A Decade of Progress

COMBINED HEAT AND POWER

A Vision for the Future

U.S. DEPARTMENT OF ENERGY

The U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) invests in a diverse portfolio of energy technologies in order to achieve a stronger economy, a cleaner environment, and greater energy independence for America.

The Industrial Technologies Program (ITP), part of EERE, works in collaboration with U.S. industry to develop technologies and practices that improve industrial energy efficiency and environmental performance. ITP's work to further the reach of combined heat and power technologies supports EERE goals.

For more information, contact:
EERE Information Center
1-877-EERE-INF (1-877-337-3463)
www.eere.energy.gov/industry

Industrial Technologies Program
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585

CHP: The Time Is Now 1
Market Solutions for a Sustainable Future 2
Potential for CHP Across the United States 3
DOE's CHP Program 4
Accelerated CHP Research and Development 4
Technology Demonstrations 4
Aggressive Market Transformation Efforts 4
A Pathway to Sustainability 5
A Decade of Progress 6
Technology Research and Development 7
Advanced Reciprocating Engine Systems (ARES) 7
Advanced Industrial Gas Turbines 8
Microturbines 9
Fuel Cells 10
Thermally Activated Technologies (TATs) 11
Integrated Energy Systems (IES) 12
Transforming the Marketplace for CHP 14
Clean Energy Application Centers: Offering Real Solutions to Local Energy Problems 14
CHP Market Assessments: Building the Case for CHP 16
Helping End Users Access CHP Technologies 16
Education and Outreach 17
Eliminating Regulatory and Institutional Barriers 18
Support of Emerging CHP Markets and Opportunity Fuels 19
Promoting Critical Infrastructure Resiliency 20
Partnerships With Industry and Market Sector Networks 22
Strategies for Continued Success 24
CHP Research and Development 25
Technology Demonstrations 26
Market Transformation and Clean Energy Application Centers 27
A Vision for the Future With CHP 28

CHP: The Time is Now

As America embarks on a bold new energy strategy, CHP is poised to deliver immediate economic and climate benefits.

Combined heat and power (CHP) technology holds enormous potential to improve the nation's energy security and reduce greenhouse gas (GHG) emissions. CHP supports our move to a clean energy economy and the creation of green jobs. The Department of Energy (DOE) has long championed CHP technologies and is now prepared to harness the full power of CHP to help the nation meet its energy and climate goals.

CHP solutions provide efficient, reliable, and more affordable power for businesses and institutions. CHP is now installed at more than 3,500 commercial, industrial, and institutional facilities across the nation, improving energy efficiency, ensuring environmental quality, promoting economic growth, and fostering a more robust energy infrastructure. CHP systems today represent 85 gigawatts (GW) – or almost 9 percent – of the nation's total electricity capacity. CHP produced 506 billion kilowatt-hours (kWh) of electricity in 2006 – more than 12 percent of total power generation for that year.

Through continued research, development, and outreach, DOE and its partners could help to dramatically increase CHP's share of U.S. electricity generating capacity. Expanded use of CHP will help meet national energy, economic, and environmental goals. A recent study by Oak Ridge National Laboratory has found that significant benefits would accrue by raising the CHP share to 20 percent. To reach 20 percent, the Department of Energy commits to the following:

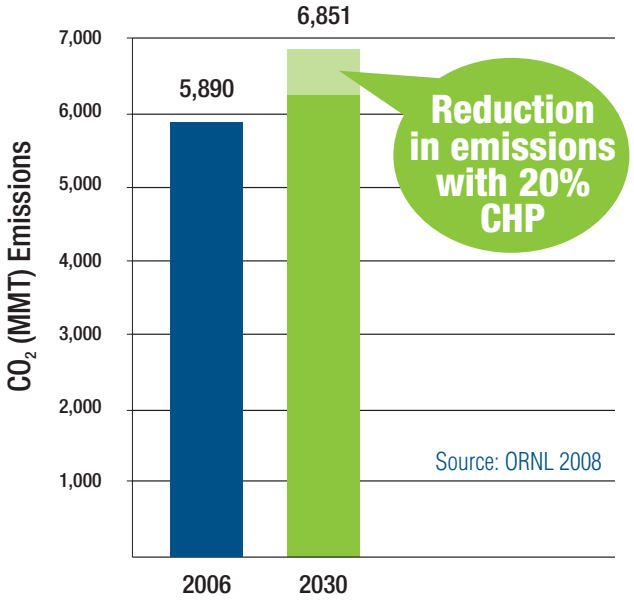
- **Develop and deploy more energy-efficient CHP** turbines, reciprocating engines, microturbines, fuel cells, heat pumps, thermally activated technologies, waste heat recovery technologies, and integrated CHP systems that are fully integrated with customer facilities and compatible with existing electric transmission and distribution systems.

- **Demonstrate CHP technologies** in collaboration with private and public organizations to emphasize long-term validation and to reduce investment risk for developers and end users.

What is CHP?

CHP is an integrated set of technologies for the simultaneous, on-site production of electricity and heat.

CHP is energy efficient, making use of heat produced during power generation and avoiding generation and transmission losses.



CHP Can Avoid 60 Percent of the Potential Growth in Carbon Dioxide Emissions Between 2006 and 2030

- **Transform the market** by promoting and publicizing the national benefits of CHP and reducing barriers to full market deployment.

This strategic approach is essential today to address the technical and market challenges inhibiting widespread adoption of CHP. A balanced set of policies, incentives, business models, and investments will stimulate sustained CHP growth and support the nation's new energy agenda.

CHP in 2030

DOE leads a national program that includes a robust portfolio of technology research and development, demonstrations, and market transformation initiatives to advance CHP as a well-recognized means to simultaneously create green jobs, reduce GHG emissions, improve energy efficiency and maximize the competitiveness of U.S. industry.

Market Solutions for a Sustainable Future

Combined heat and power systems provide effective, efficient, reliable, and less costly power to businesses across the nation. CHP has proven to:

- Significantly reduce CO_2 emissions through greater energy efficiency
- Increase production efficiency, reducing business costs
- Provide local energy solutions and green-collar jobs throughout the United States
- Relieve grid congestion and improve energy security

If the United States were to adopt high-deployment policies and achieve 20 percent of electricity generation from CHP by 2030, the nation could save an estimated 5.3 quadrillion Btu (quads) of fuel annually, the equivalent of nearly half the total energy currently consumed by U.S. households per year.[1] Through 2030, such policies could also generate $234 billion in new technology investments[2] and create nearly 1 million technical jobs throughout the United States.[3] CO_2 emissions could be reduced by more than 800 million metric tons (MMT) per year, an emissions impact similar to taking more than half of current passenger vehicles off the road.[4]

Benefits of CHP Growth

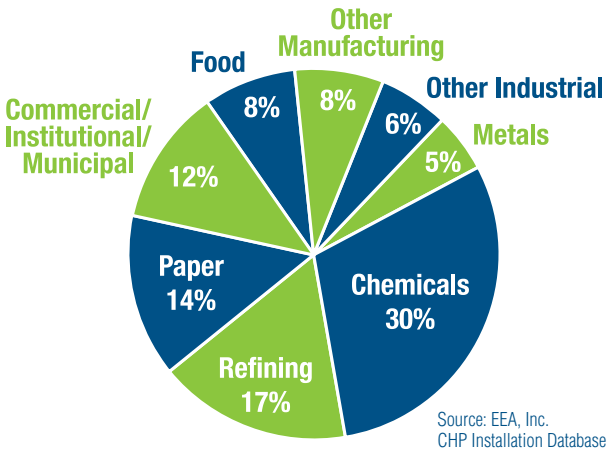
	2006	2030
CHP Capacity	85 GW	241 GW
Annual Fuel Savings	1.9 quads	5.3 quads
Total Annual CO_2 Reduction	248 MMT	848 MMT
Cars Taken off Road (Equivalent)	45 million	154 million

Source: ORNL 2008

1 Based on EIA AEO 2008 figure of 11.58 QBtu consumed in the residential sector in 2005.
2 Based on assumed cost of $1,500 per kilowatt-hour installed.
3 Based on four jobs created for every $1 million in capital investment.
4 Based on Bureau of Transportation Statistics figure of 251 million registered passenger vehicles in 2006.

CHP must be intelligently integrated into the national energy portfolio. Key industrial, commercial, and institutional markets for CHP must be targeted for development. Through research, development, and deployment of CHP components and integrated systems, these markets will grow to sustainably meet local needs and achieve national energy goals.

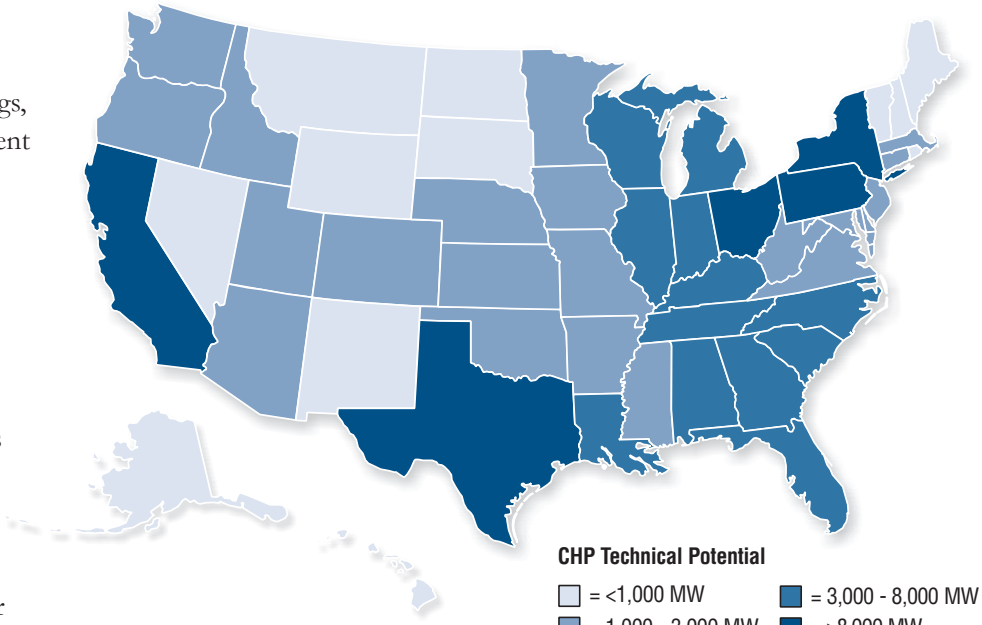
CHP Markets Today



Source: EEA, Inc.
CHP Installation Database

Potential for CHP Across the United States

- **Industrial facilities** offer major opportunities for CHP to enhance the energy efficiency of manufacturing operations, such as those used for chemical, refining, ethanol, pulp and paper, food processing, and glass manufacturing plants.
- **Institutional facilities** such as colleges and universities, hospitals, prisons, federal facilities and military bases provide cost-effective and energy-efficient CHP opportunities.
- **Commercial buildings** such as hotels, airports, high-tech campuses, large office buildings, and nursing homes, are excellent candidates for CHP.
- **District energy sites** offer major opportunities for CHP deployment.
- **Municipal** use of CHP is a growing market, including wastewater treatment facilities and K-12 schools.
- **Residential** CHP systems represent an opportunity to cost-effectively provide power and heat for multi-family housing and planned communities.



More must be done to reach the ambitious — yet attainable — goals for combined heat and power. The future is bright for CHP — but much will depend on our ability to overcome technical and institutional barriers.

DOE's CHP Program

Global energy demand, volatile energy prices, and climate change are driving a renewed national commitment to energy efficiency and renewable energy. Combined heat and power (CHP) provides a cost-effective, near-term opportunity to improve our nation's energy, environmental, and economic future. The Department of Energy is leading the national effort to generate 20 percent of U.S. electricity with CHP by 2030.

In response to a challenge by the CHP industry to achieve more than 90 GW of CHP capacity by 2010 [5], the Department established an active program of CHP research, development, and deployment. The program has aggressively led development of CHP markets and technologies, addressed regulatory and institutional barriers, and raised awareness about opportunities for CHP.

Accelerated CHP Research and Development

DOE is committed to further expanding CHP markets by working to:

- Research and develop component technology to maximize energy efficiency, optimize fuel flexibility, and minimize waste streams
- Address end-use sectors with high or growing energy use or with significant opportunities to improve energy efficiency with CHP
- Improve combustion systems that use renewable biogas/biomass fuels without sacrificing reliability, availability, maintainability, or durability (RAMD)

Technology Demonstrations

DOE is working to promote installations of innovative technologies and applications that offer the greatest potential for replication. Through private and public sector collaborative efforts, the Department is conducting full-scale demonstrations of CHP systems in high-potential, high-profile sectors, at industrial sites, colleges and universities, district energy sites, municipal facilities, and commercial and residential buildings.

Aggressive Market Transformation Efforts

DOE's Clean Energy Application Centers, formerly known as the Regional Application Centers (RACs), provide education, awareness, training, and outreach on CHP, waste heat recovery, and district energy systems. These services include on-site analyses to help businesses, facility managers, and building engineers determine the most cost-effective applications for CHP and waste heat recovery. The Centers also provide technical support to policy development efforts by DOE, state governments, and other organizations. The national labs provide program support and technical guidance to all Centers.

5 USCHPA, *National CHP Roadmap: Doubling Combined Heat and Power Capacity in the United States by 2010* (2001).

Partnerships Make It Possible

DOE partners with numerous other organizations and institutions to develop and deploy critical CHP and distributed energy resources.

- American Council for an Energy Efficient Economy (ACEEE)
- Argonne National Laboratory
- California Energy Commission (CEC)
- International District Energy Association (IDEA)
- National Energy Technology Laboratory (NETL)
- New York State Energy Research and Development Authority (NYSERDA)
- Northeast-Midwest Institute (NEMW)
- Oak Ridge National Laboratory (ORNL)
- World Alliance for Decentralized Energy (WADE)
- U.S. Clean Heat and Power Association (USCHPA)
- U.S. Department of Housing and Urban Development (HUD)
- U.S. Environmental Protection Agency (EPA)

1998
CHP Federal-State Partnership Begins

The *CHP Roadmap* set the national agenda for:

- More efficient CHP components and integrated energy systems (IES)
- Market transformation with the support of CHP Regional Application Centers (RACs)
- Key partnerships with federal and state governments, national laboratories, industry, international associations, and NGOs

46 GW Installed CHP
7% of U.S. Capacity

2009
A Strong Foundation

Today, about 3,500 CHP sites provide more than 85 GW of electricity, reducing U.S. energy use by more than 1.8% and avoiding 248 million metric tons (MMT) of CO_2 annually. DOE's CHP accomplishments include:

- Increased reciprocating engine efficiency to 44% and significantly reduced emissions
- Improved ultra-lean burn gas turbines and microturbines with 38% efficiency and reduced emissions
- Promoted and installed integrated energy systems (IES) with 70% combined system efficiency
- Co-sponsored 125 CHP training workshops and 350 CHP installations

85 GW Installed CHP
9% of U.S. Capacity

2030 AND BEYOND
A Bright Future for CHP

Providing 20% of the nation's electricity from CHP by 2030 will:

- Save an estimated 5.3 quadrillion Btu of fuel annually, nearly half of all energy now consumed by U.S. households per year
- Reduce annual CO_2 emissions by more than 800 MMT
- Cumulatively generate $234 billion in new investments and create nearly 1 million highly skilled technical jobs throughout the country

241 GW Installed CHP
20% of U.S. Capacity

A Pathway to Sustainability

Through research and development, partnerships, education, and outreach, DOE has helped to dramatically increase the CHP share of U.S. electricity generating capacity.

A Decade of Progress

Over the past 10 years, DOE has built a solid foundation for a robust CHP marketplace.

By aligning with key partners, our program has produced innovative technologies and spearheaded market-transforming projects. In addition, our commercialization activities and Clean Energy Application Centers have expanded CHP, waste heat recovery, and district energy outreach, education, and market deployment. Because of these partnership efforts, the United States now boasts more than 3,500 CHP, waste heat recovery, and district energy systems installed—actively saving energy and reducing emissions.

Historically, DOE's Combined Heat and Power Program has had four primary elements:

- **Technology research and development**
  - — Advanced reciprocating engine systems (ARES)
  - — Advanced industrial gas turbines
  - — Microturbines
  - — Fuel cells
  - — Thermally activated technologies (TATs)
- **Integrated energy systems (IES) research, development, and deployment**
- **Market transformation through project support, education, and outreach**
- **Public-private partnerships**

THE RITZ-CARLTON

The Ritz-Carlton San Francisco, the city's highest-rated hotel, planned to lower energy consumption and reduce energy expenses by installing a combined cooling, heating, and power (CCHP) package from UTC Power Company, with support from DOE. Fueled with natural gas, the 240 kW Pure Comfort microturbine system has saved the Ritz-Carlton about $120,000 per year in electricity—enough to power 200 average American households. The hotel realized a payback period of less than three years, due in part to financial incentives from the California Self-Generation Incentive Program (SGIP).

Photo courtesy of UTC

Technology Research and Development

Technology research and development (R&D) projects are the essential building blocks of DOE's CHP program. Aiming to improve efficiency, lower emissions, and facilitate market opportunities, DOE has focused on gas-fired, advanced reciprocating engine systems; industrial gas turbines; microturbines; fuel cells; and thermally activated technologies.

Advanced Reciprocating Engine Systems (ARES)

The ARES program focuses on improving reciprocating engines (piston-driven electrical power generation systems) in the 0.5–5 MW range. In collaboration with national laboratories, university research centers and private companies, DOE has improved medium-speed natural gas engines for distributed energy applications. Current research aims to increase their energy efficiency from about 36 percent to 50 percent, reduce nitrogen oxide (NOx) emissions from 1 gram per horsepower-hour to 0.1 gram, and reduce operating and maintenance costs by 10 percent. The program has made great progress in these areas, paving the way for more cost-competitive equipment.

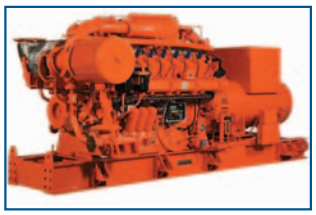
Our researchers have tested engines and produced analytical computer models to upgrade engines, pistons, piston rings, and cylinder liners and to improve ignition systems and reduce friction. They have achieved a more comprehensive understanding of ignition systems, especially at the point of ignition and the beginning of the power cycle. As a result, they have designed, developed, tested, and produced advanced reciprocating engines that approach DOE performance targets for industrial and commercial applications. A number of these engine systems have been installed at commercial sites.

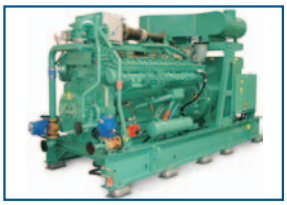
University, laboratory, and private companies throughout the United States that have participated in ARES research with DOE include:

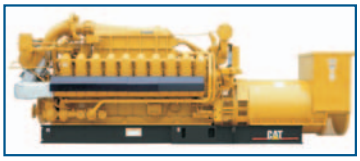
- Caterpillar
- Dresser Waukesha
- Argonne National Laboratory
- Colorado State University
- Massachusetts Institute of Technology
- Michigan Technology University
- Oak Ridge National Laboratory
- Cummins
- Ohio State University
- Purdue University
- University of Southern California
- University of Tennessee
- University of Texas
- West Virginia University

THE RIO HOTEL

The Rio Hotel in Las Vegas, Nevada, has a 4.9 MW CHP system powered by Caterpillar natural gas-fueled reciprocating engines. The system went online in May 2004. Energy cost savings have been about $1.5 million per year, providing five years payback for project owners and investors.





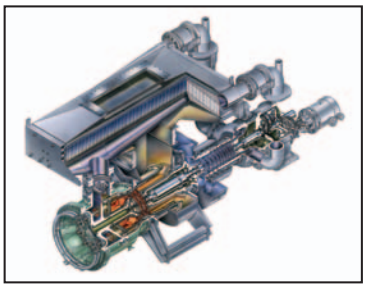


Advanced Industrial Gas Turbines

DOE aims to enhance the performance of gas turbines for applications up to 20 MW. Its research on advanced materials, particularly composite ceramics and thermal barrier coatings, is helping to achieve this objective. In addition, R&D on low-emission technologies is improving the combustion systems by reducing NOx and carbon monoxide (CO) emissions without adversely affecting turbine performance.

With DOE support, Solar Turbines has successfully developed its Mercury 50 gas turbine, targeted to meet the rapidly growing demand for highly efficient, environmentally superior turbine-based power systems. The Mercury 50 turbine uses an ultra-lean pre-mix combustor design to reduce NOx to 5 parts per million by volume (ppmv).

Cutaway Illustration of Mercury 50 Recuperated Gas Turbine, Courtesy of Solar Turbines



PCI Catalytic Pilot Burners, Courtesy of Precision Combustion, Inc.

The following companies and laboratories are among those that have participated in DOE projects:

Alzeta Corporation
Developed a novel, stabilized combustion technology for industrial gas turbines

Catalytica Combustion Systems Inc.
Extended the longevity of the catalyst for use with turbines and lowered the cost of emissions prevention

General Electric
Led a team of researchers to develop and test advanced industrial gas turbine components made from ceramic matrix composites for shrouds and combustor liners

Honeywell Engines and Systems
Developed an innovative, fuel-flexible, air-staged, catalytic gas turbine combustion system with closed-loop control

Precision Combustion Inc.
Developed a novel catalytic pilot burner and combustor for ultra-low NOx industrial gas turbines

Solar Turbines Incorporated
Developed a fully integrated combustion system with advanced materials for the Mercury 50 gas turbine combustion system

Oak Ridge National Laboratory (ORNL)
Developed enabling materials technologies, such as advanced ceramics and environmental barrier coatings, to increase temperatures, reduce emissions, and protect components from the combustion environment

Lawrence Berkeley National Laboratory (LBNL)
Developed fuel-flexible, low-swirl injectors (LSI) for industrial turbines and microturbines to reduce operating and maintenance costs and emissions, and improve reliability and performance

The Veterans Administration Medical Center in San Diego, California, recently replaced two Saturn 1210 kWe turbines with a Mercury 50 recuperated gas turbine, enabling the hospital to generate $4.2 million in emissions offset credits.

Veterans Administration Medical Center, San Diego, Photo Courtesy of Solar Turbines

Microturbines

DOE's support of microturbine R&D has aided the development of a 40 percent efficient and low-emission turbine system. These systems offer the industrial sector new choices and innovative power solutions. Key accomplishments in the last decade include:

- Development of advanced microturbine technology by five private companies: Capstone, General Electric, Ingersoll Rand, Solar Turbines Incorporated, and UTC
- Materials research focused on ceramics and metallic alloys, conducted by Oak Ridge National Laboratory
- Testing and validation by the University of California-Irvine and Southern California Edison
- Simulation of microturbines installed in rural applications, in consultation with the National Rural Electric Cooperative Association (NRECA)
- Demonstration of more efficient microturbine technology at a number of commercial, industrial, and institutional locations throughout the United States.

Courtesy of Capstone Turbine Corporation

Courtesy of UTC

DOE's microturbine demonstration projects have provided measurable benefits.

Faith Plating in Los Angeles, California, is one of the largest platers of remanufactured bumpers in the world. Since 1918, Faith Plating has plated automobile and motorcycle parts for many manufacturers. To better manage energy costs and ensure a reliable supply of electricity and hot water, Faith Plating installed a CHP system in 2001.

The system of four Capstone Model C30 microturbines and Unifin gas-to-hot-water heat exchanger saves the company between 63 and 280 million Btu each month. This equates to roughly $55,000 of savings each year, providing a payback period of about four years. In addition to the energy savings, the system avoids more than 300,000 pounds of CO_2 each year.

Fuel Cells

DOE has collaborated on fuel cell CHP development with "premium power" end users, such as data centers, computer chip manufacturers, chemical plants, and credit card processors. The Verizon Data Center project illustrates successful product-to-market achievement.

The 292,000-square-foot **Verizon Telecommunications Switching Center** in Garden City, New York, makes use of multiple CHP sources to provide 16 million Btu of useful thermal energy and 38,000 Btu of electricity. The system provides greater than 50 percent efficiency and avoids 11.1 million pounds of CO_2 emissions each year. The combination of a dual-fuel reciprocating engine and seven base-loaded fuel cells serves most of the facility's 2.7 MW requirement. The system allows optimal functioning at all times or goes into island mode, minimizing reliance on utility-provided power.

This CHP system provides
99.999% power reliability—
a critical requirement for data centers.

Thermally Activated Technologies (TATs)

Over the past two decades, DOE has worked with industry to develop on-site, thermally activated energy conversion technologies, often classified as TATs. These encompass a diverse portfolio of equipment types that transform thermal energy into useful heating, cooling, humidity control, thermal storage, and shaft/electrical power. TAT systems enable customers to directly reduce peak electricity demand and simultaneously provide load leveling of both gas and electricity. TATs are essential to CHP-integrated systems—they maximize energy savings and economic return. No other heating, cooling, and humidity control technologies have as great a potential for addressing U.S. electric utility peak demand critical issues as do TATs.

Key TAT program areas include:

- Absorption chiller, chiller/heater, and heat pump technologies
- Solid and liquid desiccant ventilation air quality (VAQ) technologies, including:
  - — Thermal energy recovery and recycling technologies with enhanced heat and mass exchangers
  - — Thermal storage and thermal management technologies
  - — Advanced heat-driven power cycles (such as Organic Rankine Cycles and Stirling Engines)
  - — Two R&D 100 award winning products (SEMCO Revolution and Trane CDQ)
- Gas engine-driven rooftop heat pump technologies

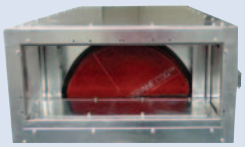
Gas Engine Heat Pump in Lab Testing, Courtesy of ORNL

Gas Engine Heat Pump in Operation, Courtesy of Southwest Gas

SEMCO Revolution Air Conditioner — 2005 R&D 100 Award Winner

Developed with DOE funding and technical contributions by ORNL's Engineering Science and Technology Division, the SEMCO Revolution air conditioner is a rooftop unit that can independently control humidity and temperature while delivering outdoor air into commercial and institutional buildings. The Revolution is more compact, cost effective, and energy efficient than conventional air-conditioning hardware packages. The Revolution's flexibility allows building operators to easily comply with building ventilation codes, maintain proper indoor humidity levels, and better control mold and mildew.

Trane CDQ — 2006 R&D 100 Award Winner



The Trane CDQ is an airconditioning-dehumidification device that controls the temperature and humidity of building interior spaces. With DOE funding and technical support provided by ORNL's Engineering Science and Technology Division, Trane and ORNL designed the Trane CDQ to control ambient air to 45-60 percent relative humidity, which is important for libraries, schools, offices, and most importantly, hospitals. Unlike other air conditioning and dehumidifying units, the Trane CDQ effectively controls humidity without adding heat to the space conditioning system. A number of medical institutions throughout the U.S. have installed the device with successful results.

With more than 150 beds, the Dell Children's Medical Center in Austin, Texas, uses an on-site 4.6 MW Mercury 50 recuperated gas turbine generator set from Solar Turbines to meet hospital process loads, including chilled water for thermal energy storage (TES) and steam for heating and other process needs. The Burns & McDonnell-designed CHP system allows the hospital to operate at 70 percent fuel efficiency and to dispatch excess electricity onto the grid after its own needs are met. In addition, the Dell Children's Medical Center is the first hospital in the world to achieve LEED Platinum certification, thanks, in part, to the CHP system.

Photo Courtesy of Solar Turbines

A&P Supermarket, Mt. Kisco, NY, Courtesy of UTC

Integrated Energy Systems (IES)

One of DOE's major R&D goals over the last 10 years has been to demonstrate the feasibility of IES in new customer classes, helping them achieve up to 80 percent efficiency and customer payback in less than four years, assuming commercial-scale production. To develop IES, researchers combine dissimilar subsystems so that they can work together to provide higher efficiency and lower cost than if they were operated individually.

As a result of previous DOE R&D support, integrated energy systems are now on the market with pre-manufactured or off-the-shelf capabilities, allowing systems to be scaled up or down in size or configured to serve a variety of applications. Such DOE-sponsored IES are often called "plug and play" systems—that is, they are designed into a package system off-site, installed and turned on with a minimum of on-site design and installation support, and replicated at numerous other sites at a reduced cost. Researchers conducted both technical and market analyses on each of the three projects that follow to assess their technical, design, and market feasibility.

A renovated **A&P supermarket in Mt. Kisco, New York,** is utilizing a UTC Power PureComfort CHP system, commissioned in January 2005. The system is pre-engineered to properly combine four 60 kWe microturbines and a double-effect absorption chiller driven by the microturbine exhaust heat. The system includes a diverter valve to bypass the exhaust flow around the chiller when additional chilling capacity is not required or desired. The store's loads include electrical power for lighting, motors, electronics, seasonal space cooling or heating, refrigeration, and dehumidification.

The PureComfort equipment, developed with DOE financial support, has proven its value. The A&P system now operates at about 80% efficiency with annual energy savings of $130,000, while producing 40% fewer CO_2 and 90% fewer NOx emissions.

The **Domain Industrial Park modular CHP system**, located in North Austin, Texas, incorporates a 4.6 MW Centaur 50 combustion turbine manufactured by Solar Turbines, that directly fires a 2,600 refrigeration ton (RT) Broad absorption chiller. This CHP system, engineered by Burns & McDonnell, employs pre-manufactured or off-the-shelf components, which cost the industrial park less and will significantly lower the cost of replicating similar on-site generation systems at other locations. The CHP system at the Domain

was delivered in two sections and assembled with seven welds. This basic package, which produces electricity, heat, and cooling for the industrial park, has served as a prototype for the CHP system installed at the Dell Children's Medical Center.

Domain Industrial Park, Courtesy of Solar Turbines

The Fort Bragg Army Base in Fayetteville, North Carolina, began an energy partnership with Honeywell in 1997 that has helped reduce its total energy costs by more than 25 percent. Honeywell's CHP plant, powered by a 5 MW Taurus 60 gas turbine from Solar Turbines, features dual use of turbine exhaust, modulating between exhaust-firing an absorption chiller to produce chilled water for air conditioning and feeding a heat recovery steam generator for serving heat loads. By recycling waste heat, system efficiency has risen to 70 percent, about double the efficiency of central station power plants—and the project is estimated to save the fort about $1.8 million per year. The large turbine that drives the CHP system has improved Fort Bragg's abilities to manage electric consumption and has helped the installation operate as an "island" during prolonged electrical outages on the main grid.

Fort Bragg Army Base, Courtesy of Honeywell

IES Expands CHP Markets

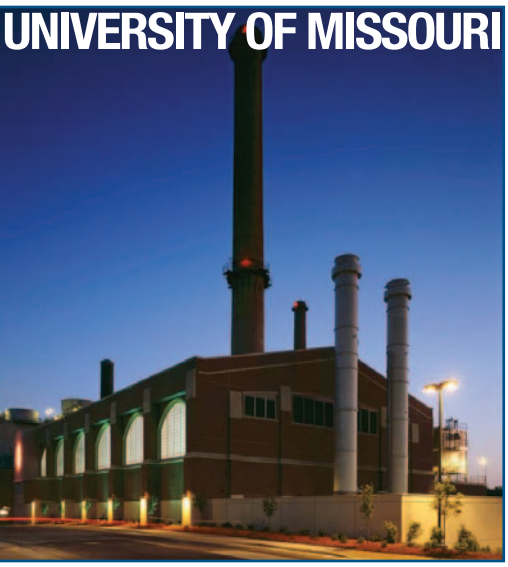
DOE has made a concerted effort to target non-traditional market sectors for CHP use—including hospitals, schools, and hotels. Its efforts to deploy and demonstrate integrated CHP components and systems in these sectors have produced a positive return on investment, and shown that public-private partnerships can produce market results. Successful projects include:

Butler Hospital in Providence, Rhode Island, installed a UTC Pure Comfort system with 110-ton absorption chiller.

Photo Courtesy of UTC

East Hartford High School in East Hartford, Connecticut, installed a UTC Pure Comfort system with a 110-ton absorption chiller.

Eastern Maine Medical Center in Bangor, Maine, installed a 5 MW Centaur 50 gas turbine from Solar Turbines, which generates 24,000 pounds per hour of steam and drives a 500-ton absorption chiller.



CHP District Energy System, University of Missouri at Columbia, Courtesy of IDEA

Recent Clean Energy Application Center Activities

The **Pacific Center** recently teamed up with Sempra Energy to hold workshops on CHP used in the food sector and for reliability and premium power.

The **Northwest Center** recently hosted a working session with the Northwest Pulp and Paper Association and member mills to discuss a broadly coordinated effort to improve mill efficiency and maximize CHP power production.

The **Mid-Atlantic Center** led efforts in the state of Maryland to develop a Model Distributed Generation Tariff.

The **Gulf Coast Center** has recently published three reports: *CHP Potential Using Texas Agricultural Wastes*; *Biodiesel Emissions Report: NOx Emissions Rates for Reciprocating Engine Generator Using Biodiesel Fuels*; and *NOx Emissions Impacts from Widespread Deployment of CHP in Houston*.

Transforming the Marketplace for CHP

DOE's extensive market transformation initiatives are reducing market barriers and creating market pull. They have positioned CHP technologies and practices to be in demand by numerous industries, chosen by project developers and builders, and readily available from manufacturers. By supporting the Clean Energy Application Centers, formerly called the CHP Regional Application Centers (RACs), and other outreach efforts, DOE has expanded the reach of CHP waste heat recovery, and district heating technologies in the United States and pursued new sectors for use.

Clean Energy Application Centers: *Offering Real Solutions to Local Energy Problems*

DOE established the CHP RACs to offer local, individualized solutions to customers on specific CHP projects. The re-named Clean Energy Application Centers also provide end-user education and outreach and lead initiatives to educate state policymakers and regulators.

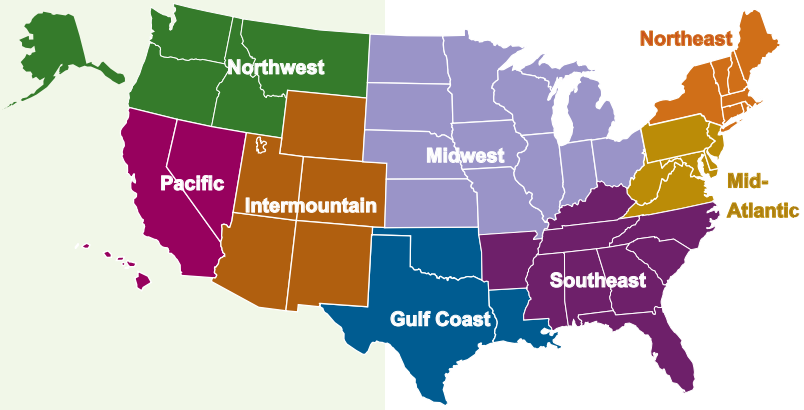
Since their formation, the RACs and now the Centers have capably accomplished the following:

- **Informed prospective CHP users** about the benefits and applications of CHP for specific targeted markets and about the resources and incentives available to facilitate CHP, waste heat recovery, and district energy projects (websites, workshops, and training)
- **Supported CHP project development** by conducting project feasibility studies, analyzing permitting issues, and assessing applicable tariffs/rates through technical and financial analyses
- **Promoted CHP as an effective, clean energy solution** to state policymakers and regulators and educated these audiences on barriers to widespread adoption of CHP

The Centers provide services throughout the United States and are led by a collaborative partnership of universities, research organizations, and non-profit organizations. By targeting specific regions, the Centers can educate local end-user groups, build effective partnerships, and address the wide range of regulatory and permitting requirements imposed on CHP systems by various states and utilities. The Clean Energy Application Centers are able to respond to their customers' individual needs with specific knowledge on the relevant issues for local project development.

The Centers have worked with a number of states and regions to establish policies and incentive programs that address barriers to CHP.

RAC and Clean Energy Application Center Accomplishments



- Supported more than 350 projects, representing 1.3 GW of CHP installed or in development
- Avoided more than 7.7 million tons of CO_2, equivalent to planting 1.9 million acres of trees and removing 1.2 million cars from the road
- Held more than 120 end-user-focused workshops for about 9,000 individuals across all market sectors, including municipal, healthcare, federal and state government, manufacturing, commercial buildings, multi-family housing, agriculture, wastewater treatment facilities, and infrastructure security

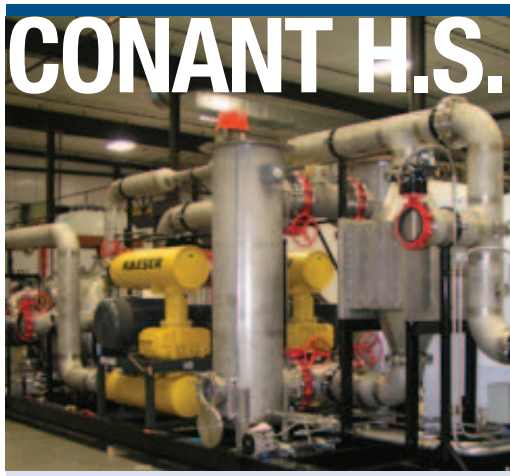
Connecticut, with support from the **Northeast Center**, has established a Distributed Energy Incentive Program to encourage CHP installations in the state. In addition, the state's Renewable Portfolio Standard offers direct incentives for CHP in congested areas and provides both investment and production tax credits.

The Western Governors Association (WGA) Clean and Diversified Energy Initiative recognizes the potential benefits and market opportunities of CHP in the western states and developed a portfolio of policies to accelerate CHP deployment. The **Intermountain Center** has shown the WGA how CHP can and should play a key role in the region's energy future.

North Carolina, with the support from the **Southeast Center**, enacted a Renewable Energy and Energy Efficiency Portfolio Standard (REPS) that requires all investor-owned utilities to generate 12.5 percent of retail electricity sales in 2020 from clean energy resources, including efficiency measures and CHP.

Utah created an energy-efficiency strategy that identifies specific proposals for removing barriers and promoting alternative fuel- and waste-heat-based CHP systems.

Maryland sponsored workshops on interconnection and standby power for policymakers and project developers, providing a strong basis for the state's recently enacted *EmPOWER Maryland* goals for energy efficiency and peak power reduction.



At the Conant High School in Hoffman Estates, Illinois, the **Midwest Center** performed engineering modeling to supplement architectural and engineering analysis, and recommended an engine-based CHP system to provide heat recovery for absorption cooling, process heating, and hot water. The school board considered CHP in the school's detailed engineering design, following Center recommendations. The project includes two 385 kW Caterpillar engines and two 300-ton York absorption chillers.

IES Webcast

CHP Market Assessments: Building the Case for CHP

Transforming the market requires building a business case for CHP. That is why DOE supports market assessments and analyses of CHP market potential in diverse sectors, such as supermarkets, restaurants, and health care facilities; industrial sites, including chemical, food processing, and pharmaceutical plants; hotels and motels; and new commercial and institutional buildings and facilities.

Many of these DOE-sponsored market assessments have led to the design, development, and installation of CHP components and systems throughout the nation. These systems are now providing efficiency and cost benefits to hospitals, schools, university campuses, commercial and industrial sites, military installations, wastewater treatment facilities, office buildings, and farms.

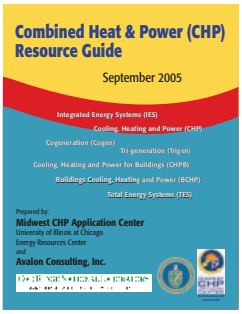
DOE has developed outreach materials promoting these assessments. A four-hour webcast featured the integrated energy systems installed at the A&P Supermarket in Mt. Kisco, New York; the Domain Industrial Park in Austin, Texas; and Fort Bragg in Fayetteville, North Carolina. DOE has used these examples to show that CHP is one of the most cost-effective technologies on the market for achieving near-term results in energy efficiency, emissions reductions, performance, and reliability.

The Ethan Allen Furniture Factory in Beecher Falls, Vermont, planned to close because of its high energy costs. The **Northeast Center** recommended replacing the factory's steam engine with a steam turbine powered by a biomass-fired boiler to save the factory 10 percent of its energy costs with a three-year payback. The factory owners accepted the Center's recommendations, and with the support and joint funding from the states of Vermont and New Hampshire and the Vermont Electric Cooperative Utility, the Ethan Allen Furniture Factory has remained open, saving 500 jobs.

Helping End Users Access CHP Technologies

DOE has developed a range of tools to address CHP market development and the educational needs of end users, product developers, project managers, and policymakers. Among these tools are databases, software, guidebooks, and policy documents, including:

- **CHP Project Installation Database**, which tracks installed CHP projects in all end-use sectors for all fifty states
- **CHP Economic Evaluation Software Tool**, which allows project developers and end users to determine the cost effectiveness of CHP projects in industrial, commercial, and institutional facilities
- **CHP Resource Guide**, produced by the **Midwest Center**, to provide project assessment and evaluation guidance, regulatory and policy information, and other analytical tools for potential CHP project developers and installers. This Resource Guide has been downloaded more than 10,000 times from the Center website.



- **Distributed Generation Operational Reliability and Availability Database**, which tracks large CHP projects in operation throughout the country

- **CHP Emissions/Credit Calculator**, which provides detailed assessment tools for estimating the emissions impacts of CHP projects
- **Existing Commercial and Industrial Boiler Database**, which inventories over 150,000 industrial and commercial boilers in the U.S. that use almost 40 percent of all energy consumed in these sectors; such energy use could be met in part by CHP
- **Air Permitting Screening Tool** for gas turbine CHP systems in the southern states
- **College and University CHP Database**, which screens college and university campus sites and ranks their potential for CHP use
- **Combined Heat and Power Education and Outreach Guide to State and Federal Government**, which equips policymakers and others to make informed decisions on CHP

These are just a few of the many technical and educational tools available to those interested in installing CHP throughout the nation. Find these tools and more information at **www.eere.energy.gov/industry/distributedenergy/**.

Education and Outreach

The RACs—now the Clean Energy Application Centers—have led or been engaged in more than 125 end-user focused workshops designed to improve the understanding and application of CHP in sites across all market sectors. More than 9,000 individuals participated in sessions across the country. Participants have included component and system manufacturers, installers, architects, building engineers and operators, project developers, financiers, and policymakers. Discussion topics have included the following:

- Waste heat recovery
- Save Energy Now (SEN) CHP opportunities in industrial, manufacturing, commercial, and institutional facilities
- CHP for food processing plants
- CHP for the forest products industry
- Ethanol produced with CHP
- Hospital CHP systems
- Wastewater treatment plants powered with CHP
- Anaerobic digesters for dairy farms
- CHP installed at schools, colleges, and universities
- CHP for critical infrastructure resiliency
- Premium power
- Municipal CHP systems
- District energy systems with CHP

Top: Veterans Administration Medical Center, Courtesy of Solar Turbines

Center: University of North Carolina at Chapel Hill, Courtesy of IDEA

Bottom: University of Texas at Austin, Courtesy of IDEA

DOE has also supported the development of the CHP Vision and CHP Roadmap; annual conferences and workshops on CHP; updates to annual CHP action plans; and bi-annual peer reviews, which inform the public about DOE's CHP research, development, and deployment efforts.

DOE produces numerous educational and outreach materials on CHP to improve national and international understanding of CHP technologies, markets, and policies. These materials include case studies, technology and project fact sheets, exhibits, websites, and webcasts or webinars.

Eliminating Regulatory and Institutional Barriers

CHP projects often face barriers in the form of environmental permitting regulations, utility interconnection and tariff practices, and air quality standards. Through extensive research, DOE has produced numerous analyses of these issues at the federal, state, and local levels. DOE's efforts to eliminate these barriers include the following:

- DOE performs analyses on output-based air quality regulations that support CHP deployment.
- DOE supports the Database of State Incentives for Renewables & Efficiency (DSIRE), which tracks state permitting rules and regulations that enhance or impede CHP development throughout the country.
- DOE has provided technical support to many states as they initiated regulatory proceedings or passed legislation to address barriers to CHP, including energy portfolio standards (EPS) and Energy Efficiency Resource Standards (EERS).
- DOE has provided technical analyses of state Renewable Portfolio Standards (RPS), which require electric utilities and other retail electric providers to supply a specified minimum amount of customer loads with electricity from renewable energy sources and/or CHP.

CHP databases provide "go-to" resources for end users

DOE and Oak Ridge National Laboratory (ORNL) have supported two major databases. The Combined Heat and Power Installation Database is maintained by Energy & Environmental Analysis, an ICF International Company. The database is continually updated with information on CHP installations across all end-use sectors (www.eea-inc.com/chpdata/index.html). The Database of State Incentives for Renewables & Efficiency (DSIRE)—at www.dsireusa.org—tracks state permitting rules and regulations that affect CHP development.

Midwest CHP Application Center Assists in Development of DG Interconnect Rules in Illinois

The Illinois Commerce Commission recently adopted a statewide interconnect policy for distributed generation (DG) projects, which was produced with the help of the Midwest Center. The policy standardizes the technical requirements for DG and CHP equipment and provides "fast-track" reviews for DG and CHP projects. The Center took a lead role in coordinating and providing technical input on behalf of the cogeneration and CHP industries. The Midwest Center has also held three public utility commission forums over the past six years to help inform the commissioners about DG and CHP regulatory issues, interconnection, standby tariffs, and state economic impacts.

MIDWEST CHP APPLICATION CENTER

Support of Emerging CHP Markets and Opportunity Fuels

An opportunity fuel is one that has the potential to be used economically for power generation, but has not traditionally been used for this purpose. Opportunity fuels are usually inferior to conventional fossil fuels, but—under the right conditions—can provide a cheap and reliable alternative.

Opportunity fuels include a vast range of common by-products, wastes, and other process derivatives. Examples are anaerobic digester gas, biomass, biomass gas, black liquor, blast furnace gas, coalbed methane, coke oven gas, crop residues, food processing waste, industrial volatile organic compounds (VOCs), landfill gas, municipal solid waste, orimulsion, petroleum coke, sludge waste, textile water, tire-derived fuel, wellhead gas, wood, and wood waste.

With the price volatility of fossil fuels and the need for more environmentally responsible energy sources, opportunity fuels are gaining market share. In addition, renewable portfolio standards, public benefit funding, and other renewable incentives have spurred investment in some opportunity fuels, particularly those fueled by biomass.

CHP Takes Advantage of These Fuels

Opportunity fuels can be used efficiently by many CHP systems and components, including microturbines, steam turbine engines, reciprocating engines, fuel cells, and combustion turbines. DOE supported initial research efforts on CHP use of opportunity fuels, particularly anaerobic digester gas and landfill gas. Additional research and successful deployment efforts have confirmed that these fuels hold great promise for further improving the economics of CHP.

"[CHP] is great because technically the water is a waste stream for us, and the biogas is another waste stream. If you have the ability to use that kind of free fuel source, it really would make no sense not to take advantage of it."

—Hillary Mizia, New Belgium Brewery

The **New Belgium Brewery** in Fort Collins, Colorado, is the third largest brewery in the state and the fifth largest craft brewery in the nation. In 2003, the brewery installed a 290 kW CHP system with heat recovery to generate thermal energy. Biogas from the brewering wastewater is combined with autolyzed yeast to fuel the CHP system. Energy savings have resulted in a three-year payback for the project. Although DOE did not provide financing for this project, its success has been cataloged and used by the CHP Application Centers to illustrate a cost-effective CHP installation.

More than 6,800 municipal/industrial wastewater treatment plants could potentially benefit from using anaerobic digester gas, as well as more than 7,000 dairy farms and 11,000 hog farms, for a total electric generation capacity of more than 6 GW. About 425 landfills currently participate in landfill-gas-to-energy projects, of which about 315 produce electricity (1.1 GW). More than 1,000 additional landfills offer CHP potential, which could add 3–4 GW.[6]

A well-designed CHP system powered by digester gas offers many potential benefits including:

- Displacing fossil fuels that would have been purchased to meet the facility's thermal needs
- Producing power at a reduced cost
- Reducing greenhouse gas emissions
- Enhancing power reliability at the treatment plant

At the Ina Road Water Pollution Control Facility in Tucson, Arizona, CHP is being used in conjunction with the anaerobic digester for the municipal wastewater treatment system. Biogas flow from the digester is used in the CHP system to generate electricity and thermal energy for the facility. The facility installed seven 650-kW Dresser Waukesha engines with heat recovery and a 950-ton absorption chiller, saving the facility more than $1.2 million annually while operating at 65 percent efficiency. The local government hopes to expand its CHP system to 6–8 MW from its current 3.3 MW. Although the Ina Road facility did not receive DOE funding, it is used as a successful case study during RAC education and outreach meetings.

Promoting Critical Infrastructure Resiliency

"This plant has been producing reliable electricity and heat for more than 25 years, and with the quality of the equipment we have, there's no reason why it couldn't continue for another 25."

—Gary Blomstrom, Plant Supervisor, Ina Road Water Pollution Control Facility

A healthy electric energy infrastructure is one of the defining characteristics of the modern U.S. global economy. It drives our telecommunications, transportation, food and water supply, banking and finance, manufacturing, and public health systems. The Northeast blackout in 2003 and hurricanes Katrina and Rita in 2005 illustrated how disruptions in power service can reach into many other sectors and underscored the need for resiliency. In emergency situations, demand-side approaches such as CHP can ensure continuity of the reliable energy service required for economic stability, emergency response, and continued operation of critical infrastructures. CHP offers an essential component of an overall risk mitigation strategy, and thus a number of CHP Application Centers have provided project and policy support on this issue to CHP end users in their regions.

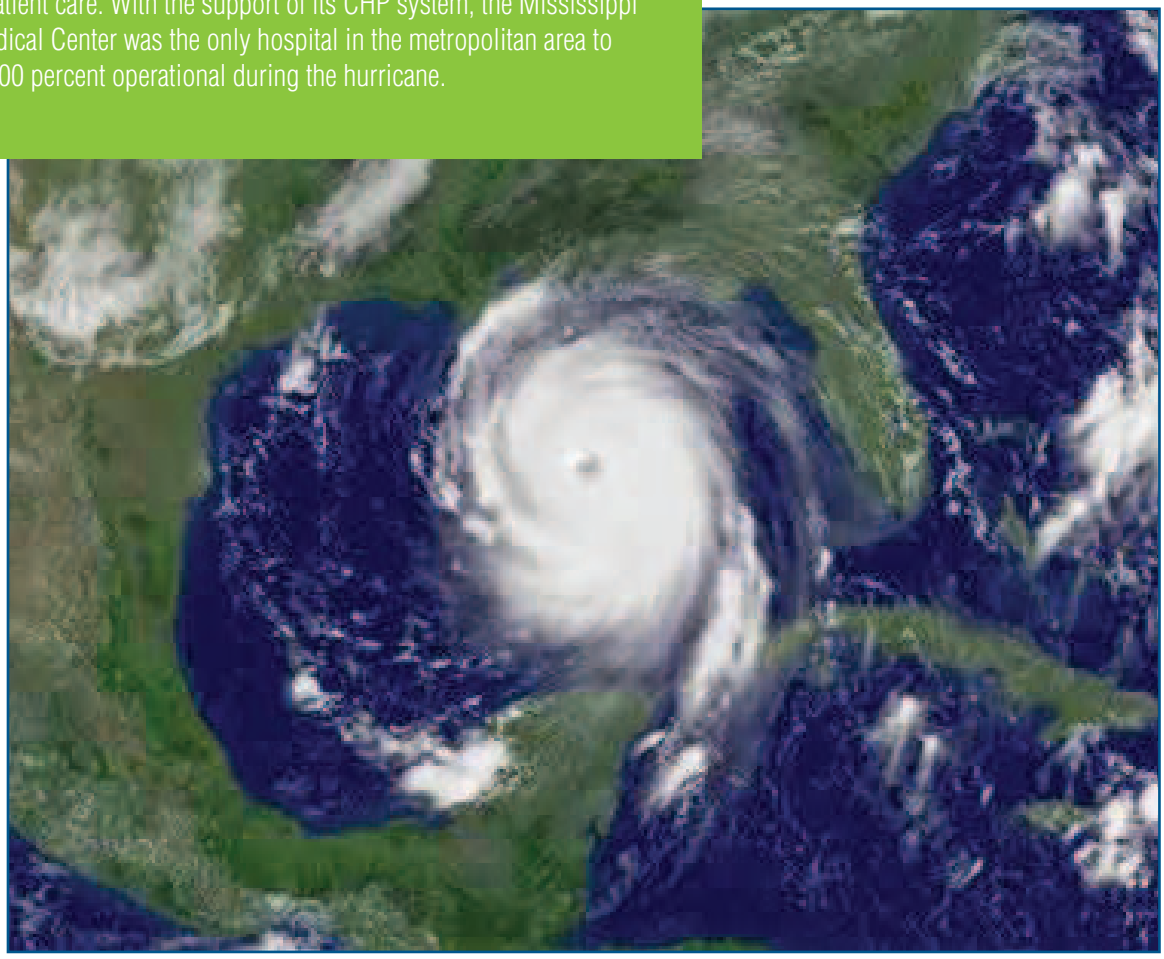
6 Resource Dynamics Corporation, *Opportunity Fuels and Combined Heat and Power: A Market Assessment* (August 2006).

Life-Saving Reliability

The Mississippi Baptist Medical Center in Jackson, Mississippi, is a 624-bed, full-service urban hospital with a medical staff of 497 and 3,000 employees. Its large electricity and steam requirements, centralized physical plant, and small daily variations in energy requirements led the hospital to invest in a CHP system. The hospital installed a Centaur 50 gas turbine generator set from Solar Turbines with a waste heat recovery boiler and steam absorption chiller as part of the package. The initial system cost $4.2 million, and was designed to meet more than 70 percent of the hospital's electricity requirements, 95 percent of its steam load, and 75 percent of its cooling load. Payback was achieved in 6.3 years.

The Mississippi Baptist Medical Center CHP system showed its value when Hurricane Katrina struck. More than 2.5 million residents were without power for a number of days. The hospital remained open, treating a high volume of patients and providing clothing, food, and housing for displaced patients during the first night of the disaster. In addition, the hospital operated a full-time day care to allow employees to focus on patient care. With the support of its CHP system, the Mississippi Baptist Medical Center was the only hospital in the metropolitan area to be nearly 100 percent operational during the hurricane.

The hospital has been a "success story" for CHP in the Southeast, its resiliency highlighted at numerous DOE and CHP Application Center events.



EPA CHP Partnership

The Partnership works to raise awareness in the effective use of CHP, especially in market sectors where there has been historically limited use. The Partnership provides technical support to all public and private industry sectors with its current focus sectors being municipal wastewater treatment facilities, data centers, utilities, and tribal casinos.

CHP
EPA COMBINED HEAT AND POWER PARTNERSHIP

Partnerships With Industry and Market Sector Networks

A key outcome of the DOE CHP program over the last decade has been the success of partnerships with CHP stakeholders. DOE has developed partnerships with diverse organizations at all levels, including the U.S. Environmental Protection Agency (EPA), the U.S. Clean Heat and Power Association (USCHPA), the International District Energy Association (IDEA), and the World Alliance for Decentralized Energy (WADE), as well as

- Private clean energy companies
- Technology developers
- Commercial builders and developers
- State governments across the country

These partnerships continue to move CHP into the mainstream of industrial, commercial, institutional, and district energy applications.

Since its formation in 1909, the **International District Energy Association (IDEA)** has served as a principal industry advocate and management resource for owners, operators, developers, and suppliers of district heating and cooling systems in cities, campuses, bases, and healthcare facilities. Today, with over 1,200 members in 26 countries, IDEA continues to organize high-quality technical conferences that inform, connect, and advance the industry toward higher energy efficiency and lower carbon emissions through innovation and investment in scalable sustainable solutions. With the support of the U.S. Department of Energy,

NYSERDA: A Key Partnership

NYSERDA

One of DOE's key partners is the New York State Energy Research and Development Authority (NYSERDA), which operates a successful CHP and clean DG research, development, and deployment program. NYSERDA supports development and demonstration of CHP systems throughout all end-use sectors. It also collects and analyzes project performance data, conducts market studies, and supports the Northeast CHP Regional Application Center. The NYSERDA-DOE partnership evaluates CHP project proposals and shares lessons learned through conferences, workshops, and other activities. This partnership has provided value to New York residents and to energy professionals across the country. NYSERDA projects have led to electric demand reduction, higher fuel efficiency, emissions reduction, lower energy costs, job creation, and increased product sales.

IDEA performs industry research and market analysis to foster high impact projects and help transform the U.S. energy industry. IDEA was an active participant in the original Vision and Roadmap process and has continued to partner with DOE on CHP efforts across the country.

The U.S. Clean Heat and Power Association (USCHPA), formerly the U.S. Combined Heat and Power Association, serves as the primary advocacy organization for the CHP industry. USCHPA activities at the national and state level helped get key CHP provisions into the Energy Policy Act of 2005 (EPACT05) and the Energy Independence and Security Act of 2007 (EISA), as well as the 10 percent investment tax credit included in the Emergency Economic Stabilization Act of 2008. In addition, the association has worked with the CHP Regional Application Centers to support CHP market transformation efforts in a number of states, including California, Connecticut, and Ohio.

DOE is actively engaged in the work of the **World Alliance for Decentralized Energy (WADE)**, which supports the worldwide development of decentralized, distributed energy generation around the globe, through financial support of technical analysis on CHP technologies, markets, regulatory issues, education, outreach, and market deployment.

International Reach

DOE's market transformation efforts have reached to European and other countries who are part of the international distributed and decentralized energy community. Through its partnership with DOE, the CHP program of the International Energy Agency (IEA) conducts research and analysis of CHP markets and deployment efforts around the world and has used lessons learned from U.S. research, development, and deployment efforts to recommend market transformation activities and policies that will lead to new CHP installations worldwide.

CHP in 2030:
Strategies for Continued Success

CHP's Significant Potential

If 20 percent of electricity generation capacity—about 240,900 MW per year—comes from CHP by 2030, the United States will see:

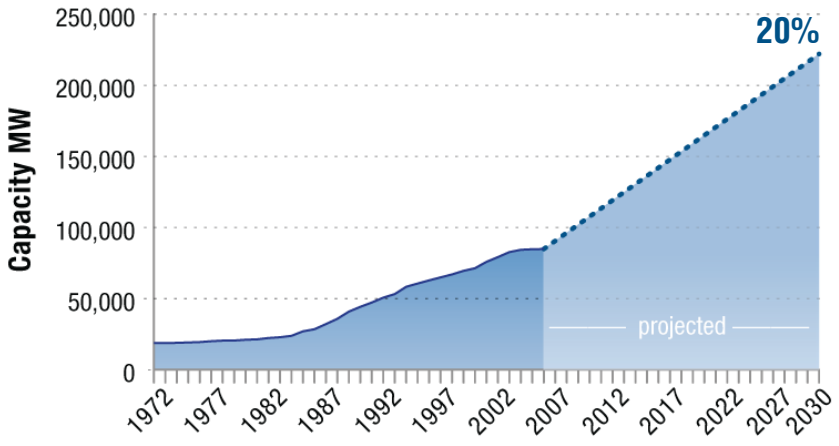
- Reduced annual energy consumption—about 5,300 trillion Btu/year
- Total annual CO_2 reduction—848 MMT
- Total annual carbon reduction—231 MMT
- Acres of forest saved—189 million acres
- Number of cars taken off the road—154 million
- Leveraged additional private investments—$234 billion
- New jobs created—1 million

Achieving 20 percent of U.S. generating capacity through CHP will accomplish key national objectives. CHP will:

- Reduce the amount of fossil fuels needed to meet U.S. electricity and thermal demands
- Mitigate the growth of GHG emissions associated with expected economic and energy demand growth
- Improve the competitiveness of U.S. businesses
- Assist in managing challenges in the electricity sector such as uncertainties about electricity supply and grid constraints
- Improve infrastructure security and resiliency against natural and man-made disasters
- Increase utilization of renewable and other opportunity fuels

Commercially available CHP technologies currently provide approximately 85 GW of U.S. generating capacity. Achieving 20 percent of U.S. generating capacity requires that the use of CHP increase to 241 GW by 2030, which is greater than historic growth rates. Achieving this level will require significant technology development and product improvements, proven performance and reliability at full-scale in a robust demonstration project portfolio, expansion of CHP into under-exploited markets, and strategic outreach and partnerships to address market and regulatory barriers inhibiting optimum CHP market development.

With more aggressive development and deployment of CHP, the United States has the potential to save energy, improve the environment, create jobs and improve the economy.



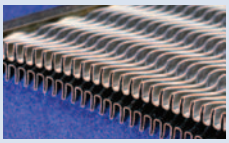
Source: ORNL 2008

DOE has adopted a strategic approach for CHP technology development, performance validation, and market transformation. The program substantially enhances the total value proposition of CHP in the context of market needs and barriers and positions CHP as a realistic solution to major energy and environmental issues confronting the nation.

DOE is advancing the technologies needed to achieve the goals of rapid expansion of CHP and reduced environmental impacts of energy production. DOE's multi-year program for combined heat and power is a balanced strategic portfolio of technology development, performance validation, and market transformation projects and activities for the CHP industry. This program targets three critical size application ranges—large CHP (>20 MW), mid-size CHP (1-20 MW) and small CHP (<1 MW). DOE is working with key private- and public-sector partners to leverage DOE resources in these three major application ranges with strategic activities that address the unique characteristics of each:

- **Research and Development** – Maximize energy efficiency, lower emissions, reduce component and system costs, optimize fuel flexibility, and minimize waste streams
- **Technology Demonstrations** – Reduce technical risk and validate full-scale performance in targeted applications and untapped markets
- **Market Transformation** – Reduce barriers that are due to regulatory frameworks, inefficient business models, and lack of awareness by key constituents and stakeholders

Alumina-Forming Austenitics – 2009 R&D 100 Winner



A new class of heat-resistant stainless steel has been developed at ORNL with DOE funding. Alumina (Al_2O_3)-forming austenitic (AFA) stainless steels boast an increased upper-temperature oxidation, or corrosion, limit that is 100 to 400 degrees Fahrenheit higher than that of conventional stainless steels. These new alloys deliver this superior oxidation resistance with high-temperature strengths approaching that of far more expensive nickel-based alloys without sacrificing the typical lower cost, formability, and weldability of conventional stainless steels. These new alloys have applications ranging from gas turbines and power plants to chemical and petrochemical processing equipment. The photo above shows an AFA recuperator air cell to be tested at Capstone Turbine Corporation.

CHP Research and Development

Past and current DOE CHP research and development (R&D) programs have focused on development of advanced distributed generation prime movers, such as gas turbines and engines. The Advanced Reciprocating Engine Systems (ARES) program is a competitively funded, multiple-participant effort involving DOE, Caterpillar, Cummins, and Dresser Waukesha Engine. To fully realize the potential of CHP, DOE will continue to support R&D in partnership with equipment manufacturers, national laboratories, universities, and end users. The strategic technology development emphasis is on achieving sizable improvements in energy efficiency and GHG emissions though a systems-based approach that reduces installation costs by lowering fuel supply and price risk, improving flexible fuel capabilities, and facilitating innovative capture and use of waste energy streams.

Courtesy of Caterpillar

The DOE CHP program emphasizes total energy efficiency and corresponding CO_2 reductions, utilization of non-fossil fuel energy inputs, and system integration on multiple levels, such as CHP systems that are integrated with facilities and with energy networks.

Courtesy of Champion

Future R&D will focus on improving the performance of CHP prime movers, including advanced reciprocating engines, gas turbines, and microturbines. Research in these technology areas will result in improved energy efficiency, enhanced flexible fuel capability, reduced capital and life-cycle costs, and reduced emissions. Overall CHP system performance will be enhanced by DOE research on improved thermal utilization (chillers, dehumidification), emissions, fuel flexibility, novel heat recovery techniques, and the use of advanced materials and system controls.

Expanded application of CHP into new markets places a greater emphasis on system integration. DOE will thus develop CHP systems for targeted applications in the large, mid-size, and small CHP markets. DOE also will research technologies and innovations for integrating CHP into facility-wide energy efficiency plans, smart grids, microgrids, and district energy systems.

The Frito Lay plant in Killingly, Connecticut, processes more than 500,000 lbs./day of corn and potatoes for snack foods. A combustion turbine CHP system has been installed in order to document energy, emissions, reliability, and economic performance in this high-growth industrial application. The system includes a Solar Turbines 4.6 MW Centaur 50 natural gas combustion turbine generator, with a Rentech heat recovery steam generator (HRSG). A selective catalytic emission reduction (SCR) system meets state and local emission requirements. The CHP system is designed to provide 100 percent of the plant's power needs and can provide over 80 percent of the plant's current maximum steam needs. This project is being managed by the Energy Solutions Center (ESC) and its member utilities' Distributed Generation Consortium, with funding from ORNL/DOE, state programs, and host sites.

Photo courtesy of Solar Turbines

Technology Demonstrations

CHP technology demonstrations are very effective tools for gaining market acceptance. DOE is working to promote and publicize installations of innovative technologies and applications that offer the greatest potential for replication. As noted earlier, key target applications include:

- **Large CHP (>20 MW)**
  - Industrial sites
  - Colleges and universities
  - District energy sites
- **Mid-Size CHP (1-20 MW)**
  - High growth industrial applications
  - Manufacturing and assembly plants
  - Institutional and municipal facilities
  - Military and government facilities
  - Large commercial sites
  - District energy sites
- **Small CHP (<1 MW)**
  - Small commercial buildings
  - Municipal buildings
  - Multi-family buildings
  - Residential buildings
- Projects in all classes that demonstrate the value to the electric utility and/or regional transmission operator

Support for CHP technologies in new sectors is essential to meeting aggressive goals for CHP growth. Thus, DOE demonstrations will be conducted in close collaboration with the private sector and other public-sector organizations and institutions.

Market Transformation and Clean Energy Application Centers

Successful market transformation of CHP requires that DOE clearly demonstrate a high degree of transferability and replicability to decision makers in market sectors with high growth potential market sectors. Clean Energy Application Centers, formerly called CHP Regional Application Centers (RACs), present one of the best communications channels for reaching these market sectors. DOE is building on RAC expertise and contacts to seek new means of influencing decision makers for even more widespread implementation of CHP.

Courtesy of Solar Turbines

Through the Clean Energy Application Centers, DOE will continue to provide technical expertise and consensus-building support to resolve regulatory and institutional barriers that inhibit market penetration.

The Clean Energy Application Centers will continue to leverage resources and partner with key public, private, and non-profit organizations to promote CHP technologies and practices, serve as a clearinghouse for local and regional CHP resources, and educate state policymakers on CHP benefits and the need to address barriers to deployment.

Section 375 of the Energy Independence and Security Act of 2007 (EISA) authorizes the Clean Energy Application Centers to continue carrying out these important activities. Specifically, EISA authorizes the Clean Energy Application Centers to:

- **Develop and distribute informational materials on clean energy technologies**
- **Conduct target market workshops, seminars, Internet programs, and other activities to educate end users, regulators, and stakeholders**
- **Provide and coordinate on-site assessments for potential CHP project developers and owners**
- **Offer consulting support to end-use sites considering deployment of clean energy technologies**

DOE will continue to support the Clean Energy Application Centers and other market transformation initiatives as they address state and regional greenhouse gas programs; encourage CHP's role in state renewable and energy efficiency portfolio standards, state incentives, and rebate programs; and support the feasibility and application of CHP and waste heat recovery projects.

A Vision for the Future with CHP

DOE stands ready to harness the full power of CHP and help the nation transform the way it consumes energy.

Our progress to date has demonstrated that widespread deployment of cost-effective CHP can help the nation advance its economic and climate goals. CHP is now installed at more than 3,500 commercial, industrial, and institutional facilities across the nation, improving energy efficiency, preserving environmental quality, promoting economic growth, and fostering a more robust energy infrastructure.

The Department of Energy has been integral to this effort and has long championed CHP technologies. By leveraging strategic partnerships with key industrial and institutional players, the Department has produced cutting-edge technologies and spearheaded market-transforming projects, commercialization activities, and educational and outreach efforts. Today, DOE continues to advance the critical technologies and market transformation activities needed to rapidly expand the use of CHP.

But more can and must be done to tap CHP's full potential. Despite its successes, the Department recognizes that, by adopting high-deployment policies to achieve 20 percent of electricity generation from CHP by 2030, the United States could save the equivalent of nearly half the total energy currently consumed by U.S. households. Through 2030, aggressive policies could also generate $234 billion in new investments and create nearly 1 million new, highly-skilled technical jobs throughout the country while reducing CO_2 emissions by more than 800 MMT per year.

As America looks forward to a new energy horizon, DOE is primed to lead the charge. The Department is pursuing a strategic approach that involves developing and deploying more energy-efficient CHP technologies and integrated energy systems, demonstrating and promoting these technologies, and validating system performance to achieve its goals. Ultimately, this balanced approach will allow DOE to seize the clear opportunity afforded by CHP and will help the nation create high quality green collar jobs, enhance domestic manufacturing competitiveness, and combat climate change.

For further information, contact:

Industrial Technologies Program

Office of Energy Efficiency and
Renewable Energy

U.S. Department of Energy

1-877-337-3463

www.eere.energy.gov/industry/distributedenergy/

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America.

Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

For more information contact:

EERE Information Center
1-877-EERE-INF (1-877-337-3463)
www.eere.energy.gov

Visit the ITP Website at
www.eere.energy.gov/industry

U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy

August 2009