ADD CHP: Accelerated Development and Deployment of Combined Cooling, Heat, and Power at Federal Facilities

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ABSTRACT

This paper describes the activities of the U.S. Department of Energy's Federal Energy Management Program (DOE-FEMP) to "ADD CHP" (Accelerate Development and Deployment of Combined Cooling, Heat and Power) at federal facilities. This effort promotes teaming with multiple partners to identify and reduce barriers to installation of CHP technologies in federal buildings. ADD CHP promotes teamwork among private- and public-sector partners—project developers, energy service companies (ESCOs), financiers, industry manufacturers, federal facility managers, and DOE staff. The paper discusses FEMP's role, CHP market potential in the federal sector, issues affecting CHP deployment, strategy to expedite CHP projects, and progress to date. This study suggests that CHP could be successfully applied in 9 percent of large federal facilities where it would annually conserve 50 trillion Btus of primary energy, reduce CO_2 emissions by 2.7 million metric tons, and cut utility bills by $170 million. Although many CHP technologies are proven and the potential savings and benefits are significant, project development lags behind potential in the federal sector.

Introduction: What Is CHP?

CHP goes by many different names—cogeneration; building cooling, heating, and power; and combined heat and power—all referring to a system that efficiently generates electricity (or shaft power) and uses the heat from that process to produce steam, hot water, and/or hot air for other purposes. The most common building applications use a prime mover (gas turbine or engine) coupled with a generator to produce electricity and capture the waste heat for process steam and space heating. Or boiler steam can pass through a turbine to generate electricity in addition to serving other thermal applications. One of the simplest systems employed recently at a federal site replaced steam pressure-relief valves with a low-cost backpressure steam turbine and electric generator. Fuel-efficient distributed energy generation systems such as combined heat and power (CHP or cogeneration) are attracting increasing attention among project developers and policy makers because they can make significant contributions to mitigating key power sector constraints. These systems can meet increased energy needs, reduce transmission congestion, cut emissions, increase power quality and reliability, and increase the overall energy security for a site.

A CHP system recovers the heat from electricity generation for productive uses. Normally, conventional power plants waste this heat. And because a CHP system generates electricity near the point of use, CHP also avoids transmission losses from distant central stations. For these reasons, properly designed CHP systems can be much more efficient than the average U.S. fossil fuel power plant.

A Proven Technology

CHP systems play an essential role in our nation's present energy supply and future plans. The United States has more than 50 gigawatts (GW) of installed CHP capacity producing about 7% of the nation's electricity. The National Energy Policy Report highlights the importance of CHP to help cost-effectively meet critical goals related to emissions reductions, reliability, and new energy production. Federal agencies have a mandate to lead by example in meeting national energy and environmental goals, and an Executive Order specifies that agencies "shall use combined cooling, heat and power systems when life-cycle cost-effective."

CHP Efficiency: Site versus Source Energy Savings

A CHP system is generally not more efficient at producing electricity alone than the central grid, and properly maintained boilers alone can be more efficient at producing thermal energy than a CHP system. But the combined generation of electricity and thermal energy on-site by a well-designed CHP system is more efficient overall than the combined efficiencies of these two alternatives. One key to ensuring an efficient CHP system is to maximize the use of thermal energy (waste heat) from the generation process. Emissions or other site-specific factors may override electrical efficiency or operating and maintenance costs when determining which CHP system best meets a facility's needs.

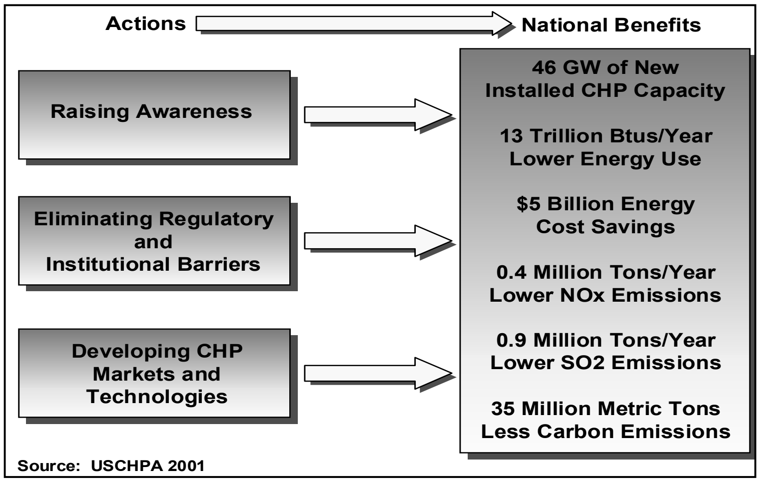
Because CHP uses energy to generate electricity on site, the total *site* energy use will increase with a CHP system. When individually considering either the grid (for electricity) or the boiler (for heat) and the associated energy use, CHP may not seem as efficient. However, because CHP systems both avoid losses associated with distributing the electricity and employ the waste heat from generating the electricity, CHP results in a net savings of primary, or *source*, energy. With a CHP system, total energy consumed to supply electrical and thermal needs for the site is decreased.

FEMP's Role and Rationale for CHP

The Federal Energy Management Program (FEMP) mission is to reduce the cost of the federal government by advancing energy efficiency and water conservation, promoting the use of renewable and distributed energy, and improving utility management decisions at federal sites. Executive Order 13123 directs federal facilities to use CHP when life-cycle cost analysis indicates energy-reduction goals will be met. FEMP can help facilities conduct this analysis. More and more federal partners are requesting information on CHP to try to reduce energy costs and emissions.

CHP systems can help federal agencies meet goals related to energy security, cost reduction and environmental quality. Recognizing the benefits of CHP, DOE, the U.S. Environmental Protection Agency, and the private sector have embarked on a joint effort to double the amount of CHP capacity in the U.S. by 2010 (Fig. 1). FEMP efforts to expand CHP in federal sites are integrated with the U.S. Combined Heat and Power Association (USCHPA) strategy.

Fig. 1. National CHP Roadmap, Objectives for 2000–2010 (All Sectors)



CHP may present some challenges, but more than 50 federal sites have benefited from CHP systems in the past, and as of February 2002, another 50 sites were actively developing opportunities to install 100 MW of additional CHP capacity.

Potential for CHP in the Federal Sector

To give FEMP a better understanding of the federal sector's CHP potential, ORNL created a simple model that calculates the energy use and costs in different types of federal buildings across the country. The model was used to estimate when and where CHP would be most likely to offer a cost-effective alternative to traditional (grid and boiler) systems. The model allows the user to select various parameters regarding CHP technology, energy prices, and energy use. It then calculates the financial payback of CHP to determine the amount that could be implemented within prescribed parameters. The base case included only those buildings with simple payback periods of less than 10 years. In a typical federal installation like those modeled for this market assessment, CHP is assumed to provide thermal energy for heating and cooling a building while at the same time generating a portion of its electricity needs. While other applications (process steam for industry, laboratories, laundry, hot water, dehumidification) and more complicated systems are possible and often result as site-specific conditions are analyzed, it was impractical to make assumptions about these alternatives in the present assessment. Site-specific information is critical to verify CHP potential.

Although the methodology used in this study was intended for assessing the CHP potential of federal facilities, it could also be applied to other sectors. The majority of new CHP potential in the United States is in private industry. It should be noted that separate calculations were made for buildings between 25,000 ft^2 and 100,000 ft^2 using the data sets for different energy intensities and different percentages of buildings with HVAC systems conducive to CHP. Smaller federal facilities offered relatively little CHP potential under the base case assumptions (10 MW). For more details on the methodology, assumptions and results presented in *Analysis of CHP Potential at Federal Sites* (ORNL/TM-2001/280, February 2002), visit ORNL's web site www.ornl.gov/femp/pdfs/chp_market_assess.pdf.

Potential CHP Capacity

The total amount of CHP potential capacity for federal facilities nationwide is estimated to be between 1500 and 1600 MW (Table 1). Under base-case assumptions, the CHP systems would produce 7.7 terawatt hours (TWh) of electricity per year representing more than 13% of the 57 TWh total electricity the federal government purchased in FY 2000 (FEMP 2002). This CHP capacity would provide electricity and thermal energy for about 580 million ft^2 of building space in 9% of all federal sites. The potential will be greatest in large sites with central plants or mechanical rooms and high electricity rates. Key assumptions behind these numbers are summarized here:

- reciprocating gas engines are used at their current estimated cost and efficiencies;
- energy prices are at 2000 industrial rates for each state;
- 75% or 50% of estimated electric demand with load factors at 85% or 35% is supplied, depending on building type and size;
- only the percentage of CHP-compatible federal facilities was considered;
- all recoverable waste heat is assumed utilized by the site; and
- only systems with a simple payback less than 10 years were considered.

Changing these parameters can give widely different amounts of CHP potential and energy savings.

Table 1. National CHP Potential by Building Category at Federal Facilities Using Base Case Assumptions

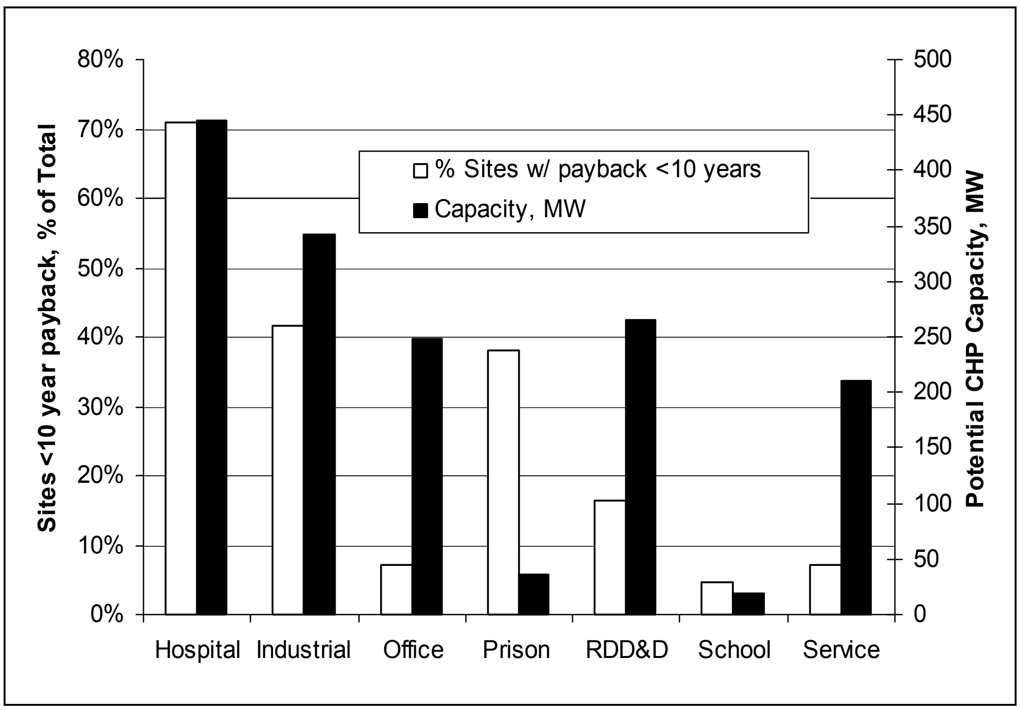
	Hospital	Industrial	Office	Prison	R&D	School	Service	Total
Total Mft^2, all buildings[a]	141	115	514	41	144	136	463	2757[b]
Mft^2 buildings with CHP payback <10 years	113	80	146	16	100	42	82	579
Total number of sites[a]	331	181	2302	99	421	917	1033	8182[b]
Number of sites with CHP payback <10 years	235	75	167	38	70	42	74	700
% of sites with CHP potential	71	42	7	38	17	5	7	9
Potential TWh of electricity from CHP	2.9	2.3	0.8	0.2	0.8	0.1	0.7	7.7[c]
Potential CHP Capacity, MW	440	340	250	40	270	20	210	1570[c]

[a] Includes buildings in GSA database >25,000 ft^2, even those without CHP potential
[b] Total includes other building types not shown.
[c] Row total differs due to rounding.

Under the base case, federal hospitals are the building category with the highest potential for CHP. They also show the most promising target of opportunity, since more than two-thirds of large hospitals are expected to have CHP potential. Industrial buildings are next in potential capacity, at 340 MW, and are second in percentage of sites at 42%. This result is influenced in part by the fact that these two categories were modeled using a 24/7 load-following, CHP profile. And since this scenario assumes a relatively high capacity factor (75%), they also represent more than two-thirds of the total electricity and potential savings estimated by the model.

R&D facilities, office buildings, and service buildings provide similar amounts of capacity (270, 250, and 210 MW, respectively) under the base case. These three categories were modeled in the base case as using the weekday occupation load profile (CHP provides 50% of electricity at a 35% capacity factor) rather than the 24/7 load-following CHP profile. Some R&D and service facilities may be more appropriately modeled using the higher loads assumed for hospitals and industrial sites. Under that alternative load profile, R&D CHP capacity increases 45%, from 270 to 390 MW. Figure 2 shows the percentage of buildings with CHP potential (payback less than 10 years) in a given category and compares that percentage to corresponding MW of capacity. Hospitals, prisons, and industrial sites offer the greatest likelihood of having CHP potential.

Fig. 2. Percent of Federal Sites with CHP Potential by Building Category and Corresponding Capacity (MW)



CHP Costs and Savings

Table 2 shows the average costs, payback and annual savings expected if all the CHP identified in the base case were implemented at federal sites. Costs include one-time installation, annual operating and maintenance costs of equipment, and annual gas purchase expenses. Estimated installed costs range from \$600–\$1300/kW, and O&M from \$5.5–\$12/MWh, depending on system size and technology (considering gas turbines or internal combustion gas engines). The thermal benefits of CHP are incorporated in the gas cost because the amount of gas needed is the amount to make the electricity minus the amount displaced by CHP waste heat utilization. Dollar savings come from reduced electricity purchases, and the net annual savings ($171 million/year) are these savings less annual costs. “Simple payback” is the installation cost divided by the annual net savings, to show the number of years until the installation cost is recovered. The payback numbers reflect national averages for each building category for states where that category showed payback less than 10 years. Hospitals, industrial and prison facilities show the shortest payback periods.

Table 2. CHP Costs, Savings, and Payback, by Building Category, Under Base Case Assumptions

	Hospital	Industrial	Office	Prison	R&D	School	Service	Total
Capacity, MW	446	342	248	36	265	18	211	1567
Installation cost, M$	319	222	174	28	163	14	135	1055
Operating cost, M$	23	17	6	2	6	0	5	59
Gas costs, M$	55	42	15	4	16	1	12	145
Electricity savings, M$	138	100	44	11	44	3	35	375
Net annual savings, M$	60	41	23	5	22	2	18	171
Average payback, years	5.3	5.5	7.5	5.8	7.4	7.5	7.4	6.2

Besides the amount of floor space and energy intensity in any state, a key factor is the relative price of natural gas and electricity. States with low gas prices and high electricity prices are the best candidates for CHP. Contrarily, high gas prices and low electricity prices make CHP less attractive. Figure 3 illustrates the national amount of potential CHP capacity and Fig. 4 shows the states with the highest difference between electricity and gas prices (spark spread). Note that there is a strong correlation between the two figures. Exceptions exist primarily because states with higher numbers of large federal buildings are more likely to have higher CHP potential.

Fig. 3. Federal CHP Potential Capacity Under Base Case, MW

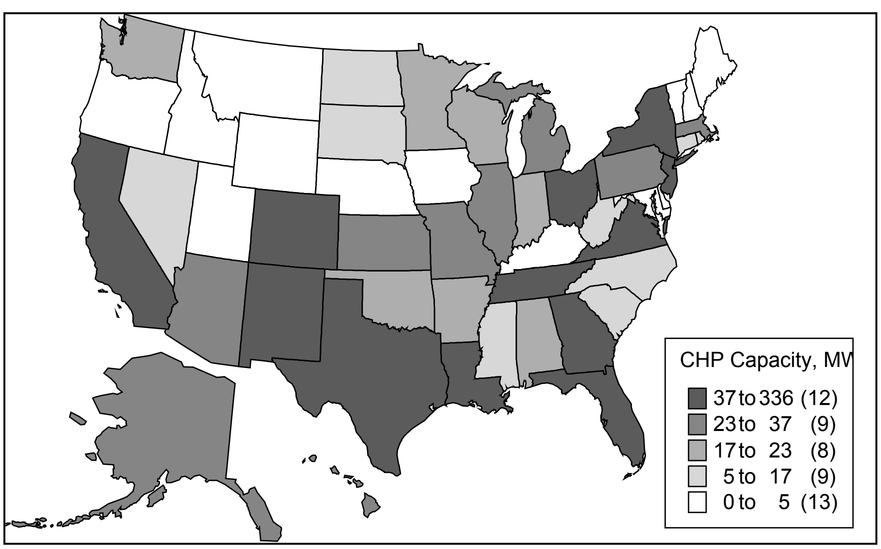
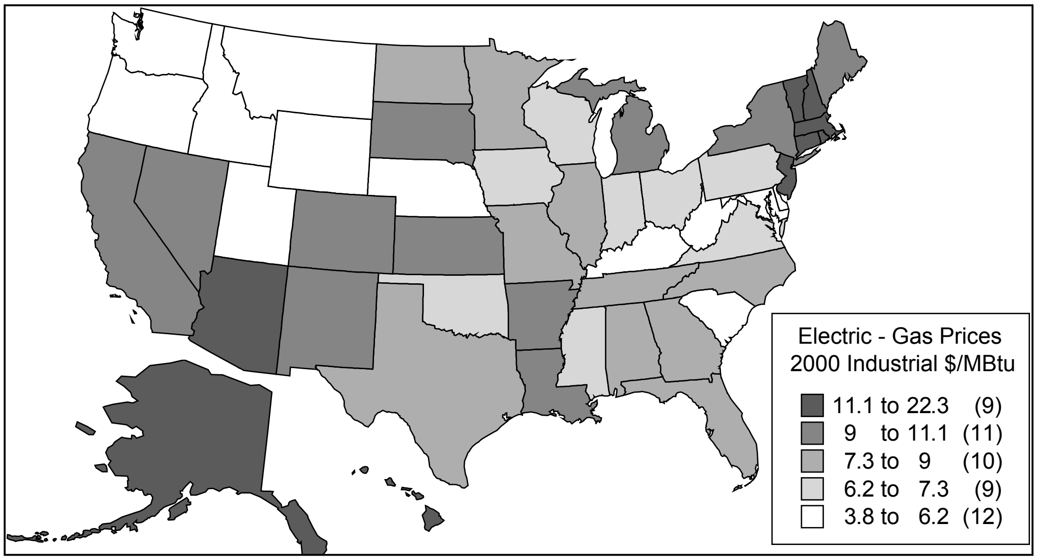


Fig. 4. “Spark Spread” Difference in Electric and Gas Prices in $/MBtu



CHP Potential by Federal Agency

Table 3 estimates the potential CHP capacity for each agency by building type. Many agencies showed little potential as calculated using the base case parameters. (The sum does not exactly match the earlier analysis, because agency-by-agency averages by state have slightly different paybacks compared to the building category averages that go above or below the threshold 10 years for simple payback.)

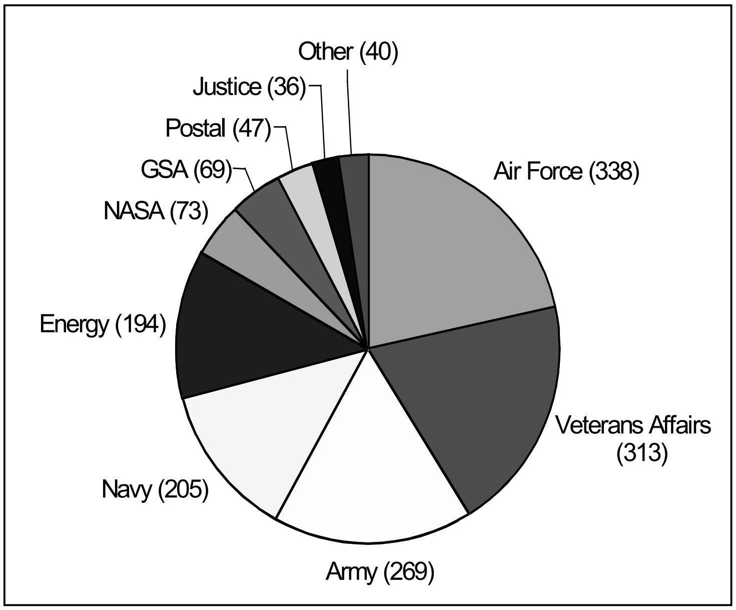
Table 3. Potential CHP Capacity by Federal Agency and Building Category, MW

Agency	Hospital	Industry	Office	Prison	R&D	School	Service	Total
Air Force	43	57	31	0	85	7	116	339
Veterans Affairs (VA)	311	0	1	0	1	0	0	314
Army	55	101	52	2	24	3	33	270
Navy	27	36	39	0	43	2	58	205
Department of Energy	0	113	15	0	64	0	2	195
NASA	0	17	10	0	43	0	3	73
General Services Administration	0	1	68	0	0	0	0	69
United States Postal Service	0	0	48	0	0	0	0	48
Justice	0	3	0	34	0	0	0	37
Health and Human Services	6	0	0	0	2	0	0	9
Treasury	0	8	0	0	0	0	0	8
Transportation	0	0	2	0	4	0	0	7
Interior	0	2	2	0	0	3	0	7
Agriculture	0	0	0	0	3	0	0	3
Other	0	0	0	0	2	0	0	7
Grand total	443	338	269	36	274	16	212	1588

Note: Other refers to Commerce, Corps of Engineers, National Science Foundation, Environmental Protection Agency and Education. Other federal agencies considered showed no potential under the assessment parameters.

Nearly all CHP potential is found among nine agencies: the three military services, Veteran's Affairs Administration (VA) hospitals, DOE, NASA, GSA, the U.S. Postal Service, and the Department of Justice (Fig. 5). And the military, VA, and DOE represent 83% of the total CHP potential identified in the base case. The military services (more than 50% of total) have significant potential CHP capacity in most types of buildings, while the VA's capacity is in hospitals. Energy and NASA capacity is concentrated in R&D and industrial buildings, while GSA and the Postal Service have capacity in the "office" category.

Fig. 5. Potential CHP Capacity for Major Federal Agencies (MW, total = 1590).



Study Results: Market for CHP in the Federal Sector

There is significant potential—1,000 to 2,000 MW of capacity—for CHP to serve federal facilities. Regions with the greatest CHP potential are the southwest, northeastern metropolitan areas, and the southeast. The actual potential could be higher or lower depending on the specific conditions of any given site. Where the federal government can obtain low-cost electricity, CHP will have difficulty competing. But if on-site energy is required for security, CHP can make the system more efficient and cost-effective. As energy prices increase and CHP system costs decrease, the amount of cost-effective CHP potential will rise.

The 1.5 GW identified under the base-case scenario would be sufficient to power more than a million homes and save the federal government $170M per year in energy costs. To install the 1.5 GW of electrical CHP generating capacity (all cases where the simple payback period is under 10 years) would require an estimated $1.5–$2 billion in capital investments. Since the average simple payback period for these projects was about 7 years, many could be financed through existing credit mechanisms supported by FEMP and agency partners [energy saving performance contracts (ESPCs), utility energy service contracts, enhanced use lease agreements, etc.]. The source (primary) energy savings from this level of CHP investment are estimated to be 50 trillion Btus per year, and projected carbon dioxide emissions would be reduced by 2.7 million metric tons per year compared to gas-fired central electric power and thermal alternatives.

Hurdles for CHP in Federal Sector

Although CHP technologies are proven and the potential savings and benefits are significant, project development over the past decade has been modest in the federal sector. Given the potential for CHP, why haven't more federal facilities installed this technology? Preliminary discussions with federal facility managers suggest that common reasons include:

- low historical tariffs for electricity;
- high initial cost of CHP systems;
- limited budgets (agencies rarely have sufficient appropriations for even much smaller energy conservation investments);
- complexity of CHP systems partly because of the need for custom engineering and design of different components for each site;
- a lack of time and capability for facility managers to evaluate potential applications and benefits to their site;
- obstacles related to local regulations and policies for interconnection, backup/standby fees, siting and emissions (see ORNL/TM- 2001/280);
- high maintenance costs of many old thermal distribution (steam) systems;
- lack of adequate fuel (gas) supply at the site; and
- a lack of trusted sources of information about the costs, operation, and performance of CHP systems.

FEMP's Strategy to Expedite Projects: ADD CHP

DOE and FEMP are working to address many of the obstacles through technical assistance, project financing, applied R&D, education and outreach. All these activities depend upon teaming with private and public partners for success.

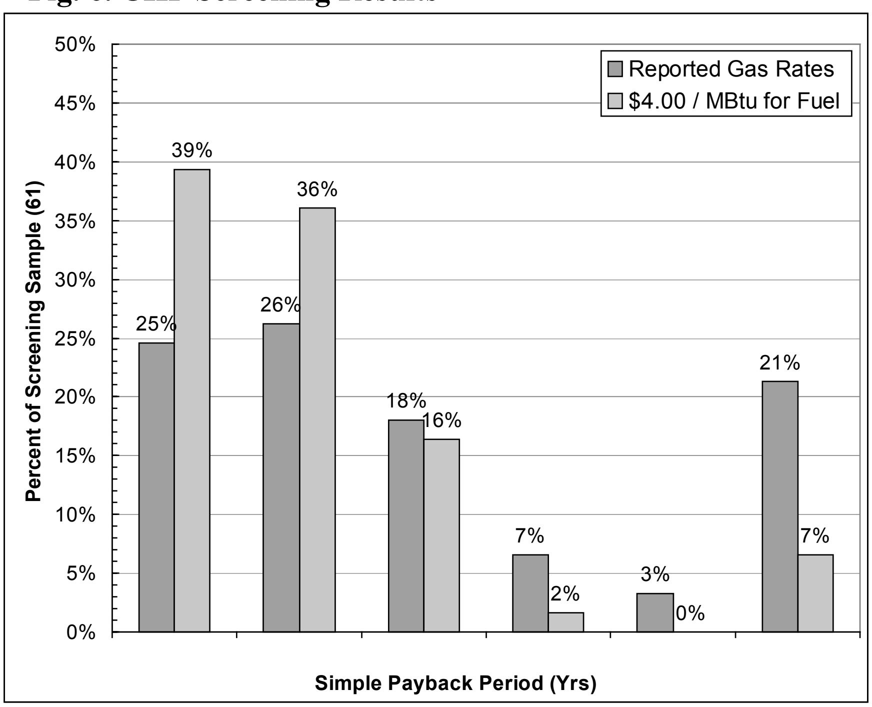
The initiative called "Accelerated Development and Deployment of Combined Heat and Power," or ADD CHP, is an integral part of FEMP's technical assistance program aimed at addressing the obstacles to CHP at federal sites. The strategy is to facilitate sound investments in CHP systems by providing qualified technical support and information focused on federal sites with good potential and champions motivated to develop a CHP project. ADD CHP offers federal agency partners support in many areas, including conducting CHP quick technical screening for interested federal sites; performing site survey and feasibility verification; fostering partnerships among federal, state, and private-sector project developers that bring financing if needed; providing support in addressing policy and regulatory constraints—siting and permitting, grid interconnection requirements, exit fees, standby/backup charges; providing conceptual design, component matching, and sizing verification (thermal/power profiles); and evaluating technical/price proposals.

CHP systems are costly to design and build. Federal agencies almost never have appropriated funds for this type of investment. Therefore, private partners who can provide financing and support design and construction are critical for success. While many private partners are already working with federal sites on traditional energy conservation measures, only a few have ventured into CHP projects. Private partners typically use their own at-risk funds to design projects and must get site approval of the design before moving forward. They naturally tend to first propose investments that can be designed at a low cost and are very likely to be approved. Uncertainties about future fuel and energy costs, changing rules and regulations related to permitting and interconnection, reluctance to "get into the power business," and the complexity of the initial design are all strong deterrents to CHP. If the site is not already convinced that CHP will be a cost-effective, mission-enhancing investment, private partners are unlikely to put their time and money at risk.

ADD CHP—Examples of Teaming for Results

As of February, more than 60 sites had requested CHP screening from FEMP. Requests have come in from 15 different states as well as Puerto Rico and the Virgin Islands, and from a broad range of federal agencies: VA, National Guard, DOE, Air Force, Army, Navy, NASA, Department of Justice (bureau of federal prisons), General Services Administration, and U.S. Postal Service. The screening form guides agency managers to focus on large buildings and campus style sites where there was over 1 MW of minimum electricity demand and clearly defined thermal needs. About 50% of the sites merited further study of their CHP potential (Fig. 6). FEMP and the private sector partner with sites to facilitate next steps. Examples of the teaming efforts on a few sites are described below.

Fig. 6. CHP Screening Results

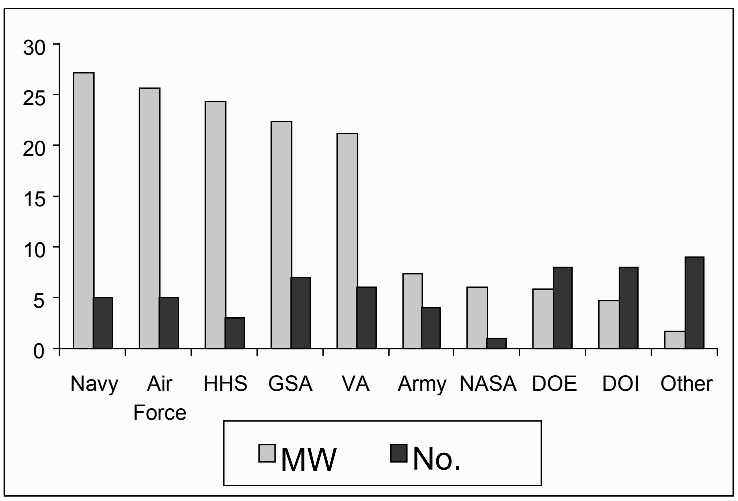


Fort Bragg, North Carolina. A memorandum of understanding formalized an ongoing relationship among FEMP, the U.S. Army's Ft. Bragg, and the Honeywell Corporation involving the evaluation of a CHP project at Fort Bragg, North Carolina. The primary private partner, Honeywell, is developing a proposal to install 5–12 MW of CHP capacity to reduce energy consumption at a central heating and cooling plant at the base. Fort Bragg, FEMP, and Honeywell have agreed to collaborate to enable FEMP to develop performance models and conduct an independent evaluation of this large advanced turbine CHP project.

National Park Service, New York. State, federal, and private partners are collaborating to fund the design and construction of a CHP micro-turbine demonstration project in the Gateway National Recreation Area in Brooklyn, New York. Microturbines will generate about 175 kW and supply heating and cooling to a Park Service building at Floyd-Bennett Field. The installation will form part of the Park Service's living demonstration of more sustainable urban development. The project is supported by the New York State Energy Research and Development Administration (NYSERDA) with cost sharing by the National Parks Service, FEMP, DOE's Office of Power Technologies (OPT), and Keyspan Energy (a gas distribution company). Landsberg Engineering received the competitive award from NYSERDA to implement the project and Capstone (turbines) and Broad USA (chiller) manufacturers are supporting the design.

About 50 federal sites (Fig. 7) are in different stages of investigating and implementing their CHP potential, including several that have already awarded contracts for design and construction.

Fig. 7. Federal Sites Planning and Developing CHP (Jan. 2002)



Conclusion: Partnerships Are Fundamental for Federal CHP

Many different types of partnerships are involved in making CHP technologies more accessible to federal facilities. DOE has partnered with the EPA and other state agencies to address emissions and regulatory issues. DOE-FEMP partners with individual sites to help identify CHP potential and facilitate next steps toward project development. Perhaps most important are the partnerships with the private sector. DOE has partnered with trade associations such as USCHPA to create a strategic path or roadmap to meet common goals.

DOE is supporting the development of "packaged" CHP systems for buildings through $18 million in cost-sharing with teams of private manufacturers. These efforts will lead to deployment of first-generation packaged CHP systems in hopes of bringing down system costs for standard applications. ORNL provides guidance to the industry contractors and manages the contracts for DOE. The Fort Bragg and NPS sites mentioned above will be test sites for these advanced systems.

Strong private partners can support sound design-build and turnkey CHP projects as well as offer a source of financing. And of course, FEMP is available to assist federal sites in their efforts to identify appropriate partners and deploy CHP. FEMP recognizes the significant potential for CHP technologies to reduce the costs of government, increase energy security, and improve air quality, and is actively working to make advanced CHP technologies more easily accessible to federal agencies throughout the nation.

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