INTERNATIONAL DISTRICT ENERGY ASSOCIATION

Smart Tools in a 111(d) Toolbox:

Combined heat and power and district energy

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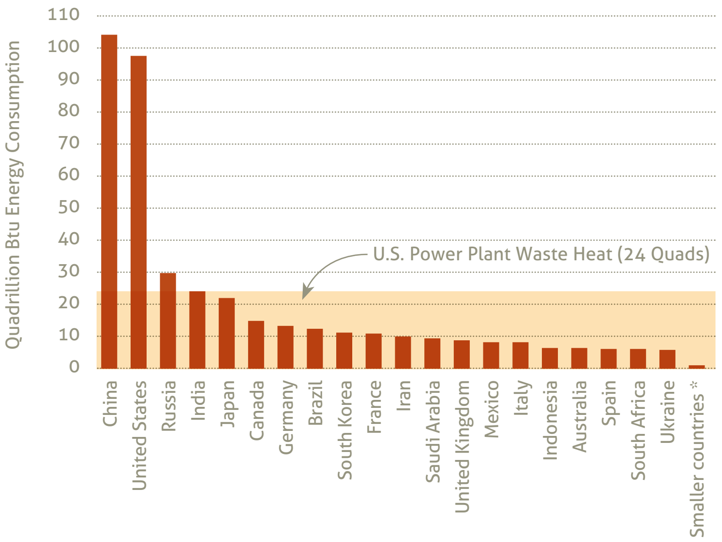
Introduction

A new proposed federal rule regulating CO_2 emissions from existing electric power plants will take effect in 2020, establishing new state goals that will cut nationwide power-related CO_2 emissions 30 percent by 2030. That's a big cut, and pundits and utilities warn it means power rates will go up significantly. But that does not have to be the case. The new rule is an opportunity to actually reduce rates [1] while building a more resilient, flexible and efficient grid.

How so? The average electric power plant turns just one-third of its input energy into useful power. The rest is squandered, dumped into the air or into lakes, bays and rivers as waste heat. But most of that excess heat is valuable thermal energy that can be captured and used to provide real services such as heating or cooling buildings, powering industrial processes, or meeting domestic hot water needs. The technology to do this is neither new nor experimental.

Combined heat and power (CHP) and district energy (DE) systems have helped cities, communities and facilities in all regions of the country reduce their emissions, improve local resiliency and stimulate economic development for more than a century. They're complementary technologies that can exist separately, but when combined together they offer states and utilities a unique set of tools to meet CO_2 requirements while providing substantial additional benefits, including a more reliable heat and power supply, the chance to utilize local and renewable fuel sources, and reduced energy costs.

FIGURE 1. Comparison of U.S. Power Plant Waste Heat to Total Energy Use in Other Countries.



The U.S. power industry is only about 34 percent efficient and rejects around 24 quadrillion Btus of waste heat annually (25 percent of total U.S. energy use). This waste heat from U.S. power generation exceeds the total national energy use in all but three of the world's 216 countries.

* Per country average for remaining 196 countries

Source: Data from U.S Energy Information Administration, International Energy Statistics (2011 data), http://tinyurl.com/kkfnavt.

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CHP and DE reduce costs simply by taking advantage of economies of scale and using more of the inherent energy in their fuel sources. CHP systems capture and use excess waste heat, while DE systems move excess heat and other thermal energy to multiple buildings in a highly efficient manner, using much less energy to heat and cool spaces and water than individual building-by-building chillers or boilers. Where the typical electric power plant converts just 34 percent of fuel into useful energy, newer CHP and DE system combinations often convert between 70 and 85 percent into usable energy, requiring much less fuel to meet community energy needs. That maximizes the cost-effectiveness of an energy system while also dramatically reducing CO_2 emissions. Indeed, CHP and DE system investments are typically made first and foremost for their cost savings; the CO_2 savings are real, but have heretofore not been the primary reason that CHP and DE projects have moved forward in the U.S.

With the new rule, states will begin seriously considering, for the first time, how their energy systems perform in terms of CO_2 emissions. This paper summarizes the scope of the new federal rule and describes how CHP and DE investments could help states comply with it by offering highly cost-effective CO_2 reductions. It then profiles seven existing CHP and DE systems in the U.S. and their known CO_2 emissions reduction impacts to better understand how CHP and DE can help states economically meet their energy needs and reduce harmful emissions.

The New Rule

In June 2014, in order to encourage the deployment of clean power and to address the threat of climate change, the U.S. Environmental Protection Agency for the first time proposed a rule regulating CO_2 from existing electric generating sources [2]. This rule, known colloquially as "111(d)" for the applicable section of the Clean Air Act, will affect almost all states. Once finalized, 111(d) will establish CO_2 goals for each affected state. These rules will require reductions in CO_2 from affected facilities and the state's electricity system as a whole, which will in turn yield tremendous environmental, economic and health benefits to society [2].

The EPA's proposed rule delineates four distinct "building blocks" to develop states' CO_2 goals [3]. Importantly, these building blocks allow affected generators to look beyond their own facilities and take advantage of the most cost-effective emissions reduction opportunities available locally or even regionally.

While states are the final arbiters of how to meet their emissions goals, the four building blocks used to set state goals are:

1. **Reducing emissions rates of affected facilities, by improving heat rates (BTU of fuel/MWh), fuel switching, or deploying carbon capture and storage (CCS) technologies**
2. **Changing the dispatch order of facilities to rely more on natural gas-powered combined-cycle generating units, and less on coal, oil and natural gas-powered steam generating units**
3. **Increasing reliance on generating units that are no- or low-carbon emitters**
4. **Improving end-use efficiency, thus reducing generation-related emissions [2], [3].**

The National Association of Clean Air Agencies offers an excellent resource for states considering their various compliance options: "Implementing EPA's Clean Power Plan: A Menu of Options," available here: http://www.4cleanair.org/NACAA_Menu_of_Options.

The proposed rule gives states substantial flexibility to meet their goals, and they can build their compliance strategy from any or all of the above building blocks or other types of efforts that yield CO_2 reductions. With 2020 as the first year of compliance, the proposed rule gives states ample time to determine how to structure their compliance approaches.

The cost of compliance to utilities, states and individual ratepayers will vary dramatically based on how they go about complying. ***In many cases, complying with these rules can actually reduce the cost of electricity to ratepayers*** [1]. CO_2 goals established for each state take into account the progress each was already making on each of the building blocks, so each state's goal is pegged to an established and unique baseline. The new 111(d) rule offers each state an exceptional opportunity to reduce harmful emissions from its electric generating fleet, while improving its performance.

The District Energy Family

What is district energy?

District energy systems are local energy networks that provide multiple buildings with hot water/steam ("district heating"), chilled water ("district cooling"), electricity (often called "microgrids") or some combination of these services. These different types of services often operate in parallel, serving all or some of the same buildings concurrently.

DE systems are uniquely designed to take advantage of local opportunities and respond to local challenges. They are adaptable to unique situations, able to meet particular local needs (such as the exacting reliability demands of hospitals) or respond to location-specific resource opportunities (such as burning locally available biomass).

To provide these energy services, a DE system is typically built around a central plant that acts as the system's heart. Once produced in the central plant, the energy makes its way to the connected buildings through pipes or wires. And much like the human vascular system, these pipes often operate in a closed-loop fashion, bringing hot water from the central plant to a building for use and then returning cooled water to the "heart" to be reheated and circulated again.

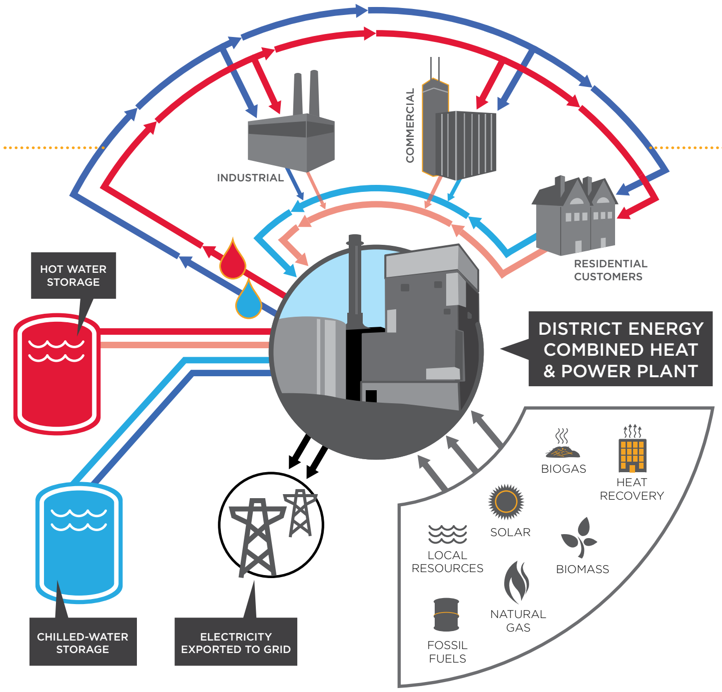
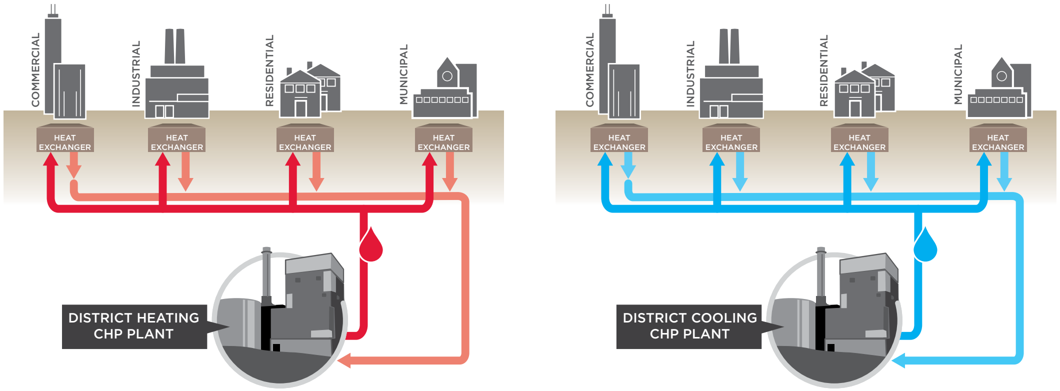


FIGURE 2. District energy systems can take advantage of local renewable resources to provide heating and/or cooling to multiple buildings using one efficient central plant. They can also incorporate thermal storage, combined heat and power and other technologies to make them even more efficient.

Courtesy District Energy St. Paul.

FIGURE 3. District energy systems distribute steam, hot water (left) and/or chilled water (right) to a group of buildings via underground pipes.



DE systems can be found at over 700 locations around the United States and are common features on large institutional campuses such as colleges, military bases and hospitals. They are also widely deployed in downtown areas such as Chicago, Denver and Boston. By aggregating the demands of multiple buildings, a DE system is generally more efficient than individual building-scale production of this energy. But the efficiency benefits are even more pronounced when the central plant is a combined heat and power (CHP) system.

What is CHP?

For most power plants, the first step in generating electrical power is to generate heat. Some of the energy in that heat eventually becomes useful electricity, but most of it is wasted, either as steam that is vented into the sky, or as hot water that is dumped into adjacent lakes, bays and rivers. Most power plants do this because there is no nearby use for all the heat generated during the electrical generation process.

CHP systems, on the other hand, capture the surplus heat generated during electricity production and use it to provide space heating, hot water or process steam for use in nearby buildings. In this way, CHP systems are much more efficient than the typical electric power generator, which usually wastes two-thirds of its input energy as heat. A new CHP system wastes less that 20 percent of its input energy and saves even more energy because its output is used across the street or down the block, greatly reducing the transmission- and distribution-related losses found in traditional centralized generation.

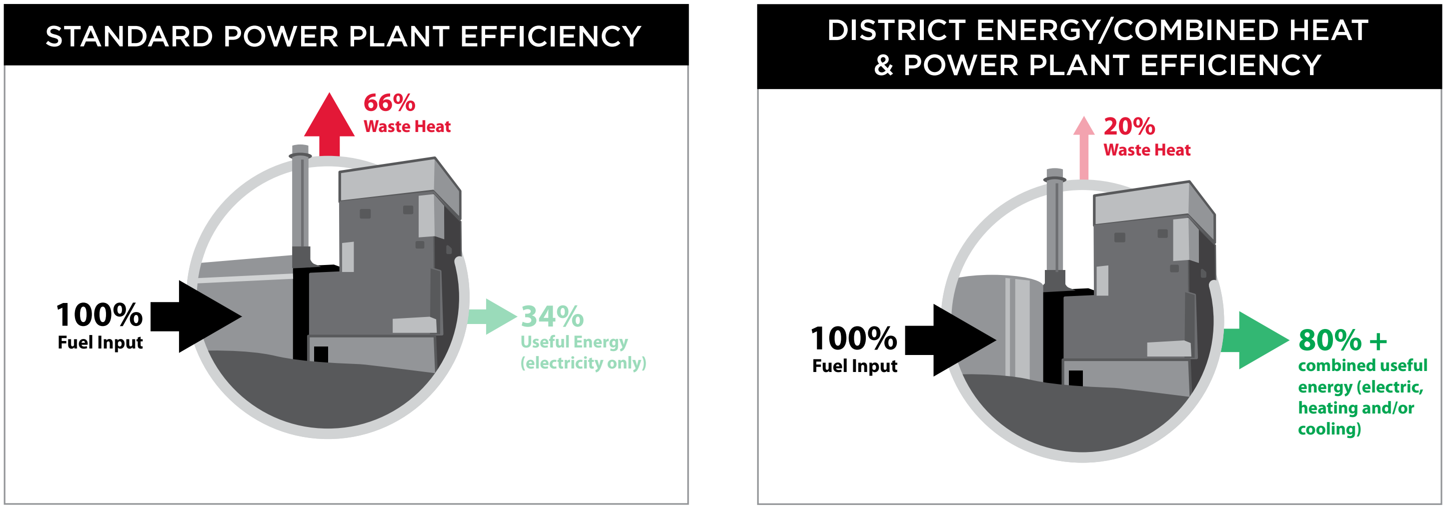


FIGURE 4. Standard fossil-fuel power plants are only about 34 percent efficient. Fully two-thirds of their energy is exhausted as waste heat into the atmosphere or nearby waterways. A CHP plant captures much of this waste heat and puts it to use, such as to heat buildings, making it twice as efficient as a conventional power plant. A CHP plant produces useful thermal energy and electricity from the same fuel.

Today CHP systems provide about 12 percent of the power generated in the U.S. and can be found at well over 4,000 locations around the country [4]. The vast majority of CHP systems in place today serve industrial facilities, though the commercial and multifamily residential sectors are increasingly turning to CHP to replace aging infrastructure and to provide power and heat to new state-of-the-art sustainable buildings.

CHP + District Energy

CHP systems are efficient on their own at the single-building scale, but the benefits of CHP are much more pronounced when paired with DE, as seen in figure 3. DE systems maximize the tremendous efficiency benefits of CHP by aggregating the heating, cooling or power needs of multiple buildings.

CHP systems are often limited in their size by the heat demand of their local host. When DE systems combine the demand of multiple buildings, CHP systems operating as the central plant can be sized larger, providing economies of scale in both equipment and fuel purchases.

The benefits of CHP and DE are many, especially when paired together. Some of these benefits include:

- **Dramatically increased efficiency.** CHP systems do more with the same fuel, reducing the amount of fuel that needs to be used. When coupled with DE systems, CHP systems can further maximize that efficiency since pooling the needs of different customers reduces the volatility of their total energy demand. That allows a CHP system to run closer to full load for more of the time, which is the most efficient way to operate a CHP system. Additionally, DE and CHP systems serve nearby users, greatly reducing the amount of energy lost when it travels great distances.

- **Sharply reduced emissions.** The increased efficiency of CHP and DE systems means that less fuel is burned to generate the same amount of power or thermal energy, resulting in lower emissions. Further, CHP and DE systems can take advantage of renewable or lower-carbon resources such as biomass, deep lake water, or solar thermal, offering additional emissions-reduction advantages over traditional centralized fossil fuel-based power.
- **Fuel and technology flexibility.** Certain technologies that would make little economic sense on a single-building scale make wonderful sense on a campus-wide or neighborhood-wide scale. And due to their size and technological flexibility, many DE and CHP systems can operate on multiple fuels. Others have successfully converted from one fuel to another over time, as particular fuels became more readily available, more cost-effective or offered a cleaner emissions profile.
- **Increased resiliency for connected facilities.** During Superstorm Sandy, buildings connected to CHP and DE systems kept the lights on and equipment running. CHP and DE systems typically rely on robust underground networks of highly insulated pipes, and often use on-site fuel and/or thermal storage, as well as the reliable natural gas interstate pipeline system. And since power generation is taking place nearby, and not many miles away, electricity supply is more reliable during storm events.
- **Increased reliability of the local grid.** CHP and DE systems are often connected to the local electricity grid at distribution voltage, and can be important providers of capacity and energy services that help stabilize the grid's voltage and mitigate unexpected drops in power supply. Additionally, during times of unplanned grid outages, such as during severe weather events, interconnected CHP and DE systems can provide nearby connected buildings with additional backup power and heating or cooling, providing safe, comfortable areas of refuge for displaced people or emergency responders. This reliability is also critical for facilities such as health care and public safety centers as well as valuable research facilities or data centers for whom business interruption is very costly.
- **Balancing services to support greater no-emissions electricity.** As more and more intermittent renewable energy resources such as wind and solar enter the generation pools around the country, transmission operators need to balance these fluctuating resources in a manner that maintains grid stability. CHP systems can and do operate as highly flexible capacity resources, and many are able to ramp up and down much faster than more traditional grid-balancing resources. CHP and DE systems often include thermal storage components, allowing them to either cost-effectively reduce electric output when the grid is oversupplied, or to increase electric output when the grid is undersupplied. Their thermal storage capabilities allow them to cost-effectively store energy generated by renewable electric generators such as wind and solar.
- **Local control and economic development.** Cities and facilities served by CHP and DE are more active players in their energy futures. In contrast, cities and facilities that rely solely on grid-provided energy services are necessarily more passive actors, less able to influence how and where their energy is generated and will be generated in the future. Additionally, some DE-supplied cities and buildings are better able to attract businesses and tenants due to the enhanced reliability for business continuity and cost-competitive DE services.
- **Reduced strain on transmission and distribution infrastructure.** Strategically sited CHP and DE systems can reduce the strain on certain challenged pieces of grid infrastructure, such as substations that are operating near their capacity. Additionally, by replacing the need for far-flung traditional electricity generation, CHP and DE systems can reduce the strain on the transmission grid and, in some cases, avoid the need for new transmission infrastructure altogether [5].

Thermal storage is an important part of TECO's chilled water system that provides more than 120,000 tons of cooling capacity for the Texas Medical Center campus.

Courtesy TECO.

CHP and District Energy as Compliance Tools

Because the emphasis of the new EPA rule is a reduction in the CO_2 intensity of the power sector, CHP and DE are excellent compliance options for states. CHP systems have always offered a way to do more with a single fuel input, offering a greater "bang for the buck" while simultaneously reducing emissions intensity. They utilize much more of the useful energy their fuels burn – more than twice as much, on average. In other words, they burn far less fuel to supply the same amount of energy, making their emissions inherently less intensive.

EPA has recognized the energy efficiency and environmental benefits of CHP by proposing that both electricity and useful thermal energy be counted when quantifying a state's average emissions rate for compliance with the new rule [3]. CHP can provide CO_2 emission reductions at a lower cost than many renewable electricity technologies as well as technologies such as carbon capture and sequestration that are discussed in the proposed rule as potential compliance strategies [33].

CHP and DE systems can directly offer or otherwise support the deployment of resources identified within the building blocks. As described in the following case studies, CHP and DE can

- improve the heat rate of existing generators by capturing and making productive use of surplus heat, thus yielding more useful energy with each BTU of fuel consumption;
- support and ease the shifting of dispatch order by providing thermal storage at night, thereby reducing daytime heating- or cooling-related electricity usage, and thus peak demand;
- foster fuel-switching from higher-emitting fuels to lower-emitting fuels, by increasing a project's economy of scale and aggregating thermal loads to make the lower-emitting fuels more cost-effective;
- operate as a proven demand-side energy efficiency resource, providing year-round efficiency benefits and lowering the demand curve for grid-generated electricity; and
- dramatically improve the electric grid's ability to accept greater levels of intermittent no-carbon renewable energy, such as wind and solar, by offering grid-balancing services and storage opportunities.

The EPA acknowledges within the proposed rule that affected utilities may be able to count CHP located at industrial and other sites toward their compliance [3]. Additionally, the proposed rule reflects EPA's support for compliance strategies that include specific actions taken at the state or even regional level. Compliance strategies are thus not necessarily limited to actions taken by individual affected facilities, but could instead include a variety of activities and investments that improve the CO_2 intensity of an energy system as a whole. For states that currently rely heavily on coal for their electricity, the incentive to deploy new CHP to comply with 111(d) rules is especially strong [1], [6]. Methodologies exist for calculating emission reductions due to CHP and DE in state clean power plans and fit into EPA's equations for state compliance [34].

There is tremendous potential for CHP in the U.S. One recent analysis found 6 GW with strong economic potential (under five-year simple payback) and over 35 GW with moderate economic potential (five to 10-year payback) [1, 7-9, 35]. These estimates are based on conservative assumptions and do not reflect the increased demand for CHP that can arise from new DE system deployment. There are about 290 DE systems in the U.S. that do not currently use CHP. These represent near-term opportunities for CHP, because the aggregated thermal demand of multiple buildings is well suited to the thermal output of a CHP system. According to internal IDEA analysis, an estimated 5.6 to 14.4 GW of new CHP capacity could be realized just by optimizing these existing DE systems, in addition to the 6 GW and 35 GW mentioned above.

The new 111(d) rule presents a unique opportunity for states, cities and individual facilities to comprehensively assess the best way to reduce fossil fuel consumption by maximizing energy efficiency, while taking advantage of local fuel opportunities and resources. CHP and DE are two of the best tools to take advantage of this opportunity. The following section details just a few examples of how CHP and DE are already providing states, cities and institutions with locally optimized cost-effective energy solutions that also happen to effectively reduce CO_2 emissions.

CASE STUDY: PRINCETON UNIVERSITY

Enjoying system resiliency and flexible dispatch

The Story: Since 1876, Princeton University in Princeton, N.J., has used a DE system to serve the needs of its now 13,800 students, faculty and staff. In 1996 the university unveiled a new 14.6 MW CHP plant that plays a critical role in the university's resilience and flexibility. The CHP/DE system today runs primarily on natural gas with fuel oil as backup, though a new solar PV facility now provides the system with 4.5 MW of electricity. Princeton's system serves 9.5 million sq ft and provides that space with heating and cooling, domestic hot water, process steam and electricity via a microgrid [29], [30]. More than 180 buildings rely on the system for all or part of these services, and the university plans to continue to see total campus square footage rise in the near future as new buildings are developed and served by the DE system.

The Path to Reduced CO_2 Intensity: Princeton offers an excellent example of how a system comprised of multiple building blocks can maximize efficiency, flexibility and emissions performance. The university has implemented a wide variety of energy efficiency investments such as lighting improvements, controls commissioning, energy plant efficiency upgrades, green roofs, increased insulation, heat recovery, advanced steam traps, modernized building controls, building HVAC replacement and ground source heat pumps [29].

The CHP system is very flexible, and the university makes decisions about whether or not to dispatch the CHP system based on the cost to generate power as compared to the real-time cost to purchase power from the grid. At night the university uses less expensive and less constrained grid-derived electricity to generate chilled water, which it then stores overnight and uses to efficiently cool buildings during the day. This reduces the need for cooling-related energy purchases during the day and reduces daytime summer peaks on the local PSEG grid in which Princeton is located. When the grid nears its peak, Princeton relies more on its on-campus resources and reduces its demand on the nearest substation. It can reduce its demand from 28 MW to 3 MW, which also lowers the capacity and transmission costs associated with grid power purchases.

Since peak power sold into the region's PJM wholesale energy market is generally less efficient and dirtier than non-peak power, emissions reductions result from relieving the grid of strain at peak periods. At times when the PJM system is more constrained and less efficient during the day, the CHP system replaces grid purchases with highly efficient onsite distributed generation. A sophisticated dispatch software and management system makes the buy/generate recommendations for the university [29]. The DE system also incorporates power produced by a nearby solar panel field that will further reduce the emissions produced to meet the university's electricity needs.

Princeton's highly efficient central energy plant has four main components: steam boilers, water chillers, CHP system and a large thermal energy storage system, visible at right.

Courtesy Princeton University.

Emissions and Energy Performance Stats:

- Shifting the time of demand for grid power allows the university to fill the thermal storage tank when the electricity mix is its cleanest, yielding a CO_2 reduction of 5-10 percent per MWh [31].
- The total overall efficiency of the CHP system is 80 percent [30].
- The system as a whole avoids 24,000 tons of CO_2 annually.
- Even as the university has added square footage each year, CO_2 emissions have dropped steadily since 2008 [32].

Additional Benefits: The university gets tremendous energy and economic savings due to its state-of-the-art DE and dispatch system. Annual energy costs have declined 10 to 15 percent [30], and the university estimates that the CHP plant has saved the university $3 - $5 million per year [29]. The university's goal of bringing CO_2 emissions down to 1990 levels by 2020 is within sight, thanks to the DE and CHP systems [29]. Additionally, the resilient qualities of DE and CHP were on full display during Superstorm Sandy, when Princeton remained online while the surrounding grid went down. The DE system maintained campus operations, especially mission-critical research buildings and areas that were supporting first responders and neighbors seeking refuge from their own cold and dark homes.

CASE STUDY: HOUSTON, TEXAS

Reducing emissions and peak grid demand

The Story: The Texas Medical Center, the largest medical center in the world, comprises 18 different institutions spread across a vast campus in the middle of Houston. Thermal Energy Corporation (TECO) is the Texas Medical Center's dedicated DE and CHP system, serving its institutions with chilled water and steam, which are used for air conditioning, space heating, sterilization and domestic hot water needs. TECO's customers have a total of 44 buildings representing over 19 million sq ft, 7,000 hospital beds and $1.7 billion of annually funded medical research.

The medical center's chiller system dates from 1969. The system became much more flexible and efficient with the addition of a thermal energy storage system in 2009 and a 48 MW CHP system in 2010. Today the system runs largely on natural gas and is the largest district cooling system in the country. The thermal energy storage tank rises 15 stories high and stores 8.8 million gal of chilled water [26] to cool the attached buildings during the day.

The Path to Reduced CO_2 Intensity: The TECO system uses cheaper, cleaner power generated by the grid at night to produce chilled water, which is then stored and used for cooling during the day. By changing its own dispatch activities and alleviating daytime peak purchases of electricity, TECO avoids buying the most expensive and dirtiest electricity from the grid [26].

The TECO system represents a tremendous improvement in energy efficiency, as the series of chillers coupled with the CHP and chilled water storage save about one-third of the electricity that would otherwise be required to cool the connected buildings. Since the CHP system can reliably supply 100 percent of the power required to meet the peak cooling requirements of all of TECO's customers, buildings connected to TECO can forgo investments in dirty and inefficient backup diesel generators and backup chillers. In emergencies, every connected building can rely on the DE system instead, dramatically reducing both onsite emissions and emissions associated with purchases of peak power from the local grid [26].

The TECO system provides reliable steam, chilled water and electricity to the Texas Medical Center's campus in Houston.

Courtesy TECO.

Emissions and Energy Performance Stats:

- The system as a whole reduces CO_2 by 300,000 tons a year, the equivalent of taking 57,000 cars off the road [27].
- With the addition of CHP, the steam-producing and cooling plant as a whole improved its efficiency from 42 percent to more than 80 percent [27], with a heat rate of 6,700 BTU/kWh [26].
- The new CHP system is expected to reduce fossil fuel consumption of the district cooling system by 60 percent, compared with business as usual [27].

Additional Benefits: Situated in a hurricane-exposed area, the Texas Medical Center requires system reliability during catastrophic weather events. The expensive and highly sensitive research and medical equipment requires exacting standards for climate control. Thus, reliable heating and cooling is a must. The TECO system reliably meets 100 percent of peak chilled water and steam demands [27] of the center. Additionally, the system can offer 64 MW of standby power generating capacity during emergencies [28], alleviating strain on the local grid during times of emergency.

For the Texas Medical Center, the new investments in the district cooling system were first and foremost sound economic decisions. With the new CHP system and thermal energy storage facilities in place, customer cooling rates were reduced by 12.2 percent in 2011, 3.0 percent in 2012, 1.4 percent in 2013 and another 6.5 percent in 2014. The entire $377 million upgrade and expansion not only met growth requirements; it is also expected to reduce costs to all TECO customers by a total of over $200 million through 2026. Indeed, the lower operating costs provided approximately $9 million in energy savings back to customers in the first year alone [26]. A stepped approach to integrating different aspects of the plan over time allowed TECO to adjust to changing economic situations and changes in actual development compared with forecasted development.

CASE STUDY: CAMBRIDGE, MASSACHUSETTS

Improving efficiency of an existing CHP plant

The 256 MW Kendall Cogeneration Station supplies steam to Veolia North America's district energy system serving Boston and Cambridge, Mass.

Courtesy Veolia North America.

The Story: Built in 1949, Cambridge's Kendall Station is a natural gas-powered CHP plant perched along the Charles River. Previously operated only during periods of high energy demand, Kendall Station was repowered in 2002, increasing the plant's capacity from 60 MW to 256 MW. To cool the plant, an average of 70 million gal of water a day was withdrawn from the Charles River, which was then discharged back into the Charles at much higher temperatures. This waste heat in the river led to concerns about harmful impacts on aquatic habitat, such as damage to fish eggs [16].

To help alleviate these concerns and make productive use of the waste heat, Veolia North America, which recently acquired Kendall Station and operates a number of nearby district energy systems, built a new 7,000 ft pipeline along the Charles to bring Kendall's waste heat to users of its existing district energy systems [17]. The project, called "Green Steam," improved Kendall Station's operations and reduced the amount of heat discharged into the river by approximately 30 percent. The low-emissions Green Steam now serves the bulk of Boston's high-rise buildings, dozens of hospitals and research centers, and many of Boston and Cambridge's biotechnology companies and institutions.

The Path to Reduced CO_2 Intensity: By making productive use of energy that had been previously wasted, the Green Steam project greatly improves Kendall Station's overall efficiency. Using waste heat – a zero-emissions resource – to meet existing heating needs and displace other fossil fuel-based energy use has yielded tremendous CO_2 savings for customers connected to the Boston steam system served by Kendall Station.

Emissions and Energy Performance Stats:

- The Green Steam project yields a total of 475,000 short tons of CO_2 reductions annually, equivalent to taking 80,000 cars off the road [18].
- The addition of the new pipeline improves plant efficiency by 13 to 15 percent. Kendall Station is now able to convert up to 85 percent of its fuel into useful energy, which equates to roughly 40 percent less fuel consumed than when heat and power are produced separately in boilers and power plants [16].
- The project reduces both Boston's and Cambridge's non-transportation CO_2 emissions by 6 percent overall [18].

Additional Benefits: In a dense urban setting like Cambridge and Boston, finding low- and no-emission ways to meet heating needs for new and existing buildings in the downtown core offers substantial economic benefits since potential owners and tenants are attracted to the cleaner cogenerated steam supply. New buildings can leverage the existing heat infrastructure, making a strong economic development case for the steam system's expansion. Both the Boston and Cambridge mayors are strong supporters of this project, reflecting the significant environmental benefits to both cities. Additionally, construction of the pipeline has helped spur regional economic growth and supported 147,500 man-hours (e.g. welders, pipe fitters and insulators), translating to $21 million in labor costs.

The direct benefits of the system itself extend beyond just emission reductions. Future additional investments in the CHP system by Veolia will totally eliminate the hot water discharge into the Charles River and enable up to 75 percent of Veolia's district energy heat to be supplied by recycled Green Steam. The system provides the energy reliability required by healthcare and research institutions requiring 24/7 operations. Finally, the recycled steam helps Cambridge and Boston make significant strides toward meeting their individual Climate Action Plan goals [19].

CASE STUDY: COLUMBIA, MISSOURI

Leveraging local low-emissions fuel

The Story: The University of Missouri (Mizzou) has long identified local fuel opportunities and worked to take advantage of them to meet campus needs. It built its first DE and CHP system in 1892. Today Mizzou's 66 MW CHP plant runs on multiple fuels, including biomass, coal and natural gas. Investments in a new biomass boiler have ensured that a variety of fuels with a variety of moisture levels can be used. The boiler primarily uses local wood residues and is flexible enough to supplement with other biomass resources that may be sourced in the future. Wood is also co-fired, up to 10 percent, in the plant's coal fired boilers.

The university's large district cooling system complements the CHP plant with a mixture of electric and steam-powered chillers. The system's 33 chillers help to serve the 15 million sq ft of facilities on the campus [12]. These facilities, which include most campus buildings as well as several hospitals and research centers, take electricity, chilled water, compressed air and drinking water from the integrated DE system [12], [13].

The University of Missouri central plant utilizes woody biomass supplied from a variety of sources including wood mill residue, forestry management and discarded shipping pallets.

Courtesy University of Missouri.

The Path to Reduced CO_2 Intensity: Mizzou's integrated CHP and DE system has resulted in increased efficiency and allowed the use of renewable fuels in place of more carbon-intense fuels. These improvements have reduced the plant's use of coal by 50 percent and lowered the campus CO_2 inventory by 36 percent since 2008. In addition to the fuel switching and energy efficiency benefits of the CHP system, the system can ramp its dispatch up and down in response to wholesale prices in the regional MISO electricity market. The CHP system thus generates power when it is economical to do so, generally during peak grid demand, and generates less when the grid-provided power is inexpensive, during non-peak periods [12]. Wind energy is also purchased within the MISO system with 11 percent of the campus electricity use sourced from wind energy. The school's renewable portfolio is now 24 percent and the school projects that it will meet over one-third of its on-campus energy needs with renewable fuels within the next few years.

Woodchips en route to the Mizzou CHP plant, where they will be efficiently burned to produce useful energy for the campus.

Courtesy University of Missouri.

Emissions and Energy Performance Stats:

- Mizzou has a long history of reducing energy intensity through energy conservation. Since 1990, while the university's square footage has grown by over 42 percent, much of it with energy-intensive uses such as research facilities, it has reduced its energy use per square foot by 19 percent and its greenhouse gas emissions per square foot by 57 percent [12], [14], [15].

Additional Benefits: The DE system provides the school with flexibility that allows it to remain open to a wide variety of energy resources. The university explicitly seeks to take advantage of local fuels, and to spread its fuel use across multiple fuels so as to not depend too much on any one [12]. The district system offers a heat sink and the aggregated electricity demand necessary to justify recent investments in wind power, solar PV and solar thermal.

Its DE system and strong conservation efforts now yield annual avoided utility costs of $8.4 million. Furthermore, students at the university use the DE and CHP system as an educational tool, and multiple departments within the school conduct research to help the energy system maximize its economic, technical and environmental performance. This work provides assurance to the university that any future emissions criteria will be satisfied economically and in the best interests of the school and its students [12].

CASE STUDY: SEATTLE, WASHINGTON

Adapting to new fuel opportunities

The Story: Seattle's steam system has served a substantial portion of the downtown core since 1893. Following a major boiler upgrade in 2009, the multi-boiler system has relied on both biomass and natural gas to produce 200 MWth equivalent of steam for approximately 200 buildings, serving about 18 million sq ft [22]. The system provides space heating, domestic hot water, sterilization for hospitals and process steam for cheese making and brewing and distilling at several of Seattle's renowned craft beer and liquor producers [23].

The Path to Reduced CO_2 Intensity: The Seattle system has consistently taken advantage of the fuel flexibility benefits of DE, responding to changes in the availability and economics of fuel resources. Originally fueled by coal, the system switched to natural gas before beginning the transition to locally sourced biomass five years ago. For the 200 buildings attached to the system, this means that their CO_2 intensity will continue to improve as more and more biomass is burned without the need for new internal equipment in each building or the hassle associated with individual building fuel switching. As the fuel sources change, the 200 buildings can immediately improve their emissions profiles by up to 50 percent. Today the system relies in part on waste wood from area construction activities, and other clean woody biomass products [24]. The system gives customers a way to benefit from renewable energy that they would likely not be able to achieve on their own [23].

As Enwave Seattle, the owner and operator of the system, looks to the future, all additional improvements in the system's CO_2 intensity will similarly yield real and immediate improvements in emissions for all of the connected buildings. Building owners receive regular updates on the emissions-related performance of their steam supply [23]. They benefit from upgrades and investments, such as a new absorption scrubber system, that address pollution issues unique to the waste wood fuel stream [22].

Enwave Seattle provides low-carbon heat to approximately 200 buildings in Seattle's central business district and First Hill neighborhoods.

Courtesy Enwave Seattle.

Emissions and Energy Performance Stats:

- When operating at full capacity, Seattle's steam system yields a reduction of 45,000 tons of CO_2 every year. This represents a reduction in carbon footprint for the attached buildings of about 50 percent.
- Seattle Steam heats about 18 million sq ft, a space the size of 11,000 average Seattle homes [25].
- When operating at full capacity the biomass plant will reduce carbon intensity for end-users to about 95 lb/MMBtu of steam delivered, which could only be achieved if a building's gas-fired boiler operated at (an impossible) 122 percent efficiency.

Additional Benefits: The Seattle steam system uses locally available waste wood and waste biomass products. These are all local fuels, mostly the products of existing recycling and composting activities. The municipal composting system was keen to develop a sourcing relationship with Enwave Seattle. Additionally, the steam company offers direct assistance and data access to customers seeking to satisfy LEED and ENERGY STAR requirements.

CASE STUDY: SAINT PAUL, MINNESOTA

Flexible dispatch of low-emissions fuel

The Story: Saint Paul's DE system was originally built as a demonstration project by the city, state and the federal Department of Energy in 1983 in partnership with businesses located in the city's downtown core. The system has been significantly upgraded over the years and today includes a highly efficient 33 MW CHP system, as well as extensive heating and cooling networks. The Saint Paul system brings the benefits of locally sourced biomass to heating customers throughout the city. A total of 200 buildings take hot water from the DE system, including the city's convention center, most of its commercial buildings downtown, government facilities at all levels (local through federal) and multiple hospitals. The system's hot water system provides space heating, domestic hot water needs and snow melting systems for more than 31 million sq ft of space.

About 100 buildings take the system's chilled water for cooling purposes. The chilled water is stored in multiple storage units on the system that can hold 6.5 million gallons, which is chilled during the night during off-peak electric demand periods [20].

The entire heating and cooling system is supplied primarily by the CHP system, which is fueled by biomass sourced from urban wood waste and forest residuals. Coal and natural gas-fueled boilers provide backup and peak supply, and the whole system can export up to 25 MW of power to the nearby grid [20].

Saint Paul's CHP plant generates both electricity and heat from the same fuel source, making use of the waste heat that results from generating electricity. The thermal storage tank (foreground) enables the system to shift a significant portion of the summer cooling load to off-peak hours.

Courtesy District Energy St. Paul

The Path to Reduced CO₂ Intensity: The Saint Paul system incorporates a number of technologies to reduce its CO_2 intensity. The highly efficient CHP system and hot water distribution offer efficiency savings, while the thermal storage allows the system the flexibility to shift more of its power use to off-peak times, when power is cleanest and cheapest. Additionally, the thermal energy system acts as a thermal grid to distribute excess thermal energy, such as that produced by a new solar thermal hot water system (the largest in the country) that was recently deployed on the roof of the convention center. Using a variety of efficient and flexible tools, the Saint Paul system displaces fossil fuels with efficient low- and no-emissions solar and biomass energy [21]. And by offering highly efficient cooling services, the system negates the need for many inefficient air-conditioning units around that city that would contribute to peak electric demand.

Emissions and Energy Performance Stats:
Annual effective emissions reductions: approximately 250,000 tons each year due to using biomass in lieu of using fossil fuels for heating and grid power, the equivalent of removing 53,000 cars from the road.

Additional Benefits: By buying local wood waste rather than out-of-state fuel, the DE system recirculates and retains more than $10 million a year into the regional economy that would otherwise be paid to fuel suppliers and other companies outside Minnesota [20].

District Energy St. Paul was the first in the United States to integrate solar thermal into a district heating system.

Courtesy District Energy St. Paul.

CASE STUDY: PHOENIX, ARIZONA

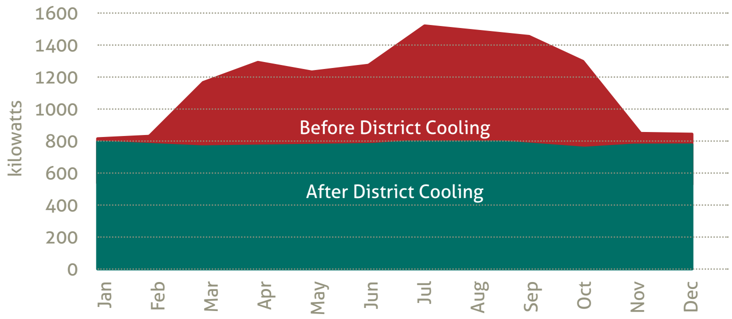
Reducing peak congestion and emissions with flexible dispatch

The Story: Beginning in 2001, a large district cooling system has grown steadily to now serve about 12 million sq ft of buildings in downtown Phoenix with efficient chilled-water cooling. About 34 different buildings and facilities use the reliable cooling system, which was greatly expanded in 2006 with the development of a new chiller plant at the city's convention center.

The entire system can provide 40,000 tons of cooling by connecting end users with its three separate plants, which include two storage facilities that make and then store ice. One of the main chiller plants is located at Chase Field, home of the Arizona Diamondbacks. Through over four miles of pipes, the whole cooling system utilizes 17 chillers and serves a variety of types of buildings, including the US Airways Center, which hosts the Phoenix Suns. The ice storage units that are integrated into the system store ice made overnight to provide daytime cooling, thus taking strain off the local electric grid during daytime peaks [10][11].

The Path to Reduced CO_2 Intensity: By connecting thermal storage to the district cooling system, the Phoenix system allows a shift in demand for cooling-related energy. At night the system uses low-cost, grid-provided electricity to generate about 8 million pounds of ice, when utility demands are lowest. At the height of a summer day, when the utility grid is straining under maximum cooling-related demand, the Phoenix system cools its connected buildings by melting ice, which enters the cooling system and replaces the need for chillers that would otherwise have to operate during the day. The peak cooling demand is thus met with often cleaner, non-peak electricity generation. By removing such a large daytime demand from the grid, the Phoenix system helps reduce utility service territory congestion and strain on other related equipment [11].

Figure 5. By connecting to a district cooling network, building owners can dramatically reduce their peak electric demand compared to using on-site chillers. The example below reflects the impact of district cooling on the peak power demand of a building in Cleveland.



350,000 sq ft commercial office building built in 1965. Located in Cleveland. Two electric chillers displaced. Actual peak meter readings varied just 2 percent Jan-July.

Emissions and Energy Performance Stats:

- Up to 10MW of peak power demand is avoided in the heat of the day in an especially concentrated area of downtown Phoenix, offering emissions reductions when that peak power is derived from less-efficient sources.

Additional Benefits: Business leaders in Phoenix see the district cooling system as a competitive advantage when recruiting new business to downtown. The flexibility in electricity demand yields cheaper cooling costs for businesses through cheaper time-of-use rates [11]. Additionally, the district cooling system uses underground ice storage coils, freeing up above-ground space that would otherwise be used for cooling or storage needs, and backup ice is generated in case a chiller unexpectedly goes offline when chiller-generated cooling is required.

Conclusion

DE and CHP make economic sense. In every one of the previous case studies, investments in DE and CHP were made primarily on their economic merit. While other benefits, such as high levels of reliability, flexibility in fuel choice and reduced greenhouse gases were often important to the host institutions, they did not alone drive the projects.

Most of these cities and institutions have measured and documented their systems' extensive reductions in CO_2 emissions for years, often to understand how they meet local or internal CO_2 goals. They have been ahead of the curve. Only now, as the new federal CO_2 rules take shape, is the CO_2 reduction value of any energy project able to be viewed within an established federal and state regulatory context. States working to develop their own compliance strategies have DE and CHP to work with as highly effective and adaptable tools in their toolbox.

The DE and CHP industries are ready to perform in this new context and are available now as energy solutions for a wide variety of facilities. They offer benefits far beyond traditional centralized power generation, and many of the major suppliers of components and services are American companies.

DE and CHP often face regulatory and policy challenges at the state level. State policymakers and utility decision-makers can address some of these policy needs to take full advantage of the cost-effective emissions reduction benefits of CHP and DE.

Future work will identify the specific policy and regulatory changes most needed to help hasten greater deployment of these technologies. For now, all policymakers and market players involved in developing state-level responses to the new federal rules ought to consider the important role DE and CHP can play in their state's clean-energy future.

The International District Energy Association (IDEA) has a number of tools and resources to help cities and states understand how CHP and DE could meet their energy needs. This includes:

- Access to a screening tool that offers a "first cut" analysis of project feasibility and assistance with project definition. The tool yields projected energy load profiles as well as initial estimates of the expense, payback and return on investment associated with deploying new CHP or DE infrastructure. Contact IDEA to learn whether this screening tool is right for your needs.
- The *Community Energy: Planning, Development & Delivery* guidebook, which offers community leaders an overview of the district energy development process along with guidance on related policy and process matters.

Finally, IDEA can help cities or states interested in learning more about DE and CHP opportunities in their regions connect to local experts who can outline current considerations and benefits associated with these systems. Though the federal rules are not yet final, it's clear that the upsides of CHP and DE far surpass just the emissions benefits. Localities that have invested in these systems now enjoy the premium benefits of reliable, flexible, cost-effective and clean on-site energy services.

To view the comments submitted by IDEA to the EPA on the Clean Power Plan, please go to: www.districtenergy.org//assets/Legislative/EPA-911d/IDEA-Comments-on-EPA-Clean-Power-Plan-Final-Review-Draft-Nov-23-2014.pdf

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Additional Resources

- IDEA home page, www.districtenergy.org
- United Nations Environment Program, "District Energy in Cities Initiative," www.unep.org/energy/districtenergyincities
- Pew Charitable Trusts, "Ten Reasons States Should Include CHP in Clean Power Plans," www.districtenergy.org/blog/2015/03/25/10-reasons-states-should-include-chp-in-clean-power-plans/
- CHP District Energy Microgrids, "Selected Cases from IDEA Conference Proceedings," www.districtenergy.org//select-microgrid-presentations-from-idea-conference-proceedings
- American Council for an Energy-Efficient Economy's 111(d) resources, http://aceee.org/topics/section-111d-clean-air-act

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