Effect of a 30 Percent Investment Tax Credit on the Economic Market Potential for Combined Heat and Power

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Prepared for:

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WORLD ALLIANCE FOR DECENTRALIZED ENERGY

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Wade USA is the US member organization of the World Alliance for Decentralized Energy (WADE). WADE works to accelerate the worldwide development of high efficiency combined heat and power (CHP), onsite power and decentralized renewable energy systems that deliver substantial economic and environmental benefits. In an effort to raise the profile of CHP as a climate change mitigation strategy in the 1997 UNFCCC climate change negotiations, the International Cogeneration Alliance was founded. In 2002 the group changed its name to WADE and broadened its scope to include all manner of decentralized energy technologies. More information about WADE can be found at www.localpower.org.

The United States Clean Heat and Power Association (USCHPA), a trade association based in Washington, DC, represents companies and organizations to foster the use of clean, efficient local energy generation including combined heat and power (CHP) and other distributed generation sources that help reduce greenhouse gas emissions. More than 60 organizations and their affiliates (including several Fortune 500 companies), 300 individuals, and allied industry groups are USCHPA members. More information about USCHPA can be found at www.uschpa.org.

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1. Executive Summary

Combined heat and power (CHP), also known as cogeneration, is an efficient and clean approach to producing electricity and thermal energy at the point of use. Instead of purchasing electricity from a distant central station power plant and burning fuel in an on-site boiler to produce heat, an industrial, commercial or residential facility can use CHP to provide these energy services in one energy-efficient step. As a result, CHP can provide significant energy efficiency and environmental advantages over the separate generation of heat and power. A 2008 report from Oak Ridge National Laboratory estimated that full deployment of CHP could efficiently provide 20 percent of the nation's power, save almost 6 quadrillion Btu's of energy annually, eliminate greenhouse gas emissions (GHG) by an amount equivalent to removing 150 million cars from the road, and help grow the economy.[1]

While CHP promises to save energy and improve the environment at the same time it reduces users' operating costs, investment in CHP systems has stalled in recent years. Economic uncertainty, volatile energy prices, regulatory barriers and lack of financing have all taken their toll on CHP deployment. Noting that a number of states are beginning to tackle regulatory barriers, the federal government, through the Energy Improvement and Extension Act of 2008, has focused on addressing financing issues and established a ten percent investment tax credit for qualified CHP projects through 2016. This existing incentive is capped at 50 megawatts (MW) and limited to a project's first 15 MW.

CHP users, developers and equipment and service providers have urged the strengthening of the CHP tax credit in order to spur additional development of efficient CHP and clean waste heat to power projects. Various proposals have been introduced to remove the 50 MW cap on qualified systems (Bingaman-Snowe – S 1639, Thompson-Linder – H.R. 4455, and Inslee – H.R. 4144). Other proposals (Tonko – H.R. 4751) consider establishing a 30 percent ITC for highly-efficient projects. Supporters note that increasing the ITC to 30 percent for "highly efficient" CHP technologies will accelerate energy efficiency, reduce greenhouse gas emissions, increase operational reliability, and provide economic savings that will enhance business strength. Since many CHP components are manufactured in the United States, enhanced tax credits also will help grow the nation's industrial base.

ICF International analyzed the projected impact on CHP development of both an expansion to the 10 percent ITC (applied to the first 25 MW of capacity for systems of any size) as well as the introduction of a 30 percent ITC for high efficiency CHP (projects with overall efficiencies of 70 percent lower heating value or greater). The analysis was limited to traditional topping cycle CHP systems utilizing reciprocating engines, gas turbines or microturbines (bottoming cycle CHP opportunities, sometimes referred to as waste heat recovery or recycled energy, were not reviewed).The projected impacts include:

- The expanded 10 percent ITC increases CHP deployment by about 20 percent over a no ITC baseline (550 additional MW between now and 2017).
- The expanded 10 percent ITC results in an annual energy savings of 118 trillion Btu's and an annual reduction in CO_2 emissions of 14 million metric tons (MMT), equivalent to removing 2.6 million cars from the road[2]. Investment in the projects represented by the expanded 10 percent ITC results in over 17,000 highly skilled, well paying jobs.[3]

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[1] Oak Ridge National Laboratory. "Combined Heat and Power: Effective Energy Solutions for a Sustainable Future." December 2008.

[2] Based on displacing eGRID 2007 national average fossil generation (heat rate = 9,934 Btu/kWh and CO2 emissions of 1,841 lbs/MWh; average T&D losses of 7 percent)

[3] Based on four jobs created for every $1 million in capital investment, Oak Ridge National Laboratory. "Combined Heat and Power: Effective Energy Solutions for a Sustainable Future." December 2008.

- The 30 percent ITC for highly efficient CHP increases CHP deployment by more than 60 percent over a no ITC baseline (1,600 additional MW between now and 2017).
- The 30 percent ITC results in an annual energy savings of 162 trillion Btu's and an annual reduction in CO_2 emissions of over 19 million metric tons (MMT), equivalent to removing 3.4 million cars from the road. Investment in the projects represented by the 30 percent ITC results in over 23,000 highly skilled, well paying jobs.

CHP technology can be deployed quickly, cost-effectively and with few geographic restrictions. Strengthening the existing ITC for CHP is a near-term path to significantly reducing our nation's energy use, improving our environment and growing the economy.

2. Introduction

Combined heat and power (CHP), also known as cogeneration, is an efficient and clean approach to generating electricity or mechanical power and useful thermal energy from a single fuel source at the point of use. Instead of purchasing electricity and then burning fuel in an on-site furnace or boiler to produce thermal energy, an industrial or commercial facility can use CHP to provide these energy services in one energy-efficient step. As a result, CHP can provide significant energy efficiency and environmental advantages over separate heat and power. For optimal efficiency, CHP systems typically are designed and sized to meet the users' thermal baseload demand.

CHP technology can be deployed quickly, cost-effectively, and with few geographic limitations. CHP systems are located at or near end-users, and therefore defer or reduce construction of new transmission and distribution (T&D) infrastructure. While the traditional method of producing separate heat and power has a typical combined efficiency of 45 percent, CHP systems can operate at efficiency levels as high as 80 percent. CHP's high efficiency results in less fuel use and lower levels of greenhouse gases emissions. CHP in the United States today avoids more than 1.9 Quadrillion Btus of fuel consumption and 248 million metric tons of CO_2 emissions compared to traditional separate production of electricity and heat[4]. This CO_2 reduction is the equivalent of removing more than 45 million cars from the road. Figure 1 depicts the emissions savings that are achievable through CHP in comparison to separate heat and power generation.

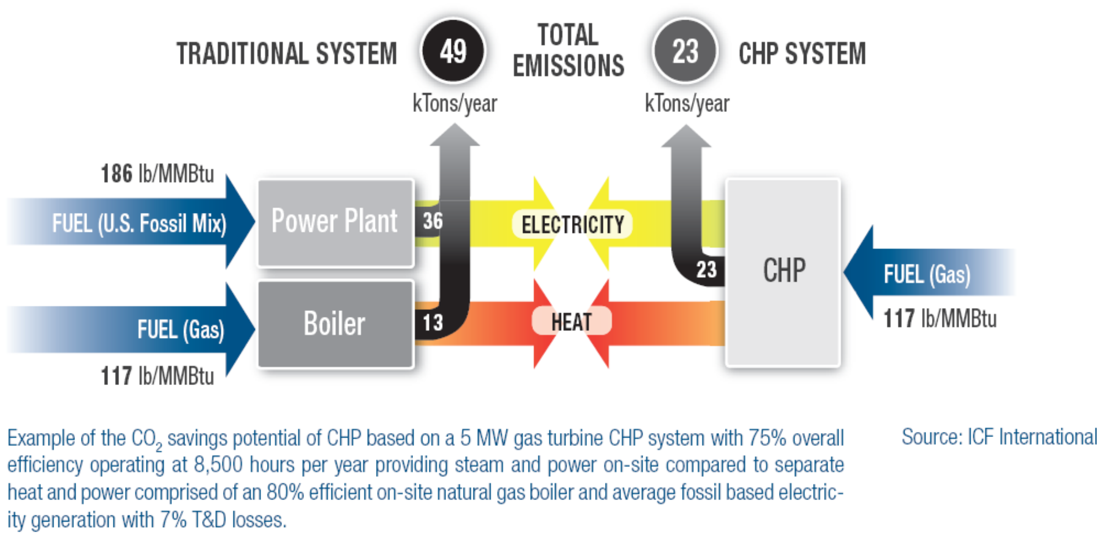

Figure 1 Increased Efficiency of CHP Results in Carbon Emissions Savings

[4] Oak Ridge National Laboratory. "Combined Heat and Power: Effective Energy Solutions for a Sustainable Future." December 2008.

The size of CHP systems can range from 1 kW (the demand of a single-family home) to several hundred MW (the demand of a large petroleum-refining complex). Due to this size flexibility, CHP can be utilized in a variety of applications. Eighty-eight percent of current U.S. CHP capacity is found in industrial applications, providing power and steam to large industries such as chemicals, paper, refining, food processing, and metals manufacturing. CHP in commercial and institutional applications is currently 12 percent of existing capacity, providing power, heating, and cooling to hospitals, schools, campuses, nursing homes, hotels, and office and apartment complexes[5].

The *Energy Improvement and Extension Act of 2008*, signed into law October 3, 2008 as part of the *Emergency Economic Stabilization Act* (P.L. 110-343) included a 10% investment tax credit (ITC) for CHP projects through 2016. The ITC is equal to 10% of the costs of the first 15 megawatts of qualifying CHP "energy property". Eligible CHP property includes systems up to 50 MW in size that meet or exceed 60% total energy efficiency (Lower Heating Value).

CHP users and developers have urged for the strengthening of the CHP tax credit to spur additional development of efficient CHP and clean waste heat to power projects. Various proposals have been introduced to remove the 50 MW cap on qualified systems (Bingaman-Snowe – S 1639, Thompson-Linder – H.R. 4455, and Inslee – H.R. 4144). Other proposals (Tonko – H.R. 4751) consider establishing a 30 percent ITC for highly-efficient projects. Increasing the ITC to 30 percent for "highly efficient" CHP technologies will help to accelerate the benefits that CHP provides of energy efficiency, reduction in greenhouse gas emissions, operational reliability, and economic savings that will enhance business strength. An enhanced CHP ITC will also support overall goals of increasing business investment and promoting economic recovery.

This report presents an analysis of the technical potential and projected market penetration for traditional topping cycle CHP in the U.S. under three different ITC scenarios in order to gauge the potential impacts of these proposals. The three scenarios analyzed include

- No ITC,
- 10 percent ITC for the first 25 MW for systems of any size, and
- 30 percent ITC for the first 25 MW for systems of any size *for highly efficient applications (defined as 70 percent lower heating value efficiency or greater)*.

For all cases, the ITC is assumed to be in place through December 31, 2017.

The analysis presented in this report is based on the *ICF CHP Market Model* that estimates cumulative CHP market penetration as a function of CHP system specifications, current and future energy prices, and electric and thermal load characteristics for target markets. The CHP analysis includes the following four steps:

- Estimate of CHP Technical Market Potential – An estimate of technically suitable CHP applications by size and by industry. This estimate is derived from the screening of facility-specific data based on application and size characteristics to estimate groups of facilities with electric and thermal load characteristics conducive to CHP.
- CHP Technology Characterization – For each market size range, a representative CHP technology is selected for evaluation. The technologies are characterized in terms of their capital cost, heat rate, non-fuel operating and maintenance costs, and available thermal energy for process use on-site
- Estimate of Energy Prices – Latest DOE Energy Information Agency (EIA) state average natural gas and electricity prices for large users were used as inputs into the CHP net cost calculation.

[5] CHP Installation Database. Maintained by ICF International for Oak Ridge National Laboratory and the US Department of Energy. 2010. http://www.eea-inc.com/chpdata/index.html

- Estimate of CHP Market Penetration – Within each market size, the amount of economically acceptable CHP capacity is evaluated based on simple payback. The rate of market penetration over time (in this case through 2017) is estimated based on an S-shaped market diffusion curve.

Limitations of the analysis

The objective of the analysis described in this report was to develop a first level estimate of the impact of various investment tax credit proposals on the anticipated market development of traditional topping-cycle CHP between 2010 and the end of 2017. Although the analysis of CHP technical potential and economic performance was conducted at the state level and aggregated to develop a national perspective, certain simplifying assumptions and approaches were necessarily used in order to complete the analysis within constraints on both schedule and resources. Simplifying assumptions include such items as:

- The analysis was limited to traditional topping cycle CHP systems utilizing reciprocating engines, gas turbines or microturbines; bottoming cycle CHP opportunities, sometimes referred to as waste heat recovery or recycled energy, were not reviewed.
- The analysis is based on average state electricity and natural gas prices. A more detailed assessment would be based on an analysis of specific prices for major utility regions within each state, and differentiate electricity and natural gas price tracks for high load and low load CHP applications.
- A more detailed analysis would also incorporate the specific standby rates and supplemental tariffs of major utilizes in each state.
- A more detailed analysis would incorporate regional differences in equipment and labor costs, and in emissions requirements into the cost and performance assumptions for the competing CHP technologies.
- A more detailed state by state analysis would include a correlation of model results with recent market activity in each state to calibrate differences in risk perception and resulting market acceptance rates among market regions.

Notwithstanding these limitations, we believe the analysis provides a reasonable estimate of the impact of targeted investment tax credits on the economic performance and resultant market acceptance of natural gas CHP systems at the national level.

Organization of the Report:

- **CHP Technical Potential** – An estimate of the overall size of the topping-cycle CHP market including the size and types of targeted applications.

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- **Market Penetration Model –** A description of the *ICF CHP Market Model* that estimates cumulative CHP market penetration as a function of CHP system specifications, current energy prices, and electric and thermal load characteristics of target markets. This section includes a summary of critical assumptions used in the analysis including the cost and performance of applicable CHP technologies, and natural gas and electricity price projections.

- **CHP Market Penetration Results –** A summary of the CHP penetration results for the three ITC scenarios.

3. CHP Technical Potential

This section provides an estimate of the technical market potential for combined heat and power in the industrial, commercial/institutional, and multi-family residential market sectors in the U.S. The CHP technical potential is an estimation of market size constrained only by technological limits – the ability of CHP technologies to fit customer energy needs. CHP technical potential is calculated in terms of CHP electrical capacity that could be installed at existing industrial, commercial and institutional facilities based on the estimated electric and thermal needs of the site. The technical market potential does not consider screening for economic rate of return, or other factors such as ability to retrofit, owner interest in applying CHP, capital availability, natural gas availability, and variation of energy consumption within customer application/size class. The technical potential as outlined is useful in understanding the potential size and distribution of the target CHP market in an area. Identifying the technical market potential is a preliminary step in the assessment of actual economic market size and ultimate market penetration.

CHP is best applied at facilities that have significant and concurrent electric and thermal demands. In the industrial sector, CHP thermal output has traditionally been in the form of steam used for process heating and for space heating. For commercial and institutional users, thermal output has traditionally been steam or hot water for space heating and domestic hot water heating, and more recently, for providing space cooling through the use of absorption chillers. Two different types of CHP markets were included in this evaluation of technical potential: 1) traditional power and heat CHP, and 2) cooling, heating and power CHP. Both of these markets were further disaggregated by high load factor and low load factor applications resulting in the analysis of four distinct market segments.

3.0.1 Traditional Power and Heat CHP

This market represents CHP systems where the electrical output is produced to meet all or a portion of the base load for a facility and the thermal energy is used to provide steam or hot water. The most efficient sizing for CHP is to match thermal output to baseload thermal demand at the site. Depending on the type of facility, the appropriate sizing could be either electric or thermal limited. Industrial facilities often have "excess" thermal load compared to their on-site electric load (meaning the CHP system will generate more power than can be used on-site if sized to match the thermal load). In this case, potential CHP capacity was limited to on-site electric demand. Commercial facilities almost always have excess electric load compared to their thermal load. Two sub-categories were considered:

- *High load factor applications:* This market provides for continuous or nearly continuous operation. It includes all industrial applications and round-the-clock commercial/institutional operations such colleges, hospitals, hotels, and prisons.
- *Low load factor applications:* Some commercial and institutional markets provide an opportunity for coincident electric/thermal loads for a period of 3,500 to 5,000 hours per year. This sector includes applications such as office buildings, schools, and laundries.

3.0.2 Cooling, Heating and Power CHP

All or a portion of the thermal output of a CHP system can be converted to air conditioning or refrigeration with the addition of a thermally activated cooling system. This type of system can potentially open up the benefits of CHP to facilities that do not have the year-round heating load to support a traditional CHP system. A typical cooling, heating and power system would provide the annual hot water load, a portion of the space heating load in the winter months and a portion of the cooling load during the summer months. Two sub-categories were considered:

- *Incremental high load factor applications:* These markets represent round-the-clock commercial/institutional facilities that could support traditional CHP, but with consideration of cooling as an output, could support additional CHP capacity while maintaining a high level of utilization of the thermal energy from the CHP system.

- *Low load factor applications.* These represent cooling and heating CHP markets that otherwise could not support traditional CHP due to a lack of thermal load

3.1 Estimating CHP Technical Potential

The determination of technical market potential consists of the following elements:

- Identify applications where CHP provides a reasonable fit to the electric and thermal needs of the user. Target applications were identified based on reviewing the electric and thermal energy consumption data for various building types and industrial facilities.

- Quantify the number and size distribution of target applications. The Dun & Bradstreet Hoovers Database was used to identify the number of facilities in each state by target application and size range[6].

- Estimate CHP potential in terms of megawatt (MW) capacity. Total CHP potential is then derived for each target application based on the number of target facilities in each size category and CHP sizing criteria appropriate for each sector.

- Subtract existing CHP from the identified sites to determine the remaining technical market potential.

3.1.1 CHP Target Applications

In general, the most efficient and economic CHP operation is achieved when: 1) the system operates at full-load most of the time (high load factor application), 2) the thermal output can be fully utilized by the site, and 3) the recovered heat displaces fuel or electricity purchases.

There are a number of commercial and industrial applications that characteristically have sufficient and coincident thermal and electric loads for CHP. Examples of these applications include food processing, pulp and paper plants, laundries and health clubs. Most commercial and light industrial applications have low base thermal loads relative to the electric load, but have high thermal loads in the cooler months for heating. Such applications include hotels, hospitals, nursing homes, college campuses, correctional facilities, and light manufacturing.

In order to identify a complete list of applications where CHP provides a reasonable fit to the electric and thermal needs of the user, ICF reviewed electric and thermal energy (heating and cooling) consumption data for various building types and industrial facilities. Data sources included the DOE EIA *Commercial Buildings Energy Consumption Survey (CBECS),* the DOE *Manufacturing Energy Consumption Survey (MECS)* and various market summaries developed by DOE, Gas Technology Institute (GRI), and the American Gas Association. Existing CHP installations in the commercial/institutional and industrial sectors were also reviewed to understand the required profile for CHP applications and to identify target applications.

There are two fundamental approaches to sizing CHP systems for a given application based on what the thermal energy will be used for:

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[6] The CHP Market Model includes estimates of electricity and thermal loads for each target application as a function of facility size (e.g., employees, square footage, etc).

- Traditional Power and Heat CHP - Size the CHP system for the base thermal load (process steam, domestic hot water, pool heating, showers, laundries, kitchens).
- Cooling, Heating and Power CHP - Size the CHP system to include thermally activated cooling to create additional thermal use during the cooling months that when combined with space heating justifies a larger CHP system that better matches the electric demand.

The following two tables show the target applications identified in these two categories as well as their assumed load profiles. Applications with a high load factor were assumed to operate for 7,000 hours a year, whereas applications with a low load factor were assumed to operate for 4,500 hours a year. The category and load profile combinations comprise the markets that were defined at the beginning of this section.

In addition to separating the technical potential into traditional and cooling markets, this analysis differentiates between high efficiency and standard efficiency CHP applications. While many CHP technologies can be configured to meet a 70 percent LHV efficiency threshold by recovering all available thermal energy, it was recognized that this efficiency level is not typical in applications with large variations in thermal demand over the year such as seasonally-dependent heating and cooling loads. The lack of significant heating and/or cooling loads in shoulder months (fall and spring) often limits the amount of thermal output usefully captured, resulting in annual CHP system efficiencies that are below the 70 percent threshold. Tables 1 and 2 indicate which applications were assumed to have year-long heating and cooling loads supporting high efficiency (qualifying for the 30 percent ITC) and which were assumed to have seasonally impacted loads or other factors that might limit full thermal recovery (standard efficiency applications that will not meet the 30 percent efficiency threshold). These standard efficiency applications still operate at efficiency levels well above separate heat and power; however their inability to utilize all of the thermal energy from the CHP system during a portion of the year limits their ability to meet the 70 percent threshold. In some applications, it is usual for CHP systems to be operated only during the business hours of the host facility, rather than round the clock like traditional power generation plants. In this case, CHP system downtime, when the system is not running, is not a factor in the efficiency of the CHP system, rather the efficiency is determined based on the utilization of the electricity and thermal energy produced by the system while it is operating.

The target applications were also categorized as tax-liable or non tax-liable. Tax-liable applications were assumed to be comprised of primarily private, for-profit firms that could utilize the CHP tax credits. Non tax-liable applications were assumed be comprised primarily of public and/or not-for-profit organizations that would have difficulty in utilizing the tax incentives.

Table 1 Traditional Combined Heat and Power Target Applications

Sector	SIC	Application	Load Factor	CHP Efficiency	Tax-Liable
Industrial	20	Food & Beverage	High	High	Yes
Industrial	22	Textiles	High	High	Yes
Industrial	24	Lumber and Wood	High	High	Yes
Industrial	25	Furniture	High	Standard	Yes
Industrial	26	Paper	High	High	Yes
Industrial	27	Printing/Publishing	High	Standard	Yes
Industrial	28	Chemicals	High	High	Yes
Industrial	29	Petroleum Refining	High	High	Yes
Industrial	30	Rubber/Misc Plastics	High	High	Yes
Industrial	32	Stone/Clay/Glass	High	High	Yes
Industrial	33	Primary Metals	High	High	Yes
Industrial	34	Fabricated Metals	High	High	Yes
Industrial	35	Machinery/Cptr Equip	High	Standard	Yes
Industrial	37	Transportation Equip.	High	High	Yes
Industrial	38	Instruments	High	Standard	Yes
Industrial	39	Misc Manufacturing	High	Standard	Yes
Commercial/Institutional	4952	Waste Water Treatment	High	High	No
Commercial/Institutional	9223	Prisons	High	High	No
Commercial/Institutional	7211	Laundries	Low	High	Yes
Commercial/Institutional	7991	Health Clubs	Low	Standard	Yes
Commercial/Institutional	7997	Golf/Country Clubs	Low	Standard	Yes
Commercial/Institutional	7542	Carwashes	Low	Standard	Yes

Table 2 Cooling. Heating and Power Target Applications

Sector	SIC	Application	Load Factor	CHP Efficiency	Tax-Liable
Commercial/Institutional	43	Post Offices	Low	Standard	No
Commercial/Institutional	52,53,56,57	Big Box Retail	Low	Standard	Yes
Commercial/Institutional	4222	Refrig Warehouses	High	High	Yes
Commercial/Institutional	4581	Airports	Low	High	Yes
Commercial/Institutional	5411	Food Sales	Low	Standard	Yes
Commercial/Institutional	5812	Restaurants	Low	Standard	Yes
Commercial/Institutional	6512	Commercial Buildings	Low	Standard	Yes
Commercial/Institutional	6513	Multi-Family Buildings	High	Standard	Yes
Commercial/Institutional	7011	Hotels	High	Standard	Yes
Commercial/Institutional	7374	Data Centers	High	High	Yes
Commercial/Institutional	7832	Movie Theaters	Low	Standard	Yes
Commercial/Institutional	8051	Nursing Homes	High	High	Yes - 67%
Commercial/Institutional	8062	Hospitals	High	High	Yes - 15%
Commercial/Institutional	8211	Schools	Low	Standard	No
Commercial/Institutional	8221	Colleges/Universities	High	High	No
Commercial/Institutional	8412	Museums	Low	Standard	No
Commercial/Institutional	9100	Government Facilities	Low	Standard	No

3.1.2 *Identification of Target Facilities*

Various commercial and industrial facility databases were used to identify the number of target application facilities in the U.S. by sector and by size (electric demand) that meet the thermal and electric load requirements for CHP. The primary data source to identify potential targets for CHP installations was the Dunn & Bradstreet (D&B) *Hoovers* Database. The D&B *Hoovers* Database contains information on the majority of businesses throughout the country and can be sorted to provide a listing of industrial and commercial facilities in a specific region. This analysis used a set of data consisting of facilities that have more than five employees and are in the target applications specified above. The site data includes information on:

- Company name
- Facility location (street address, county, latitude/longitude)
- Line of business (primary SIC code and primary NAICS code)
- Number of employees (at total company and at individual site)
- Annual sales

More than 250,000 sites from the D&B *Hoovers* database were screened for CHP potential in this study. Information on facilities in the commercial buildings and multi-family housing sectors came from US Census Bureau statistics, and data on airports came from a Federal Aviation Administration (FAA) database of airports in the U.S.

3.1.3 *Estimating Electric and Thermal Loads and CHP System Sizing*

To calculate the total technical potential for CHP, each of the potential facilities needs to have a model CHP system sized to its electrical and thermal loads. The sum of all the individual CHP system potentials for each site results in the overall total CHP potential for the region being analyzed.

It was assumed that the CHP systems would be sized to meet the base thermal loads (heating and cooling) of a site unless the CHP system sizing exceeded the average facility electric demand. In this case, the CHP system size would be limited to the site's average electric demand. Total annual kWh electricity load is estimated for each site using algorithms in the CHP Market Model based on such characteristics as number of employees, annual sales or facility square footage. The average electric demand of each facility in the dataset was estimated by dividing the total kWh electricity load by the typical operating hours corresponding with the application's load factor (7,000 hours a year for high load factor, 4,500 hours a year for low load factor).

The thermal demand was then developed for each site based on application-specific estimates of the ratio of electricity load to thermal load. Information on thermal load for the target CHP applications was derived from data in DOE's *Commercial Buildings Energy Consumption Survey (CBECS),* and *Manufacturing Energy Consumption Survey (MECS)*, the *Major Industrial Plant Database (MIPD*), and *Commercial Energy Profile Database (CEPD*), as well as studies of industrial electric and thermal profiles developed by DOE, Gas Technology Institute (GRI), and the American Gas Association. These data sources provided information on the end use energy consumption in commercial and industrial facilities, allowing an average power-to-heat ratio for each target application to be developed. This electric and thermal data was used to develop size-specific thermal factors for each target application that are used to estimate the CHP system size as a function of average electric demand. The thermal factor is based on both the power-to-heat ratio (P/H) of the application as well as the P/H ratio of a typical CHP system for that application.

3.2 CHP Technical Potential Estimates

This section presents the CHP technical potential estimates by application class (industrial and commercial/institutional) and size range (< 1 MW, 1 to 5 MW, 5 to 20 MW and > 20 MW). The estimates of CHP technical potential are based on thermally loaded CHP systems sized to serve on-site electric demands at target facilities and do not include export capacity.

Table 3 Industrial CHP Technical Potential by State

State	50 -1000 kW (MW)	1 - 5 MW (MW)	5 - 20 MW (MW)	>20 MW (MW)	Total (MW)
Alabama	209	359	266	272	1,106
Alaska	26	28	18	29	101
Arizona	122	143	167	93	525
Arkansas	148	225	162	198	733
California	1,467	1,403	1,042	245	4,157
Colorado	117	138	176	0	432
Connecticut	125	116	144	202	587
Delaware	28	90	115	363	596
Florida	376	422	248	207	1,252
Georgia	406	617	701	530	2,253
Hawaii	26	14	14	0	54
Idaho	66	83	64	50	263
Illinois	519	641	978	2,001	4,139
Indiana	331	422	427	299	1,480
Iowa	171	287	227	252	937
Kansas	117	192	184	296	789
Kentucky	193	223	418	972	1,806
Louisiana	152	294	598	688	1,733
Maine	70	58	142	334	603
Maryland	126	136	144	253	658
Massachusetts	232	284	237	312	1,065
Michigan	454	435	690	735	2,314
Minnesota	247	324	332	172	1,075
Mississippi	138	187	238	350	913
Missouri	215	345	290	223	1,073
Montana	36	36	48	25	146
Nebraska	80	118	47	21	266
Nevada	46	51	25	125	248
New Hampshire	53	52	85	65	255
New Jersey	380	472	534	328	1,713
New Mexico	37	78	61	41	217
New York	523	590	570	762	2,445
North Carolina	540	740	918	2,468	4,667
North Dakota	31	36	69	0	136
Ohio	568	873	1,042	901	3,384
Oklahoma	104	184	209	366	863
Oregon	203	253	159	272	887
Pennsylvania	517	743	943	1,721	3,924
Rhode Island	45	72	36	37	190
South Carolina	249	392	496	516	1,652
South Dakota	26	58	52	0	136
Tennessee	280	347	539	441	1,606
Texas	731	1,181	1,380	501	3,793
Utah	91	128	131	108	458
Vermont	39	40	39	0	118
Virginia	239	333	361	534	1,466
Washington	258	231	199	509	1,197
West Virginia	62	56	145	263	527
Wisconsin	375	519	642	817	2,352
Wyoming	15	36	39	443	533
Total	11,607	15,085	16,789	20,343	63,823

Table 4 Commercial CHP Technical Potential by State

State	50 -1000 kW (MW)	1 - 5 MW (MW)	5 - 20 MW (MW)	>20 MW (MW)	Total (MW)
Alabama	538	290	70	74	973
Alaska	80	38	8	0	125
Arizona	772	451	136	62	1,421
Arkansas	330	198	28	70	625
California	1,973	1,948	1,276	654	5,850
Colorado	555	321	99	54	1,030
Connecticut	492	396	78	0	966
Delaware	104	59	21	0	184
Florida	2,464	1,456	288	76	4,284
Georgia	1,093	697	130	0	1,921
Hawaii	183	165	15	20	383
Idaho	146	86	0	16	248
Illinois	1,972	1,232	40	134	3,379
Indiana	921	582	0	91	1,593
Iowa	444	279	0	15	738
Kansas	409	238	0	63	709
Kentucky	469	291	0	47	806
Louisiana	518	325	0	117	960
Maine	176	142	0	6	324
Maryland	682	457	0	75	1,214
Massachusetts	976	755	0	140	1,872
Michigan	1,391	943	0	99	2,434
Minnesota	865	515	0	55	1,434
Mississippi	312	193	0	95	600
Missouri	847	569	0	117	1,533
Montana	101	46	0	15	162
Nebraska	267	165	63	0	494
Nevada	317	264	217	25	824
New Hampshire	184	130	9	0	322
New Jersey	1,133	875	421	28	2,457
New Mexico	223	107	16	0	345
New York	2,851	2,671	820	259	6,600
North Carolina	1,018	533	133	77	1,761
North Dakota	110	63	24	0	196
Ohio	1,219	826	186	0	2,231
Oklahoma	403	249	40	49	741
Oregon	399	241	42	0	681
Pennsylvania	1,631	1,442	233	155	3,461
Rhode Island	159	117	22	0	298
South Carolina	518	248	44	0	810
South Dakota	119	67	14	0	199
Tennessee	725	443	112	0	1,280
Texas	2,020	1,375	425	44	3,863
Utah	273	169	25	0	467
Vermont	85	61	19	0	166
Virginia	966	629	186	42	1,822
Washington	705	436	85	57	1,284
West Virginia	195	132	24	0	351
Wisconsin	857	575	103	0	1,535
Wyoming	65	26	7	0	98
Total	35,252	24,516	5,458	2,831	68,056

Table 5 Industrial CHP Technical Potential by Application

SIC	Application	50 -1000 kW (MW)	1 - 5 MW (MW)	5 - 20 MW (MW)	>20 MW (MW)	Total (MW)
20	Food	2,744	3,250	1,330	697	8,021
22	Textiles	586	751	726	176	2,239
24	Lumber and Wood	1,413	854	332	164	2,762
25	Furniture	44	2	0	0	46
26	Paper	1,230	1,869	3,601	7,597	14,297
27	Printing/Publishing	173	23	5	0	202
28	Chemicals	2,306	5,875	8,165	8,223	24,569
29	Petroleum Refining	424	897	697	1,941	3,959
30	Rubber/Misc Plastics	1,023	314	120	28	1,486
32	Stone/Clay/Glass	88	122	53	0	263
33	Primary Metals	406	532	953	1,214	3,104
34	Fabricated Metals	254	21	6	0	281
35	Machinery/Computer Equip	74	62	17	0	153
37	Transportation Equip.	681	469	725	304	2,179
38	Instruments	76	23	24	0	123
39	Misc Manufacturing	85	20	34	0	139
	Total	11,607	15,085	16,789	20,343	63,823

Table 6 Commercial CHP Technical Potential by Application

SIC	Application	50 -1000 kW (MW)	1 - 5 MW (MW)	5 - 20 MW (MW)	>20 MW (MW)	Total (MW)
43	Post Offices	29	11	0	0	41
52	Retail	1,662	251	25	30	1,968
4222	Refrigerated Warehouses	67	33	9	7	116
4581	Airports	125	261	290	0	676
4952	Wastewater Treatment	111	66	0	0	177
5411	Food Stores	1,079	65	41	0	1,185
5812	Restaurants	1,179	62	15	0	1,256
6512	Commercial Buildings	20,378	12,842	0	0	33,220
6513	Multifamily Buildings	3,774	1,325	0	0	5,099
7011	Hotels	1,330	1,386	460	209	3,384
7211	Laundries	116	13	0	0	129
7374	Data Centers	272	380	339	46	1,037
7542	Car Washes	43	3	0	0	45
7832	Movie Theaters	3	1	0	0	5
7991	Health Clubs	125	26	8	0	159
7997	Country Clubs	235	28	15	0	278
8051	Nursing Homes	765	159	13	0	937
8062	Hospitals	892	3,179	769	345	5,185
8211	Schools	789	87	0	0	876
8221	College/Universities	641	1,648	1,669	1,471	5,429
8412	Museums	41	13	0	0	54
9100	Govt. Buildings	1,276	1,334	955	170	3,735
9223	Prisons	318	1,343	850	554	3,065
	Total	35,252	24,516	5,458	2,831	68,056

4. CHP Market Penetration Model

The *ICF CHP Market Model* estimates cumulative CHP market penetration as a function of CHP system economic performance (the model assumes that the acceptance decision is based on the payback achieved from on-site use of generated power and thermal energy). The economic performance is a function of the CHP system specifications, current and future energy prices, and electric and thermal load characteristics of the applications considered. There are four markets defined by application type. Within each application type, there are four size bins. Each market application and size is defined in terms of the CHP operating load factor and the degree and type of thermal energy utilization.

The CHP Technical Potential estimates by application are grouped into four market sectors as described below:

1. High load factor markets are applications that have electric and thermal load around the clock such as industrial facilities.
2. Low load factor markets are applications that have more daily load variation and are generally not considered to be 24-hour facilities like car washes, health clubs, and laundries.
3. High load factor heating and cooling markets are 24/7 facilities that require a constant amount of baseload electricity and can utilize available thermal energy in a combination of heating and cooling applications such as nursing homes, colleges, and hospitals.
4. Low load factor heating and cooling markets are facilities with shorter operating hours that would operate a CHP system intermittently using available thermal energy for both heating and cooling. Representative applications in this category include schools, post offices, and office buildings.

Within each of these market segments, CHP economic competition is considered in each of the four system size bins. Each size bin has its own assumptions about load factor and degree of thermal energy used. In addition, each size bin reflects a specific CHP technology appropriate for that size range (see Figure 2).

4.1 Major Market Model Input Assumptions

The cost and performance of the CHP systems and the relationship between natural gas and electricity prices are the major determinants of the ability of a facility to cost-effectively utilize CHP.

4.1.1 CHP Technology Cost and Performance Assumptions

The cost and performance characteristics of CHP systems determine the economics of meeting the site's electric and thermal loads. Most notable technology options available today for CHP include industrial and aero-derivative gas turbines, reciprocating engines, microturbines and fuel cells. Natural gas is the primary fuel option for these technologies because of its availability, relative cost and emissions qualities. This analysis assumes the CHP systems will run on natural gas.

Of the inventory of operating CHP capacity in the U.S., gas turbines and combined cycle units (gas turbines incorporating a steam turbine bottoming cycle) account for a majority of the capacity, while reciprocating engines dominate the number of installations. The competitive size span for the various CHP technology classes is depicted in the figure below. Also noted are the market dominant technologies by size category

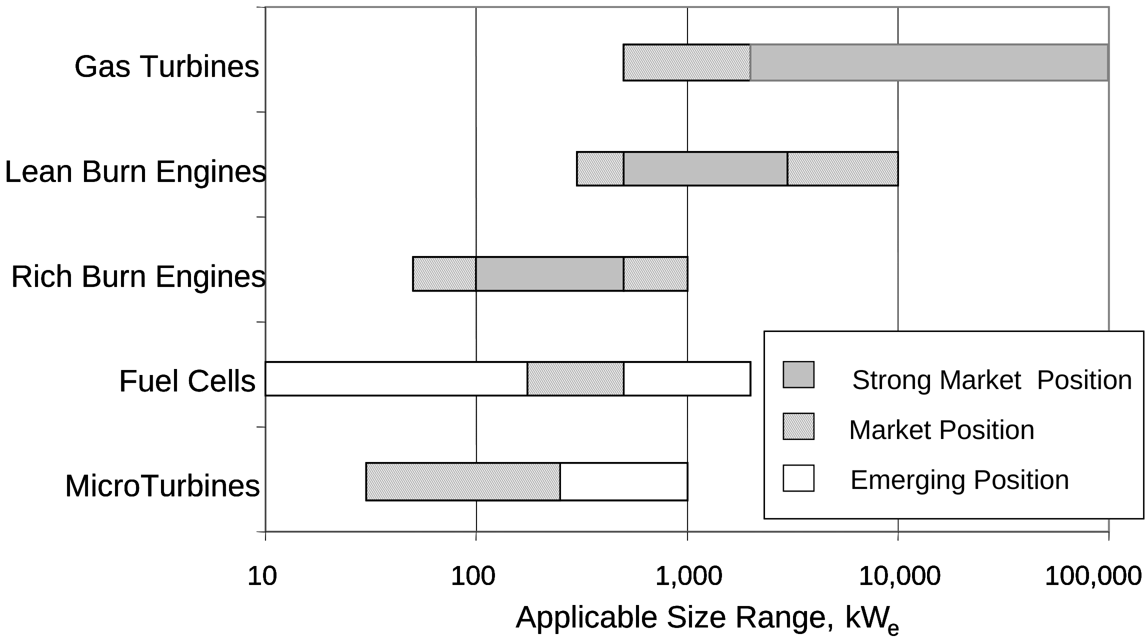

Figure 2 Technology Size Coverage

A representative sample of commercially available CHP systems was used to profile typical cost and performance characteristics in CHP applications. Cost and performance estimates for the CHP systems were based on work undertaken for the EPA[7] and currently being updated through a contract with ORNL. The foundation for these estimates is based on work previously conducted for NYSERDA[8], on peer-reviewed technology characterizations that Energy and Environmental Analysis (EEA) developed for the National Renewable Energy Laboratory[9] and on follow-on work conducted by DE Solutions for Oak Ridge National Laboratory.[10] Additional emissions characteristics and cost and performance estimates for emissions control technologies were based on work ICF conducted for EPRI.[11] Data is presented for a range of sizes that include basic electrical performance characteristics, CHP performance characteristics (power to heat ratio), equipment cost estimates, maintenance cost estimates, and emissions control cost estimates.

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[7] EPA CHP Partnership Program, Technology Characterizations, December 2007.
[8] *Combined Heat and Power Potential for New York State*, Energy Nexus Group (later became part of EEA), for NYSERDA, May 2002.
[9] "Gas-Fired Distributed Energy Resource Technology Characterizations", NREL, November 2003, http://www.osti.gov/bridge
[10] "Clean Distributed Generation Performance and Cost Analysis", DE Solutions for ORNL. April 2004.
[11] "Assessment of Emerging Low-Emissions Technologies for Distributed Resource Generators", EPRI, January 2005.

Table 7 CHP System Cost and Performance Assumptions

Cost and Performance Assumptions

Market Size Bin	50-1,000 kW	1-5 MW	5-20 MW	>20 MW
Technology	**Average**	**3000 kW RE**	**10 MW GT**	**40 MW GT**
Capacity, kW	512.5	3000	12500	40000
Capital Cost	$2,310	$1,650	$1,363	$1,021
Emissions Control Cost, $/kW	$150	$200	$140	$90
Total Capital Cost, $/kW	$2,460	$1,850	$1,503	$1,111
Heat Rate, Btu/kWh	10,880	9,492	11,765	9,220
Thermal Output, Btu/kWh	5,200	3,510	4,674	3,189
Electric Efficiency, %	31.4%	35.9%	29.0%	37.0%
CHP Efficiency	79.1%	72.9%	68.7%	71.6%
O&M Costs, $/kWh	$0.0180	$0.0140	$0.0070	$0.0040
Economic Life, years	15	15	20	20
Avoided Boiler Efficiency	80%	80%	80%	80%

Annual Operating Values

High Load Factor Hours	7,008	7,008	7,446	8,059
HiLF O&M $/kW-year	$126.14	$98.11	$52.12	$32.24
Fuel Consumption MMBtu/kW/year	76.25	66.52	87.60	74.31
Avoided Thermal Load, %	80%	80%	90%	100%
Avoided Boiler Fuel MMBtu/kW/year	36.44	24.60	39.15	32.13
Low Load Factor Hours	4,500	4,500	4,500	4,500
LoLF O&M $/kW-year	$81.00	$63.00	$31.50	$18.00
Fuel Consumption MMBtu/kW/year	48.96	42.71	52.94	41.49
Avoided Thermal Load, %	80%	80%	90%	100%
Avoided Boiler Fuel MMBtu/kW/year	23.40	15.80	23.66	17.94

Federal ITC Calculations

High Efficiency Federal ITC	$738	$555	$451	$208
Net Capital Cost, $/kW	$1,722	$1,295	$1,052	$902
ITC Value Check	30%	30%	30%	19%
Standard Efficiency Federal ITC	$246	$185	$150	$69
Net Capital Cost, $/kW	$2,214	$1,665	$1,353	$1,041
ITC Value Check	10%	10%	10%	6%

The Federal ITC Calculations section of Table 7 shows the amount of federal tax credit allowed on a dollar per kW basis for each size category for both the 10 percent and 30 percent ITC options[12]. The Net Capital Cost value is the final capital cost to the user net of the ITC, and is the value used in the economic calculation in the market model for the ITC scenarios.

For cooling markets, an additional cost was added to reflect the costs of adding chiller capacity to the CHP system. These costs are a function of the size of the absorption chiller which in turn depends on the amount of usable waste heat that the CHP system produces. A curve fitting approach was used and the values by CHP system size bins are as follows:

[12] The "ITC Value Check" in Table 7 does not equal 30 percent or 10 percent in the largest size category because of the 25 MW cap on qualified capacity

CHP System Size	Additional Cost for Absorption Chiller
50 – 1,000 kW	$300 - $530/kW
1 - 5 MW	$110 - $270/kW
5 - 20 MW	$65 - $110/kW
>20 MW	$45/kW

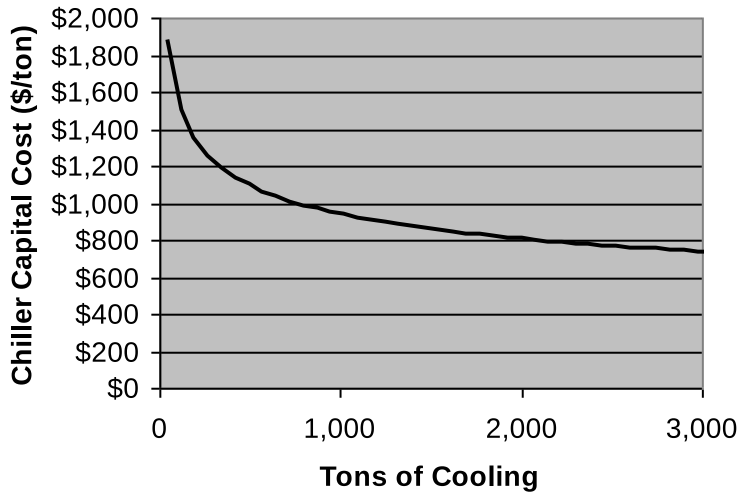


Figure 3 Absorption Chiller Capital Costs

4.1.2 Natural Gas and Electricity Price Assumptions

Energy prices used for this analysis are based on estimates of state prices from DOE's Energy Information Administration as presented in Table 8. Electricity prices are based on the state-wide average industrial electricity prices reported for 2009, except for a small number of states where more current prices were available based on ongoing analysis ICF is conducting for ORNL (New York, New Jersey, Ohio, North Carolina, Texas and California). Industrial electricity prices were used because most of the market potential for CHP is at facilities with average power demands of 500 kW or above. Facilities with these load levels would normally be on large user tariffs for most utilities, which are represented most accurately by the EIA industrial prices. For low load factor commercial applications, the electric price was assumed to be 10 percent higher than the average industrial rate due to their lower load factor and likelihood of being on a more costly tariff.

Natural gas prices used in the analysis are similarly based on estimated industrial prices for 2009. EIA data had several anomalies in the industrial gas price data. The natural gas prices used in the analysis and presented in Table 8 for each state are the lower of either the EIA reported industrial price for 2009 or the EIA reported average city gate price for gas in 2009 with $1.00/MMBtu added to cover distribution costs.

Table 8 Natural Gas and Electric Price Assumptions

State	Average Electric Price, Cents/kWh	Average Natural Gas Price, $/MMBtu
Alabama	6.06	$6.33
Alaska	12.62	$4.02
Arizona	6.26	$8.16
Arkansas	5.83	$7.42
California	10.73	$5.17
Colorado	5.88	$5.60
Connecticut	16.17	$7.81
Delaware	9.70	$7.12
Florida	9.36	$6.76
Georgia	5.97	$7.27
Hawaii	16.89	$18.82
Idaho	4.52	$6.10
Illinois	7.64	$6.71
Indiana	5.83	$6.59
Iowa	4.90	$6.00
Kansas	6.14	$4.22
Kentucky	4.85	$5.63
Louisiana	6.18	$4.33
Maine	10.54	$9.64
Maryland	10.47	$9.02
Massachusetts	11.65	$8.17
Michigan	7.08	$8.24
Minnesota	6.16	$5.68
Mississippi	6.87	$6.29
Missouri	4.98	$8.06
Montana	5.68	$6.63
Nebraska	5.58	$5.95
Nevada	7.09	$8.93
New Hampshire	14.21	$9.05
New Jersey	10.60	$8.93
New Mexico	5.92	$5.07
New York	9.98	$8.35
North Carolina	5.72	$6.06
North Dakota	5.74	$5.21
Ohio	6.54	$5.49
Oklahoma	4.97	$8.15
Oregon	5.20	$5.97
Pennsylvania	7.23	$8.84
Rhode Island	13.22	$7.70
South Carolina	5.68	$6.08
South Dakota	5.64	$6.07
Tennessee	7.07	$6.40
Texas	7.45	$5.54
Utah	4.50	$5.58
Vermont	9.30	$7.93
Virginia	6.98	$8.83
Washington	4.32	$7.59
West Virginia	5.16	$5.54
Wisconsin	6.65	$7.70
Wyoming	4.66	$5.74

4.2 Economic Competitiveness of CHP and Market Acceptance

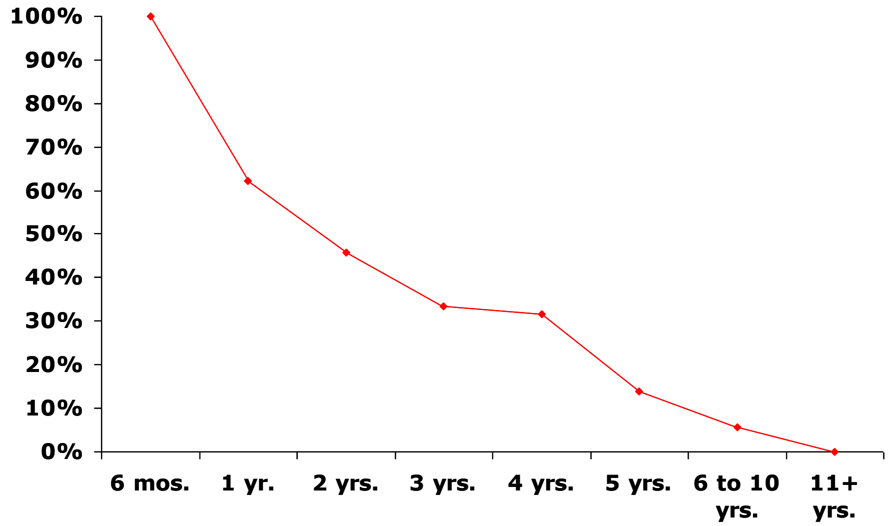
The economic competitiveness calculation within the ICF *CHP Market Model* is a simple pay-back calculation. The annual cost of operating the CHP system is compared to the avoided thermal and electric energy cost savings, allowing the number of years it would take for this annual savings to repay the initial capital investment to be calculated. This is a very common form of screening to identify potentially economic investments of any type, and it is used by facility operators and CHP developers in the early stages of identifying economic CHP projects.

The annual savings calculation consists of the following components:

- CHP operating cost (on a per kW basis) is a function of the CHP system heat rate, the CHP natural gas rate, and the assumed equivalent full load hours of operation per year.
- Avoided electric cost is a function of the CHP hours of operation and the avoided CHP electric costs.
- Avoided thermal energy is a function of the share of avoided boiler use and avoided air conditioning use. In cooling applications the share is assumed to be 50/50. In non cooling applications all thermal energy is assumed to be from avoided boiler fuel.
    - Avoided boiler use depends on the thermal energy per kWh produced by the CHP system, the assumed percentage of thermal energy utilized, the boiler fuel price, and the boiler efficiency
    - Avoided air conditioning use depends on the CHP thermal energy produced, the assumed efficiency of the absorption chiller, the assumed efficiency of the electric chiller (0.68 kW/ton used) and the avoided air conditioning electric rate.

The payback period is calculated for the representative technology in each size bin and is used to define the market acceptance rate which is estimated based on a survey of customer facilities that could potentially implement CHP. **Figure 4** shows the percentage of the market that would accept a given payback period and move forward with a CHP investment based on these customer surveys.[13] As can be seen from the figure, only about 60 percent of customers would accept a CHP project that promised to return their initial investment in just one year. A little less than half would accept a project with a payback of two years. These types of paybacks translate into projects with ROIs of between 49-100 percent. Potential explanations for these relatively low acceptance rates for projects with such high returns is that the average customer does not believe that the results are real given the uncertainty in future energy prices and/or equipment performance and is protecting himself from this perceived risk by requiring very high projected returns before going forward, or that the facility is very capital limited and is rationing its capital raising capability for higher priority projects (market expansion, product improvement, etc.). These acceptance rates are used in the model to reflect expected customer behavior in the absence of any change in perceptions regarding the risk of investing in CHP.

[13] Primen. Distributed Energy Market Survey. 2003.



Source: *Primen's 2003 Distributed Energy Market Survey*

Figure 4 CHP Market Acceptance as a Function of Payback Period

The rate of market penetration in the model is based on *Bass diffusion curves* which determine cumulative market penetration over the study period. Smaller size systems are assumed to take a longer time to reach maximum market penetration than larger systems. Cumulative market penetration using a Bass diffusion curve is based on a typical S-shaped penetration curve. The cumulative market penetration factors reflect the economic potential multiplied by the non-economic screening factor (maximum market potential) and by the Bass model market cumulative market penetration estimate.

5. CHP Market Penetration Results

Projected CHP market penetration (2010 through the end of 2017) was modeled for each state for three scenarios:

- Base Case – no federal investment tax credit for CHP
- 10 Percent ITC Case – a 10 percent federal tax incentive for the first 25 MW of all CHP systems
- 30 percent ITC Case – a 30 percent federal investment tax credit for the first 25 MW of all CHP systems that can meet as minimum 70 percent efficiency threshold (LHV); a 10 percent federal investment tax credit for the first 25 MW of all other CHP systems.

Table 9 presents the market penetration estimates predicted by the model by CHP system size category for the three scenarios. The results include:

- The Base Case (no ITC) estimates a total CHP market penetration of 2,610 MW between now and the end of 2017.
- The expanded 10 percent ITC increases CHP deployment by about 20 percent over the no ITC baseline. Market penetration in the 10 percent ITC case increases to 3,157 MW (an increase of 547 MW over the Base Case). Investment in the projects represented by the expanded 10 percent ITC creates over 17,000 highly skilled jobs.[14]

[14] Based on four jobs created for every $1 million in capital investment, Oak Ridge National Laboratory, "Combined Heat and Power: Effective Energy Solutions for a Sustainable Future" December 2008.

- The 30 percent ITC for highly efficient CHP increases CHP deployment by more than 60 percent over the no ITC baseline. Market penetration in the 30 percent ITC case increases to 4,196 MW (an increase of 1,039 MW over the 10 percent ITC case). Investment in the projects represented by the 30 percent ITC creates over 23,000 highly skilled jobs.

Table 9 Estimated CHP Market Penetration 2010 through 2017 (MW)

ITC Scenarios	50-1,000 kW	1-5 MW	5-20 MW	>20 MW	Total Penetration	Total Investment (million 2010$)
0% ITC	125 MW	371 MW	567 MW	1,547 MW	2,610 MW	$3,564
Expanded ITC (10% up to 25 MW)	181 MW	500 MW	674 MW	1,802 MW	3,157 MW	$4,383
30% ITC (30% for up to 25 MW)	258 MW	681 MW	973 MW	2,284 MW	4,196 MW	$5,893

Potential energy and CO_2 savings were estimated for each scenario, comparing the fuel use and CO_2 emissions from the installed CHP capacity to the fuel use and CO_2 emissions of the displaced onsite thermal energy use and displaced central station electricity as shown in Table 10:

- The expanded 10 percent ITC results in an annual energy savings of 118 trillion Btus and an annual reduction in CO_2 emissions of 14 million metric tons (MMT), equivalent to removing 2.6 million cars from the road.[16].
- The 30 percent ITC results in an annual energy savings of 162 trillion Btus and an annual reduction in CO_2 emissions of over 19 million metric tons (MMT), equivalent to removing 3.4 million cars from the road.

Table 10 Estimated Energy and CO_2 Savings[15]

ITC Scenarios	Energy Savings (Trillion Btu/yr)	CO_2 Reduction (Million Metric Tons)	Equivalent Number of Cars Taken Off Road (million vehicles)
0% ITC	98.8	11.9	2.2
Expanded 10% ITC	117.8	14.2	2.6
30% ITC for High Efficiency	161.8	19.5	3.4

Tables 11 through 13 present projected CHP penetration and total investment at the state level.

[15] Based on displacing eGRID 2007 national average fossil generation (heat rate = 9,934 Btu/kWh and CO_2 emissions of 1,841 lbs/MWh; average T&D losses of 7 percent)

Table 11 Base Case - No ITC

State	Non-Tax Liable Apps: Economic Potential MW	Non-Tax Liable Apps: Market Penetration MW	Tax Liable Apps: Economic Potential MW	Tax Liable Apps: Market Penetration MW	Total: Economic Potential MW	Total: Market Penetration MW	Non-Tax Liable Apps: Capital Investment Million 2010$	Tax Liable Apps: Capital Investment Million 2010$	Total: Total Capital Investment Million 2010$
Alabama	4.3	3.1	15.6	11.5	19.9	14.7	$3.5	$12.8	$16.3
Alaska	4.2	2.7	27.3	18.3	31.5	20.9	$5.0	$30.0	$35.0
Arizona	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Arkansas	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
California	492.5	331.1	594.7	385.4	1087.3	716.6	$482.6	$669.7	$1,152.3
Colorado	4.2	3.1	0.0	0.0	4.2	3.1	$3.4	$0.0	$3.4
Connecticut	38.9	24.9	211.0	140.7	249.9	165.6	$43.5	$231.2	$274.7
Delaware	2.6	1.7	93.2	67.2	95.9	68.8	$2.6	$79.3	$81.9
Florida	47.5	32.0	94.9	65.1	142.4	97.1	$46.0	$89.7	$135.7
Georgia	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Hawaii	4.6	3.4	1.1	0.7	5.7	4.1	$3.8	$1.0	$4.8
Idaho	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Illinois	17.3	12.7	288.2	212.4	305.5	225.2	$14.1	$235.9	$250.1
Indiana	1.5	1.1	7.0	5.1	8.4	6.2	$1.2	$5.7	$6.9
Iowa	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Kansas	7.1	5.2	47.2	34.3	54.3	39.5	$5.8	$39.2	$45.0
Kentucky	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Louisiana	8.8	6.5	116.4	84.4	125.3	90.9	$7.2	$97.0	$104.2
Maine	0.9	0.7	72.5	52.6	73.4	53.3	$0.8	$60.3	$61.1
Maryland	12.6	9.3	65.0	46.8	77.6	56.1	$10.3	$54.6	$64.9
Massachusetts	44.4	31.7	176.3	121.1	220.6	152.9	$41.5	$175.4	$216.9
Michigan	4.5	3.3	36.7	27.0	41.1	30.3	$3.7	$30.0	$33.7
Minnesota	2.8	2.1	18.3	13.5	21.1	15.5	$2.3	$14.9	$17.2
Mississippi	7.9	5.9	43.0	31.7	51.0	37.6	$6.5	$35.2	$41.7
Missouri	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Montana	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Nebraska	0.0	0.0	0.7	0.5	0.7	0.5	$0.0	$0.6	$0.6
Nevada	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
New Hampshire	5.6	3.6	63.0	41.9	68.6	45.5	$6.7	$67.0	$73.7
New Jersey	10.8	6.9	162.0	110.4	172.8	117.4	$11.3	$147.7	$159.0
New Mexico	0.0	0.0	4.1	3.0	4.1	3.0	$0.0	$3.3	$3.3
New York	93.1	63.7	207.4	147.4	300.5	211.1	$82.0	$176.2	$258.3
North Carolina	3.0	2.2	102.2	75.3	105.2	77.5	$2.4	$83.6	$86.1
North Dakota	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Ohio	0.0	0.0	110.7	81.6	110.7	81.6	$0.0	$90.6	$90.6
Oklahoma	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Oregon	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Pennsylvania	4.2	3.1	53.7	39.6	57.9	42.6	$3.4	$43.9	$47.4
Rhode Island	7.9	5.1	43.3	28.7	51.3	33.8	$8.8	$48.6	$57.4
South Carolina	0.0	0.0	18.8	13.9	18.8	13.9	$0.0	$15.4	$15.4
South Dakota	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Tennessee	0.0	0.0	54.2	40.0	54.2	40.0	$0.0	$44.4	$44.4
Texas	20.2	13.5	153.7	105.7	173.9	119.2	$18.2	$134.8	$153.0
Utah	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Vermont	1.0	0.6	2.2	1.4	3.2	2.0	$0.9	$2.1	$3.0
Virginia	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Washington	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
West Virginia	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Wisconsin	0.0	0.0	31.9	23.5	31.9	23.5	$0.0	$26.2	$26.2
Wyoming	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Total	852.5	579.2	2,916.4	2,030.7	3,768.9	2,609.9	$817.7	$2,746.5	$3,564.2

Table 12 Expanded 10 Percent ITC Case

	Non-Tax Liable Apps		Tax Liable Apps		Total	
State	Economic Potential MW	Market Penetration MW	Economic Potential MW	Market Penetration MW	Economic Potential MW	Market Penetration MW
Alabama	4.3	3.1	20.1	14.8	24.4	18.0
Alaska	4.2	2.7	32.9	21.9	37.1	24.6
Arizona	0.0	0.0	0.0	0.0	0.0	0.0
Arkansas	0.0	0.0	0.0	0.0	0.0	0.0
California	492.5	331.1	752.9	486.3	1245.4	817.4
Colorado	4.2	3.1	0.0	0.0	4.2	3.1
Connecticut	38.9	24.9	252.2	167.5	291.0	192.4
Delaware	2.6	1.7	110.6	79.4	113.2	81.1
Florida	47.5	32.0	140.8	95.7	188.2	127.6
Georgia	0.0	0.0	0.0	0.0	0.0	0.0
Hawaii	4.6	3.4	6.0	3.9	10.6	7.3
Idaho	0.0	0.0	0.0	0.0	0.0	0.0
Illinois	17.3	12.7	337.3	248.6	354.6	261.3
Indiana	1.5	1.1	11.2	8.3	12.7	9.3
Iowa	0.0	0.0	0.0	0.0	0.0	0.0
Kansas	7.1	5.2	58.4	42.1	65.4	47.3
Kentucky	0.0	0.0	0.0	0.0	0.0	0.0
Louisiana	8.8	6.5	146.6	105.3	155.4	111.8
Maine	0.9	0.7	85.5	61.8	86.4	62.5
Maryland	12.6	9.3	83.2	59.3	95.8	68.6
Massachusetts	44.4	31.7	234.3	158.8	278.6	190.5
Michigan	4.5	3.3	48.4	35.7	52.9	39.0
Minnesota	2.8	2.1	22.1	16.3	25.0	18.4
Mississippi	7.9	5.9	51.2	37.7	59.1	43.6
Missouri	0.0	0.0	0.0	0.0	0.0	0.0
Montana	0.0	0.0	0.0	0.0	0.0	0.0
Nebraska	0.0	0.0	1.0	0.8	1.0	0.8
Nevada	0.0	0.0	3.5	2.6	3.5	2.6
New Hampshire	5.6	3.6	76.9	51.0	82.6	54.6
New Jersey	10.8	6.9	217.0	146.9	227.8	153.9
New Mexico	0.0	0.0	4.9	3.6	4.9	3.6
New York	93.1	63.7	274.0	192.7	367.1	256.4
North Carolina	3.0	2.2	139.6	102.9	142.6	105.1
North Dakota	0.0	0.0	0.0	0.0	0.0	0.0
Ohio	0.0	0.0	131.0	96.6	131.0	96.6
Oklahoma	0.0	0.0	0.0	0.0	0.0	0.0
Oregon	0.0	0.0	0.0	0.0	0.0	0.0
Pennsylvania	4.2	3.1	78.1	57.6	82.3	60.7
Rhode Island	7.9	5.1	53.9	35.6	61.9	40.7
South Carolina	0.0	0.0	26.4	19.5	26.4	19.5
South Dakota	0.0	0.0	0.0	0.0	0.0	0.0
Tennessee	0.0	0.0	64.2	47.3	64.2	47.3
Texas	20.2	13.5	201.2	137.0	221.4	150.5
Utah	0.0	0.0	0.0	0.0	0.0	0.0
Vermont	1.0	0.6	3.1	2.0	4.1	2.6
Virginia	0.0	0.0	0.0	0.0	0.0	0.0
Washington	0.0	0.0	0.0	0.0	0.0	0.0
West Virginia	0.0	0.0	7.5	5.5	7.5	5.5
Wisconsin	0.0	0.0	44.1	32.5	44.1	32.5
Wyoming	0.0	0.0	0.0	0.0	0.0	0.0
Total	852.5	579.2	3,720.0	2,577.3	4,572.5	3,156.5

Non-Tax Liable Apps	Tax Liable Apps	Total
Capital Investment Million 2010$	Capital Investment Million 2010$	Total Capital Investment Million 2010$
$3.5	$16.5	$20.0
$5.0	$36.6	$41.6
$0.0	$0.0	$0.0
$0.0	$0.0	$0.0
$482.6	$860.9	$1,343.5
$3.4	$0.0	$3.4
$43.5	$279.7	$323.2
$2.6	$95.1	$97.7
$46.0	$140.9	$186.9
$0.0	$0.0	$0.0
$3.8	$6.8	$10.6
$0.0	$0.0	$0.0
$14.1	$276.1	$290.2
$1.2	$9.2	$10.4
$0.0	$0.0	$0.0
$5.8	$48.8	$54.6
$0.0	$0.0	$0.0
$7.2	$123.2	$130.4
$0.8	$71.4	$72.2
$10.3	$72.6	$83.0
$41.5	$244.7	$286.2
$3.7	$39.6	$43.3
$2.3	$18.1	$20.4
$6.5	$41.9	$48.4
$0.0	$0.0	$0.0
$0.0	$0.0	$0.0
$0.0	$0.8	$0.8
$0.0	$2.9	$2.9
$6.7	$83.2	$89.9
$11.3	$204.4	$215.7
$0.0	$4.0	$4.0
$82.0	$243.5	$325.6
$2.4	$114.3	$116.7
$0.0	$0.0	$0.0
$0.0	$107.3	$107.3
$0.0	$0.0	$0.0
$0.0	$0.0	$0.0
$3.4	$63.9	$67.4
$8.8	$61.5	$70.3
$0.0	$21.6	$21.6
$0.0	$0.0	$0.0
$0.0	$52.5	$52.5
$18.2	$178.1	$196.2
$0.0	$0.0	$0.0
$0.9	$3.0	$3.9
$0.0	$0.0	$0.0
$0.0	$0.0	$0.0
$0.0	$6.1	$6.1
$0.0	$36.1	$36.1
$0.0	$0.0	$0.0
$817.7	$3,565.5	$4,383.2

Table 13 30% ITC Case for High Efficiency Applications

	Non-Tax Liable Apps		Tax Liable Apps		Total		Non-Tax Liable Apps	Tax Liable Apps	Total
State	Economic Potential MW	Market Penetration MW	Economic Potential MW	Market Penetration MW	Economic Potential MW	Market Penetration MW	Capital Investment Million 2010$	Capital Investment Million 2010$	Total Capital Investment Million 2010$
Alabama	4.3	3.1	29.3	21.6	33.5	24.7	$3.5	$23.9	$27.4
Alaska	4.2	2.7	39.1	26.0	43.3	28.6	$5.0	$43.4	$48.5
Arizona	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Arkansas	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
California	492.5	331.1	982.0	632.4	1474.6	963.6	$482.6	$1,133.0	$1,615.6
Colorado	4.2	3.1	0.0	0.0	4.2	3.1	$3.4	$0.0	$3.4
Connecticut	38.9	24.9	293.2	194.6	332.1	219.5	$43.5	$324.6	$368.1
Delaware	2.6	1.7	140.3	100.1	142.9	101.7	$2.6	$122.8	$125.5
Florida	47.5	32.0	207.0	138.9	254.5	170.8	$46.0	$216.7	$262.7
Georgia	0.0	0.0	16.5	12.2	16.5	12.2	$0.0	$13.5	$13.5
Hawaii	4.6	3.4	10.1	6.5	14.7	9.9	$3.8	$12.2	$15.9
Idaho	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Illinois	17.3	12.7	489.2	353.2	506.5	365.9	$14.1	$409.3	$423.4
Indiana	1.5	1.1	20.4	15.0	21.9	16.1	$1.2	$16.7	$17.9
Iowa	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Kansas	7.1	5.2	80.1	57.1	87.2	62.3	$5.8	$67.8	$73.6
Kentucky	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Louisiana	8.8	6.5	205.6	145.5	214.5	152.0	$7.2	$175.4	$182.7
Maine	0.9	0.7	112.2	80.4	113.1	81.1	$0.8	$95.7	$96.5
Maryland	12.6	9.3	114.6	80.5	127.2	89.8	$10.3	$104.5	$114.8
Massachusetts	44.4	31.7	299.1	201.5	343.4	233.2	$41.5	$317.0	$358.5
Michigan	4.5	3.3	72.6	53.5	77.1	56.8	$3.7	$59.4	$63.1
Minnesota	2.8	2.1	29.0	21.4	31.8	23.5	$2.3	$23.7	$26.0
Mississippi	7.9	5.9	64.8	47.8	72.7	53.6	$6.5	$53.0	$59.5
Missouri	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Montana	0.0	0.0	1.1	0.8	1.1	0.8	$0.0	$0.9	$0.9
Nebraska	0.0	0.0	1.7	1.2	1.7	1.2	$0.0	$1.4	$1.4
Nevada	0.0	0.0	7.2	5.3	7.2	5.3	$0.0	$5.9	$5.9
New Hampshire	5.6	3.6	92.3	61.0	97.9	64.6	$6.7	$99.6	$106.3
New Jersey	10.8	6.9	315.5	211.2	326.4	218.1	$11.3	$309.9	$321.2
New Mexico	0.0	0.0	6.4	4.8	6.4	4.8	$0.0	$5.3	$5.3
New York	93.1	63.7	382.7	266.3	475.8	330.1	$82.0	$353.4	$435.5
North Carolina	3.0	2.2	218.8	161.2	221.7	163.4	$2.4	$179.1	$181.5
North Dakota	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Ohio	0.0	0.0	217.7	154.9	217.7	154.9	$0.0	$184.7	$184.7
Oklahoma	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Oregon	0.0	0.0	7.9	5.8	7.9	5.8	$0.0	$6.5	$6.5
Pennsylvania	4.2	3.1	131.6	97.0	135.8	100.1	$3.4	$107.8	$111.2
Rhode Island	7.9	5.1	65.9	43.4	73.8	48.5	$8.8	$75.4	$84.2
South Carolina	0.0	0.0	42.7	31.5	42.7	31.5	$0.0	$35.0	$35.0
South Dakota	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Tennessee	0.0	0.0	100.5	72.1	100.5	72.1	$0.0	$84.7	$84.7
Texas	20.2	13.5	337.4	226.4	357.6	239.9	$18.2	$315.3	$333.4
Utah	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Vermont	1.0	0.6	7.4	4.7	8.4	5.3	$0.9	$7.6	$8.5
Virginia	0.0	0.0	24.6	18.1	24.6	18.1	$0.0	$20.1	$20.1
Washington	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
West Virginia	0.0	0.0	15.3	11.3	15.3	11.3	$0.0	$12.5	$12.5
Wisconsin	0.0	0.0	70.1	51.7	70.1	51.7	$0.0	$57.4	$57.4
Wyoming	0.0	0.0	0.0	0.0	0.0	0.0	$0.0	$0.0	$0.0
Total	852.5	579.2	5,251.9	3,616.8	6,104.5	4,196.0	$817.7	$5,075.3	$5,893.1

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