughout the US

Unlike wind and solar generating technologies, CHP can operate 24 hours a day in any climate or location in the United States. The heat and power is produced at or near the site of consumption and therefore does not face T&D constraints. CHP is typically located at sites already zoned for commercial or industrial activities. CHP can be used in a wide variety of applications including large and small industrial facilities, commercial buildings, multi-family and single-family housing, institutional facilities and campuses, and district energy systems.

CHP capacity is greatest in states with the largest thermal energy-dependent industrial sectors. The gulf coast of Louisiana and Texas has one of the largest concentrations of CHP capacity in the country, with about 24 GW (28 percent of total US CHP capacity). The region's large petrochemical and petroleum-refining industries have enormous thermal demands and make expert use of CHP to provide their facilities with heat and electricity. California and New York also have more than 5,000 MW of installed CHP. Both states have large industrial demands, stringent air quality requirements, and effective policies that encourage adoption of CHP.

Examples of opportunity and local, onsite fuels include:

BIOMASS FUELS

- Anaerobic digester gas
- Biomass gas
- Black liquor
- Crop residues
- Food-Process Residues
- Landfill gas
- Municipal solid waste (and refuse-derived fuel)
- Wood and wood waste

INDUSTRIAL PROCESS WASTE AND BY-PRODUCTS

- Blast furnace gas
- Coke (coal and petroleum)
- Coke oven gas
- Industrial volatile organic compounds
- Textile waste

FOSSIL FUEL DERIVATIVES

- Coalbed methane
- Wellhead gas

PROCESSED OPPORTUNITY FUELS

- Tire-derived fuel

Rank	State	Total Capacity 2006 (MW)
1	TX	17,240
2	CA	9,220
3	LA	6,959
4	NY	5,789
5	FL	3,545
6	NJ	3,493
7	AL	3,362
8	PA	3,242
9	MI	3,104
10	OR	2,523

Mittal Steel Slashes GHGs

Mittal Steel, located in East Chicago, IN, has a 95-MW CHP system that utilizes recovered waste heat. The system meets 25 percent of the site's electrical requirements and 85 percent of its process steam needs, replacing onsite, coal-fired steam generation.

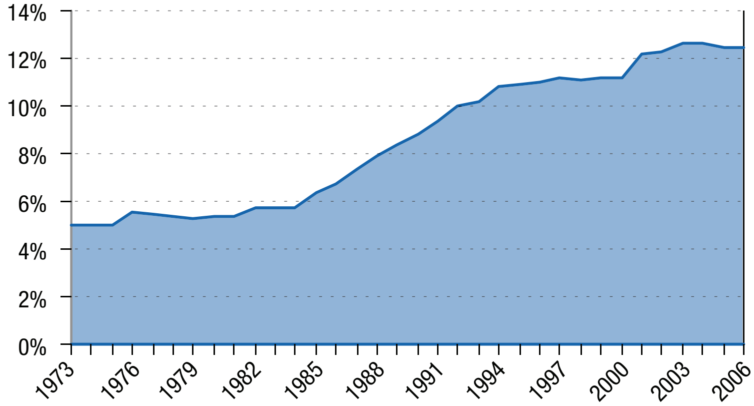
Benefits

- The CHP system serves as the pollution control device for the coke battery, substantially reducing SO_2 and particulate emissions associated with coke production.
- The system displaces 13,000 tons of NO_x, 15,500 tons of SO_2, and more than 800,000 tons of CO_2 emissions annually.

CHP Is a Significant and Growing Share of US Generation

CHP comprises a significant percentage of US power generation. The use of CHP accelerated following passage of PURPA in 1978, which enabled many industrial and institutional sector users to generate thermal energy and power onsite, have access to the grid, and sell excess electricity to the local utility at an agreed upon price.

CHP as a Percentage of U.S. Annual Electricity Generation



Fuel-Use Trends Over Time

Expansion of natural gas-fueled electricity generation is one reason behind recent increases in natural gas consumption. Natural gas has assumed an increasingly significant role in domestic electricity markets over the last 20 years. The major motivations for this expansion were the relatively low cost of new gas generation units, the clean-burning characteristics of natural gas, and the higher efficiencies of central station combined-cycle power generation units. Also, for most of the 1990s natural gas was bountiful and inexpensive. This period coincided with the emergence of deregulated wholesale markets.

Natural gas continues to be the preferred fuel for CHP systems, representing 50–80 percent of annual CHP capacity additions since 1990. This is primarily because natural gas is readily available at most industrial sites, is clean burning, and has historically been relatively plentiful and affordable.

Since 2001, natural gas prices have been consistently volatile and relatively high. However, recent increases in domestic natural gas exploration and production hold promise to moderate natural gas prices. While natural gas remains an important CHP fuel, installers and technology developers are increasingly looking to "opportunity fuels" for CHP systems. Opportunity fuels are nontraditional fuels that are frequently considered waste or by-products. When these fuels are used, fuel costs could be very low.

Infrastructure Modernization Solution

CHP systems are located close to energy consumers. Transmission and bulk power transformer losses associated with the delivery of electricity from remote power generation, which average 6-8 percent and can exceed 10 percent at peak, are avoided. CHP can further benefit the electrical system by reducing demand on the generation and transmission systems of the grid. This demand reduction can cut congestion on the electric supply system, freeing transmission and distribution capacity to serve other consumers and improving grid reliability by mitigating overloads.

Business Continuity and Disaster Response

In the distributed energy paradigm that includes CHP, local energy resources are strategically sited near demand. This approach can assist both suppliers and end users. For end users, CHP can mitigate the risk of periodic, prolonged, and expensive disruptions in service and power quality. There are a growing number of industries and enterprises whose fundamental business operations depend on a continuous supply of reliable, high-quality power such as data centers, hospitals, financial institutions, and key industrial processes.

CHP and distributed energy can help communities respond to natural disasters and prolonged energy emergencies. Electricity is essential for many of the vital services performed by hospitals and public health facilities. Life-saving equipment, lighting, space conditioning, cold storage systems, emergency communications, and potable water depend on reliable electric power. CHP and distributed energy have proven to be extremely valuable in the continuity of critical health services during prolonged power outages and natural disasters. Additionally, if coordinated with the electric utility, CHP can have a role in the safe restoration of the power grid by balancing demands with available supply.

Utility and Grid Benefits

The electric power system is extremely complex and must be kept in balance at all times. Disturbances at any point are immediately felt to some extent by every other point. Moreover, the electric power grid is inextricably linked to the country's other critical infrastructure (e.g., telecommunications, natural gas, and water). Distributed energy technologies, such as CHP, offer a more secure, modernized, reliable, and robust electricity system than the Nation's current centralized grid paradigm. Using the best features of both approaches can be mutually beneficial.

The grid is severely congested and constrained in many areas of the US during peak power use. The shift from a manufacturing to a service economy, population migration toward urban centers and southern locales, the tremendous increase in high-tech or "digital" facilities with high electric load concentrations, and new homes' increase in size and electric loads have added significant peak demand and stress to the power grid.

Missouri Ethanol, LLC

Missouri Ethanol, LLC in Laddonia, Missouri is a 45 million gallon per year ethanol plant that began operation in September of 2006. The plant uses approximately 5 MW of power and 100,000 lbs/hr of steam. The plant is served by a 14.4 MW gas turbine CHP system that is a joint ownership venture between the ethanol plant and the Missouri Joint Municipal Electric Utility Commission (MJMEUC), a joint action agency that supplies power and capacity services to 56 municipal utilities in Missouri.

MJMEUC, owns and is responsible for the gas turbine, while the ethanol plant owns and is responsible for the heat recovery boiler and steam system. Natural gas costs are shared between MJMEUC and Missouri Ethanol based on a number of factors including the avoided costs of steam for the ethanol plant.

Missouri Public Utility Alliance (MPUA) which is the umbrella organization for the MJMEUC., views the Laddonia project as a "win - win - win" effort, as it provides competitive power supply for MJMEUC, reduced steam costs for the ethanol plant, and additional baseload gas demand for the Missouri Municipal Gas Commission. MPUA sees joint ventures like Laddonia as a way of getting "combined cycle performance at simple cycle prices", and as a way of adding efficient, competitive natural gas capacity to their system in increments that they can digest.

The Calm in the Storm

Baptist Memorial Hospital in Jackson, MS, has a 4.3-MW, natural gas-fired CHP system that enabled the hospital to remain open during Hurricane Katrina, which hit the area August 29, 2005. It was the only hospital in the metro Jackson area to be fully operational during the crisis. It treated a high volume of patients and provided food and housing for displaced patients. In normal circumstances, the CHP system meets almost 100 percent of the electricity needs and 60 percent of the chilled water needs at Baptist Memorial. It also provides an average utility cost avoidance of $738,000 annually.

BAPTIST. MEMORIAL HEALTH CARE

If properly integrated, CHP can improve grid stability, increase capacity, and prevent power outages. This is accomplished through:

- Load reduction
- Contingency planning for grid congestion
- Voltage stability and reactive power support
- Reducing expensive T&D upgrade investment
- Deferring construction of generation and T&D equipment

CHP and distributed energy are part of an evolution toward a more decentralized, efficient, resilient, and integrated power system enabled by improvements in alternative energy and smart grid technology.

Improving the Efficiency of the Power System

CHP and distributed energy allow the grid to function more efficiently. CHP systems are among the most efficient heat and power generating systems available, in many cases approaching 80 percent efficiency, thus reducing energy costs to the consumer and emissions to the environment. Because CHP is located close to the energy consumer, transmission losses and transmission overloads associated with remote power generation are reduced, distribution feeder and substation transformer loading (and associated losses) are lowered, and the customer is less likely to experience total interruption of service. CHP, as well as end-use efficiency and demand response, can benefit the electrical system by reducing both baseload and peak demand.

Considerable energy losses, in some cases on the order of 15–20 percent, can occur during peak hours because of resistive losses on overloaded lines. Transmission bottlenecks also prevent the power system from operating and dispatching at maximum efficiency. Demand reduction can reduce congestion on the electric supply system, freeing transmission capacity and improving grid reliability by mitigating overloads and giving the transmission system reserve capacity to deal with contingencies.

CHP also increases the economic efficiency of the power system. Today, large investments in transmission and distribution (T&D) infrastructure are made where they may only serve the top few hundred hours in the year when the power generation system is peaking. CHP helps the utility extend the ability of the existing T&D system to serve growing peak loads.

Proposition: What If 20% of US Electricity Generation Came From CHP?

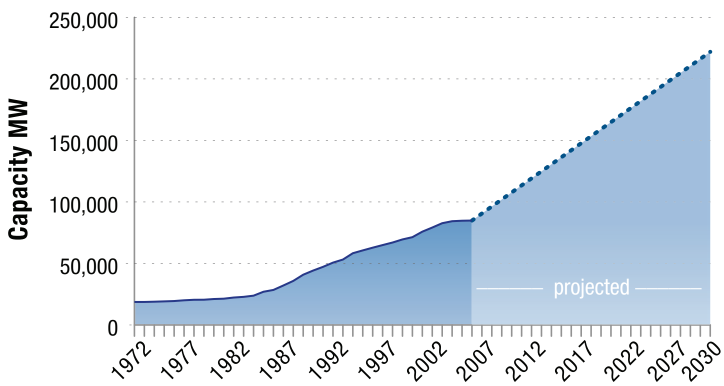
CHP currently comprises 12.6 percent of US electricity generation (i.e. MWh) and 8.6 percent of total generating capacity (i.e. MW). Achieving 20 percent generation capacity by 2030 would result in 1.16 billion MWh of generation (or 240.9 GW of capacity). Increasing CHP capacity to 20 percent, while an aggressive target, can be accomplished given the proper technical and policy circumstances.

2030 CHP – Proposition: 20% of U.S. Capacity	**240,900** MW
Reduced Annual Energy Consumption with CHP	**5.3** Quads
Total Annual CO_2 Reduction	**848** MMT
Total Annual Carbon Reduction	**231** MMT
Number of Car Equivalents Taken Off Road	**154** million

Meeting 20 percent of U.S. electricity needs with CHP by 2030 would result in:

- 848 million metric tons of avoided CO_2 emissions
- $234 billion of investment in CHP technologies
- 936,000 jobs created

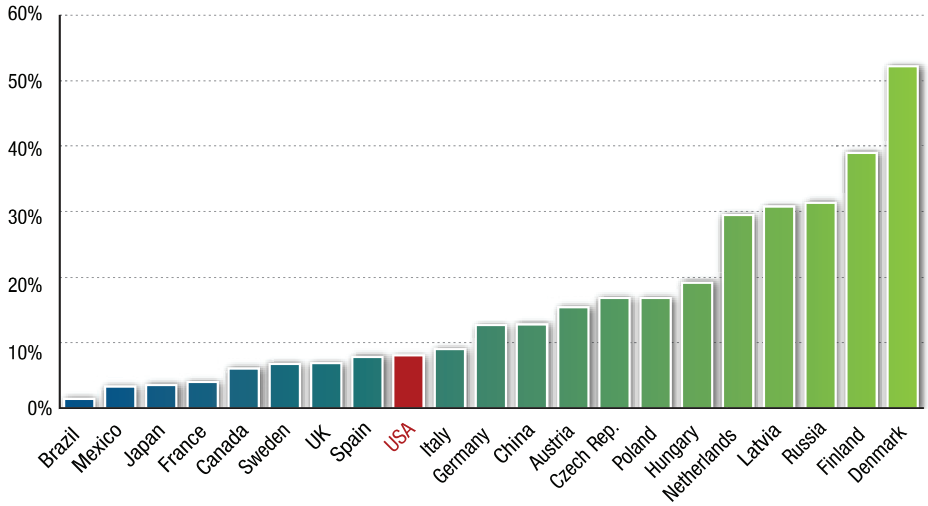
Historical CHP Capacity and Growth Needed to Achieve 20% of Generation



Several European countries have achieved more than 20 percent of total electricity generation capacity from CHP. A few of the reasons these countries have reached this level of CHP generation capacity range from climate conditions and favorable energy policies to building density and widespread use of district energy. The US does not have the same climate and building densities as some of these countries, but it does have a large and untapped industrial, commercial, and institutional potential, making it an ideal candidate to further capitalize on the benefits of CHP.

Long-term tax credits and fair and transparent interconnection practices have allowed a number of countries to achieve high levels of CHP generation.

CHP Share of Total National Power Production



Source: IEA 2008

What Is Limiting CHP Adoption in the US?

Although much progress has been made in the last decade to remove technical and regulatory barriers to wider adoption of CHP, several major hurdles remain.

Regulated Fees and Tariffs

Electric rate structures can have significant impact on CHP economics. Many current US rate structures that link utility revenues and returns to the number of kilowatt-hours sold are a disincentive for utilities to encourage customer-owned CHP and other forms of onsite generation. Furthermore, many of the system and societal benefits that CHP provides are not accounted for under current ratemaking processes. Rate structures that recover the majority of the cost of service in non-bypassable fixed charges and/or ratcheted demand charges reduce the money-saving potential of CHP.

Facilities with CHP systems usually require standby/backup service from the utility to provide power when the system is down due to routine maintenance or unplanned outages. Electric utilities often petition the regulators for the ability to assess specific standby charges to cover the additional costs they incur as they continue to provide generating, transmission, or distribution capacity (depending on the structure of the utility) to supply backup power when requested, sometimes on short notice. The structure and makeup of these charges is often a point of contention between the utility and the consumer, and without proper consideration of all benefits and costs can create unintended and burdensome barriers to CHP.[27]

Some utilities have programs that recognize the value to the utility and the ratepayer of avoided costs associated with building capacity and infrastructure. Compensation for those benefits occurs when the CHP operator enters a contract with the utility.

[27] EPA, Combined Heat and Power Partnership, http//www.epa.gov/chp/state-policy/utility.html.

Interconnection Issues

Economic viability of CHP for many customers requires integration with the utility grid for backup and supplemental power needs, and, in some cases, selling excess power. To be successful in the market, CHP systems must be able to safely, reliably, and economically interconnect with the existing utility grid system. The lack of uniformity in application processes and fees as well as the enforcement of current interconnection standards makes it difficult for equipment manufacturers to design and produce modular packages, and reduces economic incentives for onsite generation. Just as site-specific conditions drive CHP configurations, site- and regional-specific conditions should be considered when developing interconnection requirements.

CHP diversifies our generation portfolio, lessens stress on our transmission and distribution system, and enhances energy reliability and security.

In 2003, the Institute of Electrical and Electronics Engineers (IEEE) approved the IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems. The standard, which was reaffirmed in 2008, details the technical and functional requirements relevant to the performance, operation, testing, safety, and maintenance of the interconnection of distributed resources. These standards will continue to evolve as the distributed generation market develops. The Energy Policy Act of 2005 calls for state commissions to consider certain standards for electric utilities based on IEEE 1547, but does not require them to adopt the standard. Adoption of technical interconnection standards, including their application within interconnection agreements, varies by state, limiting CHP's deployment.

Environmental Permitting

Higher efficiency generally means lower fuel consumption and lower emissions of all pollutants. Nevertheless, most US environmental regulations have historically established emission limits based on heat input (lb/MMBtu) or exhaust concentration (parts per million [ppm]). These input-based limits do not recognize or encourage the higher efficiency offered by CHP, nor do they account for the pollution prevention benefits of efficiency in ways that encourage application of more efficient generation approaches. Thirty-one states currently regulate emissions on an input basis.

CHP generates both electricity and thermal energy onsite, it may potentially increase onsite emissions even while it reduces the total (onsite and offsite) emissions. Because current environmental permitting regulations do not recognize total regional emissions benefits, they can be a barrier to CHP development.

The Clean Air Act's New Source Review (NSR) is another permitting barrier to installation of CHP systems. NSR requires large, stationary sources of air pollutants to install state-of-the-art pollution control equipment at the time of construction or whenever major modifications are made that can increase net emissions. CHP systems increase the emissions of a facility but significantly reduce total gross emissions because of their high efficiencies. Because of this dichotomy, NSR requirements, especially in nonattainment areas (regions that do not meet ambient air quality requirements), effectively make CHP systems too burdensome to install in some cases.

Tax Treatment

Tax policies can significantly affect the economics of investing in new onsite power generation equipment such as CHP. CHP systems do not fall into a specific tax depreciation category, and their depreciation periods can range from 5 to 39 years. These disparate depreciation policies may discourage CHP project ownership arrangements, increasing the difficulty of raising capital and discouraging development.

Technical Barriers

Investment in CHP is fundamentally a business decision. Technology barriers have impeded full market deployment. These include system and component capital costs, emissions control, fuel costs and flexibility, and risk. There are CHP system limitations with regard to reliability, availability, maintainability, and durability that at times can adversely affect life-cycle costs. Improper installation or lack of coordination between developers and utilities in the planning and installation process of CHP systems can result in technical complications related to grid operations. Continued technology development is needed.

Technical R&D Needs for Advancement

Several technology barriers must be addressed to improve and integrate CHP projects with an energy portfolio for the 21st century. Key parameters that affect economic viability are operating costs (driven by efficiency and fuel price) and capital costs.

Strategic technology development is needed. Improving the energy and environmental performance of CHP and thermal energy recovery technologies (gas turbines, microturbines, engines, fuel cells, desiccants, chillers, and heat recovery systems) will significantly lower capital costs. Increasing fuel flexibility of combustion systems with no degradation of emissions profile, performance, or reliability, availability, maintainability and durability will reduce operating costs and fuel risk. Utilizing waste energy streams to produce useful energy forms with minimal incremental fuel input will improve efficiency. There is also a need for technology demonstrations, technical assistance in implementation, and reporting of lessons learned and best practices.

Natural gas has been the fuel of choice for CHP. Natural gas prices have increased substantially and been highly volatile. This has contributed to the recent slow adoption of CHP systems. Technological approaches to address this include improving the fuel efficiency and introducing the capability to switch to alternative fuels, i.e., fuel flexibility. Alternative fuels include renewable resources, such as biogas, or wasted/vented thermal energy. Utilizing alternative fuels requires modifications to a CHP system's prime mover (i.e. turbine, reciprocating engine, fuel cell, etc.) to use the fuel within acceptable levels of performance, emissions, durability, and ease of maintenance. It also requires investment in fuel gathering, handling, treatment, and storage equipment, which often adds a parasitic load to the system. All of these elements affect the life-cycle cost/benefit analysis.

Modular reductions in CHP systems can be made with better integration of major subsystems into packages. This is particularly valuable in the small- to mid-size CHP market. In those high-potential markets, system designs that incorporate intelligent controls, sensors, and facility energy management systems with generation and heat recovery technology would offer compelling value.

Policies Proven to Support and Promote CHP

Given adequate motivation and political drive, energy-efficient technologies are able to deliver fast and cost-effective results. For example, during its 2000–2001 electricity crisis, California undertook a massive demand-side energy efficiency campaign. In less than 1 year, peak electricity demand was reduced by more than 10 percent, with overall demand down by 6.7 percent.[28] The state avoided the need for rolling blackouts the next summer.

Interconnection Standards

Interconnection is the ability of a nonutility generator to operate while connected to the electric transmission/distribution system. Under some service agreements—power purchase or net metering contracts—the non-utility generator is contracted to sell or send excess electricity back onto the grid. Currently, each utility and service territory establishes its own interconnection rules. The lack of uniform standards for interconnection procedures is due, in part, to the fact that jurisdiction over interconnection is split between the Federal Energy Regulatory Commission (FERC) and the states' utility regulator body. In 2006, FERC adopted Small Generation (<= 20 MW) and Large Generation (>20 MW) Interconnection Procedures for facilities within its jurisdiction.[29] Model interconnection procedures have been developed by the National Association of Regulatory Utility Commissioners (NARUC)[30] and others such as Interstate Renewable Energy Council (IREC).[31] Technical requirements of IEEE 1547 are adopted by reference in many interconnection model rules. The technical standards and procedures were developed to ensure that electricity grids maintain their safety and reliability when nonutility generators are connected. As operating experiences with CHP increase and best practices are developed, the standards have evolved and their application has become more uniform. State officials and local utility personnel must also be kept apprised and educated of changes in standards and procedures.

Investment Tax Credits

Investment tax credits (ITCs) promote adoption of technologies by essentially lowering the initial financial risk involved in development of a capital-intensive project such as a CHP system. There are several effective state ITC programs for CHP, such as the Hawaii High Technology Business Investment Tax Credit. A 10 percent ITC for CHP has recently been enacted at the Federal level under the Energy Improvement and Extension Act of 2008 (H.R. 1424).

Production tax credits (PTCs) are a performance-based credit based on generation output. They promote adoption and sustained performance of generation technologies by allowing qualified systems to receive a per KWh tax credit for electricity generated.

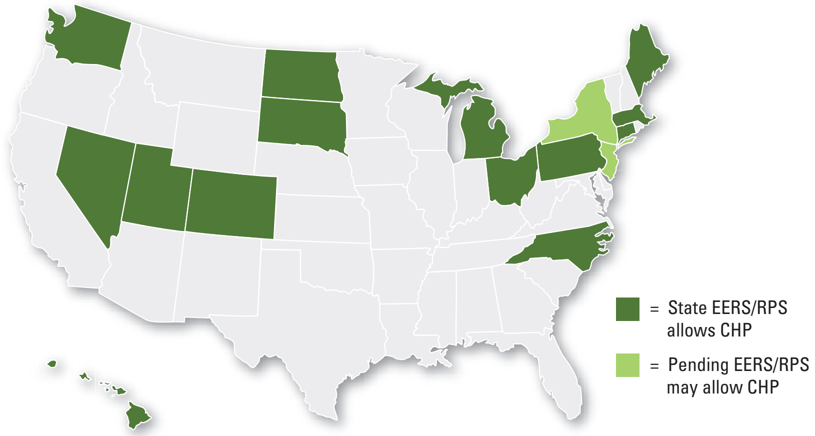
[28] Kushler, et al. 2003. *Examining California's Energy Efficiency Policy Response to the 2000/2001 Electricity Crisis: Practical Lessons Learned Regarding Policies, Administration, and Implementation.* ACEEE.

[29] 18 CFR Part 35, Docket No. RM02-12-000; Order No. 2006.

[30] National Association of Regulatory Utility Commissioners. 2003. *Model Interconnection Procedures and Agreement for Small Distributed Generation Resources.*

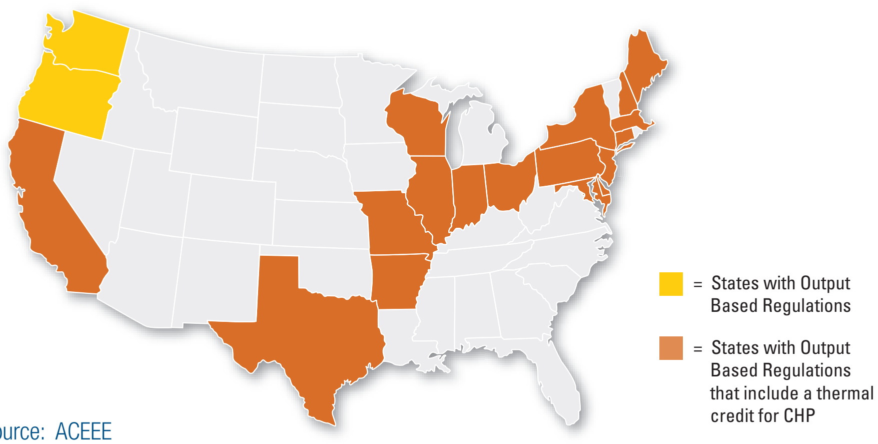
[31] Interstate Renewable Energy Council. 2005. *IREC Model Interconnection Standards and Procedures for Small Generator Facilities.*

States with Portfolio Standards That Include CHP (as of April 2008)



North Dakota and Nevada include waste heat CHP only. Source: EPA

Output-Based Emissions Standards



Source: ACEEE

Renewable Portfolio Standards

More states are adopting energy efficiency resource standards (EERS) or renewable portfolio standards (RPS) to ensure that cost-effective energy efficiency measures and renewable energy sources help offset growing electricity demand. EERS/RPS require that energy providers meet a specific portion of their electricity demand through energy efficiency or renewable energy. Fourteen states have portfolio standards that include CHP and two states have pending standards that may allow CHP to count in their programs. CHP should be universally recognized as an energy efficiency technology, and standard methods agreed upon to compute the energy efficiency contribution of CHP for RPS purposes.

Proper Emissions Treatment of CHP (Output-Based Standards)

Output-based regulations relate air emissions to the productive output of a process and encourage use of fuel conversion efficiency as an air pollution control or prevention measure. Output-based regulations that include both the thermal and electric output of a CHP process can recognize the higher efficiency and environmental benefits of CHP. Several states have implemented output-based regulations with recognition of thermal output for CHP systems, especially for smaller systems. In recent years, regulators have adopted market-based regulatory structures, primarily emission cap-and-trade programs. In these programs, allocation of emission allowances is a critical component that can create an incentive for different technologies. Most cap-and-trade programs have allocated allowances based on historic emissions, which does not encourage new or efficient technologies. More recently, some states have adopted output-based allocation methodologies that include both electricity and thermal output of CHP systems. These can create a significant incentive for CHP facilities.[32]

[32] EPA. 2004. *Output-Based Regulations: A Handbook for Air Regulators.*

EU Cogeneration Directive

The European Union has developed a cogeneration directive intended to promote and develop high-efficiency CHP. The directive includes feed-in tariffs, grants and loans, tax incentives, and provisions for national CHP market potential assessments . The directive acknowledges industrial CHP and district energy systems.

The governments of some European countries have encouraged their businesses and utilities to expand capacity for clean energy generation.[33] Germany, for example, has reduced its CO_2 emissions by 18.5 percent compared to 1990, and is on track for a 40 percent reduction by 2020.[34] This type of progress comes from a combination of finding the right technological solutions and creating a policy environment that allows the solutions to be implemented.

If we could achieve 20 percent of generation capacity from CHP by 2030, we could save more than 5 quadrillion Btu of fuel annually, the equivalent of nearly half the total energy currently consumed by US households.

Feed-In Tariffs

Feed-in tariffs have been used in Europe to encourage alternative energy development and CHP. A feed-in tariff is part of an agreement between an electricity generator and a local distribution company whereby the former is paid an agreed-upon rate (generally higher than wholesale) for electricity that is fed back onto the grid. These agreements are typically put in place for 15–20 years. Any increased savings or costs to the utility are passed on to consumers. In Germany, this has resulted in a cost increase of $3 per month for the average homeowner. This type of arrangement is attractive to CHP users because it guarantees a long-term revenue stream for excess electricity produced from sizing the system to meet thermal demand, ensuring maximum performance and efficiency. A procedure for assessment of net system and potential societal benefits of CHP would be valuable to make sure feed-in tariffs in the US are designed to be equitable for non-participants (i.e., other rate payers besides the CHP users).

Greenhouse Gas Policy Mechanisms

One market-based approach to limiting greenhouse gas (GHG) emissions is called a cap-and-trade system. This system sets a limit on GHG emissions such as CO_2 for a region or a country as a whole. Tradable permits are issued to designated sources, and the total number of permits is equal to the emissions cap. It will be important that CHP is recognized as a valuable GHG reduction option in any GHG trading system that might be implemented in the US. The main challenge facing CHP is that, with CHP, on-site emissions may increase even though overall regional emissions decrease. Care must be taken by trading system designers to ensure that CHP's regional GHG benefits can be captured in the program's allowance structure and eligibility requirements. Another approach for valuing carbon emissions is carbon taxes. This has been implemented on a limited basis in several Scandinavian countries and the Netherlands.[35] Again, any system involving carbon taxes needs to acknowledge the benefits of CHP in reducing overall GHG emissions even though on-site emissions may increase.

[33] Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC.

[34] Barber, Lois. May/June 2008. Feed-In Tariffs. EnergyBiz.

[35] Bryner, Gary. 2007. The Idea of a Carbon Tax. Utah Climate Policy Symposium. *"Feed-In Tariffs."* EnergyBiz.

Conclusions

Experience in the United States and other countries shows that a balanced set of polices, incentives, and investments can stimulate sustained CHP growth and reap its many well-documented benefits.

CHP should be one of the first technologies deployed for near-term carbon reductions. The cost-effectiveness and near-term viability of widespread CHP deployment place the technology at the forefront of practical alternative energy solutions such as wind, solar, clean coal, biofuels, and nuclear power. Clear synergies exist between CHP and most other technologies that dominate the energy and environmental policy dialogue in the country today. As the Nation transforms how it produces, transports, and uses the many forms of energy, it must seize the clear opportunity afforded by CHP in terms of climate change, economic competitiveness, energy security, and infrastructure modernization.

The energy efficiency benefits of CHP offer significant, realistic solutions to near- and long- term energy issues facing the Nation. With growing demand for energy, tight supply options, and increasing environmental constraints, extracting the maximum output from primary fuel sources through efficiency is critical to sustained economic development and environmental stewardship. Investment in CHP would stimulate the creation of new "green-collar" jobs, modernize aging energy infrastructure, and protect and enhance the competitiveness of US manufacturing industries.

The complementary roles of energy efficiency, renewable energy, and responsible use of traditional energy supplies must be recognized. CHP's proven performance and potential for wider use are evidence of its near-term applicability and, with technological improvements and further elimination of market barriers, of its longer term promise to address the country's most important energy and environmental needs.

A strategic approach is needed to encourage CHP where it can be applied today and address the regulatory and technical challenges preventing its long-term viability. Experience in the United States and other countries shows that a balanced set of policies, incentives, business models, and investments can stimulate sustained CHP growth and allow all stakeholders to reap its many well-documented benefits.

APPENDIX: CHP Fundamentals

The United States currently has 85 gigawatts (GW) of CHP electric generating capacity installed, representing almost 9 percent of total generating capacity. This installed base of CHP generates about 505 million megawatt-hours (MWh) of electricity annually, or more than 12 percent of total electricity generated in the United States.

The size of CHP systems can range from 5 kW (the demand of a single-family home) to several hundred MW (the demand of a large petroleum-refining complex). For CHP systems to operate efficiently, a continuous thermal demand is required. This demand can be for laundry or pool-water heating in a hotel, space heating or cooling in a commercial office building, or material drying at a gypsum board factory. The type of thermal demand is unimportant, but must be present close to 24 hours a day for CHP systems to achieve the high efficiencies they are capable of.

CHP can be utilized in a variety of applications. Eighty-eight percent of US CHP capacity is found in industrial applications, providing power and steam to large industries such as chemicals, paper, refining, food processing, and metals manufacturing. CHP in commercial and institutional applications is currently 12 percent of existing capacity, providing power, heating, and cooling to hospitals, schools, campuses, nursing homes, hotels, and office and apartment complexes.

GLOSSARY

Btu..... British thermal units

Quads.. Quadrillion Btu = 1×10^{15} Btu

kW..... Kilowatt = 1,000 Watts

GW..... Gigawatt = 1×10^{9} Watts

MW.... Megawatt = 1×10^{6} Watts

MMT... Million metric tons

GHG.... Greenhouse gas

CO_2 .... Carbon dioxide

SO_2 .... Sulfur dioxide

NO_x .... Nitrogen oxides

Capacity Power (power = energy/time), as measured in Watts (or MW, GW, etc.)

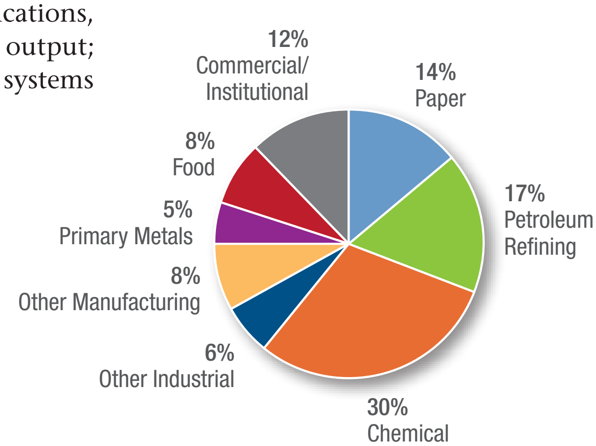
Generation Energy, as measured in Btu or Watt-hours (Wh) (or kWh, MWh, etc.)

What Does a CHP System Produce?

CHP is unique among electricity-producing technologies and methods because it generates more than one output. For most industrial applications, the thermal energy produced by the systems is the most valued output; electricity is considered a secondary, yet beneficial, by-product. CHP systems can provide the following products:

- Electricity
- Direct mechanical drive
- Steam or hot water
- Process heating
- Cooling and refrigeration
- Dehumidification

Existing CHP Capacity by Application



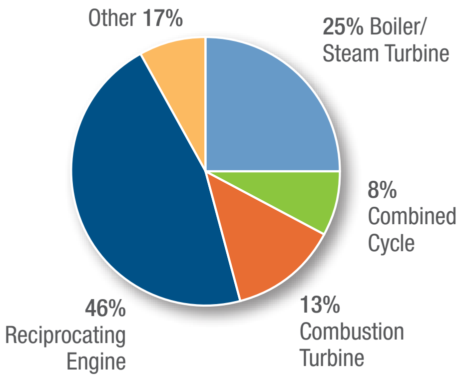
Source: EEA, Inc. CHP Installation Database.

CHP Systems

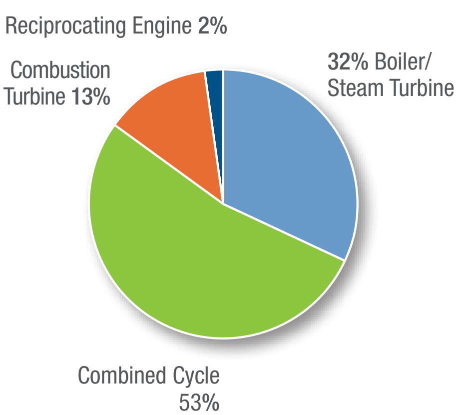
CHP systems are complex, integrated systems that consist of various components ranging from prime mover (heat engine), generator, and heat recovery, to electrical interconnection. CHP systems typically are identified by their prime movers or technology types, which include reciprocating engines, combustion or gas turbines, steam turbines, microturbines, and

Existing CHP Capacity

Sites by System Type



Capacity by System Type



Source: EEA, Inc. CHP Installation Database.

fuel cells. These prime movers are capable of consuming a variety of fuels, including natural gas, coal, oil, and alternative fuels, to produce shaft power or mechanical energy. Although mechanical energy from the prime mover is most often used to drive a generator to produce electricity, it can also be used to drive rotating equipment such as compressors, pumps, and fans. Thermal energy from the system can be used in direct process applications or indirectly to produce steam, hot water, hot air for drying, refrigeration, or chilled water for process cooling.

Reciprocating engines are by far the most numerous, but still not a majority, of the CHP prime movers. They are particularly well suited to small and medium applications, as they are cost-effective, readily available, fuel-flexible, and can achieve very high overall efficiencies. By capacity, combined cycle plants comprise just over half the CHP market. These plants typically are very large and serve industrial and utility customers

Steam Turbines

Steam turbines generate electricity from the heat (steam) produced in a boiler, converting steam energy into shaft power. Steam turbines are one of the most versatile and oldest prime mover technologies used to drive a generator or mechanical machinery. The energy produced in the boiler is transferred to the turbine through high-pressure steam that in turn powers the turbine and generator. This separation of functions enables steam turbines to operate with a variety of fuels, including natural gas, solid waste, coal, wood, wood waste, and agricultural by-products. The capacity of commercially available steam turbines ranges from 50 kW to more than 250 MW. Ideal applications of steam turbine-based CHP systems include medium- and large-scale industrial or institutional facilities with high thermal loads, and where solid or waste fuels are readily available for boiler use.

Reciprocating Engines

Reciprocating internal combustion engines are the most widespread technology for power generation, commonly for small, portable generators to large industrial engines that power generators of several megawatts. Spark ignition engines for power generation generally use natural gas, though they can be set up to run on propane or landfill and biogas, and are available in sizes up to 5 MW. Reciprocating engines start quickly, follow load well, have good part-load efficiencies, and generally are highly reliable. In many instances, multiple reciprocating engine units can enhance plant capacity and availability. Reciprocating engines are well suited for applications that require hot water or low-pressure steam.

Gas Turbines

Combustion or gas turbines are an established power generation technology available in sizes from several hundred kW to more than 100 MW. Gas turbines produce high-quality heat that can be used to generate steam for onsite use or for additional power generation (combined cycle). Gas turbines can be set up to burn natural gas, a variety of petroleum fuels, landfill or biogas, or can have dual-fuel capability. Gas turbines are well suited for CHP because their high-temperature exhaust can be used to generate process steam at conditions as high as 1,200 pounds per square inch gauge (psig) and 900 degrees Fahrenheit (°F). Much of the current US gas turbine-based CHP capacity consists of large combined-cycle CHP systems that maximize power production for sale to the grid while supplying steam to large industrial or commercial users. Simple-cycle CHP applications are common in smaller installations, typically less than 40 MW.

Microturbines

Microturbines are very small combustion turbines with outputs of 30 kW to 300 kW. Microturbine technology has evolved from the technology used in automotive and truck turbochargers and auxiliary power units for airplanes and tanks. Microturbines are compact and lightweight, with few moving parts. Many designs are air-cooled and some even use air bearings, thereby eliminating the cooling water and lube oil systems. In CHP operation, a heat exchanger transfers thermal energy from the hot exhaust to a hot water or low-pressure steam system. Exhaust heat can be used for a number of different applications, including potable water heating, absorption chillers and desiccant dehumidification equipment, space heating, process heating, and other building uses.

Fuel Cells

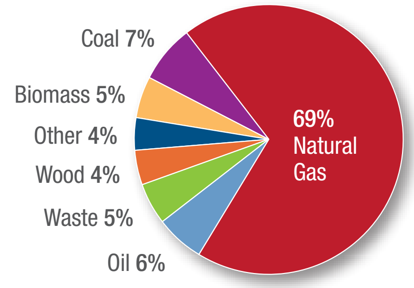
Fuel cells use an electrochemical or battery-like process to convert the chemical energy of hydrogen into water and electricity. In CHP applications, heat is generally recovered in the form of hot water or low-pressure steam (<30 psig), and the quality of heat depends on the type of fuel cell and its operating temperature. Fuel cells use hydrogen, which can be obtained from natural gas, coal gas, methanol, and other hydrocarbon fuels. Fuel cells promise higher efficiency than generation technologies based on heat engine prime movers. In addition, fuel cells are inherently quiet and extremely clean running. Like microturbines, fuel cells require power electronics to convert the direct current to 60-Hertz alternating current. Many fuel cell technologies are modular and capable of application in small commercial markets; other technology utilizes high temperatures in larger systems suited to industrial CHP applications.

What Fuels Does CHP Use?

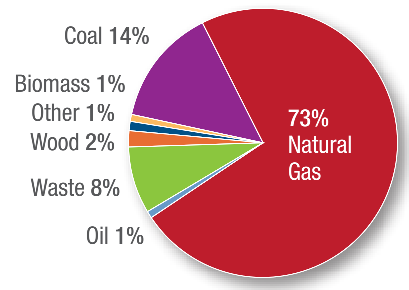
CHP is not a fuel-specific technology. Even with price volatility in natural gas markets in recent years, natural gas is still the predominant fuel for CHP systems. While natural gas will continue to be an important fuel, the ability of CHP systems to operate on diverse fuels—including coal, oil, biomass, wood, and waste fuels such as landfill and digester gas—makes them key to developing a balanced and sustainable energy portfolio.

Existing CHP Capacity

Sites by Fuel Type



Capacity by Fuel Type



Source: EEA, Inc. CHP Installation Database.

Policies and initiatives such as PURPA and the National CHP Challenge spurred significant market growth.

History of CHP Development in the US

Decentralized CHP systems located at industrial sites and urban centers were the foundation of the early electric power industry in the United States. However, as power generation technologies advanced, the power industry began to build larger central station facilities to take advantage of increasing economies of scale. CHP became a limited practice among a handful of industries (paper, chemicals, refining, and steel) that had high and relatively constant steam and electric demands and access to low-cost fuels.

By the 1960s, the US electricity market was dominated by mature, regulated electric utilities using large, power-only central station generating plants. As a result of this competitive position, utilities had little incentive to encourage customer-sited generation, including CHP. Regulatory barriers at the state and federal levels further discouraged broad CHP development.

Public Utilities Regulatory Policies Act

Partly in response to the oil crisis of the early 1970s, Congress in 1978 passed the Public Utilities Regulatory Policies Act (PURPA) to promote energy efficiency. PURPA encouraged energy-efficient CHP and power production from renewables by requiring electric utilities to interconnect with "qualified facilities" (QFs). CHP facilities had to meet minimum fuel-specific efficiency standards to become a QF.[36] PURPA required utilities to provide QFs with reasonable standby and backup charges, and to purchase excess electricity from them at the utilities' avoided costs.[37] PURPA also exempted QFs from regulatory oversight under the Public Utilities Holding Company Act and from constraints on natural gas use imposed by the Fuel Use Act. Shortly after enacting PURPA, Congress passed a series of tax incentives for energy efficiency technologies, including CHP. The incentives included a limited term investment tax credit of 10 percent and a shortened depreciation schedule for CHP systems. PURPA and the tax incentives successfully expanded CHP—installed capacity increased from about 12,000 MW in 1980 to more than 66,000 MW in 2000.[38]

Post-PURPA

While PURPA promoted CHP development, it also had unforeseen consequences. PURPA was enacted at the same time that larger, more efficient, lower cost combustion turbines and combined cycle systems became widely available. These technologies were capable of producing more power in proportion to useful thermal output compared to traditional boiler/steam turbine CHP systems. Therefore, the power purchase provisions of PURPA, combined with the availability of these new technologies, resulted in the development of very large merchant plants designed for high electricity production.

For the first time since the inception of the power industry, nonutility participation was allowed in the US power market, triggering emergence of third-party CHP developers who had more interest in electric markets than thermal markets. As a result, development of large CHP facilities (greater than 100 MW) paired with industrial facilities increased dramatically; today almost 65 percent of existing US CHP capacity, 55,000 MW, is concentrated in plants more than 100 MW in size.[39]

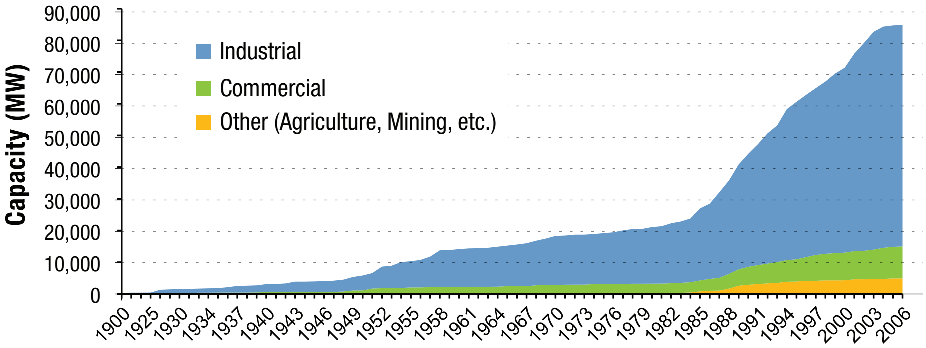
[36] Efficiency hurdles were higher for natural gas CHP.

[37] Avoided cost is the cost an electric utility would otherwise incur to generate power if it did not purchase electricity from another source.

[38] CHP Installation Database developed by Energy and Environmental Analysis, Inc. for Oak Ridge National Laboratory and U.S. DOE; 2007. www.eea-inc.com/chpdata/index.html.

[39] Ibid.

CHP Cumulative Capacity Growth by Application Type in the U.S.



Source: EEA/ICF International

The environment changed again in the mid-1990s with the advent of deregulated wholesale markets for electricity. Independent power producers could now sell directly to the market without the need for QF status, and CHP development slowed. The result was more restricted access to power markets, and users began delaying purchase decisions with an expectation of low electric prices in the future as many states began to restructure their individual power industries.

By the end of the 1990s, policy makers began to explore the efficiency and emission reduction benefits of thermally based CHP. They realized that a new generation of locally deployed CHP systems could play an important role in meeting US energy needs in a less carbon-intensive manner. As a result, the Federal Government and several states began to promote deployment of CHP. CHP has been singled out for support by the US Department of Energy (DOE) and US Environmental Protection Agency (EPA), which committed to a target of increasing CHP capacity to 92 GW between 2000 and 2010.[40]

In addition to supporting research, DOE in 2001 established the first of eight regional CHP application centers to provide local technical assistance and educational support for CHP development.[41] In 2001, EPA established the CHP Partnership to encourage cost-effective CHP projects and expand CHP development in underutilized markets and applications.[42] States also began to realize that policies were needed to remove barriers to CHP development. They developed a series of policies and incentives, including streamlined grid interconnection requirements, simplified environmental permitting procedures, and rate-payer-financed incentive programs for CHP deployment.

[40] This target, known as the National CHP Roadmap, has nearly been achieved. www1.eere.energy.gov/industry/distributedenergy/df

[41] CHP Regional Application Centers www1.eere.energy.gov/industry/distributedenergy/

[42] EPA Combined Heat and Power Partnership. www.epa.gov/chp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