U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

# Flexible Combined Heat and Power (CHP) Systems

## Many U.S. Manufacturing Facilities Well Positioned to Provide Valuable Grid Services

As intermittent renewable energy sources—like wind and solar—generate a growing share of U.S. electricity, electric utilities and other system operators face an increasing and immediate need for additional power to keep the electric grid stable and secure. Many small and mid-sized U.S. manufacturing plants could provide this dispatchable power and other grid services—earning clear financial benefits.

## Vision: Manufacturers Deliver Grid Services to Improve Bottom Line

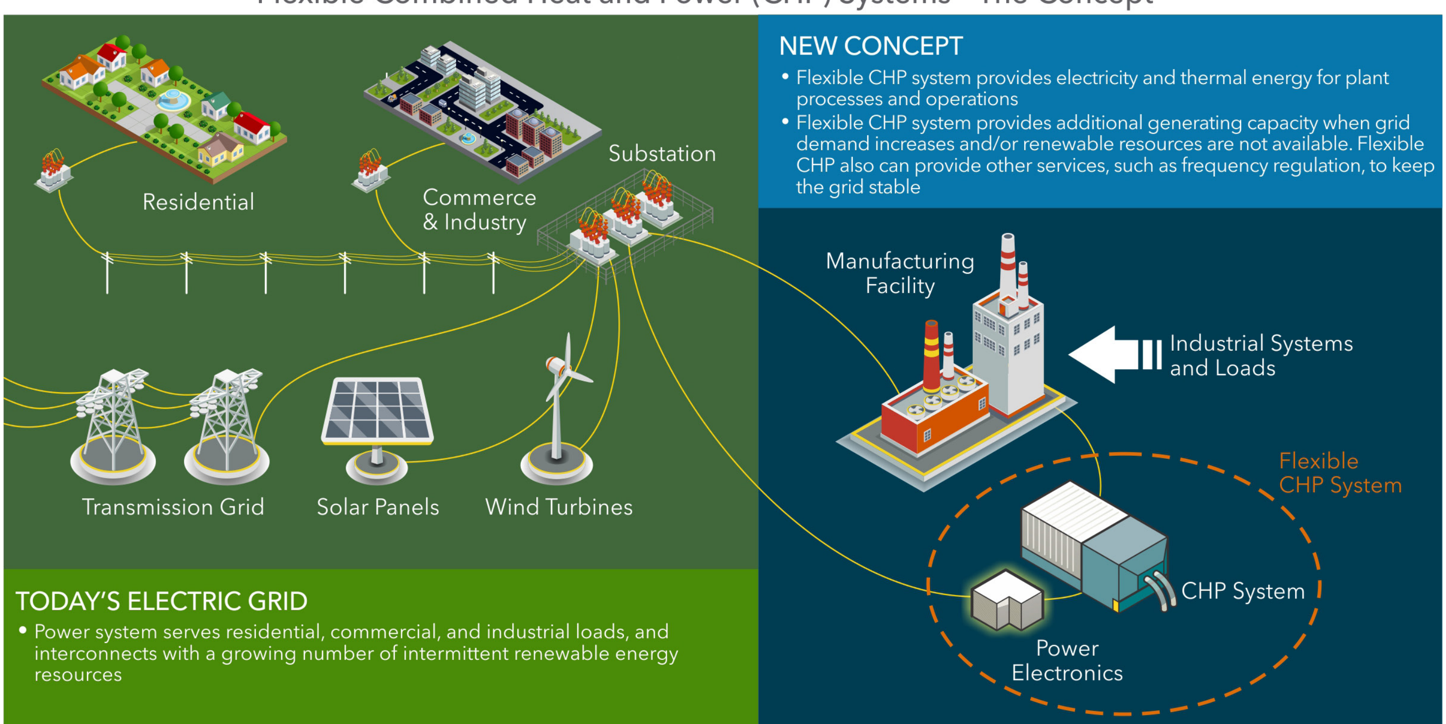
Many parts of the country have experienced a surge in renewable energy sources on the electric grid. In Iowa, for example, wind power contributions to electric power jumped from 4% in 2005 to about 31% in 2015. This increased reliance on non-constant resources can cause frequent fluctuations in power levels. As a result, grid operators need access to additional electric generation capacity to ensure an adequate and stable power supply.

Utilities and other grid operators know the high cost of increased power generation capacity and are now looking for cost-effective solutions to ensure a reliable modern grid. This quest opens a potentially lucrative opportunity for small and medium-sized manufacturers. Industrial operations with significant electrical and thermal energy loads can take advantage of combined heat and power (CHP) systems to meet their own energy demands. This technology has the potential to become an even more economically attractive investment if CHP systems are sized to also provide critical grid services.

A cost-effective, flexible CHP system that seamlessly connects to the grid and provides needed grid services would offer a win-win solution for manufacturers and grid operators. For manufacturers, revenue from grid services would provide an attractive return on their investment in CHP systems; for grid operators, partnering with industrial sites would provide cost-effective access to dispatchable generating capacity and other essential services, such as frequency regulation.

Flexible CHP systems that can automatically and seamlessly provide these grid services do not yet exist. A concentrated research and development (R&D) effort is required to develop these critically needed technologies.

Flexible Combined Heat and Power (CHP) Systems – The Concept




The Flexible CHP System concept provides benefits to both the electric grid and the manufacturing facility hosting the system.

*Graphic credit U.S. Department of Energy*

## What is the Opportunity?

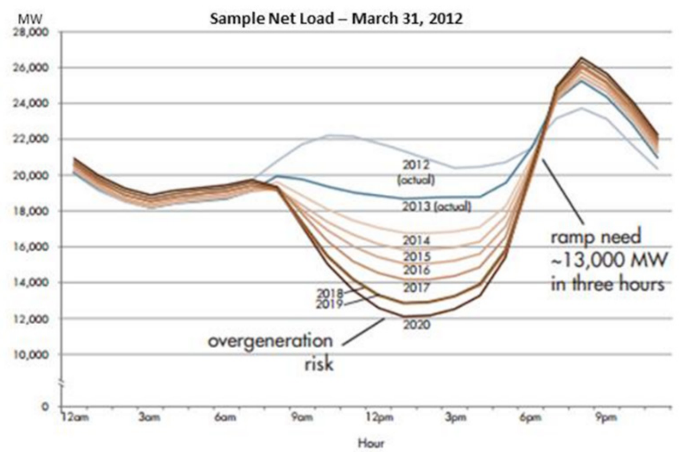
### More—and Better—Grid Services Required

Utilities and other electric grid operators have always needed a variety of grid services to help stabilize the electric power system and keep it running. During times of high electricity demand, peaking generators bolster generation to meet that demand. Additional resources also help regulate frequency and provide other services to keep the grid stable.

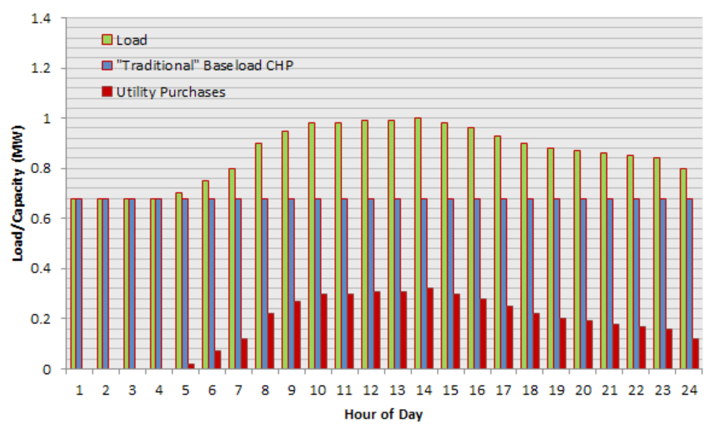
As intermittent energy sources like wind and solar become more prevalent, the need for grid services becomes even greater. Keeping the grid stable becomes far more complex and time sensitive as variable generation resources play a larger role in meeting the usual fluctuations in demand. In the past, grid operator requests for services typically required a 10-to-30-minute response. In some markets today, a 5-minute response is required; in emerging frequency regulation markets, a response is now needed in mere seconds.

CHP systems installed on the sites of utilities' industrial customers can provide many of the same benefits as the utility-owned peaking plants that use distributed generation technologies. Small- and medium-sized industrial facilities with significant thermal and electric loads are often good candidates for CHP systems. Traditionally such CHP systems have been sized to match the facility's own energy needs. However, for a relatively modest investment, industrial customer-sited CHP systems could be designed with adequate additional generating capacity to support the electric grid. Because customer-sited CHP units typically operate continuously, they can respond rapidly whenever grid services or added power are needed.

The additional revenue from grid services could greatly enhance the benefits of a CHP system, making it a revenue generator for the manufacturing facility. For example, in the Electric Reliability Council of Texas (ERCOT) market, providing generation at day-ahead pricing can generate an estimated $20,000-$90,000 annually, per installed MW. Providing other grid services could increase annual revenues to $160,000 per MW. Estimated potential revenue is even higher in other electricity markets.




Projected high penetration of renewable generation resources creates a net load curve that includes rapid decreases and increases in required generating capacity (a "duck curve"), which necessitates the availability of fast-reacting grid resources. *Graphic credit: California Independent System Operator*




A traditional CHP system is sized to match the host facility's own energy load. An "oversized" CHP system could generate additional revenue for the host site by also providing grid services. *Graphic credit. U.S. Department of Energy*

### Manufacturing Facilities Are Ideal Providers

Currently, utilities and independent power producers own and operate most of the power plants that provide variable generation for the grid. Formerly, most of these peaking plants were fairly large, but recently installed units tend to use smaller distributed generation technologies. For example, a series of 10- to 20-megawatt (MW) reciprocating engines may be installed at one facility to provide a total capacity of 50-200 MW. Such installations offer the grid needed flexibility, quick start-up, good load following, and better part-load efficiency.

### Growth Opportunity for U.S. Industry

Sophisticated monitoring and control technologies remain to be developed to seamlessly integrate customer-sited CHP systems into the electric power system and enable efficient delivery of needed grid services. The current unavailability of these technologies constitutes a significant market barrier. Innovative solutions developed through a concentrated R&D effort would enable U.S. manufacturers to become global leaders in this field. Since most of these future industrial CHP systems are likely to use natural gas, wide adoption of such distributed CHP systems would also support the U.S. natural gas industry.

## Improved System Capabilities Could Greatly Enhance Existing Concept

A customer-sited CHP system that provides grid services and economic value to the host site is not a new idea; however, such systems will not be widely adopted until new technologies enable seamless and automated connections between distributed resources and the grid. Three existing systems (described below) suggest the great potential for such technologies.

### Bristol-Myers Squibb CHP Systems Participate in Electricity Markets

Bristol-Myers Squibb, a global biopharmaceutical company, operates CHP systems at many of its manufacturing facilities. When the company was deciding whether to install a CHP system at its plant in Hopewell, New Jersey, conventional CHP project economics—including energy savings and available financial incentives—did not justify the investment. The economic feasibility of the system, which consists of two reciprocating engines for a total capacity of 4.1 MW, improved significantly when the system was configured to participate in PJM Interconnection electricity markets. Estimated annual revenue from capacity, energy, and other grid services in the PJM market totaled $1.4 million, or $340,000 per MW.

| Economic Parameter | Traditional CHP | Traditional CHP with Incentive | CHP plus Grid Support and Incentive |
|---|---|---|---|
| System Capital Cost | $9.3M | $9.3M | $9.3M |
| Incentive | | $2.0M | $2.0M |
| Net Installed Cost | $9.3M | $7.3M | $7.3M |
| Net Revenues from CHP | $1.1M | $1.1M | $1.1M |
| Net Revenues from PJM Sales | $0 | $0 | $1.4M |
| Simple ROI | 12% | 15% | 34% |
| Simple Payback | 8.5 yrs | 6.6 yrs | 2.9 yrs |

Project economics for the 4.1 MW CHP system at Bristol-Myers Squibb's Hopewell, NJ, facility improved significantly when it was configured to provide grid services for the PJM Interconnection.

The Hopewell facility is not the only Bristol-Myers Squibb site providing needed grid services. The company's facility in Wallingford, Connecticut, has had a 4.7 MW gas turbine CHP system since 1998. That facility now actively participates in the demand response program of the local system operator, ISO New England. During times of high electricity demand, the facility generates extra electricity with its CHP system and backup generators to supplement generation at power plants and to relieve grid congestion in southwest Connecticut. These support services generate additional revenue for the company and improve the reliability of the local grid.

### Princeton University Maximizes CHP System Value

Princeton University has operated a district energy system for many years to provide heating, cooling, and electricity for approximately 150 campus buildings serving over 8,000 students. A central feature of the energy plant is a natural gas-fueled 15 MW CHP system.

Princeton University's sophisticated control systems enable it to maximize the financial benefit from its CHP system based on varying prices on the energy markets. Photo credit: Princeton University

When the New Jersey electric market moved to real-time pricing in 2003, Princeton upgraded its cooling systems and installed a new monitoring and dispatch system at its campus energy plant. The system now monitors weather forecasts, campus heating and cooling needs, and market prices for electricity and natural gas—using that data to adjust its production of electricity, steam, and chilled water. During peak demand periods, Princeton reduces its use of electricity from the grid, which lowers costs and reduces stress on the local power system. Princeton's energy plant also has a thermal energy storage system, which further enhances its ability to shift energy consumption from periods of high demand.

Princeton's upgraded, high-efficiency energy plant is an economic and operational success, resulting in financial savings over the separate production of electricity and heat. The sophisticated control system that adjusts operations to market conditions significantly increases financial benefits provided by the plant. The control system reduced energy costs at the university by an estimated 10–15%, and the payback period for the control system was only three months. The control and dispatch system requires, however, active management by plant personnel.

In addition to financial benefits, the district energy system enables the university to continue operations during power outages. When Superstorm Sandy hit the area in October 2012, Princeton was able to continue powering all its essential buildings and operations using its CHP system.

## What Envisioned Flexible CHP Looks Like

Technologically advanced CHP systems are needed to enable more small and mid-sized manufacturers to support grid services. These systems must have the following characteristics:

- Provide both thermal energy and electricity for the manufacturing facility
- When called to do so, generate electricity and/or provide other grid services to the electric power system
- Interact with the grid in a fully automated manner
- Be easy to install, operate, and maintain
- Deliver cost-effective performance with an attractive payback period.

> The new, flexible CHP systems must interact seamlessly with the grid, and this interaction must be fully automated.

## What R&D Is Needed

While current technologies enable CHP host sites to participate in electricity markets, further technology development is needed to enable more small and mid-sized manufacturers to make use of these emerging opportunities. CHP systems that provide services to the grid need to be: more sophisticated and automated, easier to install and operate, and lower in cost. To achieve these goals, R&D is needed in the following areas:

- Control systems, power electronics, communication technologies, and data analytics and forecasting tools to enable seamless and automated interaction with the grid and manufacturing site operations
- Better materials that cost less
- Integration of all systems into prepackaged plug-and-play systems.

## Win-Win for Manufacturers and Grid Operators

New, flexible CHP systems would benefit the host site, grid operators, and grid customers. Manufacturers who own and operate such systems will gain an additional revenue stream, reduce their energy costs, gain better control over plant operations, and suffer fewer power outages that can disrupt production. In addition, affordable onsite electricity generation can support further electrification of manufacturing operations—a goal adopted by many manufacturing companies.

Advanced CHP systems at manufacturer sites would provide utilities and other grid operators a cost-effective way to obtain needed grid services. The distributed nature of customer-sited systems also helps create a more robust and resilient grid.

### Non-Technical Challenges

Beyond technical challenges, market and regulatory barriers must also be addressed to enable wide adoption of the envisioned flexible CHP systems:

- Reluctance of manufacturers to invest in areas that are not part of their core competency
- Corporate requirements for very short payback on energy management investments
- Inconsistent regulations across states and electricity markets.

## For additional information, please contact

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