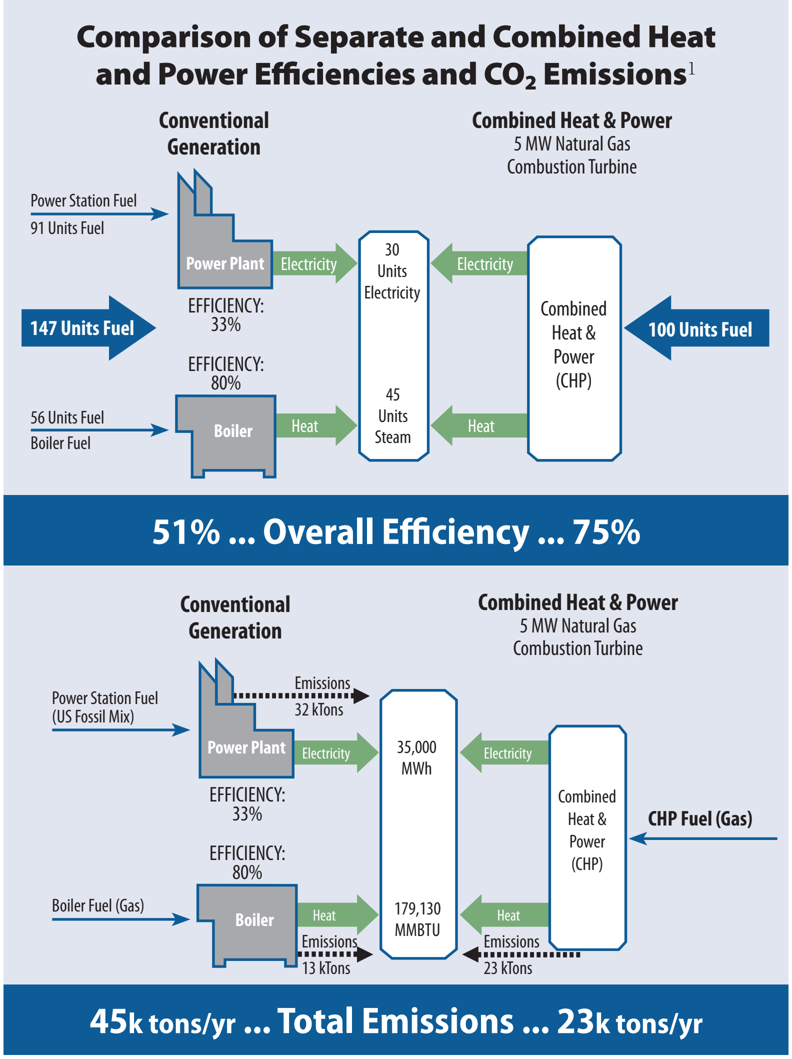
# 3. Implement Combined Heat and Power in Other Sectors

## 1. Profile

Combined heat and power (CHP) technologies in the commercial, institutional, and manufacturing sectors can reduce carbon dioxide ($CO_2$) emissions across the economy through system-wide gains in energy efficiency that improve economic competitiveness. Because CHP systems in these sectors indirectly reduce the need for generation within the power sector, they may even play a role in state plans for complying with federal regulations covering power sector greenhouse gas (GHG) emissions, such as the rules proposed by the US Environmental Protection Agency (EPA) in 2014 under sections 111(b) and 111(d) of the Clean Air Act.

CHP, also known as cogeneration, refers to a variety of technology configurations that sequentially generate both electric and useful thermal output from a single fuel source. As discussed in Chapter 2, CHP can take the form of large-capacity power producers that sell bulk electricity to the grid while supplying neighboring industrial facilities or district energy systems with thermal energy for process or space heating purposes. But CHP can also be installed at facilities with onsite or nearby demand for both heating or cooling and electricity, such as manufacturing facilities, universities, hospitals, government buildings, multifamily residential complexes, and so forth, as decentralized generation assets ranging in size and distributed across the electric grid. CHP as a form of distributed generation for these types of facilities is the subject of this chapter.

*Figure 3-1*



**Comparison of Separate and Combined Heat and Power Efficiencies and $CO_2$ Emissions**[1]

By displacing onsite boiler use and grid-supplied electricity, CHP systems can ensure supply reliability, save fuel, and reduce operating costs, typically achieving combined efficiencies of 60 to 80 percent as opposed to the 40 to 55 percent that might be expected from separate heat and power operations. These energy savings can amount to a 50-percent reduction in carbon emissions (Figure 3-1). Beyond the facility utilizing CHP, they can deliver a host of societal benefits, including improved environmental

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[1] US EPA. (2014, August). *CHP Partnership*. Available at: http://www.epa.gov/chp/. A power plant efficiency of 33 percent (higher heating value [HHV]) denotes an average delivered efficiency based on 2009 data from eGRID for all fossil fuel power plants of 35.6 percent, plus 7 percent transmission and distribution losses.

performance, high quality jobs, reduced congestion on the electric grid, reduced line losses, and embedded resiliency for emergency response and preparedness.

There are two basic types of CHP, what are referred to as bottoming and topping systems. A "topping-cycle" system is the most common configuration, in which fuel is used to power a steam turbine or combusted in a prime mover, such as a gas turbine or reciprocating engine, with the purpose of generating electricity. Rejected heat is then captured and used for process or space heating needs. In a "bottoming-cycle" system, also called "waste heat to power" (WHP), the fuel is first used to deliver a thermal input to an industrial process, and waste heat is recovered for power generation (see text box on page 3-3).

As a form of distributed generation, CHP can be based on a variety of generation technologies, summarized in Table 3-1, such as combustion turbines, steam turbines, reciprocating engines, microturbines, and fuel cells. These

*Table 3-1*

**Summary of CHP Technologies**[2]

| CHP System Type | Advantages | Disadvantages | Available Sizes | Overall Efficiency (HHV) | Installed, 2014 (Capacity/ Sites)[3] |
|---|---|---|---|---|---|
| **Gas Turbine** | High reliability.<br>Low emissions.<br>High-grade heat available.<br>Less cooling required. | Requires high-pressure gas or in-house gas compressor.<br>Poor efficiency at low loading.<br>Output falls as ambient temperature rises. | 500 kW to 300 MW | 66% to 71% | 64%/16% |
| **Steam Turbine** | High overall efficiency.<br>Any type of fuel can be used.<br>Ability to meet more than one site's heat grade requirement.<br>Long working life and high reliability.<br>Power to heat ratio can be varied within a range. | Slow start-up.<br>Low power-to-heat ratio. | 50 kW to 300+ MW | Near 80% | 32%/17% |
| **Reciprocating Engine** | High power efficiency with part-load operational flexibility.<br>Fast start-up.<br>Has good load following capability.<br>Can be overhauled onsite with normal operators.<br>Operates on low-pressure gas. | High maintenance costs.<br>Limited to lower temperature cogeneration applications.<br>Relatively high air emissions.[4]<br>Must be cooled even if recovered heat is not used.<br>High levels of low frequency noise. | 1 kW to 10 MW in distributed generation applications | 77% to 80% | 3%/52% |
| **Fuel Cell** | Low emissions and low noise.<br>High efficiency over load range.<br>Modular design. | High costs.<br>Low power density.<br>Slow startup.<br>Fuels requiring processing unless pure hydrogen is used. | 5 kW to 2 MW | 55% to 80% | 0.1%/4% |
| **Microturbine** | Small number of moving parts.<br>Compact size, light weight.<br>Low emissions.<br>No cooling required. | High costs.<br>Relatively low electrical efficiency.<br>Limited to lower temperature cogeneration applications. | 30 kW to 250 kW | 63% to 70% | 0.1%/8% |

*kW: kilowatt*
*MW: megawatt*

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[2] US EPA. (2015, March). *Catalog of CHP Technologies.* Available at: http://www.epa.gov/chp/documents/catalog_chptech_full.pdf. Note that these are illustrative values intended to represent typical CHP systems. CHP efficiency varies with size and power-to-heat ratio.

[3] The data in the last column indicate each system type's percentage of total installed US CHP capacity (83.3 gigawatt) and total number of installations (4220 sites) as of 2014. Ibid.

[4] Note that reciprocating engines can be configured to produce lower levels of emissions through engine design and add-on controls.

various technology configurations can consume a range of fuels, including oil, biomass, landfill gas, biogas, and hydrogen, but natural gas is the most common, accounting for 70 percent of existing CHP capacity.[5] The revolution in shale gas production has boosted domestic natural gas supplies, reducing both prices and volatility, which,

WHP describes any number of applications by which waste heat is captured from an industrial process through heat exchange to generate electricity. Since the 1970s, steam turbines have been used to generate power from high temperature exhaust. More recent advances allow heat recovery at lower temperatures and smaller scales – using the Organic Rankine Cycle, Kalina Cycle, and the Stirling Engine, for example – permitting power generation from a broader range of industrial applications. Technology is continuing to evolve, expanding the viability of WHP applications to low quality heat, where the majority of industrial heat losses occur.[6]

The Organic Rankine Cycle accomplishes heat transfer at low temperatures using an organic working fluid instead of water. Carbon-based refrigerants with high molecular weight can improve the heat transfer efficiency because they possess a lower boiling point than that of water.[7] The Kalina Cycle is a type of Rankine Cycle that achieves greater efficiencies by using a mixture of two fluids with different boiling points, typically ammonia and water, to extract energy across a wider range of temperature inputs. The Organic Rankine Cycle and Kalina Cycle are the same technologies used to generate power from renewable resources, such as geothermal and solar. In the industrial sector, primary metals, minerals manufacturing, chemical industry, petroleum refining, natural gas compressor stations, and landfill gas systems represent some of the industries that involve numerous processes with potential for WHP.[8,9]

As a technology category, WHP includes ***bottoming-cycle cogeneration*** as it is defined in this chapter, that is, instances in which waste heat is recovered from a thermal process, like a cement kiln or glass furnace, to generate electricity. However, WHP also includes applications in which waste heat is recovered from industrial processes that are not thermal, for example, from natural gas compressor stations. The term combined heat and power is often defined narrowly so as to exclude applications that are delivering useful services other than heating and cooling. Furthermore, Congress, federal agencies, and states have conflicting definitions, such that bottoming-cycle cogeneration and other WHP applications may be excluded from incentive programs – if not in spirit, then only by letter of the law. An example with large repercussions for the WHP market is Section 48 of the Tax Code, which provides a ten-percent investment tax credit for topping-cycle CHP only.[10] One approach taken by states seeking to support industrial efficiency through their portfolio standards has been to define CHP and WHR separately. Eighteen states specifically identify WHP as a qualifying resource in their Renewable, Clean Energy, or Energy Efficiency Portfolio Standards.[11]

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[5] The second most dominant fuel in CHP installations is coal, at 15 percent of US CHP capacity as of March 2014. ICF International for US Department of Energy and Oak Ridge National Laboratory. (2014, March). *CHP Installation Database*. Available at: http://www.eea-inc.com/chpdata/

[6] The US Department of Energy estimates that 60 percent of industrial waste heat is below 450°F, whereas 90 percent is below 600°F. US Department of Energy. (2008). *Waste Heat Recovery: Technology and Opportunities in US Industry.* Available at: http://www1.eere.energy.gov/manufacturing/intensiveprocesses/pdfs/waste_heat_recovery.pdf

[7] In the past, choice working fluids for Organic Rankine Cycle were ozone-depleting substances phased out under the Montreal Protocol and replaced by hydrofluorocarbons and perfluorocarbon compounds with high global warming potential, now also in the process of being phased out. Low global warming potential, zero ozone-depleting substance refrigerants like hydrocarbons and other compounds are now being brought into use as substitutes.

[8] US EPA. (2012, May 30). *Waste Heat to Power Systems.* (Case studies.) Available at: http://www.epa.gov/chp/documents/waste_heat_power.pdf. Case studies.

[9] For detailed project profiles, see: Heat Is Power. (2014). *Case Studies.* Available at: http://www.heatispower.org/waste-heat-to-power/case-studies/

[10] 26 US Code § 48 - Energy credit. Available at: http://www.gpo.gov/fdsys/pkg/USCODE-2011-title26/pdf/USCODE-2011-title26-subtitleA-chap1-subchapA-partIV-subpartE-sec48.pdf

[11] Heat Is Power. (2014). *Waste Heat to Power Fact Sheet.* Available at: http://www.heatispower.org/wp-content/uploads/2014/10/HiP-WHP-Fact-Sheet-10-23-2014.pdf

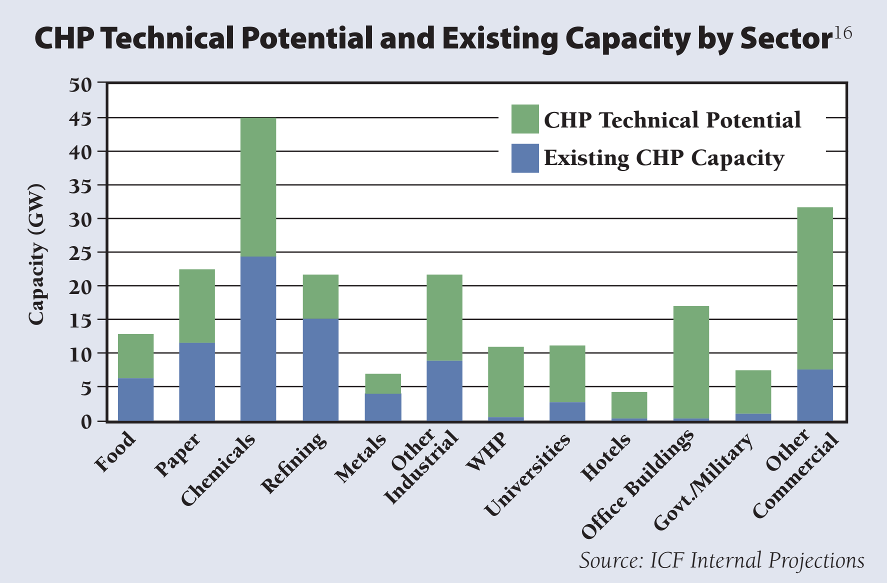
combined with the fuel's low-emissions profile, positions it as a driving force in CHP growth.

CHP technology is largely mature, which makes it deployable over the near-term at existing facilities and gives it the potential to play an important role at various scales in replacing industrial and commercial coal-fired boilers as they move toward retirement.[12] Accounting for 8 percent of current US generating capacity and 12 percent of electricity, CHP is regarded as an underutilized opportunity for emissions reductions.[13] ICF International estimates there to be a total of 125 gigawatts (GW) of remaining technical potential for CHP at existing industrial and commercial/institutional facilities across the United States (Figure 3-2).[14] A separate research effort in 2008 by Oak Ridge National Laboratory (ORNL) analyzed a goal of increasing CHP to 20 percent of generation capacity by 2030. It found that achieving 20-percent CHP would substantially reduce national energy consumption, saving 5.3 quadrillion BTU of fuel annually, the equivalent of nearly half the total energy consumed currently at the residential level.[15]

## 2. Regulatory Backdrop

A map of CHP facilities in the United States prepared by the US Energy Information Administration, shown in Figure 3-3, illustrates that US CHP capacity is geographically concentrated and that there are two kinds of conditions in which CHP has taken hold. One condition is where the economics strongly support mid- to larger-scale applications, such as in the petrochemical and refineries of the Gulf Coast (where Texas and Louisiana alone account for 30 percent of national CHP capacity), as well as in timber-rich states in the Southeast, Northwest, and in Maine, where the residual wood waste stream provides cheap boiler fuel in the pulp and paper industry (paper production accounts for 14 percent of national capacity). Large cities in the north are another example where geographic circumstances facilitate the economics of district heating and cooling. The other parts of the country where CHP shows high levels of penetration are in states, such as California (8.8 GW) and New York (5.5 GW), that have high electricity prices and have fostered favorable regulatory environments for CHP.[17] This highlights the extent to which policy is integral to creating or removing barriers to CHP.

***Figure 3-2***


**CHP Technical Potential and Existing Capacity by Sector**[16]

*Source: ICF Internal Projections*

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12 Chittum, A. (2012, September). *Coal Retirements and the CHP Investment Opportunity.* Available at: http://www.aceee.org/research-report/ie123

13 ICF International for US Department of Energy and ORNL, at supra footnote 5.

14 Note that technical potential is not the same as economic potential. Technical potential accounts for sites that have electric and thermal demands suitable to CHP, while ignoring economic considerations. ICF International for the American Gas Association. (2013, May). *The Opportunity for CHP in the United States.* Available at: http://www.aga.org/Kc/analyses-and-statistics/studies/efficiency_and_environment/Pages/TheOpportunityforCHPintheUnitedStates.aspx

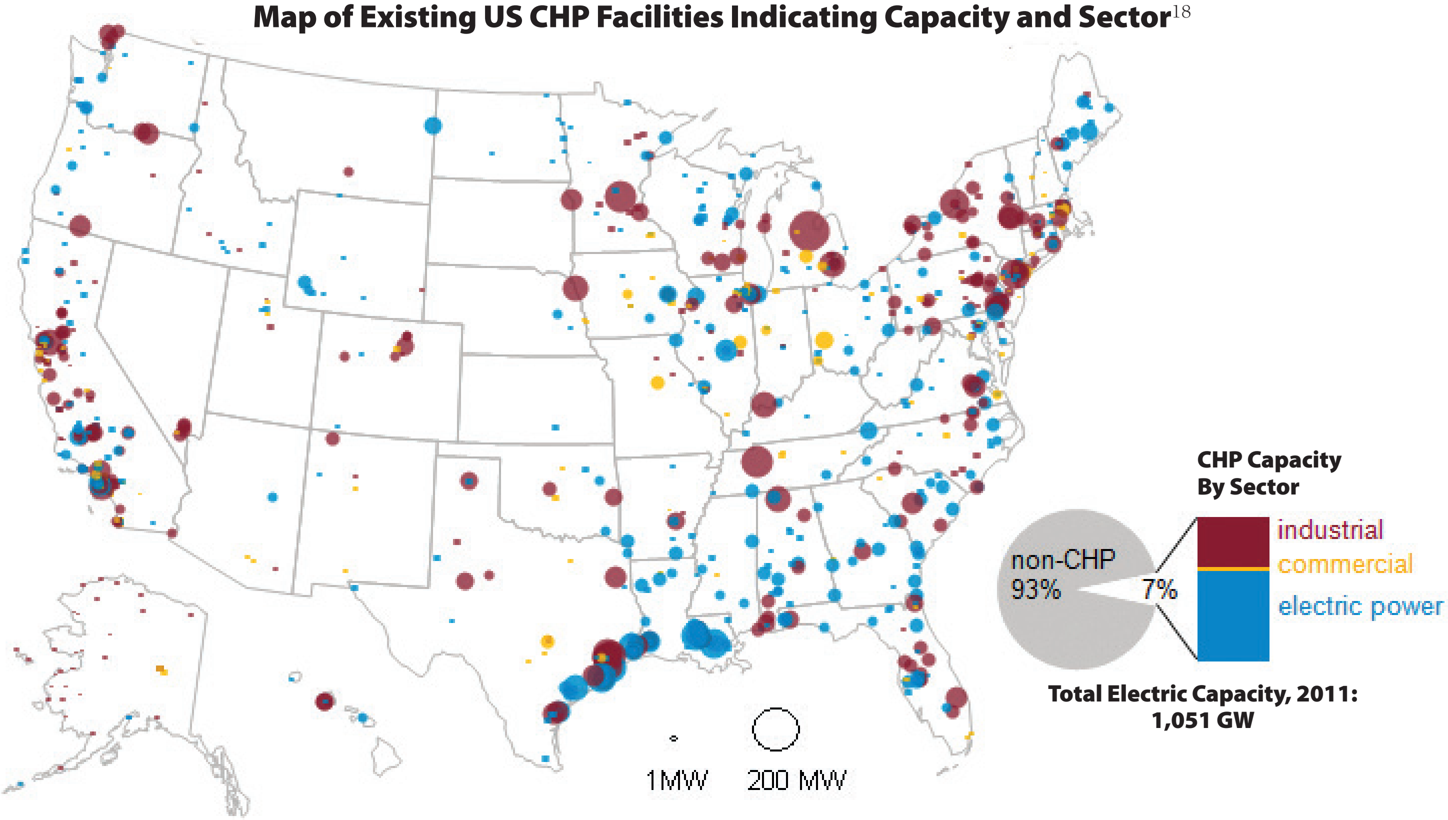
15 Shipley, A., Hampson, A., Hedman, B., Garland, P., & Bautista, P. (2008, December 1). *Combined Heat and Power: Effective Energy Solutions for a Sustainable Future.* ORNL for US Department of Energy. Available at: http://www.energy.gov/sites/prod/files/2013/11/f4/chp_report_12-08.pdf

16 ICF International. (2014, July 23). *From Threat to Asset: How Combined Heat and Power Can Benefit Utilities.* Available at: http://www.icfi.com/insights/white-papers/2014/how-chp-can-benefit-utilities?_cldee=amVubmlmZXJAZGdhcmRpbmVyLmNvbQ%253d%253d&utm_source=ClickDimensions&utm_medium=email&utm_campaign=Com%253A%20Energy_Webinar_07.08.14

17 ICF International for US Department of Energy and ORNL, at supra footnote 5.

*Figure 3-3*

**Map of Existing US CHP Facilities Indicating Capacity and Sector**[18]



Given the diversity of technologies, fuels, sizes, and sectors, the regulatory context surrounding CHP is multifaceted. The following discussion focuses on a number of regulatory drivers currently affecting CHP, namely:

- Issues in utility regulation;
- Air pollution regulations;
- National and state CHP capacity targets; and
- Grid reliability and resilience.

## Utility Regulation

Federal and state utility regulation has played a major part in promoting CHP in the industrial, commercial, and institutional sectors. Many of the barriers facing CHP pertain to economies of scale and the technical and administrative burdens facing small power producers who are usually not in the energy business. The Federal Public Utilities Regulatory Policies Act (PURPA) of 1978 had the effect of encouraging CHP by obligating utilities to buy power from independent CHP generators meeting certain eligibility standards. PURPA also requires utilities to pay prices equivalent to the utilities' avoided cost, and to offer reasonable standby rates and backup fees.[19] These rules, in conjunction with federal tax credits initiated in 1980, had the effect of stimulating investment in CHP, which increased five-fold from 1980 through 2000 (refer to Figure 2-4 in Chapter 2).

Following the development of competitive wholesale power markets in parts of the country, the Federal Energy Regulatory Commission (FERC) issued rulings pursuant to the Energy Policy Act of 2005, which exempts utilities from the PURPA must-buy provisions for larger facilities (>20 MW) in cases in which the facility has non-discriminatory access to wholesale markets.[20] This amendment, along

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[18] US Energy Information Administration. (2012, October). *Today in Energy: Combined Heat and Power Technology Fills an Important Energy Niche*. Available at: http://www.eia.gov/todayinenergy/detail.cfm?id=8250

[19] Avoided cost is defined as the cost of energy that would have been supplied from the utility's own system if the energy had not been supplied by the qualifying facility.

[20] US FERC. (2006, October 20). Ruling No. 688. New PURPA Section 210(m) Regulations Applicable to Small Power Production and Cogeneration Facilities. Available at: https://www.ferc.gov/whats-new/comm-meet/101906/E-2.pdf. All related orders by FERC pertaining to Qualifying Facilities can be found at: https://www.ferc.gov/industries/electric/gen-info/qual-fac/orders.asp

with volatile natural gas prices and general regulatory uncertainty surrounding the establishment of competitive markets, spawned a period starting in 2006 of steep decline in new CHP capacity additions.[21]

Today, PURPA is implemented variably across the country. Interconnection standards, standby rates, and tariffs are still considered regulatory obstacles to greater deployment of CHP. Although financial incentives are part of the problem, low rates of technology adoption are also attributed to administrative burdens surrounding grid interconnection. A 2013 report by the State and Local Energy Efficiency Action Network (SEE Action) provides a thorough survey of the regulatory architecture needed to support CHP deployment, including detailed recommendations on the following issues:[22]

- **Interconnection Standards.** CHP and other distributed generation resources can be facilitated through standardized interconnection rules and streamlined application procedures. Standard guidelines of some kind are in place in 43 states and the District of Columbia.[23]
- **Rates for Standby Services.** Utilities charge CHP customers standby tariffs in exchange for providing a bundle of services that includes back-up power for unplanned outages and scheduled maintenance, supplemental power for customers for whom onsite generation is insufficient, and the associated transmission and distribution delivery services, among other offerings. Originally designed in a vertically integrated electricity market with few interties, standby rates were averaged over customer classes. Today rates may be structured to more closely match actual costs incurred based on individual customer profiles.[24] They can also be accompanied by requirements and incentives that encourage customer-generators to use electric services efficiently and minimize costs on the grid.[25]
- **Prices Paid for Excess Electricity.** Avoided cost rates implemented through PURPA, Feed-In Tariffs (FITs), and competitive procurement have all been demonstrated to be effective methods for setting prices for electricity delivered to the grid from CHP systems. FERC recently ruled that the value of a resource in helping to meet state procurement obligations (i.e., renewable portfolio standards) can be incorporated into avoided cost calculations.[26] This ruling dealt specifically with California's "multi-tiered" avoided cost rate structure for a FIT to acquire smaller CHP systems (<20 MW), which FERC found to be consistent with PURPA. Usually FITs set a fixed price per unit delivered from a specific energy technology type (e.g., wind, solar, CHP) over a set period of years. Such pricing is based on the estimated cost of eligible generation plus a reasonable return to investors, but FIT prices can also be based on the value the generator provides to the electric system. Alternatively, in a restructured environment, CHP projects may bid into energy, capacity, and ancillary service markets if they meet established protocols, and a FIT may take the form of a premium payment on top of the energy market price. In jurisdictions with CHP targets, competitive procurement processes are also used to reveal costs and acquire larger projects.[27]

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[21] US Department of Energy and US EPA. (2012, August). *Combined Heat and Power: A Clean Energy Solution.* Available at: http://www.epa.gov/chp/documents/clean_energy_solution.pdf

[22] US Department of Energy, US EPA, & SEE Action Network. (2013, March). *The Guide to Successful Implementation of State Combined Heat and Power Policies.* Available at: https://www4.eere.energy.gov/seeaction/publication/guide-successful-implementation-state-combined-heat-and-power-policies

[23] For more on best practices in design of interconnection standards, see: Sheaffer, P. (2011, September). *Interconnection of Distributed Generation to Utility Systems: Recommendations for Technical Requirements, Procedures and Agreements, and Emerging Issues.* Montpelier, VT: The Regulatory Assistance Project. Available at: www.raponline.org/document/download/id/4572

[24] The Regulatory Assistance Project. (2014, February). *Standby Rates for Combined Heat and Power Systems: Economic Analysis and Recommendations for Five States.* Available at http://www.raponline.org/press-release/standby-rates-for-combined-heat-and-power-need-a-fresh. Johnston, L., Takahashi, K., Weston, F., & Murray, C. (2005, December). *Rate Structures for Customers With Onsite Generation: Practice and Innovation.* NREL/SR-560-39142. Available at: http://www.michigan.gov/documents/energy/NREL_419830_7.pdf

[25] For more detail and specific case studies, consult The Regulatory Assistance Project's policy brief outlining standby rate design features to support CHP systems, at supra footnote 24. Also see: ACEEE. *Policies and Resources for CHP Deployment: CHP-Friendly Standby Rates.* Available at: http://aceee.org/policies-and-resources-chp-deployment-chp-friendly-standby-rates

[26] US FERC. (2010). 133 FERC ¶ 61,059. Available at: https://www.ferc.gov/whats-new/comm-meet/2010/102110/E-2.pdf

[27] Supra footnote 22.

## Air Pollution Regulations

In Chapter 2, a list of existing and proposed federal New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants (NESHAP) that might impact CHP installations was provided. The applicability of each regulation depends on the fuels combusted, the heat input or electrical output of the system, how much electricity is delivered to the grid versus used onsite, and the date of construction, reconstruction, or modification.

As noted in Table 3-1, most of the installed CHP capacity in the United States uses either steam turbine or gas combustion turbine technology. Furthermore, most of the CHP units described in this chapter do not meet the definition of electric utility steam generating unit because they are designed to generate electricity for onsite consumption, and therefore are not directly affected by regulations for electric generating units such as the proposed GHG regulations under sections 111(b) and 111(d) of the Clean Air Act. Thus, the regulations most relevant to the CHP units described in this chapter are the NESHAP regulations for industrial, commercial, and institutional boilers and process heaters (40 CFR Part 63 Subparts DDDDD and JJJJJ) and for stationary combustion turbines (Subpart YYYY), as well as the New Source Performance Standards regulations for industrial, commercial, and institutional steam generating units (40 CFR Part 60 Subparts Db and Dc) and for stationary combustion turbines (Subpart KKKK). New Source Review (NSR) permitting requirements are also significant.

Finalized in January 2013, the NESHAP for new and existing boilers and process heaters covers major sources in industrial, institutional, and commercial facilities.[28] These Maximum Achievable Control Technology (MACT) standards, commonly called the "Boiler MACT," affect roughly 14,000 boilers across the country, burning a wide range of fuels and providing heat for various mechanical, heating, and cooling processes and uses.[29] Relatively few of these boilers already use CHP technology, but the impact of the regulations on CHP deployment may be much more significant. Notably, the Boiler MACT rule includes provisions that reward energy efficiency upgrades, such as investments in waste heat recovery and CHP. All existing major sources in this source category are required to do routine tune-ups and to conduct a one-time energy assessment to identify cost-effective conservation measures.

The Boiler MACT rules also set specific emissions limits for some 1750 of the largest industrial boilers, fired primarily by coal, oil, and biomass.[30] Facilities can opt to use output-based emissions limits instead of heat input-based limits. These standards are set in terms of pounds of pollution per million BTU of steam output (lb/MMBTU) and pounds of pollution per megawatt-hour of electricity output (lb/megawatt-hour [MWh]), rather than pounds of pollution per million BTU of heat input. Using the output-based standards allows firms to earn credit toward compliance because their implementation of boiler efficiency measures has the effect of reducing energy input relative to a constant level of useful output.[31] But with many of these boilers more than 40 years old,[32] owners have also evaluated options for boiler replacement, creating a timely window for new CHP installations. Subject to a January 21, 2016 deadline, compliance decisions — whether to upgrade coal boilers, convert or replace natural

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[28] 40 CFR Part 63. (2013, January 31). *National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters.* Available at: http://www.gpo.gov/fdsys/pkg/FR-2013-01-31/pdf/2012-31646.pdf. A major source facility emits or has the potential to emit 10 or more tons per year of any single air toxic or 25 or more tons per year of any combination of air toxics. Sources that emit less than this threshold are classified as area sources.

[29] US EPA. (2012, December). *EPA's Air Toxics Standard Major and Area Source Boilers and Certain Incinerators: Technical Overview.* Available at: http://www.epa.gov/airquality/combustion/docs/20121221_tech_overview_boiler_ciswi_fs.pdf

[30] US EPA. *Emissions Standards for Boilers and Process Heaters and Commercial/Industrial Solid Waste Incinerators.* Available at: http://www.epa.gov/airquality/combustion/actions.html

[31] Federal Register Section 63.7533 outlines the methodology for determining compliance using emissions credits and the EPA provides a hypothetical example online here: http://www.epa.gov/ttn/atw/boiler/imptools/energycreditsmarch2013.pdf

[32] Nearly half of the US boiler population with a capacity greater than 10 MMBTU/h is at least 40 years old. Energy and Environmental Analysis for ORNL. (2005). *Characterization of the US Industrial/Commercial Boiler Population.* Available at: http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/characterization_industrial_commerical_boiler_population.pdf

gas boilers, or switch to natural gas CHP — have largely been made and are being implemented now. This rule demonstrates how environmental regulations can drive markets for energy-efficient technologies like CHP, even while regulating emissions from CHP systems.

The rule also offers a model for how government can assist in promoting the benefits of CHP. Through the seven regional offices of its CHP Technical Assistance Partnerships,[33] the US Department of Energy (DOE) takes advantage of this Boiler MACT compliance opportunity by providing general outreach and market research, as well as site analysis to support CHP project development from feasibility to installation.[34] Outreach to nearly 700 facilities returned interest from 50, representing a potential of 752 MW of CHP capacity additions.[35] Focused on strategic markets, including hospitals, critical infrastructure, biomass, district microgrids, and federal agencies, the DOE's program has sought to develop examples with broader implications for adopting CHP in conjunction with environmental compliance activities. As part of the program, the DOE has produced a number of reports and resources, including a 2012 report prepared by ICF International enumerating financial incentives state by state[36] and a guidance document prepared by ORNL for calculating emissions credits from conservation measures.[37]

CHP applications reduce the total amount of pollution emitted onsite and offsite, yet by generating heat and power onsite they may have the effect of increasing a facility's direct onsite emissions. In this way, accounting for the benefits of CHP requires an outside-the-fence approach, which has posed a challenge to energy and environmental regulations conventionally focused on fuel-use and pollution at individual facilities within individual source categories. The NSR program illustrates this problem.[38]

The NSR permitting process, which may be triggered if modifications to an industrial plant are expected to increase onsite pollution, often requires expensive investments in end-of-pipe pollution controls for facilities seeking to make capital upgrades for CHP. Further challenging conventional regulation is the fact that a CHP facility produces multiple value streams: thermal energy, electric energy, and electricity demand reductions through energy efficiency. Especially given the diverse range of applications, sizes, and fuel types, the issue of how to quantify these values and how to regulate CHP more generally has long been problematic.

The shift in state and federal regulatory strategies over recent years from input-based to output-based regulations (OBR) helps remedy this problem.[39] OBRs, framed as pollution per unit of productive output, encourage clean energy deployment and help incorporate energy efficiency and renewable energy investments directly as compliance options, while granting businesses the opportunity to flexibly achieve the emissions limits through various means, including heat rate improvements, cleaner fuel substitutes, or end-of-pipe technologies. Output-based emissions standards can be applied to any process to promote efficiency. The recently finalized New Source Performance

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[33] The DOE's CHP Technical Assistance Partnerships (CHP TAPs) were formerly called the Clean Energy Application Centers (CEACs). Available at: http://www1.eere.energy.gov/manufacturing/distributedenergy/chptaps.html

[34] US DOE. *Boiler MACT Technical Assistance Program.* Available at: http://energy.gov/eere/amo/boiler-mact-technical-assistance-program. Starting in February of 2012, an initial pilot effort between the DOE and the Ohio Public Utility Commission was subsequently scaled to the national level. Public Utilities Commission of Ohio. *Combined Heat and Power in Ohio.* Available at: http://www.puco.ohio.gov/puco/index.cfm/industry-information/industry-topics/combined-heat-and-power-in-ohio/

[35] US DOE. (2014, May). *Boiler MACT Technical Assistance.* Available at: http://energy.gov/sites/prod/files/2014/05/f15/boiler_MACT_tech_factsheet_1.pdf. Hampson, A. (2014). Presentation at the Electric Power Conference and Exhibition. *CHP Market Status and Opportunities for Growth.* ICF International.

[36] ICF International for US DOE. *Financial Incentives Available for Facilities That are Affected by the US EPA NESHAP for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters: Proposed Rule.* Available at: http://www1.eere.energy.gov/manufacturing/states/pdfs/incentives_boiler_mact.pdf

[37] ORNL. (2012). *National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers, Guidance for Calculating Emission Credits Resulting from Implementation of Energy Conservation Measures.* Available at: http://info.ornl.gov/sites/publications/Files/Pub37258.pdf

[38] US EPA. (2013, July 30). *New Source Review.* Available at: http://www.epa.gov/NSR/

[39] US EPA CHP. (2014). *Output-Based Regulations: A Handbook for Air Regulators.* Available at: http://www.epa.gov/chp/documents/obr_handbook.pdf

Standards for Electric Utility Steam Generating Units, for example, include output-based emissions standards for particulate matter, nitrogen oxides ($NO_X$), and sulfur dioxide ($SO_2$).[40]

OBRs are especially useful in addressing sources that have more than one productive output. A 2013 EPA guidance document on "Accounting for CHP in Output-Based Regulations" recommends two approaches for incorporating a secondary output into emissions rate calculations.[41] The first is an *equivalence approach,* whereby the secondary output — be it electricity or thermal energy, depending on the configuration — is converted into the units of the primary output by way of a conversion factor. The conversion factor may be a direct unit conversion (e.g., 3.412 MMBTU/MWh) or may reflect a certain valuation of the secondary energy output by discounting as per regulatory objectives. This method has been used by the state of Texas in its permit by rule and standard permit regulations, and in California in its conventional emissions limits and emissions performance standards for CHP.[42]

Alternatively, the EPA outlines an *avoided emissions approach,* which involves developing assumptions about the pollution that would have been emitted if the same outputs had been generated separately.[43] Offset emissions are subtracted from the CHP system's actual emissions to capture its offsite benefits. OBRs thus could specify the default assumptions, for example, *Avoided Thermal Efficiency* would typically be based on the performance of a new natural gas-fired boiler (80 percent) and the Avoided Central Station Emission Factor would be based on fleet data from the EPA's Emissions & Generation Resource Integrated Database (eGRID) database. Connecticut and Massachusetts are using avoided emissions methods in accounting for small distributed generation; Delaware and Rhode Island have also used this approach in conventional emissions limits for CHP.[44]

These two approaches for incorporating a secondary output into emissions rate calculations are described in greater detail in Chapter 2. There is some controversy about which method is most appropriate for regulatory purposes. Although both methods reward efficiency, there is general consensus that quantifying avoided emissions produces a more accurate emissions signature of a CHP system, yet the equivalence method has been preferred historically for its simplicity. Within the equivalence method there is additional debate over the conversion factor. Historically, the EPA has discounted thermal energy 50 percent in OBRs, whereas California and Texas are states that ascribe 100 percent credit for thermal output in their OBRs. In its recent proposal to regulate GHG emissions from existing EGUs [under section 111(d)], the EPA assigned a value of 75 percent credit and requested comment on a range of two-thirds to 100-percent credit for useful thermal output.[45] The same regulatory proposal further rewards CHP by applying an additional five percent line loss credit to the net electric output to capture the transmission and distribution losses that are avoided through onsite power generation.

## Capacity Targets

In 2012, the Obama Administration set a national goal of 40 GW of new, cost-effective CHP by 2020 through an Executive Order to Accelerate Investment in Industrial Energy Efficiency.[46] This has helped to motivate greater coordination of existing federal activities on the issue, predominantly between the EPA and the DOE. The SEE

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[40] 40 CFR Part 60, Subpart Da. *Standards of Performance for Electric Utility Steam Generating Units.* Available at: http://www.ecfr.gov/cgi-bin/text-idx?SID=324a6cdb45a7b9a1f8c055dc6e64982d&node=sp40.7.60.d_0a&rgn=div6

[41] US EPA CHP Partnership. (2013, February). *Accounting for CHP in Output-Based Regulations.* Available at: http://www.epa.gov/chp/documents/accounting.pdf.

[42] Ibid.

[43] The Regulatory Assistance Project. (2003). *Output Based Emissions Standards for Distributed Generation.* Available at: http://www.raponline.org/docs/RAP_IssuesLetter-OutputBasedEmissions_2003_07.pdf

[44] Supra footnote 41. Other examples can be found in Appendix B of the EPA's 2003 handbook for air regulators on output-based regulations, at supra footnote 39.

[45] 79 FR 34829. Available at: https://www.federalregister.gov/articles/2014/06/18/2014-13726/carbon-pollution-emission-guidelines-for-existing-stationary-sources-electric-utility-generating

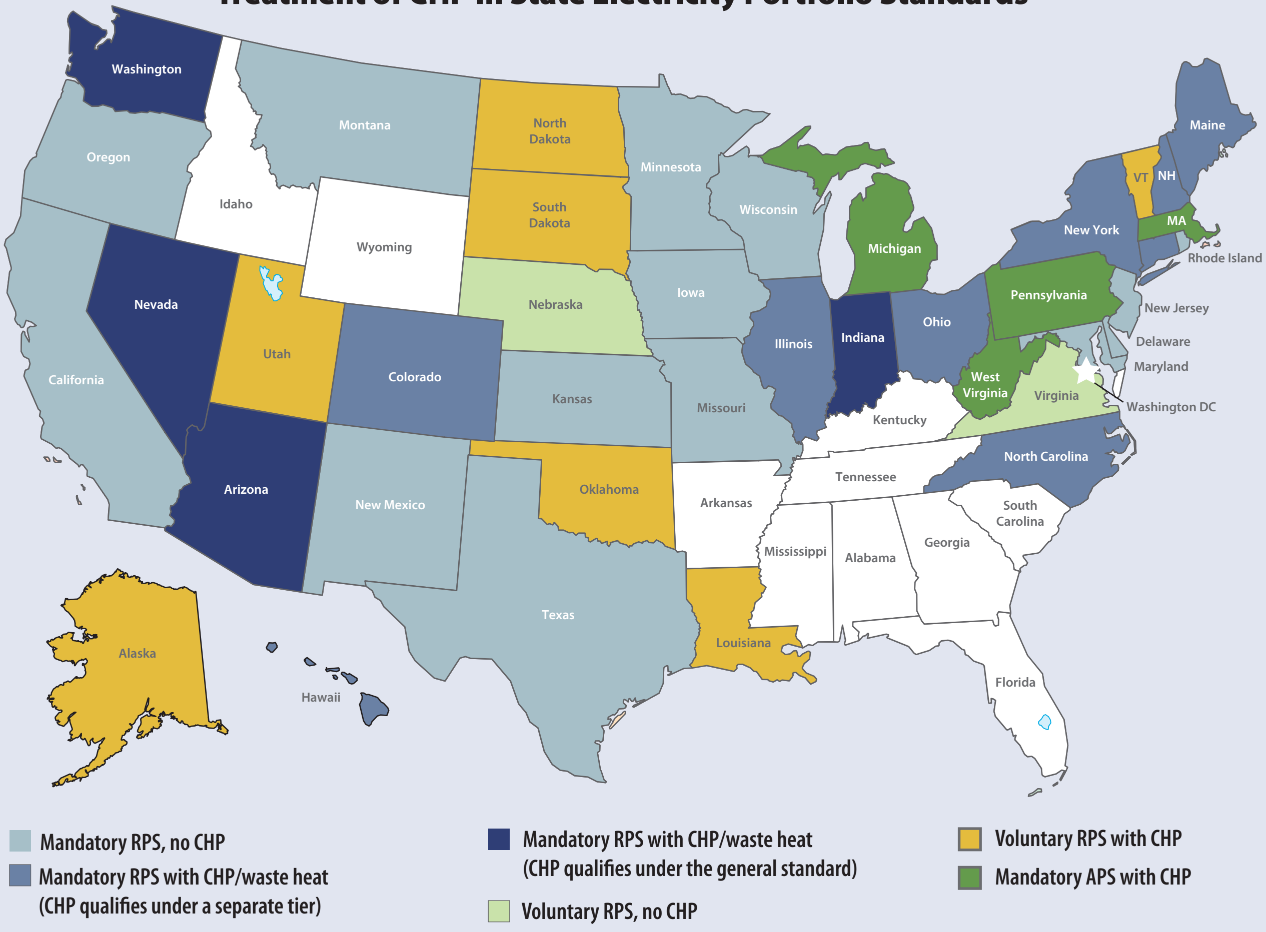
[46] Executive Order 13624. (2012, August 30). *Accelerating Investment in Industrial Energy Efficiency.* 77 FR 54779. Available at: http://www.gpo.gov/fdsys/pkg/FR-2012-09-05/pdf/2012-22030.pdf

Action Network has taken the lead, convening stakeholders and providing technical assistance to states. Many resources related to these efforts can be found on SEE Action's website, the EPA's website for its Combined Heat and Power Partnership program, and the DOE's website for CHP Deployment and Technical Assistance Partnerships.[47]

A number of states have supported CHP through portfolio standards. Portfolio standards require electric utilities and retail providers, often through legislation, to meet a certain portion of load with specified clean energy resources. As of 2013, 23 states include CHP in either energy efficiency or renewable energy portfolio standards (Figure 3-4). Energy efficiency portfolio standards are discussed in detail in Chapter 11, and renewable portfolio standards are the focus of Chapter 16. These programs are typically designed to allow eligible projects to generate credits, the sale of which adds a stream of revenue for project finance. However, the terms of eligibility vary across states, often reflecting narrow definitions of CHP that, for example, capture only bottoming-cycle (WHP) or renewable fuel-powered configurations. Where portfolio standards have been more effective at incentivizing investment, they have clearly defined CHP, defined it broadly enough to include fossil fuels, established minimal efficiency requirements (i.e., minimum 60 percent annual combined electric and thermal efficiency with fuel input

***Figure 3-4***

**Treatment of CHP in State Electricity Portfolio Standards**[48]



*Source: Map based on ICF International research. December 2012.*

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[47] US DOE, US EPA, & SEE Action Network. Available at https://www4.eere.energy.gov/seeaction/. US EPA CHP Partnership. Available at: http://www.epa.gov/chp/. US DOE CHP Deployment. Available at: http://energy.gov/eere/amo/chp-deployment

[48] Supra footnote 22.

expressed on a higher heating value basis), and set dedicated CHP targets as a distinct class of resources.

Specific CHP targets have also been enacted through broader legislation and/or issued executive orders in some states. California, for example, established a goal of 6500 MW of new CHP through executive order. New Jersey set a target of 1500 MW of new CHP capacity through its Energy Master Plan.[49]

### Grid Reliability and Resiliency

CHP has also been noted for its ability to strengthen grid reliability and improve the resiliency of critical infrastructure. The events of September 11, 2001, the Northeast blackout in 2003, Hurricane Katrina in 2005, and Superstorm Sandy in 2012, among other disasters, have underscored the importance of having independent and reliable power supply for critical infrastructure, such as hospitals, public safety facilities, emergency response communications, and care centers for elderly and other vulnerable populations. CHP has been demonstrated to provide reliability over both instantaneous outages as well as prolonged outages,[50] and systems can be designed to meet power needs more adequately —that is, more seamlessly, at lower cost, and with lower environmental impacts — than traditional backup generators. In the wake of the storms of 2011 and 2012, New York, New Jersey, and Connecticut adopted CHP incentive programs designed to enhance resiliency for disaster response and preparedness.[51] Texas and Louisiana have laws requiring critical government buildings to undertake feasibility studies for implementing CHP.[52,53]

## 3. State and Local Implementation Experiences

Examples can be found across the country of CHP units that are designed primarily to meet onsite or nearby energy needs, rather than to supply electricity to the grid. These examples include CHP systems owned by state or municipal governments, universities, hospitals, manufacturers, and others. Case studies featuring certain aspects of the policy and regulatory context are enumerated in many of the reports cited earlier, especially The Regulatory Assistance Project (2014), SEE Action (2013), and ICF (2013). The Database of State Incentives for Renewables and Efficiency, which is currently run out of North Carolina State University, provides an online database of CHP policies searchable by type and state; the EPA maintains a similar database.[54] Additional examples are provided in Chapter 2.

CHP projects can be built with the help of public policies and incentives, yet fail to achieve the high efficiency goals anticipated from the technology. Proper sizing for the project demand, engineering, construction, and operation are all critical to a project attaining its goals, and relatively minor variations can have significant impact. Studies that included efficiency evaluations for a number of completed CHP projects in California and New York indicated that the operating efficiencies of some projects were far below expectations and similar to non-CHP EGUs. To ensure accountability for public funds and emissions reductions, incentives programs should be linked to project performance. An example comes from New

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[49] The Industrial Energy Efficiency and Combined Heat and Power Working Group of the SEE Action Network released a “Guide to the Successful Implementation of State Combined Heat and Power Policies” in 2013, which details options and case studies for effective support of CHP through portfolio standards-like tools. Supra footnote 22.

[50] ACEEE. (2012, December 6). *How CHP Stepped Up When the Power Went Out During Hurricane Sandy.* Available at: http://www.aceee.org/blog/2012/12/how-chp-stepped-when-power-went-out-d

[51] CT P.A. 12 148 Section 7. (2012, July). *Microgrid Grant and Loan Pilot Program.* Available at: http://www.cga.ct.gov/2012/act/pa/pdf/2012PA-00148-R00SB-00023-PA.pdf

[52] Texas HB 1831. Available at: http://www.capitol.state.tx.us/tlodocs/81R/billtext/pdf/HB01831F.pdf. Texas HB 4409. Available at: http://www.capitol.state.tx.us/tlodocs/81R/billtext/pdf/HB04409F.pdf. Louisiana Senate resolution No. 171. (2012). Available at: http://www.legis.la.gov/legis/BillInfo.aspx?s=12RS&b=SR171&sbi=y

[53] For more extensive information on case studies, see: ICF International for ORNL. (2013, March). *Combined Heat and Power: Enabling Resilient Energy Infrastructure for Critical Facilities.* Available at: http://energy.gov/eere/amo/downloads/chp-enabling-resilient-energy-infrastructure-critical-facilities-report-march

[54] Database of State Incentives for Renewables & Efficiency. Available at: http://www.dsireusa.org/; US EPA. (2014, August). *CHP Policies and Incentives Database.* Available at: http://epa.gov/chp/policies/database.html

York State Energy Research and Development Authority's CHP performance program, in which projects are subject to measurement and verification procedures and the incentive payment schedule is contingent on monitored performance.[55]

For the purposes of this document, the implementation experiences of the state of Massachusetts are presented in greater detail to illustrate the components of a cohesive state policy in support of CHP.

In 2008, Massachusetts started what has become a concerted push to develop CHP using two main policy vehicles. The first is the utility energy efficiency program called "Mass Save," mandated by the Green Communities Act of 2008 (S.B. 2768), and launched in 2011.[56] The program is funded through: (1) a system benefit charge on electricity use; (2) an energy efficiency reconciliation factor on electricity distribution rates; (3) proceeds from the Regional Greenhouse Gas Initiative; and (4) the New England Independent System Operator's (ISO) Forward Capacity Market.[57] Mass Save provides incentive rebates to residential, commercial, and industrial customer classes for energy efficiency investments, including CHP.

Eligible CHP must pass a benefit-cost ratio (BCR) test, whereby the lifetime benefits are greater than or equal to lifetime costs (i.e., BCR ≥1). The BCR model captures societal value by incorporating:

- Annual power output (net kW);
- Electricity output (net kilowatt-hour [kWh]);
- Installed cost of equipment;
- Annual maintenance costs;
- Quantity and type of fuel consumed and displaced; and
- The timing of power production (i.e., peak/off-peak, summer/winter).

The model uses marginal values for fuel and electricity and the value of deferred transmission and distribution, according to the peak period terms of the ISO of New England.[58]

Qualifying retrofit projects earn rebates based on where the project fits within three tiers of efficiency performance. At the low end of the scale, Tier 1 can earn up to $750/kW. At the high end, Tier 3 can earn up to $1100/kW ($1200/kW for projects <150 kW). The grant of a rebate is contingent on:

- Achieving a system efficiency of greater than 65 percent;
- Undertaking an ASHRAE Level 2 Audit;[59] and
- Implementing efficiency measures to reduce overall energy use at the facility by ten percent within three years.

New construction projects are eligible for a rebate of $750/kW that can be increased on a case-by-case basis, contingent on a project achieving the 65-percent efficiency threshold and implementing additional energy efficiency measures.[60]

A November 2013 review of Mass Save's CHP program found that it had been successful, with high realization rates, accounting for 30 percent of commercial and institutional energy efficiency target savings in 2011. CHP was also found to deliver the lowest cost per kWh of all Mass Save measures.[61] Because proper sizing of a CHP system is essential to its cost-effectiveness, one key lesson learned in Massachusetts has been that reducing load through energy efficiency needs to be the first step in determining the appropriate size and design of a CHP system.[62] This is partly why providing incentives for CHP based on efficiency performance has proved to be so successful.

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[55] New York State Energy Research and Development Authority. (2015, January). *Combined Heat and Power Performance Program.* Available at: http://www.nyserda.ny.gov/All-Programs/Programs/Combined-Heat-and-Power-Performance-Program

[56] Mass Save public website. Available at: http://www.masssave.com/

[57] Mass Save. (2012, November). *2013-2015 Massachusetts Joint Statewide Three Year Electric and Gas Energy Efficiency Plan.* Available at: http://www.mass.gov/eea/docs/doer/energy-efficiency/statewide-electric-and-gas-three-year-plan.pdf

[58] Mass Save. (2014, May 27). *Combined Heat and Power: A Guide to Submitting CHP Applications for Incentives in Massachusetts.* Available at: http://www.masssave.com/~/media/Files/Business/Applications-and-Rebate-Forms/A-Guide-to-Submitting-CHP-Applications-for-Incentives-in-Massachusetts.pdf

[59] See Chapter 15 for a discussion of ASHRAE building energy codes.

[60] Supra footnote 58.

[61] US DOE/IIP Webinar. (2013, November 20). *Massachusetts Incentives for Combined Heat and Power: Mass Save Energy Efficiency and the Alternative Portfolio Standard.* Dwayne Breger, Director, Renewable Energy Division, Massachusetts Department of Energy Resources. Available at: https://cleanenergysolutions.org/webfm_send/964

[62] Supra footnote 57.

The second major policy vehicle supporting CHP in Massachusetts is the state's Alternative Energy Portfolio Standard (APS), which puts an obligation on retail electricity suppliers to acquire Alternative Energy Certificates (AECs) equal to a set percentage of served load. Established pursuant to the 2008 Green Communities Act[63] and administered under the Alternative Energy Portfolio Standard Regulation,[64] compliance obligations began in 2009, requiring one percent of retail sales to come from qualifying energy sources, a level that increases to five percent by 2020. The APS covers a range of nonrenewable technologies, including flywheel energy storage, CHP, and renewable thermal technologies, but as of 2013, nearly all AECs were generated from CHP projects.[65]

The APS complements the Mass Save rebate program. While the latter defrays upfront capital costs, the APS rewards metered performance. CHP units are responsible for metering both thermal and electricity output, as outlined in the APS metering guidelines,[66] where credits are earned based on fuel savings compared to grid power and a separate thermal conversion unit. AECs are calculated as follows:

> The number of Credits = (electricity generated/0.33) + (useful thermal energy output/0.8) – (total fuel consumed by the CHP unit), where all quantities are expressed in MWh.

Massachusetts uses an Alternative Compliance Payment (ACP) mechanism as a price ceiling. The ACP was set at $21.72 per MWh for the 2014 compliance year.[67] In 2013, for example, earned credits fell short of the 1448 gigawatt-hours required to meet the three-percent obligation on utilities for that year. As a result, some 64 percent of the obligation was met through ACPs, totaling nearly $19.8 million[68] — revenues that were recycled back into clean energy initiatives through the Commonwealth's Department of Energy Resources.[69] The supply of credits follows the pace of project approval through the Mass Save rebate program, such that as the number of certified projects grow and with several large projects in the pipeline, the supply of AECs is expected to increase. As of 2014, 329 MW of CHP capacity was either approved or was under review through the APS program.[70]

One example of a successfully supported project highlighted by the Department of Energy Resources was installed on the campus of the University of Massachusetts Medical School. There, a 7.5-MW expansion to the existing 9-MW cogeneration facility boosted overall efficiency from 71 percent to 86 percent, resulting in an annual reduction in GHG emissions of 19 percent. The project was awarded $5.6 million through Mass Save, the equivalent of 20 percent of capital expenditure,[71] and is projected to earn 135,488 credits through the Alternative Portfolio Standard,

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[63] Part 1, Title II, Chapter 25A, Section 11F1/2. Alternative Energy Portfolio Standard. Available at: http://www.malegislature.gov/Laws/GeneralLaws/PartI/TitleII/Chapter25A/Section11F1~2

[64] Code of Massachusetts Regulation. 225 CMR 16.00. Alternative Energy Portfolio Standard. Available at: http://www.mass.gov/eea/docs/doer/rps/225cmr1600-052909.pdf

[65] Massachusetts Department of Energy Resources. (2014, December 17). *Massachusetts RPS & APS Annual Compliance Report for 2013.* Available at: http://www.mass.gov/eea/docs/doer/rps-aps/rps-aps-2013-annual-compliance-report.pdf

[66] Massachusetts Department of Energy Resources. (2011, June 14). *APS Guideline on the Eligibility and Metering of Combined Heat and Power Projects.* Available at: http://www.mass.gov/eea/docs/doer/rps-aps/aps-chp-guidelines-jun14-2011.pdf

[67] Massachusetts, Executive Office of Energy and Environmental Affairs. (2014, August). *Alternative Compliance Payment Rates.* Available at: http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/rps-aps/retail-electric-supplier-compliance/alternative-compliance-payment-rates.html

[68] Subject to increases with the consumer price index. Supra footnote 65.

[69] Massachusetts Department of Energy Resources. (2014, December 17). *CY 2013 Alternative Compliance Payments – Spending Plan.* Available at http://www.mass.gov/eea/docs/doer/rps-aps/cy-2013-acp-spending-plan.pdf

[70] Massachusetts Department of Energy Resources. *APS Qualified Generation Units – Updated May 1, 2014.* Available at: http://www.mass.gov/eea/docs/doer/rps-aps/aps-qualified-units.xls

[71] Sylvia, M. (2013, June 26). *Clean Energy Opportunities in Massachusetts.* Presentation before the Juniper Networks Energy Summit. Massachusetts Department of Energy Resources. Available at: http://competitive-energy.com/CES_JuniperNetworksSummit_MADOER_Presentation_062613.pdf

equivalent to more than \$2.9 million of annual revenue.[72]

Massachusetts further enables CHP development by providing standardized application procedures and contracts for grid interconnection overseen by the Massachusetts Department of Public Utilities. These procedures apply uniformly across the state's four investor-owned utilities. They offer generator customers transparent rules for expeditious interconnection, while ensuring the safety and reliability of the grid. The model interconnection tariff provides three different review paths based on the complexity of the project, that is, generation type, size, customer load, and the characteristics of the grid where the system is to be located. The "Simplified and Expedited" review paths are designed to streamline projects that pass pre-specified screening tests, whereas the "Standard" path is reserved for all other projects in which system modifications may be required to accommodate the project. These procedures were most recently amended in July 2014 with Order 11-75-F to assign an enforceable timeline for interconnections.[73] Interconnection activity is reported monthly and made available online to give customers a clearer understanding of expectations for the interconnection process.[74]

## 4. GHG Emissions Reductions

A CHP system can reduce $CO_2$ emissions roughly 50 percent compared to separate heat and power systems, as shown in Figure 3-1, by reducing fuel consumption. Emissions of other GHGs may also be reduced, including methane, nitrous oxide, precursors to ground-level ozone, and particulate pollution, which can also interact with the climate. The 2008 report by ORNL cited previously in this chapter analyzed a goal of increasing CHP to 20 percent of generation capacity by 2030. It found that achieving 20-percent CHP would reduce $CO_2$ emissions by more than 800 million metric tons per year, equivalent to 60 percent of projected growth in emissions over that time period.[75] These results echo those of numerous other studies that have shown that CHP is one of the most cost-effective strategies for reducing $CO_2$ emissions economy-wide.

It is important to note that CHP may not always be an appropriate strategy for reducing carbon emissions. In parts of the country with low GHG electricity, like the gas-dominated grid in California, CHP emissions could conceivably exceed those of separate heat and power. To account for this, eligibility for incentives typically includes threshold efficiency rates, but could also be structured to reward only net-GHG-reducing facilities.

Estimates of $CO_2$ emissions reductions associated with CHP systems are derived from fuel savings. Calculating fuel savings associated with a CHP system uses a similar methodology to the avoided emissions approach described previously. The fuel used onsite is deducted from the displaced fuel that would have been used for separate production of thermal and electric energy, including transmission and distribution losses, according to the basic series of equations included below.[76]

The first step is to calculate emissions displaced from onsite thermal production.

***Equation 1:* Avoided Emissions From Displaced Thermal Energy Production**

$$C_T = (CHP_T/\eta_T) * EF_F * (1 \text{ x } 10^{-6})$$

*where:*

$C_T$ = $CO_2$ Emissions From Displaced Onsite Thermal Production (lb $CO_2$)

$CHP_T / \eta_T$ = CHP System Thermal Output (BTU) ÷ Estimated Efficiency of the Thermal Equipment = Thermal Fuel Savings (BTU)

$EF_F$ = Fuel-Specific $CO_2$ Emissions Factor (lb $CO_2$ / MMBTU)

$1 \text{ x } 10^{-6}$ = Conversion Factor From BTU to MMBTU

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[72] Breger, D. (2013, March 5). *Alternative Portfolio Standard and the Energy Efficiency Rebates.* Presentation at the NGA Policy Academy, Philadelphia, PA. Massachusetts Department of Energy Resources. Available at: http://www.nga.org/files/live/sites/NGA/files/pdf/2013/1303PolicyAcademyBREGER.pdf

[73] Massachusetts Department of Energy Resources. (2014, August). *Interconnection Project Review Paths (With Recent Changes to Resulting From DPU Order 1-75-E).* Available at: https://sites.google.com/site/massdgic/home/interconnection/interconnection-project-review-paths. See also: DSIRE. (2014, August). *Massachusetts Interconnection Standards.* Available at: http://programs.dsireusa.org/system/program/detail/2774

[74] Massachusetts Department of Energy Resources. (2014, August). *Distributed Generation and Interconnection in Massachusetts.* Available at: https://sites.google.com/site/massdgic/home/interconnection

[75] Supra footnote 15.

[76] US EPA CHP Partnership. (2012, August). *Fuel and Carbon Dioxide Emissions Savings Calculation Methodology for Combined Heat and Power Systems.* Available at: http://www.epa.gov/chp/documents/fuel_and_co2_savings.pdf

The second step is to calculate emissions of displaced grid electricity.

### *Equation 2:* Avoided Emissions From Displaced Grid Electricity

$$C_G = [CHP_E / (1 - L_{T\&D})] * EF_G$$

*where:*

$C_G$ = $CO_2$ Emissions From Displaced Grid Electricity (lb $CO_2$)

$CHP_E$ = CHP System Electricity Output (kWh)

$L_{T\&D}$ = Transmission and Distribution Losses (Percentage in Decimal Form)

$CHP_E / (1 - L_{T\&D})$ = Displaced Grid Electricity From CHP (kWh)

$EF_G$ = Grid Electricity Emissions Factor (lb $CO_2$ / kWh)

In the final step, $CO_2$ emissions from the CHP plant are deducted from the sum of Equations 1 and 2.

Fuel-specific $CO_2$ emissions factors — that is, $EF_F$ in Equation 1 — are typically derived from the inherent energy density of a particular fuel. Table 3-2 lists default emissions factors for select fuels typically used in separate thermal production.

***Table 3-2***

### Default $CO_2$ Emissions Factors for Fuels Typically Displaced by CHP (HHV)[77]

| Fuel Type | $CO_2$ Emissions Factor (lb/MMBTU) |
|---|---|
| Natural Gas | 116.9 |
| Distillate Fuel Oil #2 | 163.1 |
| Residual Fuel Oil #6 | 165.6 |
| Coal Anthracite | 228.3 |
| Coal Bituminous | 205.9 |
| Coal Sub-bituminous | 213.9 |
| Coal Lignite | 212.5 |
| Coal (Mixed Industrial) | 207.1 |

As for displaced grid emissions factors — that is, $EF_G$ in Equation 2 — there are several methods used to estimate this value. Most accurate among them is to use a dispatch model. Dispatch modeling demonstrates how generation dispatch for a given region and resource mix would respond to a reduction in demand resulting from the addition of specific CHP resources. The change in emissions is then calculated for that change in dispatch. However, dispatch models are complicated and costly to run. Consequently, the EPA offers a very simple alternative derived from historic performance characteristics of regional electric systems, as reported in the eGRID.[78]

The EPA's eGRID provides two aggregation measures: one based on the average emissions of non-baseload generators and a second based on the average emissions of all fossil fuel generators. Both measures recognize that certain clean energy technologies like CHP are more likely to substitute for existing and/or new fossil generation and not generation from existing "must run" resources, such as nuclear, hydro, and renewables. For baseload CHP systems with high annual capacity factors (i.e., >6500 operating hours), EPA analysis suggests that the average emissions factor of fossil fuel plants provides a reasonable estimate. For CHP operating less than 6500 hours per year, the system can be assumed to displace marginal generating units. In this case, the EPA has recommended using the average emissions factor for non-baseload generation. Average $CO_2$ emissions rates of fossil fuel generation are generally greater than those of non-baseload generation,[79] but vary from being 35 percent greater (for the Western Electricity Coordinating Council) to 10 percent less (in the case of Nonprofit Coordinating Committee NYC/Westchester) than non-baseload rates across subregions. The EPA has developed an online tool, the CHP Emissions Calculator, which uses the series of equations shown previously with eGRID subregional emissions rates to estimate reductions in $CO_2$, $NO_X$, $SO_2$, methane, and nitrous oxide.[80]

Because the eGRID geographic averages do compromise accuracy for simplicity, this approach (like the thermal credit discussed earlier) has been a point of contention.

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[77] 40 CFR Part 98, Mandatory Greenhouse Gas Reporting, Table C-1 of Subpart C. Available at: http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=1&SID=f483e9df938aea70b74776fc6a440d02&ty=HTML&h=L&r=PART&n=pt40.21.98#ap40.21.98_138.1

[78] US EPA, eGRID. (2012). *Summary Tables for Subregions.* Available at: http://www.epa.gov/cleanenergy/documents/egridzips/eGRID2012V1_0_year09_SummaryTables.pdf

[79] Supra footnote 76.

[80] US EPA. (2014, July 30). *CHP Emissions Calculator.* Available at: http://www.epa.gov/chp/basic/calculator.html

To help address concerns and facilitate state air quality and energy planners in developing clean power plans, the EPA recently released a new online tool, AVoided Emission and geneRation Tool (AVERT). AVERT quantifies the $CO_2$, $NO_X$, and $SO_2$ emissions benefits of energy efficiency and renewable energy policies and programs based on temporal energy savings and hourly generation profiles using a marginal emissions rate method.[81] AVERT generally falls between dispatch models and eGRID emissions factors in terms of both simplicity and accuracy.

## 5. Co-Benefits

CHP systems outside of the electric power sector can deliver an unusually wide range of benefits, not just for the host facilities but also for society and the utility system.

For industrial and commercial enterprises, a primary motivation for investing in CHP systems is to meet electricity and thermal energy demands at lower cost. In this way, CHP is set apart from other GHG compliance options in that it directly improves a business' competitiveness. CHP upgrades can improve operations and energy supply reliability, mitigating the risk of grid outages to the firm. By saving energy, CHP reduces all air and solid pollution associated with the substituted fuel consumption, including criteria pollutant and toxic emissions — and therefore can lead to lower compliance costs for other environmental regulations. The methods for quantifying those reductions are essentially the same as the methods used to calculate GHG reductions, with the avoided emissions approach offering a more accurate picture of the impacts.

As to system benefits, CHP installations represent low-cost generation capacity additions, which can be dispatched as firm capacity. If appropriately scaled and strategically targeted within certain locations, CHP can relieve congestion on the grid, effectively delaying costly expansions and upgrades, which can translate into lower utility rates. By consuming energy onsite, CHP avoids transmission and distribution line losses. CHP can also conserve water resources when compared to the 0.2 to 0.6 gallons of water consumed per kWh in a typical coal-fired power plant.[82] With opportunities at manufacturing, commercial, and institutional facilities in every state, CHP development can stimulate the creation of technically demanding and highly skilled jobs[83]

The full range of potential co-benefits for society and the utility system are summarized in Table 3-3. Benefits that

*Table 3-3*

**Types of Co-Benefits Potentially Associated With CHP in the Commercial, Institutional, and Manufacturing Sectors**

| Type of Co-Benefit | Provided by This Policy or Technology? |
|---|---|
| **Benefits to Society** | |
| Non-GHG Air Quality Impacts | Yes |
| Nitrogen Oxides | Yes |
| Sulfur Dioxide | Yes |
| Particulate Matter | Yes |
| Mercury | Yes |
| Other | Yes |
| Water Quantity and Quality Impacts | Yes |
| Coal Ash Ponds and Coal Combustion Residuals | Yes |
| Employment Impacts | Yes |
| Economic Development | Yes |
| Other Economic Considerations | Yes |
| Societal Risk and Energy Security | Yes |
| Reduction of Effects of Termination of Service | No |
| Avoidance of Uncollectible Bills for Utilities | No |
| **Benefits to the Utility System** | |
| Avoided Production Capacity Costs | Yes |
| Avoided Production Energy Costs | Yes |
| Avoided Costs of Existing Environmental Regulations | Yes |
| Avoided Costs of Future Environmental Regulations | Yes |
| Avoided Transmission Capacity Costs | Yes |
| Avoided Distribution Capacity Costs | Yes |
| Avoided Line Losses | Yes |
| Avoided Reserves | Yes |
| Avoided Risk | Yes |
| Increased Reliability | Yes |
| Displacement of Renewable Resource Obligation | Maybe |
| Reduced Credit and Collection Costs | No |
| Demand Response-Induced Price Effect | Yes |
| Other | |

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[81] US EPA. (2014, July 30). *AVERT.* Available at: http://epa.gov/avert/

[82] EPRI. (2002). *Water & Sustainability: US Water Consumption for Power Production.* Available at: http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001006786

[83] The aforementioned 2008 ORNL study found a CHP goal of 20 percent of generation capacity would stimulate $234 billion in capital investment and create nearly one million new jobs by 2030.

accrue to the utility customer who owns a CHP system are additional to those listed.

## 6. Costs and Cost-Effectiveness

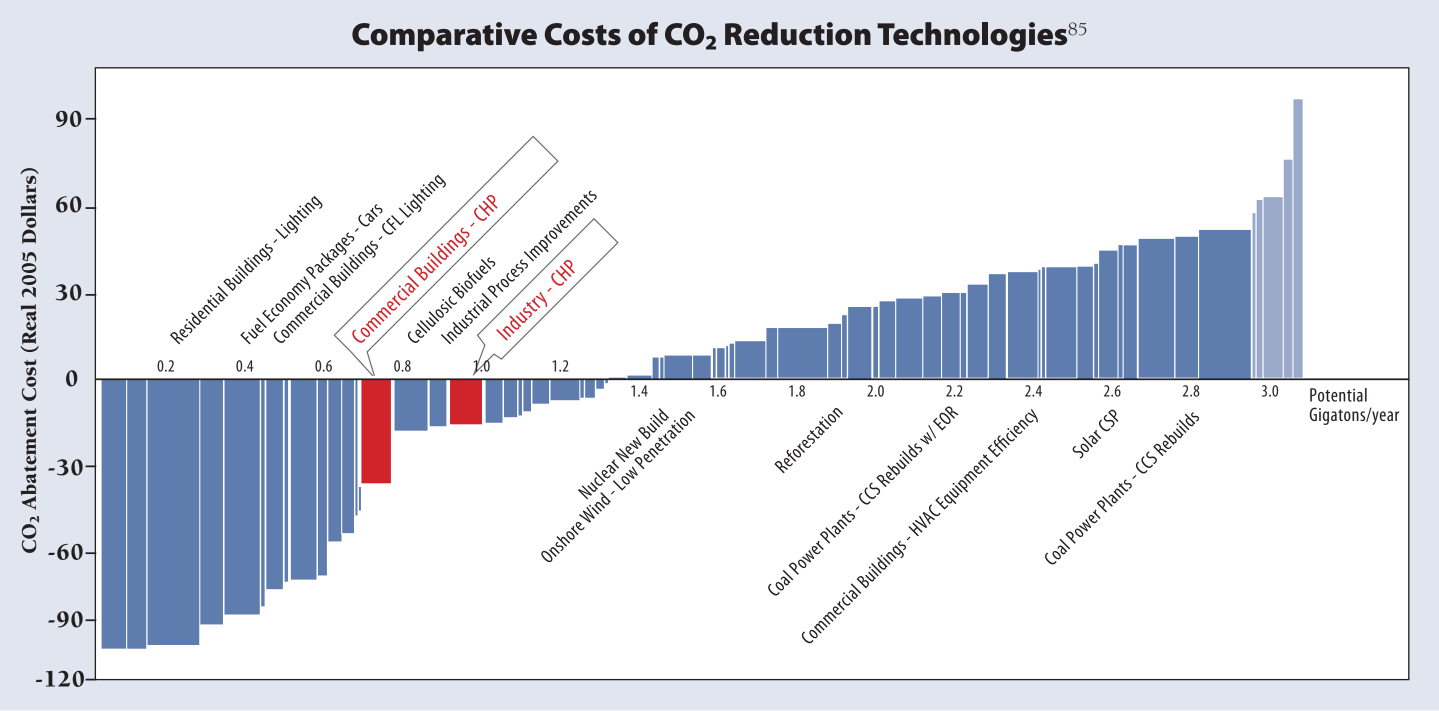
CHP is one of the most cost-effective ways to reduce $CO_2$ emissions. That CHP is an underutilized opportunity for GHG emissions reductions is a conclusion reinforced by the findings of various studies in recent years.

A 2009 report by McKinsey & Company estimated there to be 50 GW of cost-effective CHP in industrial and large commercial/institutional applications through 2020, in which "cost-effective" denotes only investments that had positive net-present values over the lifetime of the measure.[84] These projects were estimated to reduce 100 million metric tons of $CO_2$ annually (Figure 3-5). Substituting today's natural gas prices and market outlook in the analysis would presumably boost this estimate of economic feasibility.

Mentioned earlier, a 2013 analysis by ICF International found a total of 125 GW of technical potential for CHP at existing industrial (56 GW) and commercial (69 GW) facilities, corresponding to a capacity roughly five times the capacity of the coal-fired generation poised to retire between 2012 and 2016.[86] Technical potential here accounts for sites that have high thermal and electric demands suitable to CHP, but does not consider economic factors relevant to project investment decisions.[87] The states with the greatest technical potential (>5 GW) were California, Florida, Illinois, Michigan, New York, Ohio, Pennsylvania, and Texas.[88] When ICF screened for economic viability by incorporating energy prices (excluding other economic incentives), it found that 42 GW of technical potential had an investment payback period of less than ten years, 6 GW of which would pay for itself through energy savings within five years.[89]

Another more recent study evaluated the impacts of the EPA's proposed GHG regulations on CHP deployment. Using ICF International's CHPower and IPM models, the Center for Clean Air Policy analyzed rates of technology adoption at existing and new facilities across the country in light of the EPA's proposed 111(d) GHG regulations for

***Figure 3-5***


**Comparative Costs of $CO_2$ Reduction Technologies**[85]

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[84] McKinsey & Company. (2009). *Unlocking Energy Efficiency in the US Economy.* Available at: http://www.mckinsey.com/client_service/electric_power_and_natural_gas/latest_thinking/unlocking_energy_efficiency_in_the_us_economy

[85] Supra footnote 15.

[86] Supra footnote 14.

[87] Also note that the ICF analysis of technical potential does not include EGUs.

[88] For summary tables broken down by state, size, and sector, see: supra footnote 14.

[89] Ibid.

existing EGUs.[90] Reflecting technical limitations, economic factors, as well as rates of market acceptance, the study determined that a future scenario with 111(d) rules in effect would result in 10 GW of new CHP by 2030, where these 10 GW represent projects that are both economically feasible and "accepted" by firms. The study concludes that 111(d)

***Table 3-4***

**Summary Table of Typical Costs and Performance Characteristics by CHP Technology**[91]

| Technology | Recip. Engine | Steam Turbine | Gas Turbine | Microturbine | Fuel Cell |
|---|---|---|---|---|---|
| **Electric efficiency (HHV)** | 27-41% | 5-40+%* | 24-36% | 22-28% | 30-63% |
| **Overall CHP efficiency (HHV)** | 77-80% | near 80% | 66-71% | 63-70% | 55-80% |
| **Effective electrical efficiency** | 75-80% | 75-77% | 50-62% | 49-57% | 55-80% |
| **Typical capacity (MW)** | .005-10 | 0.5-several hundred MW | 0.5-300 | 0.03-1.0 | 200-2.8 commercial CHP |
| **Typical power to heat ratio** | 0.5-1.2 | 0.07-0.1 | 0.6-1.1 | 0.5-0.7 | 1-2 |
| **Part-load** | ok | ok | poor | ok | good |
| **CHP Installed costs ($/kW)** | 1,500-2,900 | $670-1,100 | 1,200-3,300 (5-40 MW) | 2,500-4,300 | 5,000-6,500 |
| **Non-fuel O&M costs ($/kWh)** | 0.009-0.025 | 0.006 to 0.01 | 0.009-0.013 | 0.009-.013 | 0.032-0.038 |
| **Availability** | 96-98% | near 100% | 93-96% | 98-99% | >95% |
| **Hours to overhauls** | 30,000-60,000 | >50,000 | 25,000-50,000 | 40,000-80,000 | 32,000-64,000 |
| **Start-up time** | 10 sec | 1 hr -1 day | 10 min -1 hr | 60 sec | 3 hrs -2 days |
| **Fuel pressure (psig)** | 1-75 | n/a | 100-500 (compressor) | 50-140 (compressor) | 0.5-45 |
| **Fuels** | natural gas, biogas, LPG, sour gas, industrial waste gas, manufactured gas | all | natural gas, synthetic gas, landfill gas, and fuel oils | natural gas, sour gas, liquid fuels | hydrogen, natural gas, propane, methanol |
| **Uses for thermal output** | space heating, hot water, cooling, LP steam | process steam, district heating, hot water, chilled water | heat, hot water, LP-HP steam | hot water, chiller, heating | hot water, LP-HP steam |
| **Power Density (kW/$m^2$)** | 35-50 | >100 | 20-500 | 5-70 | 5-20 |
| **$NO_X$ (lb/MMBTU) (not including SCR)** | 0.013 rich burn<br>3-way cat.<br>0.17 lean burn | Gas 0.1-.2 Wood 0.2-.5<br>Coal 0.3-1.2 | 0.036-0.05 | 0.015-0.036 | 0.0025-.0040 |
| **$NO_X$ (lb/$MWh_{Total\ Output}$) (not including SCR)** | 0.06 rich burn<br>3-way cat.<br>0.8 lean burn | Gas 0.4-0.8<br>Wood 0.9-1.4<br>Coal 1.2-5.0. | 0.17 - 0.25 | 0.08 - 0.20 | 0.011-0.016 |

** Power efficiencies at the low end are for small backpressure turbines with boiler and for large supercritical condensing steam turbines for power generation at the high end.*

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90 Davis, S., & Simchak, T. (2014, May). *Expanding the Solution Set: How Combined Heat and Power Can Support Compliance With 111(D) Standards for Existing Power Plants.* Center for Clean Air Policy. Available at: http://ccap.org/assets/CCAP-Expanding-the-Solution-Set-How-Combined-Heat-and-Power-Can-Support-Compliance-with-111d-Standards-for-Existing-Power-Plants-May-2014.pdf

91 US EPA CHP Partnership. (2015, March). *Catalog of CHP Technologies.* Available at: http://www.epa.gov/chp/documents/catalog_chptech_full.pdf. Note that values are illustrative for commercially available technologies. Installed cost for most CHP technologies consists of costs related to equipment, installation labor and materials, engineering, project management, and financial carrying costs during the construction period. All costs are in 2014$.

rules will not be sufficient to drive development of CHP resources toward the full technical potential, and that the emissions limits must be accompanied by complementary policies to support CHP uptake as a compliance option.

Generalizing about costs on the project level is problematic, given the extent to which site-specific factors determine the configuration requirements and the extent to which the local regulatory environment can add considerably to administrative overhead. According to the National Regulatory Research Institute, whether using payback period, net-present value, upfront capital costs, technical and economic potentials, or other indicators of economic value, each have advantages and disadvantages in communicating the underlying issues influencing technology adoption.[92] There are furthermore multiple points of view from which to evaluate the cost-effectiveness of CHP, whether from that of the participants, the gas utility, the electric utility, the ratepayer, or society generally. Below, three different analyses of cost-effectiveness are summarized on a project basis. For additional analyses, refer to Chapter 2.

Isolating installed costs for new projects, Table 3-4 compares typical applications by technology class (in 2013$). Gas turbines ranging in size from 5 to 40 MW may have costs from $1200/kW to $3300/kW. Steam turbines may range anywhere from $670/kW to $1100/kW. Reciprocating engines have installed costs ranging from $1500/kW to $2900/kW, whereas microturbines in grid-tied CHP installations can cost from $2500/kW to $4300/kW. Lastly, fuel cells are the most costly, with total installed costs ranging from $5000/kW to $6500/kW.

Cost-effectiveness can also be illustrated by comparing cash outlays over the course of the investment lifetime. In

***Table 3-5***

**Financial Comparison of Two Typical Options for Boiler Replacement**[93]

| | Natural Gas Boilers | Natural Gas CHP | Impact of CHP Increase / (Decrease) |
|---|---|---|---|
| **Peak Boiler Capacity, MMBTU/hr input** | 120 | NA | |
| **Peak Steam Capacity, MMBTU/hr** | 96 | 96 | |
| **Average Steam Production, MMBTU/hr** | 76.8 | 76.8 | |
| **Boiler Efficiency** | 80% | NA | |
| **Electric Generating Capacity, MW** | NA | 14 | |
| **CHP Electric Efficiency** | NA | 31% | |
| **CHP Total Efficiency** | NA | 74% | |
| **Steam Production, MMBTU/year** | 614,400 | 614,400 | 0 |
| **Steam Production, MMlbs/year** | 558.6 | 558.6 | 0 |
| **Power Generation, kWh/year** | NA | 106,400,000 | 106,400,000 |
| **Fuel Use, MMBTU/year** | 768,000 | 1,317,786 | 549,786 |
| **Annual Fuel Cost** | $4,608,000 | $7,906,716 | $3,298,719 |
| **Annual O&M Cost** | $729,600 | $1,687,200 | $957,600 |
| **Annual Electric Savings** | 0 | ($6,703,200) | ($6,703,200) |
| **Net Annual Operating Costs** | $5,337,600 | $2,890,719 | ($2,447,331) |
| **Net Steam Costs, $/1000lbs** | $9.56 | $5.18 | ($4.38) |
| **Capital Costs** | $4,200,000 | $21,000,000 | $16,800,000 |
| **10 Year Net Cash Outlays** | $65,389,602 | $54,138,850 | ($11,250,752) |
| **Payback – CHP vs. Gas Boilers** | | | 6.9 years |
| **10 Year IRR - CHP vs. Gas Boilers** | | | 10% |
| **10 Year NPV – CHP vs. Gas Boilers** | | | $2,580,588 |

*Source: ICF International*

***Notes:*** Based on 8,000 hours facility operation, 7 cents per kWh electricity price, and $6/MMBTU natural gas price. Natural gas boiler estimated capital cost of $35/MBTU/hour input and O&M cost of $0.95/MMBTU input were provided by Worley Parsons. CHP capital cost of $1,500/kW, turbine/generator and heat recovery steam generator O&M costs of $0.009/kWh and 31 percent electrical efficiency are taken from a California Energy Commission Report, "Combined Heat and Power: Policy Analysis and 2011 – 2030 Market Assessment," 2012. Annual CHP O&M cost includes an amount to maintain the steam system, which is approximated by the O&M cost of the boilers, which produce the same steam output. CHP availability of 95 percent and portion of electric price avoided by on-site generation of 90 percent are values based on typical CHP feasibility analyses. 10 year net cash outlays are the sum of 10 year's operating costs escalated at 3 percent annually. NPV determined using a 7% discount rate. All efficiency values and natural gas prices are expressed as higher heating values.

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[92] Costello, K. (2014, June). *Gas-Fired Combined Heat and Power Going Forward: What Can State Utility Commissions Do?*Report No. 14-06. National Regulatory Research Institute. Available at: http://www.nrri.org/documents/317330/16dd1f89-c8ec-44db-af73-7c6473a3ef09

[93] US EPA CHP Partnership. (2013, March 11). *Fact Sheet: CHP as a Boiler Replacement Opportunity.* Available at: http://www.epa.gov/chp/documents/boiler_opportunity.pdf

the context of Boiler MACT compliance, a common choice for facilities seeking to replace a coal-fired or other boiler system is a natural gas boiler. The financial analysis shown in Table 3-5 was developed by ICF International for the EPA's CHP Partnership program. It juxtaposes two options for meeting the average steam demand of a small industrial or medium-sized institutional facility.[94] The first consists of two natural gas boilers, and the second is a CHP system based on a natural gas combustion turbine and a heat recovery steam generator. As the financial comparison details, the CHP system requires an upfront capital expenditure of $16.8 million more than the gas boilers, but produces net annual operating savings of $2.4 million, which yields a payback period of less than seven years, and over ten years generates an internal rate of return of ten percent and a net present value of approximately $2.6 million.

Yet another way to characterize the cost-effectiveness of a CHP project is to compare performance across other generation classes of similar capacity size. Table 3-6 does this, listing annual electric output, thermal output, and avoided emissions from a typical 10-MW gas turbine CHP system, alongside a 10-MW apportionment of utility-scale wind, photovoltaic, and natural gas combined-cycle generators. On a capacity basis, the 10 MW of CHP displaces more $CO_2$ emissions than any of the other options. Homing in on a comparison with wind power, the CHP project achieves 60 percent more $CO_2$ savings than the wind project, while generating 2.5 times the electric output, at 83 percent of the capital cost.

In utility regulation, standard tests for cost-effectiveness are used to evaluate energy efficiency programs,[96] and can also be useful for determining the relative value of CHP programs. Cost-effectiveness can be assessed from many different perspectives, whether from that of the gas utility,

***Table 3-6***

**CHP Energy and $CO_2$ Emissions Savings Potential Compared to Other Generation Options**[95]

| Category | 10 MW CHP | 10 MW PV | 10 MW Wind | 10 MW Natural Gas Combined-Cycle |
|---|---|---|---|---|
| **Annual Capacity Factor** | 85% | 25% | 34% | 70% |
| **Annual Electricity** | 74,446 MWh | 21,900 MWh | 29,784 MWh | 61,320 MWh |
| **Annual Useful Heat Provided** | 103,417 MWh | 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 |

***The values in Table 3-6 are based on:***

- 10 MW Gas Turbine CHP - 28% electric efficiency, 68% 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 Capacity factor, capital cost and efficiency for natural gas combined-cycle system based on Advanced Energy Outlook 2011 (540 MW system proportioned to 10 MW of output), NGCC $NO_X$ emissions 9 ppm
- CHP, PV, Wind and NGCC electricity displaces National All Fossil Average Generation resources (eGRID 2010 ) - 9,720 BTU/kWh, 1,745 lbs $CO_2$/MWh, 2.3078 lbs $NO_X$/MWh, 6% T&D losses; CHP thermal output displaces 80% efficient on-site natural gas boiler with 0.1 lb/MMBTU $NO_X$ emissions
- CHP, PV, Wind and NGCC electricity displaces EPA eGRID 2010 California All Fossil Average Generation resources - 8.050 BTU/kWh, 1,076 lbs $CO_2$/MWh, 0.8724 lbs $NO_X$/MWh, 6% T&D losses; CHP thermal output displaces 80% efficient on-site natural gas boiler with 0.1 lb/MMBTU $NO_X$ emissions

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[94] Supra footnote 93.

[95] Supra footnote 14.

[96] National Action Plan for Energy Efficiency. (2008). *Understanding Cost-Effectiveness of Energy Efficiency Programs: Best Practices, Technical Methods, and Emerging Issues for Policymakers.* Energy and Environmental Economics, Inc. and The Regulatory Assistance Project. Available at: www.epa.gov/cleanenergy/documents/suca/cost-effectiveness.pdf

the electric utility, ratepayers, or the participating entities. Tests like the Program Administrator Cost test, the Total Resource Cost test, and the Rate Impact Measure tests can help account for how costs and benefits affect all parties involved. Appendix A of the 2013 SEE Action report describes how these tests can be used to evaluate benefits and costs as they accrue across parties and energy types.[97]

## 7. Other Considerations

Increased deployment of CHP outside of the electric sector will have impacts both on natural gas utilities and electric utilities. Each is discussed briefly below.

### Natural Gas Distribution Utilities

CHP in commercial and institutional sectors, where ICF International estimates that more than half of untapped technical potential is located (69 of 125 GW), may offer a substantial new market opportunity for natural gas local distribution companies.[98] Gas utilities can bring their technological expertise to bear, working with customers to develop energy efficiency solutions that ensure customer retention. A gas utility can also potentially provide financial support for capital upgrades over longer-term investment horizons, consistent with its business model.

A case study from Philadelphia Gas Works (PGW) exemplifies a partnership of this nature. PGW collaborated with the Four Seasons hotel in downtown Philadelphia to develop a technology configuration that would deliver reasonable savings, including introducing the customer to the microturbine technology it would ultimately select. The project was based around three 65-kW gas microturbines to provide 100 percent of the hotel's domestic hot water, 25 percent of its electric, and 15 percent of its heating needs. To address upfront costs, PGW developed an arrangement whereby it provided $1.2 million in upfront capital, to be paid back through a surcharge on the hotel's energy bills. Recovery of PGW's cost was estimated to take three years, after which the customer would financially benefit from the energy savings over the lifetime of the investment.[99]

Oregon is one state adopting specific provisions to enable natural gas utility ownership and investment in CHP. Oregon Senate Bill 844 of 2013 created an inventive program for gas utilities that would allow recovery of investments in GHG reduction projects.[100] As of August 1, 2014, the rules were still being finalized by the Public Utility Commission, but gas utilities had identified CHP as a primary area of interest.[101] Baltimore Gas and Electric and New Jersey Natural Gas also provide financial support and incentives to industrial and commercial customers who install CHP. Baltimore Gas and Electric funds this through a ratepayer-funded energy efficiency program, and New Jersey Natural Gas through loan repayment schemes negotiated between the utility and the participant. A 2013 report from the American Council for an Energy-Efficient Economy (ACEEE) provides an extensive discussion of the role for natural gas utilities in developing CHP more fully.[102]

### Electric Utilities

Distributed generation, including CHP, is causing a transformation in the way electricity is generated, delivered, and paid for in the United States, and how it fits within existing regulatory frameworks. The shift away from centralized production toward dispersed, demand-side resource solutions signifies a reduction in utility revenue and has been perceived as chief among threats to the traditional utility business model. This stance is beginning to evolve, however, as utilities engage stakeholders and look for ways to position themselves in this new order.[103,104] Perhaps especially with regard to CHP, where energy falls outside the

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[97] Supra footnote 22.

[98] Larger industrial facilities, in contrast, are usually connected to interstate gas pipelines or consume other fuels. CHP applications smaller than 100 MW would usually be connected to a distribution network.

[99] Supra footnote 22.

[100] Oregon State Legislature, Senate Bill 844. Available at: https://olis.leg.state.or.us/liz/2013R1/Measures/Text/SB844/Enrolled

[101] Oregon Public Utility Commission, Docket No. AR 580. Available at: http://apps.puc.state.or.us/edockets/docket.asp?DocketID=18862

[102] Chittum, A., & Farley, K. (2013, July). *How Natural Gas Utilities Can Find Value in CHP.* ACEEE. Available at: http://www.aceee.org/files/pdf/white-paper/chp-and-gas-utilities.pdf

[103] Kind, P. (2013, January). *Disruptive Challenges: Financial Implications and Strategic Responses to a Changing Retail Electric Business.* Edison Electric Institute. Available at: http://www.eei.org/ourissues/finance/documents/disruptivechallenges.pdf

[104] ICF International. (2014). *From Threat to Asset: How CHP Can Benefit Utilities.* Available at: http://www.icfi.com/insights/white-papers/2014/how-chp-can-benefit-utilities

core business of most participating enterprises, utilities are uniquely positioned to shoulder risk and responsibility and provide assistance in design, installation, and operations to maximize benefits to the electrical system. Examples of how electric utilities can profit from distributed CHP development are discussed in Chapter 2. Creating avenues for utility participation in CHP development is expected to be a growing focus for regulators seeking to address the administrative, financial, and technical barriers that have led to persistently low rates of adoption. Both the 2013 SEE Action study and a 2013 ACEEE report highlight possible considerations for utility participation in CHP markets.[105]

## 8. For More Information

Interested readers may wish to consult the following reference documents for more information on CHP in the commercial, institutional, and manufacturing sectors.

- ACEEE. *Technical Assistance Toolkit, Policies and Resources for CHP Deployment*. Available at: http://energytaxincentives.orgwww.energytaxincentives.org/policies-and-resources-chp-deployment
- ICF International for the American Gas Association. (2013, May). *The Opportunity for CHP in the United States*. Available at: http://www.aga.org/Kc/analyses-and-statistics/studies/efficiency_and_environment/Pages/TheOpportunityforCHPintheUnitedStates.aspx
- NASEO. (2013). *Combined Heat and Power: A Resource Guide for State Energy Officials*. Available at: http://www.naseo.org/data/sites/1/documents/publications/CHP-for-State-Energy-Officials.pdf
- The Regulatory Assistance Project. (2014, February). *Standby Rates for Combined Heat and Power Systems: Economic Analysis and Recommendations for Five States*. Available at: http://www.raponline.org/press-release/standby-rates-for-combined-heat-and-power-need-a-fresh
- The Regulatory Assistance Project. (2003). *Output Based Emissions Standards for Distributed Generation*. Available at: http://www.raponline.org/docs/RAP_IssuesLetter-OutputBasedEmissions_2003_07.pdf
- US DOE, US EPA, & SEE Action Network. (2013, March). *The Guide to Successful Implementation of State Combined Heat and Power Policies*. Available at: https://www4.eere.energy.gov/seeaction/publication/guide-successful-implementation-state-combined-heat-and-power-policies
- US DOE. *Boiler MACT Technical Assistance Program* website. Available at: http://energy.gov/eere/amo/boiler-mact-technical-assistance-program
- US DOE. *CHP Technical Assistance Partnerships* website. Available at: http://www1.eere.energy.gov/manufacturing/distributedenergy/chptaps.html
- US DOE & ORNL. (2012). *Guidance for Calculating Emission Credits Resulting From Implementation of Energy Conservation Measures*. Available at: http://info.ornl.gov/sites/publications/Files/Pub37258.pdf
- US DOE & ORNL. (2008, December). *Combined Heat and Power: Effective Energy Solutions for a Sustainable Future*. Available at: https://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_report_12-08.pdf
- US EPA. (2014, August). *Output-Based Regulations: A Handbook for Air Regulators*. Available at: http://www.epa.gov/chp/documents/obr_handbook.pdf
- US EPA CHP Partnership website. Available at: http://www.epa.gov/chp/
- US EPA CHP Partnership. (2015, March). *Catalog of CHP Technologies*. Available at: http://www.epa.gov/chp/documents/catalog_chptech_full.pdf

## 9. Summary

CHP offers a technologically mature, cost-effective, and near-term strategy for reducing GHG emissions, with technical potential distributed across the industrial, commercial, and institutional sectors. Grid-tied CHP facilities, however, can be complex, site-specific installations that carry significant technical and administrative burdens that have led to low rates of adoption, even in jurisdictions where financial incentives improve economic feasibility. Designing CHP to maximize co-benefits to the system, such as grid reliability, critical infrastructure resilience, and reduced congestion, further requires careful consideration and expertise that is typically beyond the field of participating enterprises. Concerted effort through supporting policy and regulation, as well as utility cooperation, will be required to take full advantage of CHP as a GHG reduction compliance option.

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105 US DOE, US EPA, & SEE Action Network. Available at https://www4.eere.energy.gov/seeaction/; US EPA, CHP Partnership. Available at: http://www.epa.gov/chp/; Chittum, A. (2013, July). *How Electric Utilities Can Find Value in CHP.* ACEEE. Available at: http://aceee.org/files/pdf/white-paper/chp-and-electric-utilities.pdf