As the Grid Gets Greener, Combined Heat and Power Still Has a Role to Play

By David Jones, Deborah Harris, and Bill Prindle

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- Estimated combined heat and power (CHP) emissions impacts can vary widely depending on the assumptions used for displaced utility emissions.
- CHP will continue to be an emissions winner when compared to separate sources of heat and power for at least another 20 years.
- As a highly efficient and resilient resource, CHP can act as a bridge towards a future with zero carbon emissions.

Executive Summary

Combined heat and power fueled by natural gas will play a role in achieving the increasingly-bold greenhouse gas (GHG) reduction and renewable energy goals set by many states, cities, and utilities. While these goals focus on deploying more low- or no-carbon energy, which might seem to squeeze CHP out of the picture, CHP can still fit prominently within the framework of these goals due to its superior efficiency and reduced emissions compared to all other fossil fuel resources. According to our analysis, CHP will continue to reduce carbon emissions through at least 2040.

CHP's Role in Decarbonization and the Grid

CHP remains an emissions winner because it will continue to displace fossil fuel power on the margin. While nuclear, hydroelectric, and renewable electricity from solar and wind resources produce zero emissions, they are typically considered "must run" resources in grid operations—and will be dispatched by grid operators to the fullest extent possible at all times. Because of this, most fossil fuel resources will continue to be used as "load following" units in U.S. power systems, meaning they run "on the margin" of the system—or after grid renewable and nuclear energy resources to help meet the remaining demand.

As long as fossil fuel generation is used this way, natural gas CHP systems will always result in fewer emissions than separate heat and grid power, even when compared to the most efficient combined cycle gas turbine plants.

As grid operators shift their generation mix to lower-emission technologies and energy sources, CHP can help reduce grid emissions by operating more efficiently and with fewer emissions than traditional options. It is bridging the gap until we achieve a 100% clean energy system.

Climate Action Plans (CAPs) are used to set goals and pathways for mitigating future greenhouse gas emissions. Often one of the most impactful ways to reduce GHG emissions is through reducing emissions associated with electricity.

Due to available data and resources and the wide number of potential power sector technologies and program strategies, which could have different emission impacts, CAPs generally compare emission savings using "average all-source emission factors." This method provides a common framework to evaluate various strategies when a more granular analysis is not feasible or necessary.

For many distributed energy resources, marginal emission factors can better represent displaced grid emissions; in such cases using these factors may show greater greenhouse gas savings. Agencies engaging in CAPs may consider taking this extra step of calculating marginal emissions when assessing the potential emission savings of various programs over time.

Measuring Emissions Impacts for a Changing Grid Mix

Efforts to reduce and eliminate greenhouse gas emissions from the electric grids require a better understanding of the relative emissions impacts from different efficiency and renewable energy measures over time. Many state and local government agencies have implemented Climate Action Plans (CAPs) and similar tools to assess the impacts of such clean energy policy and program solutions, using GHG inventories to track their progress over time.

Along with energy efficiency and renewable energy, CHP should be part of the menu of options for reducing emissions in CAPs. However, care must be taken to properly categorize the displaced emissions from resources like CHP. A recent CAP update created by ICF for the state of Pennsylvania showed a negative impact from CHP compared to average grid all-source emission factors, but a positive impact when compared to the resources that were most likely to be displaced on the grid margin (i.e., those resources not considered must-run).

To estimate historical and current grid emissions, analysts use tools from the U.S. Environmental Protection Agency (EPA) such as eGRID (Emissions & Generation Resource Integrated Database)[1] and AVERT (AVoided Emissions and geneRation Tool)[2]. eGRID provides average values for regional emissions factors based on a comprehensive source of historical utility generation resources and emissions data. AVERT allows users to calculate marginal emissions factors based on estimated hourly load impacts on regional grid operations.

As an alternative to applying AVERT calculations for each demand-side resource, different eGRID factors can be used to simulate the avoided emissions from the grid generation sources that are most likely to be displaced. The distinction between average grid all-source emission factors and average marginal grid emissions is key to understanding CHP's impact on emissions.

ICF has leveraged EPA's CHP Energy and Emissions Savings Calculator to estimate avoided grid emissions for a number of different applications using eGRID factors. We also developed a methodology document for EPA to help users choose the most applicable emission factors.[3] We found that avoided displaced grid emissions for CHP applications can be estimated using either the average Fossil Fuel or Non-Baseload eGRID emissions factors.

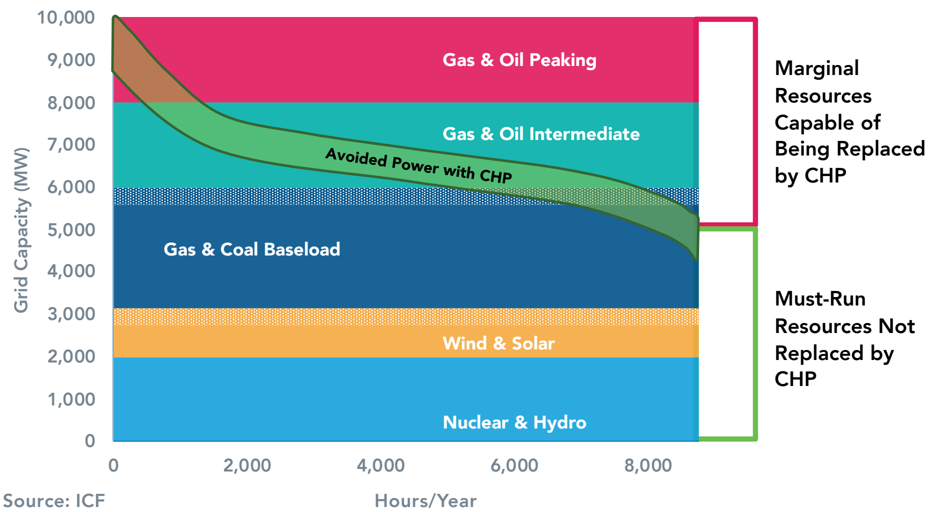
Figure 1 shows an analysis performed for a hypothetical vertically-integrated utility with a 10 GW peak using a typical load duration curve and dispatch order. The chart shows the effect that multiple baseload CHP systems would have on the load curve, and which sources of generation would be displaced.

[1] U.S. Environmental Protection Agency, Emissions & Generation Resource Integrated Database (eGRID), https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

[2] U.S. Environmental Protection Agency, AVoided Emissions and geneRation Tool (AVERT), https://www.epa.gov/statelocalenergy/avoided-emissions-and-generation-tool-avert

[3] U.S. Environmental Protection Agency, Combined Heat and Power Partnership, Fuel and Carbon Dioxide Emissions Savings Calculation Methodology for Combined Heat and Power Systems, February 2015.

FIGURE 1. EXAMPLE OF GRID RESOURCES AVOIDED WITH CHP POWER



Source: ICF

- The generators that are designated "must-run" (nuclear, hydroelectric, and PV/wind) operate whenever they are available. This is illustrated in the figure, which shows that these generators will operate under the load curve throughout the entire year.
- The textured areas in the chart represent the variability of wind and solar resources—both the wind and solar output and total must-run/baseload capacity are affected by this variability.
- Coal plants and natural gas combined cycle plants are typically used for baseload power, but they can also be modulated as customer loads decline. This is indicated in the area above the load curve and below the "Gas & Oil Intermediate" zone line.
- Intermediate and peaking-generation units, which historically have been natural gas and oil-fired single-cycle turbines, can be dispatched rapidly to meet peak loads. They also typically have the highest operating costs of all units on the system.

While the relative amount of fossil fuel, renewable, and nuclear or hydro generation will change based on several variables—including electric system operational factors, technology advances, and the timeframe of the analysis—marginal emissions impacts can be estimated using both AVERT and eGRID factors. AVERT provides a more precise measurement of marginal emissions, but eGRID emission factors can provide reasonable approximations of displaced grid emissions of baseload resources from CHP.

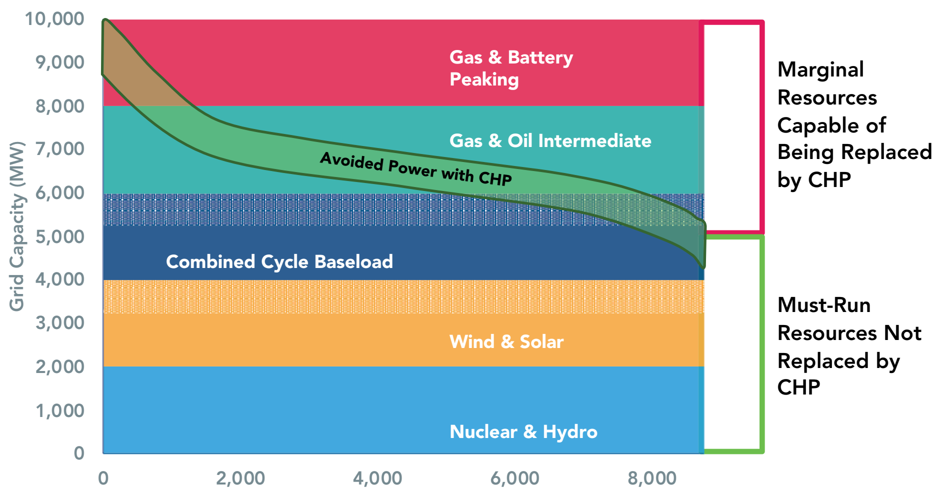
As long as fossil fuel generators are used as marginal units in system dispatch, the average fossil fuel emissions factor can serve as a proxy for displaced grid emissions of CHP systems that operate 24/7. For distributed energy resources that operate during daytime hours only, baseload generation is not as likely to be displaced. The average eGRID Non-Baseload emission factors would provide a strong indicator of displaced grid emissions. With some analysis of future changes to the regional generation mix, both of these emission factors can be adjusted over the timeframe of a study to estimate future grid emission reductions.

How will avoided grid emissions change over time?

When thermal energy is fully recovered and utilized, CHP is the most efficient way to generate electricity with natural gas. CHP will always yield a net reduction in emissions compared to other fossil fuel technologies. But how will the grid mix change over time, and how will this affect CHP emission reduction estimates?

Figure 2 depicts a potential representation of the 2040 grid mix and dispatch order for the hypothetical utility that has retired all coal units and increased deployment of renewables and energy storage—including the load duration curve and expected generation sources avoided by CHP.

FIGURE 2. EXAMPLE OF FUTURE 2040 GRID RESOURCES AVOIDED WITH CHP POWER



Source: ICF

Energy storage batteries are likely to become a strong peaking resource with large-scale utility deployments. This could change the avoided emissions calculations if renewable energy resources are used to charge the batteries. However, gas turbines are also expected to be a source of battery charging, and the overall emissions impact of battery peaking units is not likely to be significant. As long as fossil fuels are still being used for intermediate and peaking power, adjusting the eGRID fossil fuel emission factors over time to remove coal and oil-based units (as they are expected to retire) can provide a reasonably accurate representation of future avoided grid emissions from baseload CHP.

Estimating the Future Emissions Impacts of Natural Gas CHP

The estimated emission impacts of CHP can vary greatly depending on whether average or marginal emission factors are used. As the grid gets cleaner, the difference between average (all-source) and marginal emission factors widens. Average emission factors will decline, while marginal factors will tend to remain higher as fossil units continue to run on the margin. Applying average emission factors for all sources will, therefore, underestimate the emission reduction impacts of additional natural gas CHP resources.

In the recent Climate Action Plan Update[4] that ICF supported for the Commonwealth of Pennsylvania, the initial CHP analysis showed a net GHG emissions increase with the CAP implemented in later years towards 2050 when applying average emission factors (including nuclear and significantly increased renewable generation). To provide a more accurate comparison to displaced electric system emissions, we worked with the Department of Environmental Protection to provide an alternate calculation for CHP using marginal emission factors—showing significant GHG reductions over the course of the analysis.

To further analyze the potential for this type of calculation sensitivity, we looked at 2016 average fossil fuel and overall grid emission rates for several states. These are shown in Table 1 below.

Compared to a 20 MW gas turbine CHP system, the 2016 marginal rates for all states are higher than the net emission rates of the CHP system (estimated by ICF at 652 lb/MWh CO_2), which take into account the avoided emissions from displaced boiler fuel. This would result in emission savings from CHP for all states compared to marginal (fossil fuel) grid emissions. However, note that compared to the average grid emissions rate from all sources—including must-run nuclear, hydroelectric, and renewables—CHP would currently result in a net increase in emissions for California and New York compared to the net emissions of 652 lb/MWh from CHP.

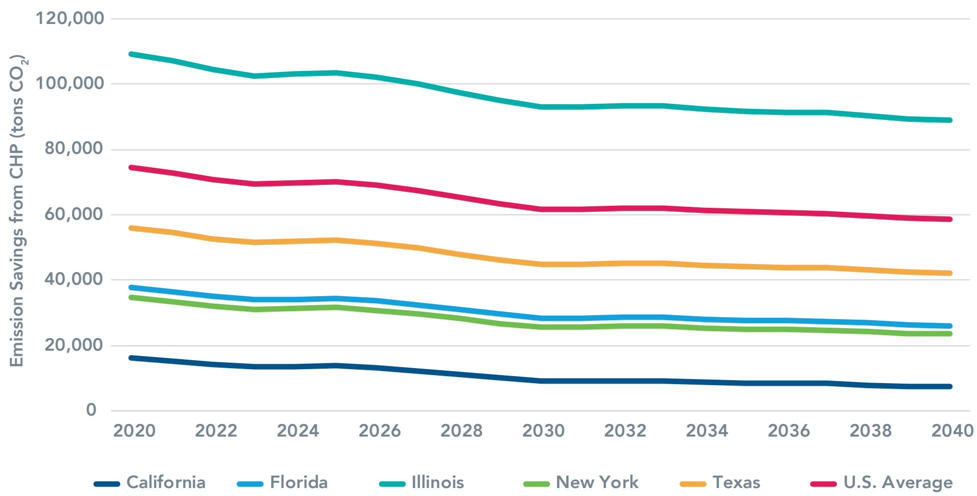
TABLE 1. MARGINAL AND AVERAGE GRID EMISSION RATES (EGRID2016, LB/MWH CO_2)

State	Marginal Grid Emissions Rate—Fossil Fuels (lb/MWh CO_2)	Average Grid Emissions Rate—All Sources (lb/MWh CO_2)
California	867	453
Florida	1,193	1,024
Illinois	1,970	811
New York	1,000	464
Texas	1,361	1,050
U.S. Average	1,565	990

[4] https://www.governor.pa.gov/pennsylvania-releases-state-climate-action-plan-join-u-s-climate-alliance/

Emission savings from CHP are substantial compared to current marginal grid emissions rates across states. This will continue to be the case well into the future. ICF investigated the topic at a high-level by applying the EIA projected power sector emission factors to estimate the impact on CHP emissions reductions over 20 years. Figure 3 shows the potential emission savings from a 20 MW CHP system as estimated using the marginal emission rates for five states and the U.S. average.

FIGURE 3. ANNUAL EMISSION SAVINGS (TONS CO_2) FROM 20 MW CHP SYSTEM COMPARED TO ESTIMATED MARGINAL GRID EMISSION RATES, 2020-2040



Source: ICF

As policymakers and industry leaders seek technology, policy, and programs to meet ambitious carbon emission reduction targets, CHP will continue to be a solution that reduces emissions compared to traditional intermediate and peaking power grid resources.

Key Takeaways

Assumptions are an important part of any policy analysis. Depending on the assumptions and data sources used for average versus marginal emission factors, CHP can be seen as either an additional source of GHG emissions or a potential way to reduce them compared to conventional grid power.

Average emission factors will continue to be appropriate for certain types of policy analyses, especially those involving a wide range of electric grid impacts. However—when available and in the proper situations and calculations—marginal emissions factors will offer a more accurate estimate of emission reductions. The application of average and marginal emissions factors should, therefore, be considered carefully, taking technology-specific characteristics into account. Our analysis—summarized above—shows that marginal emission factors based on current and future grid generation mix provides a more accurate indicator of future emissions reductions for CHP.

Efficient natural gas CHP systems will continue to provide substantial greenhouse gas reductions well into the future. CHP will thus be a critical resource for policymakers, grid operators, and others seeking to reduce emissions as they integrate new resources—all with the aim of achieving renewable energy goals.

[5] U.S. EIA. Annual Energy Outlook (2018). Available at: https://www.eia.gov/outlooks/aeo/

[6] CHP system performance characteristics based on U.S. DOE Gas Turbine CHP Technology Fact Sheet, available at https://www.energy.gov/sites/prod/files/2016/09/f33/CHP-Gas%20Turbine.pdf. Additional assumptions include industrial CHP application, 8,000 full load hours of operation at 100% thermal utilization.

About the Authors

David Jones is a manager at ICF with over 15 years of experience analyzing markets and modeling the performance of distributed energy resources for government clients and energy industry stakeholders. David leads ICF's efforts to evaluate technologies and markets for CHP and microgrids by developing analysis strategies, managing project teams, and communicating findings to clients. He also leads ICF's technical support for the Environmental Protection Agency's CHP Partnership and Green Power Partnership. Prior to joining ICF, David served as senior engineer at Resource Dynamics Corporation and Engineering Aide for the Defense Information Systems Agency. David holds a Mechanical Engineering degree from the University of Virginia, with a concentration in energy systems.

Deborah Harris is a greenhouse gas (GHG) mitigation expert with substantial experience in state and local mitigation and energy planning work. In her tenure at ICF, she has been managing and working on interdisciplinary teams to serve a range of international, federal, state, and local clients in the GHG mitigation and accounting, decarbonization, policy development and analysis, and engineering spaces. Deborah has an M.S.E. in Environmental Engineering from Johns Hopkins University and two B.S. degrees in Chemical Engineering and Engineering and Public Policy from Carnegie Mellon University.

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