# Gas-Fired Combined Heat and Power Going Forward: What Can State Utility Commissions Do?

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# National Regulatory Research Institute

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# Executive Summary

## Preview of CHP

Combined heat and power (CHP), also known as cogeneration, is an integrated energy technology that produces both electricity and useful thermal energy with a single source of fuel. It allows the recovery of heat for space, hot water and process heating, cooling and dehumification that the producer would normally lose in the electricity generation process. Relative to conventional generation, CHP can both reduce energy costs to the host, and emit fewer greenhouse gas emissions and other pollutants. CHP facilities reside at or near the point of consumption. CHP technologies differ in installed costs, operation and maintenance (O&M) costs, fuel input, energy efficiency, capacity, start-up times and environmental effects. Most of them are mature and gas-fired, having been deployed for decades internationally.

Decentralized CHP systems located at industrial and municipal sites were a major part of the U.S. electric power industry during the early 20$^{th}$ century. Technological advances in electricity generation over time favored larger central station facilities that exploited increasing economies of scale. CHP confined its use within a few industries (namely, paper, chemicals, refining, and steel) that had high and relatively constant steam and electric demands and access to low-cost fuels. CHP systems are normally designed to meet the on-site thermal needs, rather than electricity demands. Utilities had little incentive to encourage customer-sited generation, including CHP. This condition continues even today and, as contended by CHP supporters, constitutes a barrier to CHP development. Other barriers, at both the federal and state level, had further discouraged CHP growth.

Then along came PURPA in 1978 and federal tax incentives that bolstered installed CHP capacity from 12 gigawatts (GW) in 1980 to 82 GW today. Most of the growth occurred during the 1980-2005 period. After that time, because of new federal energy legislation, rising and highly volatile natural gas prices, electric industry restructuring and weakening of PURPA requirements, interest in CHP expansion eroded until after 2011. Capacity additions rose in 2012 and estimates report even higher additions in 2013. The prospects for CHP technologies, according to many experts, appear bright given recent developments on the energy and environmental fronts.

The 82 GW of current CHP generating capacity represents about 8 percent of U.S. generating capacity. To some CHP proponents and policymakers, this percentage represents a suboptimal use of CHP within the U.S. energy sector. The U.S. Environmental Protection Agency (EPA) estimates that the potential market for CHP at existing industrial facilities is about 65 GW with roughly an equivalent potential market for CHP at commercial and institutional facilities. About 87 percent of the current installed CHP capacity resides in the industrial sector, with the remaining capacity in the commercial or governmental sectors. The three sectors with the most CHP capacity are chemicals, refining and paper.

CHP systems can deploy different prime-mover technologies and fuels. They also come in a wide-range of sizes. Natural gas is the most common primary energy source used in CHP plants and is the focus of this paper.[1] The abundance of natural gas will make gas-fired CHP systems the preferred technology of the future. The scale of CHP systems ranges from the micro, residential scale of around 1 kW to large-scale industrial systems with a capacity greater than 100 MW.

From around 2005 until the last couple of years, CHP received little attention. Renewed interest in CHP technologies then emerged for different reasons. In 2012, the President issued Executive Order 13624, "Accelerating Investment in Industrial Energy Efficiency," directing federal agencies to promote the expansion of CHP by an additional 40 GW by 2020. The Order added that meeting the national goal set out by the Obama Administration will require "encouraging private sector investment by setting goals and highlighting the benefits of investment, improving coordination at the Federal level, partnering with and supporting States, and identifying investment models beneficial to the multiple stakeholders involved."[2] Following up in a 2012 paper, the U.S. EPA commented that:

> An additional 40 GW of CHP (approximately 50 percent more than the current levels of U.S. CHP capacity) would save 1 Quad of energy (equivalent to 1 percent of total annual energy consumption in the U.S.), reduce $CO_2$ by 150 million metric tons annually (equivalent to the emissions of over 25 million cars), and save energy users $10 billion a year relative to their existing energy sources. Achieving this goal would also result in $40 – 80 billion in new capital investment in manufacturing and other U.S. facilities over the next decade.[3]

The paper also noted that to meet the Administration's goal of an additional 40 GW of CHP by 2020, "…barriers to CHP development need to be removed, and effective policies, programs and financing opportunities promoted."[4]

Interest in CHP technologies at the state level has also accelerated in the past five years. Some states have established special incentives and given CHP technologies the same consideration for utility planning as renewable energy and other clean energy sources. In 2012 the National Association of Regulatory Utility Commissioners (NARUC) passed a resolution that "encourages State public service commissions to evaluate opportunities for combined heat and power…to work with stakeholders and other agencies, as needed, to encourage cost effective investment in CHP… explore educational opportunities and forums on CHP [and]…evaluate

[1] Over 70 percent of CHP capacity currently operating in the country uses natural gas as a primary energy source. Gas-fired technologies include steam turbines, reciprocating engines, gas turbines, microturbines and fuel cells.

[2] White House, Office of the Press Secretary (2012), "Section 1: Policy."

[3] U.S. Department of Energy and U.S. Environmental Protection Agency (2012), 22.

[4] Ibid., 22.

regulatory mechanisms and consider and identify ways to best deploy cost-effective CHP technologies."[5]

Low natural gas prices and heightened interest in power resiliency have also contributed to the growing support for CHP technologies.[6] These factors should continue in the future to make long-term financial commitments to CHP investments more likely.

**Focus of this paper**

Studies and CHP proponents have alluded to unfavorable state regulations as major barriers to development of CHP. This paper identifies these barriers and examines their role as obstacles to development of CHP. It also reviews policy options to mitigate these barriers when (1) they produce uneconomic and socially-damaging outcomes and (2) their mitigation passes a cost-benefit test and, thus, their amenability to policy intervention. The paper refers to these barriers as "market/regulatory failures." On the other hand, some barriers alleged by analysts and others may derive from natural market forces and would, most surely, fail a cost-benefit test to mitigate. For example, mitigation may involve a high cost that, on net, would inevitably make matters worse. The paper refers to them as "normal market barriers." A recent report commented on one possible barrier:

> For CHP to grow, regulatory and policy changes are likely to be necessary, particularly at the *state level*. Some, but not all, states include gas CHP in energy efficiency and renewable portfolio standard programs. It is important for all policy makers to recognize that they may be biasing outcomes against gas-fired CHP and in favor of renewables or other technologies, perhaps in an unintended manner.[7] [Emphasis added]

An encapsulation of the arguments presented by CHP proponents would go something like the following:

> *As a proven technology, CHP is beneficial in a number of ways and it is greatly being underappreciated. The potential for expanding cost-beneficial CHP is enormous. Governments at different levels need to step in to give incentives, subsidies and overcome barriers to grow the penetration of CHP or else society will forgo large benefits.*

As its major objective, this paper critiques the validity of this statement as it relates to the role that state utility regulation should play in overcoming barriers to CHP development. One contention of CHP proponents is that state utility regulation and energy policy show favoritism toward renewable energy or other technologies that has hindered the growth of CHP. Another argument is that electric utilities erect obstacles to CHP development that state utility

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[5] National Association of Regulatory Utility Commissioners (2012).

[6] Resiliency is especially important for commercial and industrial customers, who suffer disproportionately from power outages attributable to natural disasters.

[7] IHS CERA (2014), ES-18.

commissions should recognize and eliminate. This paper examines the veracity of these allegations. At this time, it remains unclear what policies on CHP regulators should support, other than the uncontroversial action to eliminate any market/regulatory failures that pass a benefit-cost test.

This paper does not advocate for CHP, unlike many other studies that support CHP technologies rather than examining them objectively. Some CHP proponents contend that additional subsidies would place CHP on a "level playing field" with other generation technologies, some of which have received generous subsidies. They characterize these actions as a "no regrets" policy in which no one becomes worse off. In other words, these studies contend that lifting barriers offer "free lunch" opportunities to expand investments in CHP technologies. An alternative interpretation, more in line with economics, is that new subsidies could potentially put CHP a leg up on its competitors; that is, give CHP an unfair advantage that would be socially undesirable.

Key questions for state utility commissions are three-fold: (1) What are the major obstacles to CHP development; (2) are CHP technologies socially desirable, and if so, (3) are they able to compete on a "level playing field" with other generation technologies? Four distinct obstacles to CHP development seem most prominent. The first is the natural bias that electric utilities have against CHP. After all, CHP is a form of distributed generation that directly competes with utility sales. Both a utility's short-term and long-term profits are prone to erosion from third-party CHP development. Second, the current policy environment places higher priorities on renewable energy and energy efficiency, relative to CHP technologies, as socially desirable energy resources. This observation reflects federal and state policies that assign higher importance to renewable energy and energy efficiency. Whether justified or not, these policies do place CHP at a disadvantage for government support. Third, potential CHP hosts tend to want excessively fast payback of their investments and prefer those investments that directly contribute to their firms' growth.[8] Fourth, specific state regulatory policies may erect unfounded barriers, such as excessive standby rates, faulty rate design, costly permitting and a cumbersome interconnect process. Overall, deficient CHP capacity could exist for these reasons, vouching for more proactive utility regulatory strategies.

At the minimum, commissions should reevaluate their policies to assure that CHP gets a "fair shake" relative to other technologies, especially those that ostensibly have stronger advocates exerting greater pressure on commissions and other policymakers for their support. The preferred policy would focus on addressing market/regulatory failures rather than subsidizing CHP as a second-best policy -- for example, trying to create "equal" subsidies across competing technologies. Owners and operators, after all, receive virtually all of the benefits from CHP facilities, either in lower energy costs, from the sale of surplus power at a profit, or increased reliability. Subsidies, whether for CHP or other technologies, often have adverse effects that are not transparent, lying outside the radar of policymakers. Subsidies, especially when poorly structured, can be (1) unfair to funding parties (e.g., ratepayers or taxpayers), (2) economically inefficient, and (3) unfair to competing energy sources. Overall, subsidies, more times than not, are likely to fail a cost-benefit test from a public-interest perspective.

[8] The simple payback of a CHP system is the number of years that it will take for the annual operating cost savings from CHP to pay back the upfront costs of installing the CHP system.

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# Gas-Fired Combined Heat and Power Going Forward: What Can State Utility Commissions Do?

One definition of combined heat and power (CHP), also known as cogeneration, is as follows:

> CHP [refers] both to systems that include an on-site electricity generation unit that recovers the heat normally wasted in power generation for useful heating or cooling, and also to waste-heat-to-power systems…that capture the heat released by an existing manufacturing process to generate electricity.[9]

CHP systems, in other words, recover the energy normally lost in the prime mover's hot exhaust and cooling systems to provide heat for industrial processes (such as petroleum refining or food processing), hot water (e.g., for laundry or dishwashing), or for space heating, cooling, and dehumidification.[10]

CHP technologies are an important electric generating resource in the United States, with about 82 gigawatts (GW) of generation capacity at over 4,100 facilities representing about 8 percent of total U.S. power generation capacity.[11] CHP represents over 12 percent of annual U.S. power generation, reflecting the relatively high operating hours of CHP systems.

CHP installed capacity grew from 12 GW in 1980, to 66 GW by 2000 and 82 GW by 2012. In addition to the Public Utility Regulatory Policies Act (PURPA), federal tax incentives also bolstered the development of CHP. CHP owners, for example, can use accelerated depreciation for tax purposes and, under special conditions, qualify for investment tax credits.[12]

Growth in CHP capacity slowed precipitously, starting in 2005. As explained in one report:

> A variety of forces in 2005-2006 effectively ended the large CHP capacity additions to the U.S. energy economy. Increasing deregulation of utilities, open access to electricity transportation by utilities, a revision of PURPA regulations to limit mandatory purchase provisions in regions with competitive power markets, and a period of very volatile and high natural gas prices (to a large extent caused

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[9] National Association of State Energy Officials (2013), 1.

[10] In the U.S., about two thirds of the fuel used to produce electricity is wasted heat.

[11] More than 85 percent of all generating capacity at industrial and commercial sites uses a CHP technology. Only 4 percent of the generating capacity within the electric power sector uses a CHP technology. Typically, a utility would sell the waste heat to a neighboring industrial facility.

[12] Qualified CHP facilities can receive a 10 percent investment tax credit, which expires in 2016. [Bloomberg New Energy Finance (2014), 60]

by disruption of gas supplies by Hurricanes Katrina and Rita) combined to discourage CHP installations.[13]

Seventy one percent of existing CHP capacity is fueled by natural gas, which is the focus of this paper. CHP systems consume annually about 4.5 Tcf of natural gas, or an estimated 2.2 Tcf more than the natural gas consumed by onsite boilers or furnaces in the absence of CHP. Coal and process wastes make up the remaining fuel mix (15 and 9 percent respectively), followed by biomass, wood, oil, and other waste fuels. There has been growing interest in biomass and waste fuels in recent years as renewable fuel sources.

In the U.S., gas turbine[14] and steam turbines are the major CHP technologies that use natural gas as a fuel. For example, combined cycles and combustion gas turbines represent 50 and 13 percent of existing CHP capacity, respectively. Boiler/steam turbine systems, which use primarily coal and wood waste, represent 34 percent of total CHP capacity. Reciprocating engines, fueled by natural gas, represent 3 percent of CHP capacity in the United States while microturbine systems and fuel cells make up less than one percent.[15]

## I. Purpose of This Paper

This paper concentrates on those barriers to gas-fired CHP generation that fall under the purview of state utility commissions ("commissions"). Some of the barriers may warrant commission review or mitigation. Because studies and energy observers have alleged that CHP capacity in the U.S. is deficient does not make it so. In some instances, advocacy characterizes their arguments; proponents would contend, for example, that CHP has diverse benefits that the market or regulators fail to account for in their decision-making. For others, any barrier to CHP development justifies its elimination through governmental action, irrespective of its source and the associated cost.

The focus of this paper is on those state utility regulatory policies and practices that could compensate for artificial barriers to CHP development. The paper separates barriers into two categories: (1) those that are detrimental to both the CHP sector and society's interest and (2) those that are detrimental to the CHP sector but *not* society's interest. It makes a distinction between "normal market barriers" and "market/regulatory failures" and discusses the policy implications for each category.[16] Market/regulatory failures can include insufficient information, average-cost electricity prices, myopia, externalities, utility obstructions against CHP development, and any regulatory policy or practice that unduly hinders the development of CHP.

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[13] Pace Global (2013), 4-2.

[14] Gas turbine systems include combustion turbines and combined cycle turbine technologies.

[15] Reciprocating engines, however, is the most common gas-fired CHP technology in the number of installations.

[16] This paper only mentions governmental-derived barriers other than those erected by state utility commissions. Examples of these barriers are environmental restrictions, and permitting and siting rules.

Normal market barriers include less-than-perfect information,[17] capital market constraints, uncertainty of the future, risky investments, and immature technologies.

Correcting for market/regulatory failure could not only assist the CHP sector but it could also improve societal welfare.[18] In contrast, alleviating normal market barriers is unlikely to produce a win-win outcome. For example, by under-pricing standby service to bolster CHP technologies, while benefiting the CHP sector and overcoming an obstacle, would leave full-requirements customers paying for the subsidy. Whether this outcome would improve aggregate welfare depends on the economic justification for "artificially" bolstering the CHP sector. Policymakers, including state utility commissions, should determine whether barriers in a generic sense are actually socially harmful or whether they simply represent normal market features for which external intervention would make matters worse.

## II. Characteristics of CHP Systems

### A. Two outputs with a single fuel source

CHP technologies are integrated systems that produce electricity and useful thermal energy (heating and/or cooling) from a single source of fuel. CHP systems are most economical when residing at facilities with large and concurrent electric and thermal demands. In the industrial sector, CHP thermal energy is in the form of steam used for process heating and for space heating. For commercial and institutional users,[19] thermal energy is more often 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. Thermal energy can also produce air conditioning or refrigeration services with the addition of a thermally activated cooling system. Systems with this capability can expand the benefits of CHP, especially for facilities that lack year-round heating load.

### B. Individual features

CHP systems have unique features that distinguish them from other electricity generation technologies. They also have attributes that make them similar to those technologies. The following identifies the salient features of CHP systems:

1. **A type of distributed generation, unlike central station generation, that resides at or near the point of consumption:** Since most distributed generation, including CHP, requires interconnection to the central power grid, the host must rely on standby

[17] People typically make decisions with less-than-perfect information because of limited time and mental capacity. They exhibit what some analysts call "rational ignorance." *See*, for example, Thaler and Sunstein (2008); and Frank (2007).

[18] The word "could" implies that mitigating market/regulatory failures might not always be desirable, as the costs might exceed the benefits.

[19] The largest commercial and institutional CHP systems reside in large office buildings, military bases, universities and healthcare facilities.

service from the local utility. What price the utility charges for this service can affect the economics of a CHP system, which this paper will discuss shortly.

2. **CHP technologies can use a variety of fuels (both fossil and renewable):** While the most common fuel in current CHP systems is natural gas, other fuels include coal, biomass and wood.

3. **CHP technologies come in two broad categories, topping and bottoming cycle:** A topping-cycle CHP system (which is more popular) first uses fuel in a prime mover such as a gas turbine or reciprocating engine to generate electricity. It then recovers the energy normally lost in the prime mover's hot exhaust or cooling systems to produce useful thermal energy. The optimal design and size of topping-cycle CHP systems matches the facility's base load thermal demand. A bottoming-cycle CHP system, sometimes referred to as waste heat to power, first uses fuel to produce thermal energy, with part of the heat rejected from the process then recovered and used for electricity production, typically in a waste heat boiler/steam turbine system.

4. **Optimal energy efficiency requires the sizing and designing of CHP systems to meet the host's energy profile:** For many industrial hosts sizing their CHP system based on thermal needs results in surplus electric power that they can sell back to the local utility or other potential buyers.[20] According to one study:

   > CHP plants are typically sized to meet the power and thermal needs of the installation, rather than being designed to sell power to the grid, but opportunities often exist to sell excess power to the grid. The value of energy generated is based on the time of day that it is produced and also its probability of being produced as planned (i.e., its reliability).[21]

5. **Some gas-fired CHP technologies have much faster start-up times than others:** The fastest technologies are reciprocating engines and microturbines, which can almost immediately provide electricity when the local-utility grid goes down.[22] This feature has received greater attention over the past two years because of severe weather conditions.

6. **The costs of different gas-fired CHP systems vary widely:** Large systems have much lower capital cost per kW, reflecting economies of scale. Steam turbines have the lowest capital costs. O&M costs are highest for small systems, such as fuel cells, microturbines and reciprocating engines.[23]

7. **The economics of CHP systems is site-specific:** CHP project economics depend on such factors as electricity rates and tariff structures, natural gas prices, site specific conditions, like space availability and integration into existing thermal and electric

[20] Other systems sized to thermal load may have deficient electricity production, requiring the host to depend on the local utility for standby service.

[21] IHS CERA (2014), IX-8.

[22] Ibid., IX-6. Some microturbines can operate in either grid-connected or island mode.

[23] Ibid., IX-6.

systems, vulnerability to central-station outages from severe storms,[24] and permitting, siting and grid interconnection requirements.[25]

8. **Economies of scale places large CHP systems at an advantage over smaller systems:** Experience has shown that large CHP systems are more likely to be cost-effective than small systems. According to experts, small systems will require a technological breakthrough before they become economical to a large number of households and small businesses.

9. **CHP has been employed for many years, mostly in industrial, large commercial and institutional applications:** Large CHP systems in particular are a mature technology, having a proven track record for operation reliability and being economical.[26]

10. **CHP has been providing electricity and process heat to major industries, large employers, urban centers, and campuses in the United States:** The diverse use of CHP technologies speaks to its economic potential in different environments. CHP technologies have served commercial and institutional facilities such as schools and hospitals, district energy systems, and military installations.

11. **CHP applications can operate at 75 percent efficiency, compared with the national average of around 50 percent for electricity and heat when separately provided:** For this reason, many policymakers consider CHP systems as an energy-efficiency resource.

12. **CHP systems emit less pollution than separate electricity and thermal energy systems in producing the same amount of energy output:**[27] As one study noted: "A new CHP installation using a gas-fired turbine with low-nitrogen oxide burners and no end-of-pipe emissions controls substantially reduces nitrogen oxide emissions from levels that would result from the continued operation of an existing onsite boiler to provide process heat and an offsite power plant to provide power."[28]

13. **CHP facilities are clustered in a relatively few areas of the country:** These include the Gulf Coast where many refineries and chemical plants reside, in the South with its many pulp and paper mills, in northern Wisconsin and Maine where facilities burn wood waste byproducts as fuel, and in states with favorable utility regulation

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[24] The observed heightened interest in CHP systems in the East stems partially from recent storms that have produced prolonged power outages.

[25] For example, as stated in one publication: "…even in states where thermal generation is regulated at the state level, CHP may not meet the capacity threshold requirements to qualify for centralized state permitting and, as a result, CHP may be thrust into a confusing maze of state and local permitting requirements." [Kaufman and Frenkil (2013), 3]

[26] Corporate giants that rely on CHP to meet their substantial electricity and thermal energy demands include Dow Chemical, ExxonMobil and International Paper. [Bloomberg New Energy Finance (2014), 62]

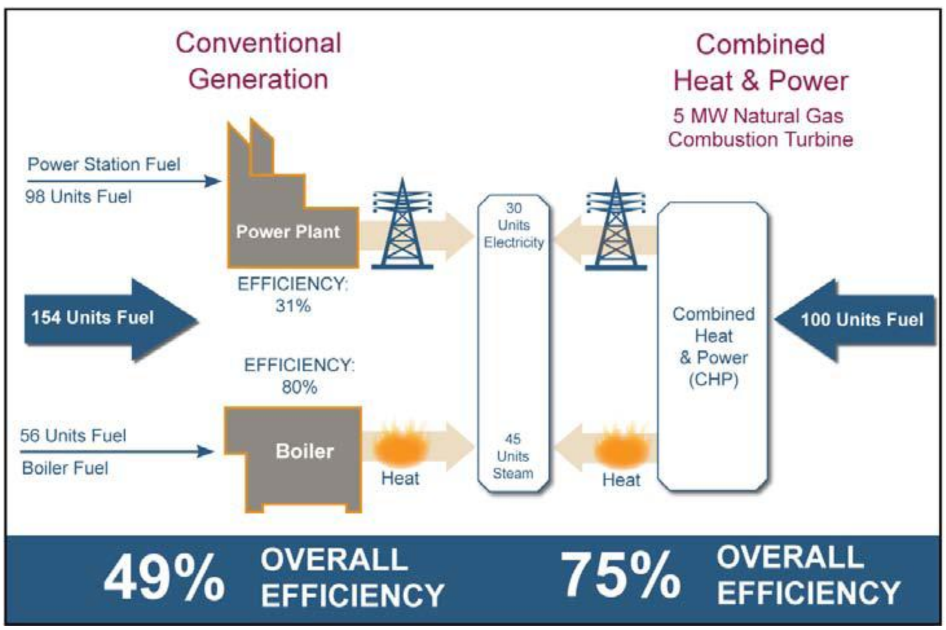
[27] The assumption is that both systems consume the same kind of fuel.

[28] Gruenspecht and Stavins (2002), 20.

toward CHP, like California and New York. The greatest potential for future development of CHP is in California, New Jersey, New York, Ohio, Pennsylvania and Texas where industries have both substantial thermal and electricity needs.

Figure 1 shows schematically the difference between a CHP system and a conventional system in which separate facilities (namely, a power plant and a boiler) produce electricity and thermal energy. A conspicuous difference is that in producing the same amount of electricity and steam, fuel input declines by about 35 percent in a CHP system (from 154 units to 100 units). Energy efficiency improves in the sense that the same level of useful energy (i.e., the sum of electricity and steam, or 75 units) requires less fuel input. One obvious outcome is fewer emissions of pollutants and lower energy costs.

**Figure 1: Fuel Savings from a CHP System**




**Source:** U.S. Department of Energy, and U.S. Environmental Protection Agency, August 2012, 7.

### C. Gas-fired technologies

Over 90 percent of gas-fired CHP systems in the U.S., measured by capacity, use either combined cycle, boiler/steam turbine or combustion turbine technologies.[29] Gas-fired reciprocating engines[30] and gas turbines represent the most cost-effective technologies today in the small and large size categories, respectively. Other gas-fired technologies are fuel cells[31] and microturbines.[32]

Boiler/steam turbines generally applies the bottoming-up process, where the primary output is heat or steam, with electricity generation as a byproduct.[33] They have the disadvantage of a slow start-up time. They also tend to have a low power-to-heat ratio. Boiler/steam turbines have the advantages, however, of relatively low installation and O&M costs, and high energy efficiency.[34]

Gas turbines apply either combustion turbine or combined cycle technologies.[35] Both technologies have high power-to-heat ratios.[36] They exhibit economies of scale; for example, a 40 MW system has much lower installed cost per kW than a one MW system.[37] Like boiler/steam systems, gas turbines have relatively low O&M costs. The "PURPA machines" mentioned earlier were largely gas turbine systems.

Other gas-fired CHP technologies such as fuel cells and microturbines have grown in smaller-scale applications. Yet, their presence in the residential and commercial sectors is negligible up to now. Fuel cells, although today largely at the demonstration stage of development, hold promise. They emit less pollution than gas turbines and have the potential for further efficiency gains and lower capital cost. Overall, residential-scale CHP systems ("microchip systems") are uneconomical, with a long payback period. Experts agree that their

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[29] IHS CERA (2014), IX-14. In Ohio, for example, over 97 percent of the CHP capacity is either boiler/steam boilers or combustion turbines. [Wissman (2012)]

[30] Ibid., IX-16. The capacity of reciprocating engines range from 10 kW to 5mW and are often used for back-up generation. Their best applications are in commercial and institutional buildings that have space and water heating requirements.

[31] They range in size from 0.5 kW to 1.2 mW.

[32] The maximum size for microturbines is in the 500 kW range. They have high reliability and can use different fuels, including natural gas, propane and hydrogen.

[33] They range in size from 50 kW to several hundred mWs.

[34] Constant thermal load helps to improve energy efficiency.

[35] As of 2012, combustion turbines accounted for 13 percent of CHP capacity and 11 percent of the number of installations, while the respective numbers for combine cycle turbines were 50 percent and 6 percent. [IHS CERA (2014), IX-16]

[36] The high temperature exhaust produced during the process of energy generation makes both of these technologies well-suited for CHP applications. Simple cycle systems, in contrast, are less efficient since they are unable to recover heat in the exhaust gas.

[37] IHS CERA (2014), IX-6.

capital and installation costs must decline substantially before small-scale CHP systems can hope to attract households and small businesses in large numbers.[38] Most households are probably unaware of the availability of CHP in the home. Small systems work best in cold weather where homes use substantial heat. Some analysts view the U.S. as a "sleeper market" for fuel cells given its large number of buildings and potential for energy-efficiency gains.[39]

To summarize, larger CHP units presently have a definite economic advantage over smaller units, especially in having lower capital costs.[40] Fuel cell technologies have the highest installed cost among all gas-fired CHP technologies. Microturbines have relatively high O&M costs. Steam turbines have low installed costs per kW but a long start-up time. Out of all the gas-fired CHP technologies, they produce the most useful thermal energy per unit of electricity. Large-scale CHP systems have mature and time-tested technologies. In contrast, the microCHP technology (i.e., less than 50 kW dedicated to the residential market) is less mature and has the most potential to improve economically as vendors and operators will continue to move down their learning curve.[41] Today, they are uneconomical.[42] Other than steam turbines, the other technologies generate electricity as their primary product, capturing waste heat from electric generation for thermal uses – that is, they apply a "topping cycle."

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[38] Another factor that would improve the economics of small-scale CHP systems is to increase the life cycle of gas turbines.

[39] Observations across industries have shown that the diffusion of new technologies is a gradual process. The fraction of potential users that invests in a new technology, like fuel cells, typically follows an S-shaped path over time, rising only slowly at first, then experiencing rapid growth, followed by a slowdown in growth as the technology reaches maturity and most potential adopters have switched. One explanation is that potential technology adopters face different conditions so that the economics of a new technology differs across potential users. Another explanation relates to the intrinsic risk associated with investing in a new technology; this risk requires a potential user to acquire much information on both the generic features of the new technology and its use in the particular application under review. *See*, for example, Adam B. Jaffe et al. (2001), 41.

[40] One study assessed that smaller CHP systems can be economical and compete with retail electricity rates, if they have high capacity factors, local utility rates are high and the system sizes match the operator's electricity and thermal energy requirements. [Bloomberg New Energy Finance (2014), 63]

[41] "Learning by doing" refers to firms over time making fewer mistakes, with production costs falling as a consequence. Because first movers may not capture all of the benefits from this experience—with some of those benefits going to rivals—this "spillover" effect would tend to underallocate resources to research and development (R&D) as well as commercialization activities. This outcome provides a rationale for government-funded financial incentives.

[42] Since large CHP systems are currently more cost-effective than small systems, should policymakers direct financial incentives and other subsidies at small systems? This paper later addresses the "subsidy" issue.

# III. Brief History of CHP

## A. Pre-PURPA period

CHP systems located at industrial and municipal sites were the core of the early U.S. electric power industry. In 1882, Thomas Edison used CHP technology to establish the world's first commercial power facility at Pearl Street Station in New York City. This facility produced electricity to supply hundreds of customers and used the thermal energy to heat buildings in the neighborhood. Many early consumers of CHP were industrial facilities that generated electricity and used the thermal energy for heating or processes.[43] In the late 19th and early 20th century, industrial firms produced more than half of the electricity generated in the U.S.[44]

Because of economies of scale, large new generation technologies became more economical and central station facilities grew rapidly as a percentage of total electricity generation. CHP gradually became marginalized over the years, limited to a small number of industries (e.g., paper, chemicals, refining and steel) that had high thermal energy and electricity demands and access to low-cost fuels.

By the 1970s, mature, regulated electric utilities using large, power-only central station generating plants dominated the U.S. electricity market. Utilities had little interest in expanding CHP generation. Regulatory barriers at the state and federal level also hindered the growth of CHP.[45] The prospects for CHP appeared dim.

## B. PURPA

In 1978, Congress enacted PURPA, which was part of a national effort to promote energy independence and energy efficiency.[46] Under PURPA and subsequent rulemaking by the Federal Energy Regulatory Commission (FERC), qualifying cogeneration (a.k.a. CHP) and small power production facilities enjoyed certain benefits and exemptions. State utility commissions assumed responsibility for developing qualifying facilities (QFs) programs and determining avoided-cost pricing.[47] States in effect enforced and implemented PURPA standards.

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[43] *See* Quinn et al. (2013), 4-1.

[44] Rose and McDonald (1991).

[45] ICF International (May 2013), 4.

[46] Back in the late 1970s, oil consumption for electricity generation and boiler use was much higher than it is today.

[47] A QF is either a CHP facility or a small power production facility that meets the requirements of PURPA section 201.

To meet the definition of a QF, CHP facilities had to meet minimum fuel-specific efficiency standards.[48] PURPA required utilities to provide facilities with reasonable standby and back-up charges, and to purchase excess electricity from these facilities at the utilities' avoided costs.[49] PURPA originally prohibited an electric utility from owning more than 50 percent of a QF. The Energy Policy Act of 2005 (EPAct 2005) eliminated that provision by allowing electric utilities to own 100 percent of a QF.[50] PURPA also exempted QFs from regulatory oversight under the Public Utilities Holding Company Act and from constraints on natural gas use imposed by the Fuel Use Act.[51]

PURPA greatly bolstered the CHP sector.[52] Operators benefitted from lowered energy costs, because self-generation allowed them to buy less electricity from the local utility. They also had the opportunity to sell surplus power at a profit, assuming they could produce it at a lower cost than the utility's full avoided cost.[53] For some CHP generators, this profit motive drove them to just meet the standards for thermal output and focus on producing and selling electricity.[54] Some states offered extremely attractive buyback rates, stimulating CHP investments. In those states, in particular, much of the motive for CHP was in profiting from the sale of surplus electricity rather than from saving energy costs. In a way, this motive violated the original spirit of PURPA to promote energy efficiency and reduce the consumption of energy.

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[48] For example, to satisfy the efficiency standard, a gas-fired CHP would have to show the useful power output plus half the useful steam output is no less than 42.5 percent of the energy content of the natural gas used as fuel.

[49] PURPA contains a simultaneous purchase-sale provision that allows the CHP operator to purchase all of its electricity demand at the normal utility retail rate, while at the same time selling all of its electricity output to the utility.

[50] *See*, for example, Burns and Rose (2014).

[51] The Fuel Use Act restricted the use of natural gas or oil in new generating facilities. One of its intent was to encourage use of coal or nuclear energy. Policymakers considered natural gas a "premium fuel" whose best use was in home heating. They also viewed natural gas as a scarce resource that could not accommodate demand growth in the industrial and electric power sector. [*See*, IHS CERA (2014), I-3]

[52] It is fair to say that prior to PURPA non-utility generators could not sell their electricity outside the grasp of regulation.

[53] The avoided-cost criterion intended to reach a balance between encouraging CHP electricity production and benefitting the utility and its other customers. Of course, setting a purchased price at avoided cost would tend to (a) have a neutral economic effect on the utility and its customers (i.e., avoid any cross-subsidization) and (b) benefit the CHP operator when it could produce electricity below the avoided cost. Avoided cost corresponds closely to the utility's marginal cost.

[54] Industry observers referred to these facilities as "PURPA machines", which are essentially a single-purpose facility that exploits PURPA for becoming a QF with the thermal load comprising only a small fraction of the total energy output of the facility. Rules originally set by FERC require that only 5 percent of total annual energy output be useful thermal energy. "PURPA machines" are more responsive to the buyback rate than other CHP systems are. EPAct2005 attempted to discourage QF facilities from being "PURPA machines" by requiring more stringent standards for the production of useful thermal energy.

In sum, methodologies for measuring avoided cost played a crucial role in creating incentives for CHP. Generous methodologies led to a dual incentive for industrial firms considering CHP: (1) an energy efficiency (i.e., energy-cost savings) incentive and (2) a profit incentive (i.e., the difference between the CHP cost of electricity and the utility's avoided cost). To little surprise, a significant amount of cogenerated power came on line during the early years after the passage of PURPA.

In EPAct 2005, Congress gave the Federal Energy Regulatory Commission authority to terminate the utility obligation to buy electricity from QFs in regional markets that are "workably competitive." In Order 688, FERC ruled that four regional transmission organizations (RTOs) satisfy the statutory criteria for member utilities to be exempt from the "must purchase" obligation. The Order specifically established a rebuttable presumption that QFs greater than 20 MW have non-discriminatory access to at least one of those competitive markets.[55] QFs can, however, rebut the presumption of access because of special operational conditions or transmission constraints.

Finally, EPAct2005 also exempts the local utility from providing standby service under two conditions. First, retail electric suppliers are willing and able to provide standby service to the QF. Second, state law does not require the local utility to sell electricity in its service territory.[56]

### C. Post-2000

CHP capacity additions declined during 2001-2010. In 2001 CHP additions were over 6 GW compared to less than 2 GW additions in 2005. CHP growth started to taper off even more dramatically starting in 2005: Since 2006, no year had more than 1 GW of capacity additions;[57] in fact, during 2006-2011 new capacity additions averaged just 570 MW annually.[58]

Factors contributing to the slowdown included restructuring of the electric power industry, energy market and policy uncertainties, EPAct 2005 that amended PURPA, sluggish industrial growth, rising and volatile natural gas, and an uncertain economic outlook. Another, more cynical, account comes from a CHP supporter:

> One of the most significant barriers to growth in CHP over the last 10 years has been disincentives created by electric utilities. If an industrial customer installed CHP, the utility would not only lose revenue from a customer that had a relatively steady, predictable load, but could have requirements to supply backup and supplemental power at the industrial customer's peak load as well as buy back

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[55] FERC's current rules establish a rebuttable presumption that facilities with a rated capacity of 20 mW or less do not have nondiscriminatory access to markets.

[56] Burns and Rose (2014).

[57] *See*, ICF International (May 2013), 7.

[58] Bloomberg New Energy Finance, February (2014), 61.

> power when the customer had a slack period. To discourage CHP, some utilities charged very high rates for supplying backup and supplemental power but bought back excess power at very low rates. In addition, some utilities required the customer to install expensive power conditioning and control equipment purported to be needed to overcome power quality problems. At the same time attractive electricity rates may have been offered at the expense of other ratepayers to reduce the appeal of self-generated power...While most of the advantages of CHP are widely accepted, CHP has not benefitted from state or federal programs to the degree renewable energy has. For example, the federal investment tax credit offers a 30 percent credit for solar and small wind, whereas the credit for CHP is 10 percent.[59]

The extent to which these factors -- largely influenced by state utility regulation -- contributed to the downward growth in CHP after 2005 is speculative, devoid of any quantitative analysis. Although the cynical remarks lack empirical support, as discussed shortly it is plausible that electric utilities would have an incentive to obstruct the development of CHP.

### D. Today's status of CHP

Over the past two years, interest in CHP has once again revived. One factor is the need for industrial facilities to invest in improving or replacing aging boilers to comply with new pollution standards or to address aging problems (e.g., high maintenance costs).[60] Investments in industrial facilities open up an opportunity for CHP technologies. There has also been growing interest in certain states, for example, New York and Ohio, to reclassify CHP as a clean energy resource. All levels of government have given increased attention to CHP not only because of its improved economics but also because of its attractiveness as a reliable electricity resource during major storms. The improved economics stems largely from the widened "spark spread." The "spark spread" is the difference between natural gas costs and the price for which CHP operators can sell their power or avoid electricity purchases. One metric for the "spark spread" is the ratio of electricity price to natural gas price. Most forecasts for the next decade or two call for an increase in electricity prices relative to natural gas prices.[61]

Taking everything into account, conditions have rapidly made CHP more attractive to both energy industry participants and policymakers. Policymakers have elevated the status of CHP as a future energy resource and investors have given more attention to CHP. Later, this paper will look at whether the prospects for CHP growth are unduly hindered by market conditions and state utility commission policies.

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[59] Quinn et al. (2013), 4-7-4-8.

[60] Major closings or replacements of coal boilers seem likely because of boiler Maximum Achievable Control Technology (MACT) regulations.

[61] *See*, for example, U.S. Energy Information Administration (2014).

# IV. The Prospects for Gas-Fired CHP Technologies

## A. Distinguishing technical potential from economic feasibility

The *technical potential* of CHP or any technology can provide useful information to decision-makers in better understanding the maximum penetration of a technology in different locales. It is an initial step in assessing the potential for a technology in terms of its technical practicality. For example, one study remarked that:

> 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. However, the technical potential as outlined is useful in understanding the potential size and distribution of the target CHP markets among the states.[62] [Emphasis added]

Another study describes technical potential somewhat differently:

> The *technical market potential* is an estimation of market size constrained only by technological limits—the ability of CHP technologies to fit existing customer energy needs. The technical potential includes sites that have the energy consumption characteristics that could apply CHP. The technical market potential does not consider screening for other factors [which] affect the feasibility, cost, and ultimate acceptance of CHP at a site and are critical in the actual economic implementation of CHP.[63] [Emphasis added]

In terms of *economic feasibility*,[64] a CHP project has the ability to lower energy costs, provide insurance against extended outages on the central grid, and create profits from selling surplus electricity. Energy cost savings correlate to the difference between the utility price and the cost of the fuel (i.e., the "spark spread"). The cost-effectiveness of a CHP project compares these benefits, in present value terms, to the sum of the initial capital cost and O&M costs.

As noted in one study, the economic benefits of CHP depend on several factors and are State specific:

> States where gas-based CHP is likely to be successful include those that have a combination of policies that facilitate permitting and construction, potential for

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[62] ICF International (May 2013), 29. The study estimated that almost half of the technical potential is in the commercial and institutional sectors, with over half of the technical potential comprising of CHP systems with less than 5 mW capacity.

[63] State and Local Energy Efficiency Action Network (2013), 4 (fn. 32).

[64] Economic feasibility has no single definition. Some analysts refer to it in terms of the payback period, with one definition specifying the payback period of five years or less. Other analysts consider a project economical if its net present value (NPV) exceeds zero. One study distinguishes between economic feasibility and strong economic potential with the latter condition requiring a CHP project with a payback period of less than five years [IHS CERA (2014), IX-2].

> electricity sales back to other end-users or the grid, reasonable standby rates and interconnection rules, and high spark spread values.[65]

Studies have generally found a large discrepancy between CHP systems that have technical potential and are economically feasible. One study, for example, concluded that:

> The technical potential for additional CHP applications at existing industrial, commercial, and institutional facilities is large, at approximately 130 GW. However, this represents an upper bound and does not consider capital costs, regulatory barriers, policy uncertainty, market conditions, and other factors impacting the feasibility of CHP system investments that can affect the market potential for CHP. Consumer perceptions and tolerance for risk is another critical element. Past analysis has shown that potential industrial CHP candidates have low risk tolerance – less than 50% of potential CHP candidates view a two year payback as acceptable for a CHP project. This report includes an analysis of the impact of economic considerations on the technical potential of the CHP market, but does not estimate the impacts of consumer acceptance rates on market potential…6,355 MW of the technical potential that was modeled of 123,300 MW had paybacks less than 5 years located in twelve states: Alaska, California, Connecticut, Florida, Hawaii, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Texas and Vermont. Thirty six states had 41,612 MW with paybacks less than 10 years. Fourteen states and the District of Columbia had little or no potential, having paybacks greater than 10 years.[66]

This quote makes two salient points. The first is the low percentage of CHP with technical potential that is economical (e.g., less than a 5 year payback) -- a little over 5 percent. The second is the wide discrepancy in payback periods across states. Although payback periods are not a theoretically sound investment criterion, as this paper points out shortly, these large differences are stark.[67] They point to the importance of local conditions, as well as the energy demand requirements of potential hosts, in affecting the economic feasibility of a CHP project.

### B. Potential benefits

The benefits from CHP are diverse and mostly private in nature.[68] They include:

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[65] IHS CERA (2014), IX-2. Areas with favorable spark spreads for CHP include the Northeast, California and Texas. "Favorable" refers to high electricity prices relative to natural gas prices in a region.

[66] ICF International (May 2013), ES-1 and 2.

[67] The only advantages that payback-period analysis seems to have over more sophisticated methods is that it is easy to understand and communicate.

[68] Private means that the benefits flow to investors and operators, rather than to outside parties, including utilities and their full-requirements customers. To the extent that CHP benefits the local utility grid, for example by lowering delivery losses, a policy question becomes who should receive the gain from this outcome. This paper will shortly address this issue. *See*, for example, Kalam et al. (2009).

1. *Higher overall energy efficiency compared to producing power and steam in separate facilities:* For the same amount of fuel input, a CHP system is able to produce more useful output than achievable from the combination of a conventional power plant and an on-site boiler.[69] Relative to intermittent renewable energy, CHP offers higher energy savings because of its continuous operations.[70] While the public may benefit from higher energy efficiency,[71] most of the gains accrued to the CHP host in the form of lower energy bills. For many proponents of specific energy technologies like those for CHP, public benefits are a major rationale for government support. Yet, although easy to list, public benefits are difficult to quantify for setting financial incentives or levels for other subsidies.

2. *Energy-cost savings:* DOE and EPA estimate that by installing 40 GW of new CHP capacity, U.S. businesses and industry could save $10 billion per year in energy costs and reduce overall national energy demand by one percent.[72]

3. *Reduction in lost electricity from transmission and distribution:* Distributed generation like CHP reduces electricity flows on the power delivery system. This reduced flow lowers transmission and distribution (T&D) losses.

4. *Environmental benefits:* A 2007 McKinsey study calculated that CHP can deliver $CO_2$ reductions at negative marginal cost for both commercial and industrial sectors.[73] Another study by Oak Ridge National Laboratory concluded that increasing the CHP share of electricity generating capacity would significantly reduce $CO_2$ emissions.[74] The Obama Administration has estimated that adding 40 GW of new CHP capacity by 2020 would reduce metric tons of $CO_2$ annually equivalent to the annual emissions from over 25 million cars.[75] Other environmental benefits from CHP derive from increased energy efficiency and reduced fossil-fuel usage.

5. *Power security and reliability:* CHP can relieve grid congestion in addition to providing backup during central grid outages and disasters.[76] Improving grid

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[69] Most of the fuel savings comes from the recycling of waste heat.

[70] CHP systems typically have much higher capacity factors than solar and wind systems.

[71] "Public benefits" result from private actions that benefit third parties (e.g., the general citizenry), but which market participants have no financial incentive to consider in their decisions.

[72] U.S. Department of Energy and U.S. Environmental Protection Agency (2012), 3.

[73] McKinsey and Company (2007).

[74] Oak Ridge National Laboratory (2008).

[75] Pielli (2013), 8.

[76] As expressed in one study:

A focus of infrastructure resilience is investing in resources that allow for as much of the relevant critical infrastructure system as possible to remain functional in the event of an attack or disaster, and for compromised parts of the system to resume functionality as quickly as possible. In this context, the value of CHP to infrastructure resilience becomes clear; critical assets across sectors can be insulated from disruptions to the electricity grid through the use of CHP and other forms of distributed energy.

resiliency and grid security has become a hot topic in view of extreme weather and cyber-security concerns.[77] These concerns have triggered heightened interest in distributed generation in general.[78]

6. *Increased competitiveness of U.S. manufacturing:* By lowering their energy costs, for example, industrial firms can compete better in the world market.
7. *Positive macroeconomic effects:* Lower energy costs leading to a more robust industrial sector can spur higher economic growth. The extent to which CHP would produce those results depends on several factors.
8. *Advantages over other electric generation technologies:* Some studies have shown that CHP systems have greater benefits relative to other generation technologies, including renewable energy and central system power. Appendix A illustrates these benefits derived from one study. As shown, compared with similarly sized (10MW) solar photovoltaic (PV), wind and conventional natural gas combined systems, a CHP gas turbine has: (a) a higher capacity factor, (b) a lower footprint, (c) lower capital costs than solar and wind systems, (d) higher energy savings, and (e) lower $CO_2$ and $NO_x$ emissions. The CHP system has the added benefit of producing thermal energy. Although one can question the assumptions used in the study, the table reveals the potential societal benefits from CHP. An apparent paradox is that although CHP appears competitive with other generation technologies, it has failed to attract the same attention from policymakers and investors.[79]

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[ICF International, March 2013, 34.]

[77] *See*, for example, ICF International (March 2013). One state that has taken action after Hurricane Sandy is New Jersey. The Office of Clean Energy initiated dialogue on how to prioritize use of CHP technologies for hospitals, prisons, wastewater treatment plants and other essential facilities in the event of future severe storms.

[78] CHP supporters point to the advantages of CHP systems over backup generators: (a) backup generators may take time to start up after grid failure, and this lag time can result in the shutdown of critical systems; (b) backup generators typically rely on reciprocating engines burning diesel fuel, an inefficient and polluting method of generating electricity; and (c) backup generators only supply electricity, whereas CHP systems supply both thermal loads and electricity to keep facilities operating as usual. Overall, CHP is more effective than traditional backup generation in mitigating the damage done by severe storms and other sources of grid failure.

[79] *See*, for example, Rogers (2013), 9. Another study calculated that:

> The average capex for large-scale (over 40MW) CHP is approximately $1.3m/MW, compared with approximately $1m/MW for a stand-alone utility-scale CCGT plant. The higher cost is primarily due to the additional equipment necessary to recover and process thermal energy. Despite the higher capex, the average unsubsidized [levelized cost of electricity] LCOE for a natural gas-fired CHP project of this size is around $60/MWh compared with $67/MWh for a CCGT plant. Overall, then, for projects that can make efficient use of the heat energy, CHP can be a cost-effective source with lower levelized costs than CCGT.
>
> [Bloomberg New Energy Finance (2014), 63]

Overall, the prospects for growth in CHP appear bright. Policymakers at the federal and state level have given more recognition to (1) the potential benefits that CHP offers and (2) the role CHP could play in providing clean, reliable, cost-effective energy services to industry and businesses. More states are paying more attention to CHP. Some firms are looking at CHP to upgrade or replace old coal- and oil-fired boilers. CHP also has the potential to provide a cost-effective source of new generating capacity to replace older power plants. Finally, CHP has also benefitted from the shale gas phenomenon, as natural gas is the fuel of choice for most CHP applications.

### C. Summary of policy studies on CHP

Supporters of specific technologies often ask policymakers to redress allegedly unfair or excessive obstacles to their market success. Their advocacy might seek subsidies, other forms of financial incentives, or the explicit lifting of particular obstacles that they feel place their favored technology at a disadvantage relative to competing technologies.

Many policy studies on CHP fall in the category of advocacy by presenting a one-sided perspective that emphasizes the benefits of CHP while slighting its shortcomings. They sometimes refer to friendly or friendlier policies toward CHP, some of which seems too "chummy" and potentially leading to outcomes unduly favoring CHP. These studies are akin to sales pitches directed at policymakers. They characterize any action favoring CHP as a "no regrets" policy in which no one becomes worse off. Because these studies presume that additional CHP is socially desirable, they focus on policies that would spur higher growth in CHP investment.

One problem is that these studies seem to understate CHP costs, who would pay for the new policies (e.g., subsidies), and the limitations of CHP technologies. CHP proponents are not alone in showing bias toward their favored technology. Nuclear, coal and renewable advocates have exhibited the same prejudices. Objective policymakers have the difficult but necessary task of sorting through their lobbying efforts to identify those technologies that would best promote the public interest.

CHP proponents have devoted much of their efforts toward identifying barriers to CHP development that have stifled its growth. The presumption is that the current level of CHP capacity is below the socially desirable level. This paper makes no such presumption, since empirical evidence for this assertion is lacking; instead, it tries to identify obstacles that may unduly restrict CHP technologies and place them at an economic disadvantage relative to alternative generation technologies. A disadvantage, as defined in this paper, occurs anytime a barrier imposed by government or a market failure unduly impedes the development of CHP. Studies claiming the underdevelopment of CHP apply a broader definition of barriers that risks unwarranted government intervention. They tend to recommend any mitigation of barriers whether cost-beneficial or not.

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Another study shows the competitiveness of CHP with other generation technologies. [Linvill et al., (2013), 20 (Figure 4)]

One example would be subsidizing CHP investments because of the fast payback (e.g., 1-2 years) that hosts require. Although such a short payback might seem like irrational behavior requiring outside intervention, it can reflect the high uncertainty that hosts place on future benefits from CHP investments. Another example would be setting standby rates below the local utility's cost. Although stimulating additional CHP growth, it would require either the utility shareholders or full-requirements customers to pay for any revenue shortfalls. A third example is executing lax interconnection standards to lighten the burden on the CHP host that may jeopardize the safety and reliability of the utility system in addition to driving up its cost.

Appendix B includes quotes from policy studies conducted and funded by governmental and industry groups. Most of them convey the similar theme that CHP technologies have large, unexploited societal benefits because of various obstacles.[80] Their general recommendation is to have state utility commissions and other parts of government mitigate these supposedly welfare-reducing obstacles.

## D. Factors affecting the economics of CHP

### 1. Listing of factors

Table 1 lists fifteen determinants of the economic attractiveness of CHP. They span the gamut from state and federal environmental policies, state permitting rules and state ratemaking practices to initial investments costs, future uncertainty over natural gas and electricity prices, the required payback period and general economic conditions. The relative effect of each determinant on CHP investments requires an empirical analysis that falls beyond the scope of this paper.[81] The effects of individual factors would be site-specific, explaining why CHP facilities are unevenly distributed across the country.

Highlighting some of the items from the table, we observe the following:

- *Industrial and commercial firms will allocate their limited capital funds to physical investments with the highest returns, adjusted for risk.* One possible obstacle to investments in CHP is the high uncertainty over future benefits. To the extent

[80] Somewhat ironically, in the author's opinion the studies with the least advocacy are the two funded by the natural gas industry -- namely, the ICF International and the IHS CERA studies.

[81] One empirical study, Rose and McDonald (1991) measured the effects of individual factors on the demand for CHP investments. It concluded that the economics of CHP depends largely on the demand for electricity, the price of electricity and the marginal cost of producing CHP electricity. Specifically, an increase in CHP is likely when: (a) the demand for electricity increases, (b) the price of utility electricity increases; and (c) the marginal cost of CHP electricity generation deceases. All of these are expected results. The study found less significant the buyback price for surplus electricity. The analysis also suggested that utilities offering discounted rates to discourage CHP generation could be effective.

Another study quantified the effect of standby rates on the diffusion of CHP technologies. It showed that they can have a decisive influence on CHP investments. Specifically, it concluded that "reducing standby rates to reflect the cost of serving a large number of small, spatially clustered CHP systems significantly increases the adoption of these technologies." *See* Jackson (2007).

investors see high risk because of uncertainty over future natural gas and electricity prices, for example, they will demand a higher expected rate of return. A key question relates to whether current (or historical) gas and electricity prices are suitable proxies for expected energy prices.

- *Some analysts contend that for-profit entities may require a shorter payback period than other entities, such as colleges, prisons and municipalities.* One explanation is that for-profit entities place greater emphasis on the short-term because of financial pressures from investors.
- *Analysts and financial scholars have questioned the appropriateness of using a payback period to evaluate capital projects.* They consider net present value (NPV) as a preferred approach.[82] The major flaws with the payback-period approach are that it (1) ignores the time value of money, the useful life of a project and the year-to-year cash flows and (2) arbitrarily chooses the cut-off period. One outcome is that the payback-period approach will tend to accept poor short-term projects and reject good long-term projects, such as CHP systems.
- *As discussed earlier, an important economic metric is what analysts call the "spark spread," which represents the difference between the wholesale electricity and natural gas prices.* A decline in natural gas prices has two opposing effects. The first is to discourage investments in energy efficiency by lowering the electricity price. The second, and presumably more important, is to encourage new investments by lowering the operating costs of a gas-fired CHP facility.
- *Most analysts would agree that the initial capital cost of a CHP is a barrier to CHP growth, especially for small systems.* As explained in one study:

> High costs (equipment, installation and maintenance costs) are the single largest barrier to more widespread acceptance of CHP in the United States. As long as high costs persist, growth in CHP is likely to be limited. Complicating matters, individual project economics vary considerably and depend on a myriad of local factors that make it hard to generalize about installing CHP.[83]

- *Black start capability refers to the ability of a CHP facility to separate itself automatically from the grid by shutting down and then restarting under its own*

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[82] For example, Joskow and Jones (1983) studied optimal decision making, using a *net present value* criterion, of a representative cost minimizing industrial firm that plans to invest in a CHP technology. They developed a model to identify the relationships between investment costs, fuel and electricity prices, steam load characteristics, and plant scale in determining the conditions under which a firm would invest in a CHP system. Although the authors found large energy-efficiency gains from industrial CHP, they pointed out that energy savings do not necessarily translate into economic or financial savings. For example, the capital and operating costs can offset the energy savings. The authors stressed the importance of distinguishing between the technical potential of CHP and its economic potential (a matter that this paper will take up shortly).

[83] IHS CERA (2014), IX-5.

*power*. This capability can add important benefits from a CHP system by providing an insurance against extended outages on the local-utility grid.

- *Surplus power sales provide a revenue stream for a CHP project, improving the project's economics.* The buyback rate is crucial in determining the revenues and, at least in the early days of PURPA, was an important contributor to the rapid growth of CHP capacity.
- *In industrial applications with very large thermal needs, such as in chemical, paper, refining, food processing, and metals manufacturing, sizing the CHP system to the thermal load can result in surplus power generation capacity (i.e., more capacity than needed on-site).* In these instances, the host can increase its revenues by selling surplus power.
- *2011 EPA Boiler Maximum Achievable Control Technology (MACT) regulations on industrial boilers will require companies nationwide to drastically reduce emissions from coal and oil boilers, with the potential to replace old boilers with CHP technologies.* According to one study:

> This rule [MACT] applies to a wide range of large and small boilers burning coal or oil. Compliance with the rule will likely require many existing coal boiler operators to refit or replace their boiler. DOE estimated that there is a target of 791 coal boilers in 351 facilities representing a potential of about 18,000 MW that will need to be upgraded or replaced…CHP will be proffered as a potential cost-effective option.[84]

[84] Pace Global (2013), 4-7.

## Table 1: Factors Affecting the Economics of CHP

| Factor | Influence |
|---|---|
| **1.** Returns from CHP relative to competing internal investments | ▪ Firms allocate their fixed capital to projects with the largest returns adjusted for risk<br>▪ Required returns increase with greater uncertainty over future benefits |
| **2.** Investment payback period | ▪ Studies show private firms require less than a 5-year payback with some demanding as low as a 1-year payback<br>▪ Short payback period makes acceptance of CHP investments less likely<br>▪ Government and other not-for-profit entities generally use different investment criteria that tolerate a longer payback period<br>▪ Financial experts question the validity of the payback-period approach |
| **3.** Uncertainty of benefits over long-term period | ▪ Future benefits are discounted, meaning CHP investments are less attractive<br>▪ CHP is not unique in having risk because of uncertain benefits |
| **4.** Electricity and natural gas prices | ▪ "Spark spread" is important for CHP host profitability<br>▪ Most forecasts call for widening of "spark spread" over time<br>▪ "Spark spreads" differ widely across the country<br>▪ Higher gas-price stability reduces the uncertainty of future benefits and reduces the overall risk of a CHP project |
| **5.** Initial investment costs | ▪ Large upfront costs can pose a serious barrier to CHP investments even when net present value (NPV) is positive<br>▪ This condition is typical for large investments |
| **6.** Operating conditions | ▪ Most CHP systems have high capacity factors relative to intermittent renewable energy resources<br>▪ Gas-fired systems differ widely in their O&M costs |
| **7.** General economic conditions | ▪ Stronger economy stimulates demand for energy, both electricity and thermal energy<br>▪ Economic conditions also affect investment demand |
| **8.** Black start capability | ▪ This capability is costly for small CHP systems<br>▪ This capability is highly valued during times of extended outages on the central utility grid |

| **Factor** | **Influence** |
|---|---|
| **9.** Thermal load of host | ▪ Technical potential of CHP depends on a good match between electricity and thermal demands<br>▪ CHP becomes more valuable with greater uses for thermal energy (e.g., heating, cooling industrial process, dehumification)<br>▪ CHP economics strongly correlated with the constancy of thermal load |
| **10.** Revenues from electricity sales | ▪ Applications with large thermal needs often have surplus electricity to sell<br>▪ The utility's avoided cost is a crucial factor<br>▪ The CHP host can increase its revenues by selling to non-utility entities |
| **11.** Environmental regulations | ▪ MACT boiler regulations are favorable to CHP growth as firms replace old coal and oil boilers<br>▪ State regulations may drive up costs |
| **12.** Economies of scale | ▪ Initial cost per kW decline drastically with large CHP systems<br>▪ Smaller CHP systems have economic disadvantages, partially for this reason |
| **13.** Standby rates | ▪ Most CHP systems must rely on the utility grid for standby service<br>▪ Higher standby rates can diminish the economic attractiveness of CHP<br>▪ Disputes over the cost-causation nature of standby service have occurred since the early 1980s |
| **14.** Interconnection rules | ▪ Uncertainty and protracted process for interconnection can hinder and delay CHP investments<br>▪ Utility-subsidized interconnection costs can hurt full-requirements customers<br>▪ Standardized rules, although potentially beneficial to CHP systems, may not be feasible, especially for larger systems |
| **15.** Permitting and siting requirements | ▪ Stricter permitting rules drive up costs<br>▪ Rules vary considerably across locales |

### 2. Relationships between the utility's retail price, the utility's avoided cost and the cost of producing CHP electricity

Assume the following definitions and measured costs:

- The utility's avoided cost or buyback rate ($AC_u$): 12¢
- The utility's retail price ($P_r$): 10¢
- The CHP operator's unit cost ($C_c$): 9¢

The CHP operator profits when it sells surplus electricity at a price ($AC_u$) that exceeds its unit cost of self-generating electricity ($C_c$). Without CHP, the firm's effective price for electricity is the price it pays the utility, namely $P_r$. With a CHP facility, the firm deducts from the price it pays the utility the profit that it makes by selling surplus electricity to the utility. Since the CHP operator profits by 3¢ for each kWh it sells back to the utility (i.e., $AC_u$ - $C_c$ = 3¢) and the operator pays the utility 10¢ per kWh for electricity it buys, the net price of electricity for the CHP operator reduces to 7¢.

Another observation is that CHP is economical anytime the CHP operator is able to produce electricity cheaper than the utility (i.e., $C_c$ is less than $AC_u$). This outcome occurs anytime the CHP operator profits from sales to the utility, since the utility's avoided cost measures its incremental cost of producing the electricity that it instead purchased from the CHP operator.[85]

Other than for "PURPA machines"[86], the primary motivation for CHP operators is to avoid paying the utility at the price $P_r$.[87] Yet, in our example, the CHP operator could reap maximum benefits by selling all of the electricity it produces and buying all of its electricity needs from the utility. Using the same numbers above, when the firm lacks a CHP system it buys all of its electricity, which we assume is one million kWhs. Its cost would be $100,000 ($10^6$ kWhs · 10¢). If it now has a CHP system sized to just meet its electricity needs, its electricity cost reduces to $90,000 ($10^6$ kWhs · 9¢). If alternatively the operator decides to sell all of the electricity it produces and buy all of its electricity needs from the utility, its net cost for electricity reduces further to $70,000 [$10^6$ kWhs · (10¢ - 3¢)].[88] In this example, a rational CHP operator would opt to be a "PURPA machine" and be indifferent to the energy-efficiency benefits that would derive from a CHP system.

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[85] Another interpretation of the avoided cost to the utility is that it represents the economic value of the electricity produced from a CHP facility; that is, it measures the long-run cost of the electricity that the utility need not produce, measured in terms of the economic opportunity cost of the resources saved.

[86] As indicated earlier, the major purpose of "PURPA machines" is to sell electricity to the local utility.

[87] One analyst refers to the "PURPA machine" motive as the arbitrage mode and the "avoidance motive" as the displacement mode [Fox-Penner (1990)].

[88] 3¢ is the profit that the CHP operator makes for each kWh of electricity it sells to the utility.

Even though the intent of a policy to stimulate CHP no longer holds (i.e., to bolster energy efficiency) in the above illustration, all things being equal, CHP production solely for profit is superior from an economic-welfare perspective. The reason is that the CHP operator replaces electricity that the utility would have otherwise produced at 12¢ with its own electricity that costs only 9¢.[89] On the downside, the CHP operator receives a subsidy from the utility: The utility buys electricity at 12¢ from the operator and sells its electricity at only 10¢. The difference (2¢) is a short-term loss to the utility that ultimately flows to full-requirements customers.[90]

Some utilities in the past have offered special rates to discourage industrial customers from self-generating. Industry observers referred to them as "cogeneration deferral rates." As long as the utility is not charging below its incremental cost, according to the conventional economic argument, it is not uneconomical to offer a lower rate.[91] There are three potential problems, however, with discount rates. First, they are definitely discriminatory: The only reason the utility is offering a special rate is that the customer has a "bypass" option (i.e., CHP production); it is not because it is cheaper for the utility to serve that customer compared with other similarly situated customers. Price discrimination is often defensible, so cogeneration deferral rates are socially desirable under specific conditions.[92] Second, there is a "fairness" issue of who absorbs the "revenue losses." A net-revenue shortfall requires that the CHP-potential customer would have continued to buy its electricity from the utility even in the absence of a rate discount.[93] In this instance, any revenue losses would likely lead to higher rates to other utility customers. Third, discount rates could act as a barrier to CHP, stifling the

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[89] If the CHP operator produces electricity at lower cost than the utility does, from the perspective of economic efficiency the utility's price to the firm should exceed the operator's cost. In our example, if the utility price was 6¢, the firm would be better off by not investing in CHP but the societal cost of producing electricity would increase from 9¢ to 12¢. The reader might question why the utility would ever set a price below its avoided cost. One possible reason lies with the mechanics of traditional utility ratemaking in which prices are normally based on historical average cost while marginal cost is a forward-looking measure. For a utility with little surplus capacity and a short-term need for additional capacity, its marginal cost may well be higher than its existing price.

[90] One obvious way to eliminate this subsidy would be for the utility to set its retail price at marginal cost.

[91] For electric utilities with surplus capacity, often their embedded cost or the price they normally charge is above their marginal cost. Thus, a rate discount rate could still be above marginal cost, allowing utilities to collect a margin. Although the margin is lower with the discounted rate, utilities could argue that without the reduced rate a customer would invest in a CHP facility and they would suffer higher "earnings" erosion. Utilities have also argued that discount rates are merely a rational response to competitive forces stimulated by the viability of bypass technologies such as CHP facilities.

[92] For example, the literature of Ramsey pricing shows that price discrimination can improve total economic welfare.

[93] To say it differently, the company is a "free-rider" in the sense that the rate discount did not change its action but allowed the customer to benefit from the lower rate. Another less transparent problem occurs when the utility does not charge the company the maximum price that would prevent the customer from bypassing to a CHP technology. In other words, the utility could charge a higher price and still retain the customer on its system.

long-term growth of the CHP sector. In fact, some opponents of discount rates argue that these rates are anticompetitive and in violation of PURPA.[94] In addition, stifling competition can reduce pressure on utilities to price, plan and operate efficiently.

### E. Push by the Obama Administration

The Obama Administration has promoted CHP as an energy-efficiency investment that will create benefits for the industrial sector and the general economy. In 2012, the President issued *Executive Order 13624, Accelerating Investment in Industrial Energy Efficiency*, directing federal agencies to promote the expansion of CHP by an additional 40 GW by 2020.[95] As noted in the Executive Order, "Accelerating [CHP] investments in our Nation's factories can improve the competitiveness of United States manufacturing, lower energy costs, free up future capital for businesses to invest, reduce air pollution, and create jobs."[96]

The Order added that meeting the national goal set out by the Obama Administration will require "encouraging private sector investment by setting goals and highlighting the benefits of investment, improving coordination at the Federal level, partnering with and supporting States, and identifying investment models beneficial to the multiple stakeholders involved."[97] Specifically, the Executive Order directed both DOE and EPA to conduct regional workshops for the purpose of initiating a dialogue on how to promote the growth of CHP. It also directed federal agencies to provide general guidance, technical analysis and information on the benefits of CHP to states, utilities and potential industrial hosts of CHP. Subsequently, the EPA created the CHP Partnership to work with energy users and CHP industry stakeholders to (1) facilitate the development of new CHP projects and (2) disseminate information on their environmental and economic benefits.

## V. Different Barriers to CHP Development

One recent study for the American Gas Foundation sums up well the predicament for CHP technologies:

> One of the biggest advantages of CHP includes the higher electrical efficiency that comes first from the cogeneration of heat and power on site and second from the avoidance of the losses associated with the transmission and distribution of moving power from a central generating unit to an end user site. For this reason, a number of states allow CHP to be counted in their Renewable Portfolio Standards. However, *high costs (equipment, installation and maintenance costs) and the need for constant thermal loads are the two most significant barriers to*

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[94] *See*, for example, Cogeneration Coalition of America (1987).

[95] White House, Office of the Press Secretary (2012).

[96] Ibid, "Section 1: Policy."

[97] Ibid, "Section 1: Policy."

*more widespread acceptance of medium- and small-scale CHP in the United States*."[98] [Emphasis added]

This quote makes a few pertinent points. First, more states are elevating the status of CHP to the level of renewable energy. Although natural gas is a fossil fuel, it has environmental benefits over other fossil fuels and economic and technical advantages over some forms of renewable energy (*see* Appendix A, for example).[99] Like many physical projects with long lives, CHP technologies have high initial costs that could discourage investors who require a quick payback. Another point is that uniform thermal demand is a key prerequisite for investments in CHP facilities. Whether barriers to CHP investments warrant third-party support to alleviate them is a policy question. An argument against intervention is that some barriers are normal market features best addressed, over time, by buyers and sellers of CHP systems. For example, the advancement of CHP technologies that would lower capital costs reflects an expected market response to enhancing the economics of CHP.[100] Other barriers to CHP development may, however, justify governmental/regulatory intervention, particularly when originating from market/regulatory failure.[101] This section of the paper will identify possible failures that state utility commissions may want to address.[102]

What have been the biggest impediments to CHP? How do we know, if at all, that we have deficient CHP capacity? These are questions that policymakers like state utility commissions should ask.[103]

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[98] IHS CERA (2014), ES-18.

[99] Renewable energy tends to be intermittent, for example, usually requiring gas back-up.

[100] The presumption is that the market would have the motivation to innovate when the expected return adjusted for risk is sufficiently high.

[101] This paper shortly discusses the distinction between different barriers to CHP investments and their policy implications.

[102] For a thorough description of the barriers to development of CHP technologies, *see* Chittum and Kaufman (2011). Without identifying them, the reader can judge which barriers identified in the report originate from market-regulatory failures or reflect normal market conditions. The report groups the barriers into four categories: economic, financial, political and regulatory.

[103] The American Council for an Energy-Efficient Economy compiles what it calls a "state energy efficiency scorecard." [Downs et al., (2013)]. The scorecard includes CHP and ranks the states based on regulations and policies favoring CHP investments. A state gets a higher score if it encourages CHP development through the following seven factors: (a) standard interconnection rules, (b) eligibility of CHP in the state's renewable portfolio standard (RPS) and energy efficiency resource standards (EERS), (c) financial incentives, (d) net metering regulations, (e) output-based emission regulations, (f) loan guarantees, and (g) technical assistance and other supportive programs. The methodology ranks the states on the basis of a numeric score that ranges from zero to five. Weights for interconnection rules, CHP eligibility in RPS and EERS, and financial incentives are twice the weights assigned to the other four factors. Although a numeric score conveys the appearance of objectivity, selecting the factors and weighing their separate influences on CHP investments are largely subjective.

The appropriate responses to market/regulatory failures can range from doing nothing and disseminating information on CHP technologies, to compensating prospective CHP hosts by offering them financial incentives.[104] Doing nothing is a good policy when the barriers are not serious enough to offset the cost of intervention. An analogous situation exists when the government tries to intervene in markets with minor problems. In these instances, government policies frequently cause counterproductive results or mitigate the problem at an excessive cost.[105] As an illustration, a commission might want to bolster the CHP market by allowing a gas utility to offer below-cost delivery rates to CHP customers. The aggregate cost of the rates to utility customers as a whole might exceed any benefits derived from this subsidy. On the other hand, doing nothing might produce inferior market performance when serious market/regulatory failures prevail. If, for example, little information is available on the benefits of CHP, companies could forgo investing in CHP that would be profitable and socially desirable.

The State and Local Energy Efficiency Action (SEEAction) network has identified five key areas for fostering CHP.[106] They include: (1) the design of standby rates, (2) interconnection standards, (3) surplus power sales, (4) clean energy portfolio standards[107] and (5) exploitation of emerging market opportunity, such as for critical infrastructure and utility participation in CHP activities. Its *Guide* views deficient actions by policymakers in these areas as obstacles to CHP development.[108]

A pro-CHP study argues that the gap between technical potential and economic feasibility (previously discussed) originates from barriers that policymakers should attempt to mitigate:

> …given current policies and recent installation trends, it appears taking advantage of that [CHP] technical potential could be a challenge… Policies and regulations do not always encourage CHP deployment, though, and this report finds that almost all of the states that are facing higher levels of potential coal retirements

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[104] Financial incentives can come from utilities or from governmental entities, in the form of direct grants, tax incentives, low-interest loans, rebate programs, low standby rates, attractive buyback rates and so forth.

[105] *See*, for example, Winston (2006); and Wolf, Jr., (1979).

[106] SEEAction is a state and local effort facilitated by the federal government that assists states, utilities, and other local stakeholders in taking all cost-effective energy efficiency initiatives by 2020.

[107] Clean energy portfolio standards (CEPS) are tools that states can apply to increase the adoption of clean energy technologies, including CHP, by requiring electric utilities and other retail electric providers to meet a specified amount of load through eligible clean energy sources. One of the goals of CEPS is to stimulate market and technology development so that, ultimately, clean energy will be economically competitive with conventional forms of electric power. A number of states have explicitly included some CHP technologies as eligible resources in the CEPS. Some contention exists over whether gas-fired CHP production is actually a clean-energy resource.

[108] State and Local Energy Efficiency Action Network (2013).

do not have most of the critical policies in place that yield a healthy investment environment for CHP.[109]

Some commissions have recognized the value of CHP by calling for new regulatory policies that would promote it. For example, the California Public Utilities Commission considers CHP as an emissions reduction strategy and supports action to remove barriers to CHP development by revisiting current commission policy.[110]

The discussion below identifies various market barriers to CHP development. These barriers overlap with obstacles identified in various studies on CHP. Listing barriers, and showing how they might stifle CHP development, is a simple matter while recommending appropriate action to address them is the real challenge to policymakers. Which of them, for example, require any action by state utility commissions has no clear answer. One alternative is for commissions to address barriers on a case-by-case basis. For example, some utilities might have reasonable standby rates and interconnection rules, while others in the same state do not. Some barriers, as mentioned elsewhere in this paper, may require no action, as they reflect normal market features that buyer and sellers of CHP systems can best address in the marketplace.

### A. Market obstacles

Studies have identified several barriers to CHP development initiated by market forces. They include:

1. **Excessively short payback period or the use of payback-period analysis *per se* for investment decision-making:** As discussed earlier, many firms use the theoretically inferior payback-period approach as a criterion for CHP investments.[111] Why firms fail to use the net present value method is somewhat surprising. Perhaps even more puzzling is the extremely short payback period that firms require for investment in CHP systems.[112] Apparently other energy-related investments also use payback-period analysis in their decision-making.[113] It would seem a stretch to support any regulatory intervention just because firms voluntarily use a questionable approach for evaluating investments.
2. **Uncertain rate of return or benefits to CHP investors:** The unpredictability of natural gas prices and facility operating performance, for example, makes the benefits from an investment in CHP uncertain. This uncertainty may explain the short

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[109] Chittum and Sullivan (2012), vi-vii.

[110] *See* California Public Utilities Commission Decision in D.10-12-035 (2010).

[111] *See* the earlier critique of the payback-period approach.

[112] One survey conducted for the California Energy Commission showed that more than 30 percent of respondents would reject a CHP project that returns its original investments in just one year. (ICF International, May 2013.) Another study came to the same general conclusion of an extremely short payback period that seems to defy economic logic [Chittum and Kaufman (2011)].

[113] *See*, for example, Jackson (2007), 1898.

payback period that many CHP investors require; the uncertainty would increase the required rate of return that investors would expect. Uncertainties for CHP projects include: (a) financial, (b) cost performance, (c) utility actions and (d) regulatory and government in general.[114] Of course, other technologies face similar uncertainties, and some even additional ones. In the absence of evidence showing that uncertainties are more pronounced for CHP or inflated by flawed regulatory practices, policymakers should not consider uncertainty of future events as a reason to bestow special treatment upon CHP technologies. Investors typically endure risk, especially when their investments have a long life. Thus, uncertainty of the future does not constitute a market failure; instead, it simply reflects a normal market condition that can hinder investments, but not in an uneconomical way. To the extent that state utility commissions are able to cost-effectively reduce the uncertainty for CHP investors, they can help bolster CHP investments. For example, by approving well-defined interconnections rules and standby rates based on cost-causation principles, commissions can create a more supportive environment for CHP investments.

3. **Inadequate information about CHP technologies:** DOE and EPA have partnered to assist industrial facilities in accessing information on alternative cost-effective, clean energy strategies such as CHP when making investment decisions. Vendors of CHP systems on their own should have the incentive and ability to disseminate the benefits of CHP to prospective investors. After all, because CHP systems have existed for decades, they represent a mature technology. Prospective CHP operators would seem to have access to a wealth of information on CHP systems to make informed decisions. Economic theory predicts that when market participants have access to good information and lower transaction costs, they will tend to make more rational decisions, for example, investing in a technology when it is profitable.
4. **Inertia:** The hesitancy of firms to invest in apparent cost-effective CHP might reflect uncertainty of the future rather than irrational behavior. Often in other contexts the unwillingness of market participants to take actions that on the surface appear to be in their self-interest presumes a flawed market. Inertia, instead, may simply reflect the reluctance of prospective CHP operators to invest because of uncertain outcomes that could make them worse off. It may also reflect high transaction cost of switching to self-generation (see later discussion). Mitigating or eliminating some barriers like inertia when they reflect rational behavior is ill-advised: they are simply not cost-beneficial. Spending taxpayers' or ratepayers' monies to alleviate this "problem" in most instances would be bad policy.
5. **Myopic behavior by potential investors:** Reasons for investors' shortsightedness include high uncertainty of the future or excessive discounting future benefits. Again, policymakers might criticize investors for having a short-term perspective, but trying to modify their behavior would not be a simple task, let alone justifiable in principle.

[114] A firm contemplating a CHP facility might consider uncertainty over future natural gas and electricity prices as a deterrent by increasing the risk of the facility relative to the firm's other investment opportunities.

6. **High initial investment costs:** This condition is normal for large projects and does not infer any market failure.[115] Undoubtedly, high capital costs can act as an obstacle to any investment. It would seem more appropriate for the market itself to address this problem rather than having government subsidize upfront costs to stimulate investments. Sellers of CHP systems, for example, can create innovative financial plans to ease the upfront costs. Perhaps for immature technologies, government assistance of some form to reduce capital costs would have greater rationale. But most CHP technologies that are economical today do not fall in this category.

7. **High transaction costs:** Self-generation might pose too much of a hassle for industrial firms and other businesses. Firms might prefer to focus their time on their core business instead of on internal electricity generation.[116] The federal government is trying to facilitate the decision-making process for prospective CHP operators with its partnership program that this paper described earlier.

To elaborate on some of these market obstacles, empirical evidence has shown that information is more effective when it tells people about their losses when they fail to take a specific action. For example, companies might be more willing to invest in CHP if they have information that shows that they could lose millions of dollars over time if they fail to invest in CHP. Behavioral economics combines economics and psychology to explain how people make decisions.[117] It assumes "bounded rationality," where people make decisions with less than perfect information because of limited time and capacity. They exhibit what some analysts call "rational ignorance." Individuals, companies and other entities are susceptible to making predictable and avoidable mistakes. Ideas from behavioral economics include: (1) faulty discounting (consumers under-valuing future benefits relative to present costs), (2) *status quo* bias (even if consumers know that the current situation is not in their self-interest, they will take no action), (3) overconfidence (believing that natural gas prices, for example, will stay low indefinitely), (4) complexity delaying decisions, and (5) loss aversion (the possibility of losses or simply uncertainty over the benefits of switching to a CHP system, for example, discouraging action). These conditions hold in many market situations but, typically, without warranting government intervention.

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[115] One study calculated, for example, that capital costs for a 7-MW gas-fired CHP system would total over $12 million. [ICF International (May 2013), C-5]

[116] As noted in one study:

> Installing and operating an onsite generation unit is a difficult decision for many end-users, because it represents the addition of new lines of business – power plant operation and energy management. These new business lines require personnel and management with unique skills, present new risks, and consume already limited management attention. Some end-users choose to enter these new lines of business themselves, while others opt to have a third party handle the construction, ownership, and operation of the CHP system. [ICF International (May 2013), 28]

[117] *See*, for example, Richard H. Thaler and Cass R. Sunstein (2008); and Robert H. Frank (2007).

Management incentives based on sales and production might also steer firms away from CHP investments. Firms have limited available capital; thus, even if CHP is economical for the firm, it may have a lower priority than alternative investments. In other words, firms may undergo a capital budgeting review in which investments that save energy costs, like CHP systems, compete with alternative investments that various departments of the firm propose to senior management. Typically, management ranks these investments based on profitability, corporate goals and other criteria. To infer, therefore, that a firm exhibits irrational behavior when it fails to invest in a CHP facility that passes a net present value or life-cycle cost test is incorrect given all the other factors that affect the firm's decision.

### B. State utility regulation

The economic viability of distributed generation (DG), including CHP facilities, depends on the regulatory policies that affect its interaction with the central electricity network. State commissions assume a vital role in the development of CHP. Electric utilities might act to hinder CHP development, as often that would be in their financial interest. Commissions should make sure that they do not erect artificial obstacles impeding the public interest. Growth of CHP technologies will depend mostly on economic factors,[118] federal and state energy and environmental policies, technological advancements, and past successes. At the least, state commissions should attempt to remove those barriers that would obstruct the socially desirable development of CHP. They need to walk a tightrope, however, between overly encouraging CHP and obstructing justifiable CHP development. Regulatory intervention, especially in bestowing favors upon CHP, requires knowing the seriousness and nature of the problem at hand. Regulatory intervention should only occur if (1) the imperfections reflect a systematic failure of markets or current regulatory policies to achieve a socially desirable outcome and (2) the cost of intervention is less than the benefits. An analogous situation exists when the federal government tries to intervene in markets with minor problems or presumed major problems. Government policies frequently cause counterproductive results or mitigate a problem at a higher-than-necessary cost.[119]

Market problems sometimes correlate with past regulatory actions. Regulators may approve inefficient rate designs, for example, inducing consumers to make choices that fail to reflect the full economic costs of producing and delivering energy.[120] Regulators may also restrict promotional practices, such as advertising by gas utilities on the benefits of CHP that could provide customers with valuable information on the life cycle costs of alternative energy

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[118] Economic factors affect the life-cycle cost of CHP. The relevant cost is the annual cost of owning, operating, and maintaining CHP systems. Cost depends, therefore, on the initial installation costs, operating times, fuel cost and efficiency, and maintenance cost. Similar to other generation technologies, investing in a CHP requires consumers to trade-off the high installation costs with cost savings over time. A similar compromise exists when households decide whether to purchase durable goods (e.g., attic insulation or a high energy-efficient furnace).

[119] *See*, for example, Winston (2006); and Wolf, Jr. (1979).

[120] One outcome could be "uneconomic bypass," where consumers turn to a CHP technology when utility electricity has an artificially high price but lower total costs. It is uneconomic because society incurs higher cost in meeting the energy demands of a customer.

sources. Any regulatory action that favors one source over another inevitably would lead to a distortive outcome.[121]

Some observers, largely CHP proponents, allege that unfavorable conditions at the state level are the most prevalent barriers facing CHP systems. Listed below are potential barriers that fall within the purview of state utility commissions.

### 1. Benefit-cost tests for evaluating CHP

Most state commissions mandating utility energy-efficiency actions require that these initiatives pass some benefit-cost test. If investments in CHP systems lead to greater energy efficiency, however defined, that outcome by itself would not justify regulatory intervention.[122] Most state commissions promoting energy efficiency use what analysts call the Total Resource Cost (TRC) test for evaluation.[123] Utility energy-efficiency initiatives presume the existence of market barriers hampering consumer investment in energy-saving hardware. Many of these alleged barriers might apply to CHP, although the significance of their consequences can differ. Regulators generally rationalize these initiatives on the premise that market problems have hindered consumers from making energy-efficiency investments that are in both their self-interest and in society's interest. When regulatory support for CHP technologies rests only on grounds of energy efficiency, the relevant tests for evaluating CHP should correspond to those applied to conventional utility energy-efficiency programs.

Any benefit-cost test for CHP should account for the effects on electric and gas utilities, their customers and the CHP operator. For example, customers converting to a CHP technology would likely have both a long- and short-term adverse effect on electric utilities and a positive effect on gas utilities. Some analysts have criticized tests currently being used as excluding public benefits and the benefits to the utility grid that CHP provides. Public benefits are external to the CHP operator, the utilities and their customers. These analysts are, in other words, saying that the tests being applied understate the society-wide benefits of CHP.

CHP may have greater benefits and fewer costs to an electric utility than renewable DG has. The reasons are that most CHP technologies are dispatchable and normally depend less on ancillary and balancing services. CHP may also be able to achieve public benefits designated by policymakers as relevant (e.g., job creation, cleaner environment) more cheaply than renewable energy can (*see*, for example, Appendix A).

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[121] Regulatory actions can potentially have a greater effect on creating or aggravating market problems than other sources, such as a non-competitive market structure, consumer inertia, and insufficient and confusing consumer information.

[122] This criterion could also apply to utility initiatives that aim, for example, to increase consumer purchases of energy-efficient appliances. These initiatives usually receive regulatory approval only when they pass some cost-effectiveness test.

[123] This test accounts for all quantifiable costs and benefits (e.g., avoided supply and delivery costs) accrued by all of those affected (e.g., program participants, the utility) by a utility energy-efficiency program. *See*, for example, California Public Utilities Commission (2001).

Measuring the cost-effectiveness of CHP programs becomes complicated by the involvement of both electric and gas utilities. Gas delivery for the local gas distributor would increase while the electric utility would see its sales decline.

Any cost-benefit test should examine how CHP would affect individual stakeholders. Of particular concern to utility regulators is whether electricity rates would increase to full-requirements customers. By losing revenues at a higher level than cost savings, a utility would experience lower earnings that ultimately translate into higher rates over time.

### 2. Interconnection rules

CHP operators require interconnection with the central grid for standby power and sale of surplus power to the utility.[124] As a barrier, interconnection can be costly, time consuming and complex for CHP systems, diminishing their attractiveness. For example, interconnection procedures can delay the project development process and add expenses by requiring costly studies, onerous technical requirements, or significant delays in the process.

Good interconnection rules try to balance the interests of the CHP operator and the connecting utility. Any technical requirements should ensure the protection of the electric grid's safety and reliability. Overly stringent requirements and uncertainty in the timing and cost of the application process, however, can act as a hindrance to CHP development. Some observers have argued, notwithstanding the absence of empirical evidence, that interconnection rules in some jurisdictions have greatly hampered CHP investments. Specifically, some have contended that many states lack interconnection standards.[125] Standards would create clear guidelines streamlining the process, in addition to specifying technical requirements that reduce interconnection and cost uncertainty.[126] A standardized application process, for example, can save developers time and money. Critics of current interconnection rules say these rules are too protective of the utility and too inconsiderate of the cost effect on CHP operators.

Utilities seemingly benefit from restrictive rules.[127] It is important, therefore, to prevent this condition. On the other hand, CHP proponents may be overstating the problem by posturing to gain commission approval for utilities and their full-requirements customers to subsidize the cost of interconnection.

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[124] The latter reason is especially important for over-sized CHP systems that sell electricity back to the local utility.

[125] A utility counterargument is that standardized rules, although potentially beneficial to CHP systems, may not be feasible, especially for larger systems.

[126] One state (Ohio), for example, uses a multi-level approach tailored to match a customer's unit size and circuit location for the purpose of streamlining interconnection requests. [Wissman (2012)]

[127] The assumption is that by discouraging CHP investments the utility prevents revenue erosion and eliminates a competing source of electricity.

### 3. Standby rates

Most CHP operators require backup, supplemental or maintenance service from a utility.[128] The rates charged for these services can affect the economics of a CHP project. In fact, some analysts contend that a major barrier to CHP development is excessive standby rates.[129] For example, rates that include non-bypassable fixed charges and ratcheted demand charges can reduce the economic benefits of CHP.[130]

Standby rates have been contentious in state regulatory proceedings since the 1980s. Views on standby rates vary: They range from the perspective that they should encourage CHP development to the position that they should recover the utility's cost of providing standby service. The first perspective deducts from the standby rates any public benefits (e.g., lower $CO_2$ emissions) that CHP provides. In effect, full-requirements customers would be funding these benefits. The second perspective is more aligned with commissions' definition of "just and reasonable" rates. Of course, reaching agreement on the relevant costs for standby service is the challenge.[131]

Some analysts support applying "options" and "insurance" pricing principles to set standby rates. For example, a utility could determine the reliability requirements of standby customers based on their past forced outage rates to set a demand or reservation charge. Option theory asks the question: How much are CHP operators willing to pay the utility for the availability of standby service whether or not they actually use the service?[132] Alternatively, the standby customer could determine how much reliability it wants (e.g., how much it is willing to pay for higher reliability); the utility could then charge accordingly based, for example, on the required utility reserved capacity. More of the customers' bill using "insurance" principles will be in the form of a fixed monthly charge and less reliant on the actual electricity consumed.[133] A

[128] *See* Tom Stanton (2012); and London Economics International (2006).

[129] *See*, for example, U.S. Environmental Protection Agency (2009). *See* also, the website of the Regulatory Assistance Project (RAP) at http://www.raponline.org/press-release/standby-rates-for-combined-heat-and-power-need-a-fresh, which states: "Under some electricity rates, CHP customers face confusing and potentially contradictory tariff conditions, leading to excessive costs for the back-up electricity and grid services provided by their local utility and a disincentive to invest in CHP resources."

[130] The position of some CHP supporters is that standby rates (a) are typically "ratcheted" to customer's peak demand for the entire year and (b) overcharge certain CHP operators, especially those with low forced outage rates.

[131] Although the author did not undertake an independent review, it is probably safe to say that some utilities have standby rates that are favorable to CHP operators while others have unfavorable rates, possibly even in the same state.

[132] This compensation can deviate from the utility's cost of providing standby service, for example, because of the risk aversion of customers toward interrupted service. That is, customers are willing to pay more than the expected cost of not having electricity when needed.

[133] *See* London Economics International (2006).

fixed monthly charge corresponds to premiums insurance companies charge whether or not the insured party ever files a claim.[134]

Reasonable standby rates compensate the utility for: (1) the costs associated with preparing for contingencies (e.g., forced outage) in which the CHP facility is unable to generate at a normal or expected level and (2) the costs of providing any supplemental power that the customer requires beyond the capacity of its CHP facility.[135] One suggestion is for utilities to set standby rates applying the same pricing principles that they use for full-requirements service. This does not infer that the rate levels are the same; but only that they allocate common and capital costs to full-requirements and CHP customers based on the same criteria.[136] For example, the utility would allocate what it considers a "fair share" of the common costs to both CHP operators and full-requirements customers.[137] Setting standby rates on the same principles would improve price transparency for CHP operators. The effect would be to lower risks to the operators, making CHP projects more economically attractive.

One outcome of just-and-reasonable standby rates is that they do not discourage economical CHP while avoiding a subsidy funded by full-requirements customers: Less-than-full cost recovery by the utility requires funding by other customers;[138] more-than-full cost recovery results in excessive payment by CHP operators making CHP less economically attractive. In sum, a good standby rate would result in no subsidy, be fair to CHP operators and full-requirements utility customers, and not discourage good CHP projects or encourage bad CHP projects.[139] To what extent current standby rates follow these tenets is utility-specific and difficult to generalize, given the lack of empirical evidence.

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[134] For an insurance company, the set-aside pool of funds compensates an injured party in the event of an accident.

[135] *See* Selecky et al. (2014) for an evaluation of issues surrounding standby rates.

[136] In other words, the utility charging different rates for standby and full-requirements service would not be discriminatory.

[137] Utilities bear certain fixed costs in order to keep the CHP operator connected to their distribution system even when the operator needs no electricity. For example, a utility incurs maintenance costs for idle standby capacity.

[138] Inadequate cost recovery might occur when the utility fails to recover both the cost of the (a) readiness to supply electricity and (b) actual electricity delivered when needed.

[139] One analyst noted that:

> Contrary to the positions of …[distributed generation] proponents, providing subsidized standby service is a mistake. First…, it should not be assumed that all DG brings external social benefits. Subsidized standby service is a shotgun approach to encouraging beneficial projects…manipulating standby rates to benefit DG constitutes a hidden tax on other consumers…When subsidies are buried in obscure rate designs...transparency is thwarted.
>
> [Parmesano (2003), 89]

Critics of current standby rates offer many suggestions to improve them. The major ones include:

- Rates should contain no ratchets when they depend on the customer's peak demand for an entire year (e.g., the customer's highest 15-minute demand).[140]
- Rates should be transparent and understandable (e.g., unbundling of generation, transmission and costs).
- The reservation charge should depend on an individual customer's historical outage rate.[141]
- Charging of the standby demand charge should be on an as-used daily and an on-peak basis.
- Maintenance service should have a lower demand charge when (1) the CHP operator notifies the utility in advance and (2) the maintenance occurs during the utility's off-peak period.[142]
- The standby energy-usage charge should depend on time of use.
- Standby customers should have the opportunity to purchase power in the open market.
- Customers should have the option to take interruptible service.
- The facility charge should only account for dedicated distribution facilities.
- High-voltage transmission should account for load diversity.[143]

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[140] Ratcheted demand charges in standby rates means that the utility continues to apply some percentage (often as high as 100 percent) of the customer's highest peak demand in a single billing month up to a year after its occurrence. The use of ratchets is controversial: Some view them as increasing the fairness of fixed cost allocation, while others see them as barriers to economic applications by CHP customers. Although demand ratchets may be appropriate for recovering the cost of delivery facilities dedicated to an individual customer-generator, they are less defensible in reflecting cost causation for shared distribution and transmission facilities, which are farther removed from the customer. Because utilities design distribution and transmission facilities to serve a pool of customers with diverse loads rather than a single customer's needs, coincident outages drive their costs. Utilities favor demand ratchets to reduce the risks of serving certain customers whose demand fluctuates widely during the year.

[141] The presumption is that past outage rates are a good predictor of future rates. One counterargument is that to the extent that outages are random events, forecasting future outages defy precision.

[142] For example, a utility can reduce its demand charge by 50 percent when the operator schedules maintenance during the spring and fall seasons.

[143] The presumption is that not all CHP facilities will shut down during the utility's peak hours. That is, the probability of interruptions for one CHP operator is unrelated to interruptions for other customers. This is akin to insurance companies not expecting accidents to occur simultaneously.

### 4. Utility ratemaking

Electric utilities have expressed growing concern that distributed generation is compromising their revenues, earnings, and even their entire business model.[144] In response, many utilities have sought revisions to their tariff design. One of their proposed changes is to increase the fixed charges paid by distributed generators for interconnection to the utility grid.

Traditional ratemaking motivates electric utilities to obstruct CHP development.[145] The metric that best explains this utility posture is *earnings*. Specifically, three aspects of traditional ratemaking can result in negative earnings for utilities. First, utilities lose revenues that may exceed their avoided costs. This is likely given that almost all utilities have a rate design that requires them to recover a portion of their fixed costs in the volumetric charge. Second, to the extent that utilities pay more than their avoided costs for surplus power sold by a CHP facility, they would also experience a loss in earnings. Although utility shareholders would likely shoulder these losses in the short term, ultimately utilities would presumably recover them from full-requirements customers in future rate cases. Third, CHP development would likely lower the rate base of utilities in the long term, depriving them of profit opportunities that they would otherwise have.[146]

The dependency of CHP development on utility ratemaking originates from different sources:[147]

- The *standard two-part tariffs* provide utilities with a disincentive to support both energy efficiency and distributed generation.
- *Rate basing of new investments* allows utilities to earn a rate of return on their investments. CHP operations should lower utilities' capital requirements over time.
- *Less-than-full recovery of incremental costs* by utilities would inflict financial harm upon utilities. Relevant costs include interconnection and other costs to accommodate a distributed resource like CHP.

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[144] Utilities and analysts do not see the potential for utility revenue losses from CHP applications as serious as the potential losses from customers installing rooftop solar systems. Some industry observers refer to severe revenue losses as a "death spiral" event.

[145] One study noted that municipal utilities have less opposed CHP than their privately-owned counterparts. [ICF International (May 2013), 28] One explanation might be the "profit" threat to privately-owned utilities that does not exist for municipal utilities.

[146] We should expect less resistance from a combination utility than from a straight electric utility. A combination utility can offset the revenue losses in the electric sector by increasing earnings in the natural gas sector from additional throughput on its distribution system.

[147] *See*, for example, National Economic Research Associates (2006). The presumption is that the local utility has the ability to stifle CHP development because CHP operators must depend on the utility for interconnection and standby service.

- Some utilities charge an *exit fee* to customers who decide to satisfy at least a portion of their electricity needs from self-generation.

- Some electric utilities may, as some have done in the past, offer *special discounted rates* to those customers contemplating investments in CHP. To counter this deliberate action to prevent bypass, some gas utilities have offered special transportation rates to encourage CHP investments.

- *Buyback rates* for surplus electricity generated by a CHP can affect the profitability of CHP investments. These rates generally relate to the local utility's avoided costs. One policy question is whether CHP operators should be able to sell their surplus electricity to other than the local utility.

### 5. Characterization of CHP as an energy resource

An increasing number of states consider CHP as a source of both clean energy and energy efficiency.[148] In 2012, for example, Ohio expanded the definition of its Energy Efficiency Resource Standards (EERS) to include CHP.[149] Under EERS, utilities are subject to energy efficiency standards, typically measured as a target volume of kWh (often as a percentage of the previous year's kWh sales). At the time of this writing, 24 states have EERS for electricity or for both electricity and natural gas. In a few states, utilities are pursuing CHP as part of ratepayer-funded energy efficiency programs.

Some states have adopted clean energy portfolio standards (CEPS) to bolster clean energy technologies, including CHP, by requiring electric utilities and other retail electric providers to satisfy a specified amount of load through eligible clean energy sources. The major goal of CEPS is to stimulate market and technology development, with the hope that in the future clean energy will become economically competitive with conventional forms of electric power. Twenty-three states consider CHP as part of their renewable or clean energy portfolio standards or energy efficiency resource standards.[150]

Some states are still contemplating whether CHP is both a clean energy resource and an energy-efficiency resource.[151] If policymakers consider CHP as either, the question then becomes how policymakers should value it and what cost-benefit metric is appropriate. For example, should state utility commissions give CHP the same treatment that they give renewable energy when evidence shows that CHP has economic and other advantages over renewable energy? The following quote from a study describes one such advantage:

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[148] For a comprehensive database on individual state policies and financial incentives for CHP, *see* the EPA website at [Combined Heat and Power Partnership | US EPA](Combined Heat and Power Partnership | US EPA).

[149] Ohio also includes waste heat to energy under its Renewable Portfolio Standard (RPS).

[150] Energy Information Administration (2012); and U.S. Environmental Protection Agency (2013).

[151] A report by the National Association of State Energy Officials (2013) identified 38 states in 2011 having a state energy plan. Seventeen of those plans referenced CHP at least once, with some plans considering CHP as renewable energy while others referring to CHP as energy efficiency.

> ...the addition of renewable energy plants has created congestion and a need for massive investment in transmission and distribution infrastructure. The addition of CHP at industrial sites actually unloads the grid by siting generation at the point of demand. This results in cost savings for both the end-user and potentially reduces investment requirements by the utility."[152]

### 6. Utility business model

A broad question relates to the proper roles of both electric and natural gas utilities in the future development of CHP. As one analysis recommended, a key element is to give electric utilities "sufficient incentives to make them facilitators of CHP installations rather than barriers to CHP implementation."[153] Some states erect barriers to utility participation in the CHP market. For example, they impede utilities from owning, building or operating CHP facilities. CHP proponents view utility active participation in the CHP market as a potential game-changer.[154] That is, even with the reform of utility ratemaking and inclusion of CHP in utility planning on an equal footing with clean energy technologies, the potential benefits from CHP could fall short under a passive-utility scenario. "Equal footing" is synonymous with the concept of "equal opportunities" in which the market produces winners solely on the basis of satisfying consumers and society as a whole.

Electric utilities, with few exceptions, have traditionally been reluctant participants in the CHP market.[155] Many utilities, as discussed earlier, consider CHP as a threat to their revenue streams. Utilities tend to take a defensive posture with the goal of preserving existing revenue levels. For example, they might focus their efforts on better cost management and rate-design reforms (e.g., recovery of embedded capital costs in a fixed monthly charge). A proactive utility, in contrast, would recognize that its participation in the CHP market has the potential to enhance profit opportunities, or to defer large capital investments in generation, transmission and distribution infrastructure. It would contemplate creating new services and investing in CHP technologies. Overall, its objective would be to exploit opportunities for revenue growth in a changing marketplace

An electric or a gas utility can participate in CHP markets in different ways, depending on the regulatory environment:

- Utility partnerships[156]
- Ownership of CHP facilities by utilities[157]

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[152] Pace Global (2013), 4-5.

[153] Pace Global (2013), 4-11.

[154] *See*, for example, Watson (2012).

[155] *See*, for example, Kind (2013). The author suggested strategic actions that electric utilities can take in responding to the proliferation of distributed resources like CHP technologies. These actions might lead to a new utility business model that would allow utilities to remain attractive to investors.

[156] Two partners combining their different and complementary skills can improve efficiencies and, thereby, lower the cost and increase the value of energy services.

- Service provider to customers who own their CHP facility

One example of a partnership is the utility entering into a commercial arrangement with a third-party, who would develop and build a CHP facility. The utility then could sign a long-term lease or operating agreement with the third party. Another example would relegate the utility's role to working with a vendor or customer to facilitate the application of the CHP technology.

Concerning utility ownership of a CHP facility, the utility can enter into a leasing agreement with a customer by charging a fixed monthly fee. The customer can be either a large industrial firm, a small business or a household. An alternative is for the customer to sign a power purchase agreement (PPA) with the utility. The customer would pay the utility an agreed-upon amount for the electricity. The price presumably would be less than the utility tariff applicable to the customer.

Utility ownership has at least three benefits. First, the utility is able to recoup some of its lost revenues when a customer switches from full-requirements service to partial service. Second, the customer does not have to pay the upfront capital cost for the CHP system. Even when cost-effective, some companies may shy away from investing in CHP because of high initial capital costs or the higher priority they place on revenue-producing investments.[158] A third possible benefit is that the utility could exercise greater control over the operation of the CHP facility and its integration with its distribution system, for example, through its contract with the customer.

One word of caution is that the utility's presence in the CHP market can discourage the entry of third-parties. The utility might have cost advantages because of economies of scale or scope, or have a contrived foothold from erecting barriers to third-party participation. Two examples of the latter condition are cost shifting of CHP related costs to core utility services and discriminatory actions toward third-party CHP entities.[159] The pertinent policy question then becomes: How can a state commission assure a "level playing field" between utility-owned and third-party CHP facilities? Utility ownership (or via affiliate) would require regulatory rules to ensure non-discriminatory access by third parties wanting to enter the CHP market in the utility's service territory and compete with the utility. Cost-shifting[160] and other problems can arise that

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[157] The utility can sell both power and heat to the host.

[158] The short payback period that many of them require (see earlier discussion) reflects their reluctance to invest in CHP.

[159] The *leverage theory* supports the idea that a firm with power in one market (e.g., a public utility with a franchised service area) can exploit that power to acquire or preserve power in a second market. This behavior can harm competitors and create monopoly power in a market that is otherwise competitive. This theory reflects what analysts call a *vertical-control problem*, where an electric utility, for example, providing local distribution service under regulated and monopolistic conditions can misuse its position to attain market power for an affiliate selling electricity and other competitive services.

[160] Cost shifting is not necessarily anticompetitive. It always has the effect of raising the prices of regulated services. Yet it might have no effect on the unregulated market: It might simply allow the utility to increase its profits by cost manipulation, rather than predation or other strategies giving its affiliate an unfair advantage over its competitors.

commissions will have to address in regulatory rules.[161] On the other hand, imposing undue restrictions on the utility or its affiliate can prevent them from investing in CHP even when they are the least-cost provider.

To promote CHP opportunities, natural gas distributors could play an active role in alleviating the local, state, and federal barriers that might be hindering CHP growth. They can also collaborate with other entities to support regulatory approaches that both bolster CHP investments and hold electric utilities financially harmless.

## VI. Consideration of State Regulatory Practices to Guide Future CHP Development

State utility commissions should ask five primary questions about CHP:

1. What should society expect from electric utilities in accommodating or supporting CHP?
2. How should electric utilities meet those expectations?
3. What can commissions do to require or encourage utilities to meet these expectations? Possible actions include performance incentives, mandates, removal of utility barriers, and support for a proactive utility.
4. What financial incentives and other promotional practices initiated by gas utilities should commissions allow in order to stimulate CHP growth?
5. What should commissions do to change their current policies and practices to assure the full exploitation of cost-effective CHP?

One commission practice in support of CHP is to promote education and information dissemination in general,[162] and level the playing field by eliminating any artificial barriers. Commissions might want to revisit current ratemaking practices to remove any utility disincentive to accommodate distributed resources like CHP systems, while leaving untouched natural barriers to CHP growth. Violation of the later outcome, for example, would come from ratepayer funding of special incentives to promote those CHP investments that can financially stand on their own.

Most fundamental, commissions should adhere to the principle that the market should be the primary driver of CHP investments. Markets function typically well when private owners of capital projects receive the returns and bear the risks. Assuming normal market conditions, energy consumers are in the best position to make decisions affecting their well-being. This principle does not preclude regulatory and other governmental intervention: With serious market

[161] Commissions will want to assure general ratepayers that they are not subsidizing the CHP facility or that the benefits they receive at least equal the added costs they pay. Protections can include ring fencing and prohibitions against information and employee sharing with an unregulated affiliate.

[162] As previously stated, both the federal government and the market itself seems adequately fit and active in providing information to prospective CHP operators.

or past regulatory failures, intervention can alleviate distortive decision-making leading to undesirable outcomes.

Consistent with a market-oriented approach, commissions should strive to place gas-fired CHP systems on an equal footing with other generation technologies. Assuring that CHP systems are competing fairly with these technologies would go a long way toward establishing a sound regulatory policy on CHP. Only when CHP has substantial public benefits, which this paper calls into question, should policymakers go beyond removing legitimate barriers to actively promoting CHP growth.[163]

A commission's objective should be to allow the market and the inherent features of the technologies themselves "pick winners," rather than policymakers. One outcome is the higher market penetration of cost-effective technologies. In its 2012 resolution, NARUC encourages CHP investments that are cost-effective.[164] The resolution also encourages state utility commissions to "evaluate regulatory mechanisms and consider and identify ways to best deploy cost-effective CHP technologies." This paper agrees with this perspective by advocating a measured but orderly role for commissions in allowing all generation technologies to compete on an equal basis.

Commissions should exercise caution in supporting subsidies or taking other actions funded by general ratepayers; it is questionable whether CHP should enjoy subsidies or special incentives. After all CHP is a mature technology whose efficient presence in the energy market would seem to require no special treatment from regulators and other government entities.[165] One rationale for subsidies offered by CHP advocates is that if competing distributed resources are the beneficiaries of generous subsidies, CHP would be at an economic disadvantage. Two wrongs, however, don't necessarily make a right: Subsidies to CHP technologies -- most of which have years of operating experience -- justified as a second-best mechanism comes across as a bad policy. Generation technologies, including CHP, should be competing in the marketplace with each other and the technologies they seek to replace – not for government handouts or regulatory/legislative favors. Any external support or subsidies to CHP should

[163] When benefits from a technology, for example, extend beyond those received directly by direct beneficiaries (i.e., public benefits are greater than zero), regulators should ask whether it is appropriate to spread the costs to all customers. Assume that the benefits from a new technology include a cleaner environment for the general public and less dependency on foreign oil. Regulators might approve the recovery from all utility customers of costs associated with the technology. If, on the other hand, the direct beneficiaries -- for example, industrial firms who purchase a CHP system -- alone stand to benefit from the new technology, the risks should not fall on the general ratepayer. In this instance, a policy of balancing the risks and benefits would require the direct beneficiaries, and perhaps the utility as well, to shoulder the entirety of the risks.

[164] National Association of Regulatory Utility Commissioners (2012).

[165] As emphasized in this paper, policymakers should distinguish between market/regulatory failures and normal market barriers. For example, a technology like CHP might appear superior to other generation technologies in performance and cost but has low penetration in the marketplace. What has caused the slow diffusion should determine the appropriate policy. Handing out subsidies to bolster a certain technology can expose taxpayers or utility ratepayers to excessive risk-taking and poor investment choices by recipients.

require projects to pass a rigorous cost-benefit test and maintain an otherwise unattainable "level playing field" among competing electricity-generation resources. In sum, a public-interest-oriented commission does not infer that it should give undue favors and excessively make CHP more economical at the expense of other energy technologies and utility full-requirements customers.

Policymakers should, therefore, be leery of calls for subsidies and special incentives to bolster CHP to what proponents consider a "societal optimal" level. They should ask (1) why a mature technology should require financial support and (2) whether the cost of this support to funders such as taxpayers and utility ratepayers exceeds the societal benefits from additional investments in CHP. Four general problems with subsidies to CHP, as well as to other generation technologies, come to mind: (a) They are difficult to terminate once their initial purpose has passed; (2) they may have a pronounced "free rider" effect if they are structured poorly, with large windfall gains to recipients and a marginal effect on growing CHP capacity;[166] (3) their targeting area may not be most effective; targeting areas include R&D, pre-commercial, post-commercial,[167] and (4) some subsidies are destined for failure at the outset -- they have little justification and benefits other than to bestow favors upon the recipients.

## VII. Conclusion

CHP is on the verge of making a comeback after almost ten years of stagnant growth and little interest by energy policymakers. PURPA stimulated CHP technologies but subsequent unfavorable conditions hampered CHP until recently. If CHP is ever to elevate its standing in the energy sector, it is apparent that now is the time to begin. The economics of CHP is site-specific, with expected uneven growth across the different regions of the country. Some parts of the country hold potential for high CHP growth while other parts will likely see little growth.

The extent to which state regulatory policies are obstructing CHP development requires more detailed examination than what this paper can provide. Because CHP has positive features compared with some other generation technologies that have received greater attention, state utility commissions may want to revisit their policies in a wide range of areas, including standby rates, general ratemaking, interconnection rules and the status of CHP as clean energy and energy efficiency. State regulatory and legislative policies ostensibly favor renewable energy over gas-fired CHP technologies: Does net energy metering, for example, give rooftop solar systems an unfair economic advantage over CHP? The incentives commissions give to electric utilities through ratemaking and other practices might cause them to resist self-generation, such as from CHP technologies. For these reasons alone, state utility commissions might want to evaluate whether CHP technologies are receiving due consideration in their states.

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[166] Technology financial subsidies can require larger taxpayer and ratepayer expenditures per unit of effect to the extent beneficiaries would have purchased the technology even in the absence of the subsidy.

[167] The economic attractiveness of microCHP, for example, hinges on additional R&D efforts to lower the initial capital cost to homeowners and small businesses. In the U.S. at least, CHP technology is far from being economical to these sectors.

Although studies have assessed regulatory policies of individual states as to their friendliness toward CHP, they lack information to measure their effects on CHP investments. Besides, "friendliness" has different interpretations, one being support in the form of subsidies and undue favorable treatment. To reside in a state that has "friendly" polices toward CHP might, therefore, not be socially desirable or in the public interest. In other words, friendly states toward CHP might not be models for other states.

One important policy question relates to the distribution of public benefits or benefits that accrue to the local utility and its full-requirements customers, like the utility's avoided costs. Assume that a CHP operator has no surplus electricity to sell back to the utility. Assume also that CHP production defers utility investments in generation, transmission and distribution. Should the operator receive some compensation from the local utility, for example, in the form of a subsidized standby rate or should the utility and its full-requirements customers retain all of the benefits? One argument for the latter scenario -- which seems more sensible -- is that the CHP operator already benefits from energy-cost savings and increased resilience, which are its main reasons for investing in CHP in the first place. The external benefits are incidental or simply fall out of the CHP operations. The situation is similar to when a utility customer uses less electricity. She benefits from lowering her utility bill. Should she receive additional compensation from lowering the utility's cost? Other than possibly receiving a financial incentive *ex ante* from her utility to use less electricity because of market barriers, the common practice is for the utility not to separately compensate her for actual electricity saved. Normally, the avoided costs transfer into lower future revenue requirements and general rates, other things held constant, benefitting other customers.

Finally, as emphasized in this paper one option for consideration by policymakers is to focus on market/regulatory failures rather than to subsidize CHP as a second-best policy -- for example, "equal" subsidies across competing technologies. This course of action would likely drive CHP investments toward the socially optimal level. While CHP faces several barriers, not all, and perhaps only a few, require regulatory action. Some barriers reflect normal market conditions while others represent market/regulatory failures that on occasion might require external action. Subsidies, whether for CHP or other technologies, can have adverse effects that are not transparent, lying outside the radar of policymakers. Subsidies, especially when poorly structured, can be (1) unfair to funding parties (e.g., ratepayers or taxpayers), (2) economically inefficient, and (3) unfair to competing energy sources. Overall, subsidies, more times than not, are likely to fail a cost-benefit test from a public-interest perspective.

# Appendix A: Benefits of CHP over Alternative Generation Technologies

| Output | 10 MW CHP | 10 MW PV | 10 MW Wind | 10 MW NGCC |
|---|---|---|---|---|
| Annual Capacity Factor | 85% | 25% | 34% | 70% |
| Annual Electricity Production | 74,446 MWh | 21,900 MWh | 29,784 MWh | 61,320 MWh |
| Annual Useful Heat | 103,417 $MWh_t$ | None | None | None |
| Footprint Required | 6,000 sq ft | 1,740,000 sq ft | 76,000 sq ft | N/A |
| Capital Cost | $20 million | $48 million | $24 million | $9.8 million |
| Annual National Energy Savings | 343,787 MMBtu | 225,640 MMBtu | 306,871 MMBtu | 163,724 MMBtu |
| Annual National $CO_2$ Savings | 44,114 Tons | 20,254 Tons | 27,546 Tons | 28,233 Tons |
| Annual National $NO_x$ Savings | 86.9 Tons | 26.8 Tons | 36.4 Tons | 76.9 Tons |

Assumptions:

- 10 MW Gas Turbine CHP — 28 percent electric efficiency, 68 percent total CHP efficiency, 15 ppm NOx emissions
- Capacity factors and capital costs for PV and wind based on utility systems in DOE's Advanced Energy Outlook 2011
- Capital cost and efficiency for a natural gas combined cycle system based on Advanced Energy Outlook 2011 (540 MW system proportioned to 10 MW of output), NGCC 48 percent electric efficiency, NOx emissions 9 ppm
- CHP, PV, Wind and NGCC electricity displaces National All Fossil Average Generation resources (eGRID 2012 ) — 9,572 Btu/kWh, 1,743 lbs CO2/MWh, 1.5708 lbs NOx/MWh, 6.5 percent T&D losses; CHP thermal output displaces 80 percent efficient on-site natural gas boiler with 0.1 lb/MMBtu NOx emissions

**Source:** ICF International, May 2013, 22.

# Appendix B: Selected Quotes from Policy Studies on CHP

| Study | Highlights |
|---|---|
| *IHS CERA, January 2014* | "One of the biggest advantages of CHP includes the higher electrical efficiency that comes first from the cogeneration of heat and power on site and second from the avoidance of the losses associated with the transmission and distribution of moving power from a central generating unit to an end user site. For this reason, a number of states allow CHP to be counted in their Renewable Portfolio Standards."<br><br>"[H]igh costs (equipment, installation and maintenance costs) and the need for constant thermal loads are the two most significant barriers to more widespread acceptance of medium- and small-scale CHP in the United States." "For CHP to grow, regulatory and policy changes are likely to be necessary, particularly at the state level. Some, but not all, states include gas CHP in energy efficiency and renewable portfolio standard programs. It is important for all policy makers to recognize that they may be biasing outcomes against gas-fired CHP and in favor of renewables or other technologies, perhaps in an unintended manner."<br><br>"New business models are likely to be required that better align the interests of customers, regulators, energy suppliers, and manufacturers of CHP technology."<br><br>"States where gas-based CHP is likely to be successful include those that have a combination of policies that facilitate permitting and construction, potential for electricity sales back to other end-users or the grid, and high spark spread values." |
| *SEEAction, March 2013* | "Economical CHP may encourage large energy users to reduce purchased electricity or leave the grid entirely by self-generating. This impacts regulators and utilities because large customers leaving the grid may shift costs to other customers, requiring these remaining customers to carry the costs of the departing CHP user. Therefore, the challenge for all affected parties is to identify the most equitable arrangement that encourages adoption of CHP while ensuring that costs are not inequitably transferred to those not participating in CHP."<br><br>"Whether a CHP system exports excess electricity or not can create additional issues that must be considered…CHP project that generates excess electricity may compete with a utility or other generators, and merits different regulatory and contractual considerations."<br><br>"While advocates of renewable energy would agree that waste heat to power (also known as waste heat recovery or bottoming cycle CHP) is a clean energy source, others have expressed skepticism that CHP can truly be considered clean energy because it often fundamentally uses a fossil fuel, namely natural gas, albeit efficiently and with lower environmental impact."<br><br>"As with all power generation, CHP deployment has unique cost, operational, and other characteristics, but it is a proven and effective available clean energy option that can help the United States enhance energy efficiency, reduce greenhouse gas (GHG) emissions, promote economic growth, and maintain a robust energy infrastructure." |

| Study | Highlights |
| --- | --- |
| *DOE/EPA, August 2012* | "CHP is a commercially available clean energy solution that directly addresses a number of national priorities including improving the competitiveness of U.S. manufacturing, increasing energy efficiency, reducing emissions, enhancing our energy infrastructure, improving energy security and growing our economy."<br><br>"While CHP has been in use in the United States in some form or another for more than 100 years, it remains an underutilized resource today. CHP currently represents approximately 8 percent of U.S. generating capacity compared to over 30 percent in countries such as Denmark, Finland and the Netherlands."<br><br>"Its use in the U.S. has been limited, particularly in recent years, by a host of market and non-market barriers. Nevertheless, the outlook for increased use of CHP is bright."<br><br>"Combined Heat and Power (CHP) represents a proven, effective, and underutilized near-term energy solution to help the United States enhance energy efficiency, improve environmental quality, promote economic growth, and maintain a robust energy infrastructure." |
| *ICF, May 2013* | "The technical potential for additional CHP applications at existing industrial, commercial, and institutional facilities is large, at approximately 130 GW. However, this represents an upper bound and does not consider capital costs, regulatory barriers, policy uncertainty, market conditions, and other factors impacting the feasibility of CHP system investments that can affect the market potential for CHP."<br><br>"Past analysis has shown that potential industrial CHP candidates have low risk tolerance – less than 50% of potential CHP candidates view a two year payback as acceptable for a CHP project."<br><br>"While the potential for additional CHP in the U.S. is large, development in recent years has stalled due to regulatory barriers, policy uncertainty and market conditions all of which increase risk to potential CHP users."<br><br>"Active participation by the natural gas industry in this market could help reduce perceptions of market risk by users and stimulate CHP development."<br><br>"The main benefits of CHP for the user are reduced energy costs and increased energy reliability. CHP provides lower energy costs by displacing higher priced purchased electricity and boiler fuel with lower cost self-generated power and recovered thermal energy." |

| Study | Highlights |
|---|---|
| *ACEEE, various publications* | "The aversion to longer payback projects has had a significant impact on CHP project development, especially in the industrial sector which faces greater competition for capital funds. Institutional customers, such as educational and healthcare facilities, can accept longer payback periods, as they take more long-term approaches to their capital budgeting processes."<br><br>"Why are utilities building all sorts of other assets instead of CHP? The answer: economics and inertia. The benefits of CHP are most often considered in terms of direct benefits to the individual facility hosting the system, like a manufacturing facility or a hospital. And while these benefits are important, they are likely less compelling than those that accrue to the utility system at large and all of its users."<br><br>"If utilities could better understand and value the benefits of CHP to their systems as a whole, they could stimulate tremendous growth in CHP, offering their customers lower cost energy and improved system resiliency, all while reducing harmful emissions."<br><br>"Utilities' business and regulatory structures tend to discourage investments in CHP and encourage them instead to pursue investments in other types of assets, such as new centralized generation resources or distribution infrastructure. Additionally, utilities' investment decisions are tied to cost-benefit analyses that usually ignore or deeply discount CHP's system-wide benefits."<br><br>"Due to its increased efficiency, CHP confers economic and environmental benefits to both the facilities that use it and society at large. For these reasons, policymakers are increasingly interested in encouraging CHP in their states and regions. However, economic and policy barriers can make some states far more attractive to CHP developers than others."<br><br>"A key finding of this research is that, while there are some unique regulatory barriers in each state, CHP suffers generally from its upfront cost, inexpensive and widely available electricity, and a lack of prioritization by regulators in all capacities. In addition a clear market for excess power – and long-term expectation of such a market—would help enhance CHP deployment substantially."<br><br>"…given current policies and recent installation trends, it appears taking advantage of that [CHP] technical potential could be a challenge… Policies and regulations do not always encourage CHP deployment, though, and this report finds that almost all of the states that are facing higher levels of potential coal retirements do not have most of the critical policies in place that yield a healthy investment environment for CHP." |

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