Distributed Generation: Benefits and Barriers

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Distributed generation configured as combined heat and power (CHP)/district energy systems, if implemented widely, will provide substantial improvements in energy efficiency and dramatic reductions in emissions of pollutants including greenhouse gases (notably carbon dioxide, the major contributor to global climate change). These efficiency and emission benefits will not cause economic belt-tightening and, in fact, can be obtained while capturing economic benefits for energy consumers.

However, the realization of the full potential of the benefits, and doing so in a timely manner, requires that existing institutional barriers are recognized and effectively eliminated[1].

Distributed generation can take a variety of forms, utilizing diverse technologies and being deployed in a very wide range of capacities. There is also a broad range of costs associated with the different technologies. And while some technologies are still undergoing extensive technological development, other technologies are relatively mature, exhibiting an extensive past history of successful implementation. In this article, distributed generation is described solely from the perspective of a developer/owner/operator of dozens of CHP/district energy systems, which in fact represent one of the distinct technologies employed as distributed generation.

The benefits of distributed generation are varied, and include benefits to energy efficiency, to the environment, and to energy consumers.

REDUCED ENERGY AND EMISSIONS

The author's corporate mission statement serves to illustrate some of the key benefits of distributed generation CHP/district energy systems, namely:

"to provide heating, cooling and electricity
with half the fossil fuel
and half the pollution
of conventional generation."

CHP provides the potential for these dramatic improvements in energy efficiency and emission reduction by its ability to *burn fuel once, but use it twice,* once for electric power generation and again for the production of useful thermal energy.

As an example, in 1998 the author's corporation utilized CHP/district energy systems in approximately two dozen locations serving over 1,500 customers with over 5,000 megawatts of combined heating, cooling and electric generation, and did so while producing half the emissions of conventional (non-CHP) generation. Specifically, corporate-wide consumption of fossil fuel was approximately 77% of that which would have been consumed by conventional generation[2]. The corporate-wide emissions of criteria pollutants (including nitrogen oxides, sulfur dioxide, carbon monoxide and particulate matter) were 46% of conventional generation emissions[3]. And corporate-wide emissions of greenhouse gas (carbon dioxide) were 55% of conventional generation emissions[3].

TECHNICAL APPROACH AND EXAMPLES

An integrated approach, incorporating the provision of heating and cooling, as well as electric power, is generally found to be advantageous. Unique technological advances have been developed and commercially deployed where justified. They include such technologies as "trigeneration," hybrid chiller plants, distributed chilling plants, serial chilling combined with low temperature thermal energy storage, distributed back-pressure steam turbine generators, and the use of biomass fuels.

"Trigeneration"

A single piece of equipment, the patented "trigeneration machine" can be utilized for the simultaneous production of electric power, chilled water and steam or hot water. Specifically, in several district energy plants, we employ a gas turbine drive, a refrigerant compressor, and an induction motor/generator, integrated on a single driveline. The refrigerant compressor, which is used to produce chilled water, can be driven either by the gas turbine, or by the induction motor, or by both working in combination. The gas turbine can drive either the screw compressor, or the induction generator, or both. Additionally, whenever the gas turbine is operating, waste heat is recovered in a heat recovery steam generator (HRSG) either for use as steam or hot water heat, or for use in powering absorption or steam turbine-driven chillers.

Hybrid Chiller Plants

Chiller plants are advantageously configured to incorporate both electric motor-driven chillers and one or more forms of non-electric chillers, such as gas engine-driven, gas turbine-driven or steam turbine-driven chillers, or heat-driven absorption chillers (using either gas, steam, or hot water as their heat source).

Distributed Chilling Plants

Two or more interconnected chiller plants are often employed in large district energy networks. Interconnection of the plants can be via chilled water piping; however, interconnection can also be via district heating piping, for example when the distributed chillers are steam turbine-driven chillers or heat-driven absorption units.

Serial Chilling

The multiple chillers employed in large district energy systems are often advantageously configured in a series-parallel arrangement. By staging the chillers in series, it is practical to achieve large temperature differences between the chilled water system's supply and return temperatures. The serial chilling arrangement allows a low chilled water supply temperature to be efficiently produced for delivery to the system customers. The large temperature differential also reduces both the capital and the operating costs associated with the distribution piping network.

Low Temperature Thermal Energy Storage

Thermal Energy Storage (TES) is often utilized effectively to shift the use of electric chillers to low-cost, off-peak periods, and to level the demand for chilled water, thus reducing the installed capacity of the chiller plant. A patented low temperature TES system has also been developed and deployed. It combines the low supply temperature capability of ice storage systems with the simplicity, dependability and economy of chilled water storage systems. This is achieved using an additive that allows the stored supply water to be thermally stratified at temperatures below the conventional minimum of 39°F, down to temperatures of 30°F or lower. The reduced supply temperature also minimizes the required storage volume and the size of distribution piping and pumps[4].

Distributed Back-Pressure Steam Turbine-Generators

Steam District Heating networks generally involve steam transmission in the main distribution piping at pressures well above the pressures employed in the end-user facilities. Accordingly, it is common practice to use pressure-reducing valves to lower steam pressure from the relatively high transmission pressure to the lower end-use pressure. The pressure reducing valves represent significant energy loss.

However, it is practical to capture most of this otherwise wasted energy through the utilization of distributed back-pressure steam turbine generators. Rather than the steam flowing through the valve to reduce its pressure, the steam flows through a steam turbine, thus reducing its pressure but also powering a generator to produce electricity at the end-use site. Typical capacities range from 50 kilowatts to several megawatts of electric power[5].

Biomass Fuels

Various types of biomass fuels are employed in CHP plants, where practical. Examples of such fuels include municipal waste, wood residue, rice hulls and paper sludge. Applications using biomass fuels include numerous industrial CHP systems, as well as some urban district energy/CHP systems, such as those in St. Paul, Minnesota and Charlottetown, Prince Edward Island. Typically, the biomass is utilized as the baseload fuel, with conventional fossil fuel being employed if required for peaking and back-up[6].

CUSTOMERS

The customers of the distributed CHP/district energy systems cover a broad cross-section of large commercial, institutional and industrial, public and private end-users of thermal energy for heating and/or cooling. A short list of specific customers, from among the more than 1,500 served by the author's corporation, serves to demonstrate the wide-ranging applicability of distributed CHP/district energy systems, in terms of customer type, size and geographic locale.

Commercial Office and Retail Facilities
- Blue Lake Corporate Center (business park, 2 million square feet)—Boca Raton, FL
- Cincinnati Gas & Electric Building—Cincinnati
- CNL Center—Orlando
- John Hancock Building—Boston
- MetLife Building—Philadelphia
- Williams Headquarters Complex (5 buildings, 2.5 million square feet)—Tulsa, OK

Hotels and Residential Complexes
- Hilton—Baltimore, Boston and London (Ontario)
- Holiday Inn—Baltimore, Cincinnati, Kansas City, Philadelphia (2 locations) and St. Louis
- Hyatt—Baltimore and Chicago
- Marriott—Boston (2 locations), Kansas City, Long Island and St. Louis
- Sheraton—Boston and Philadelphia
- Wyndham—Baltimore, Boston and Philadelphia

Hospitals and Medical Facilities
- Boston University Medical Campus—Boston
- Massachusetts General (Spaulding) Rehabilitation Hospital (284 beds)—Boston
- Queen Elizabeth Hospital (350 beds)—Charlottetown, P.E.I., Canada
- Thomas Jefferson University Hospital (over 600 beds)—Philadelphia
- Tufts University Medical School—Boston
- University of Maryland Hospital (747 beds)—Baltimore

Universities and Colleges
- Drexel University (12,000 enrollment)—Philadelphia
- Nassau County Com. College (26,000 enrollment)—Long Island

- Suffolk University (2,900 enrollment)—Boston
- University of Maryland (2 campuses: 5,000 and 35,000 enrollment)—Baltimore and College Park
- University of Pennsylvania (25,000 enrollment)—Philadelphia
- University of Prince Edward Island (2,500 enrollment)—Charlottetown, P.E.I., Canada

Government Facilities and Convention Centers

- Bartle Hall Conference Center, Convention Center and Municipal Auditorium—Kansas City
- Civic Center Complex (5 buildings, 1 million square feet)—Tulsa, OK
- Federal Courthouse and Federal Office Facilities—Cincinnati
- McCormick Place Exhibition Center (North America's largest at 5 million square feet)—Chicago
- Nassau County Government Facilities—Long Island
- State of New Jersey Facilities—Trenton

Sports and Entertainment Facilities

- Busch Memorial Stadium (home to Major League Baseball's St. Louis Cardinals)—St. Louis
- Camden Yard (home to Major League Baseball's Baltimore Orioles)—Baltimore
- Nassau County Coliseum (home to the NHL's New York Islanders)—Long Island
- Paul Brown Stadium (future home to the NFL's Cincinnati Bengals)—Cincinnati
- PSI Net Stadium (home to the NFL's Baltimore Ravens)—Baltimore
- Trans World Dome (home to the NFL's St. Louis Rams)—St. Louis

Industrial Facilities

- Baxter Healthcare—Marion, NC
- Boeing Company (rocket booster core manufacturing facility, 1.5 million square feet)—Decatur, AL
- Coors Brewing Company (world's largest single-site brewery)—Golden, CO
- London Free Press (newspaper printing facility)—London, Ontario
- Sara Lee/National Textiles (3 locations)—Eden, NC, Forest City, NC and Greenwood, SC
- United States Mint—Philadelphia

It is interesting to note that many of these types and sizes of customers are not typically considered to be realistic candidates for on-site cogeneration applications, either due to their small size or due to their lack of substantial and continuous demand for both electricity and thermal energy. However, by combining customers into district energy networks, CHP can typically be economically justified and implemented.

Testimonials

Testimonials illustrate some of the common benefits realized by district energy customers and by the communities in which the systems are located.

"As the largest hotel on Long Island, we pretty much guarantee our guests a certain level of service, and we count on a lot of different purveyors to help provide us with this. Nothing will make for a worse stay than a hotel that's uncomfortable, and [our district energy provider] gives us that comfortable feeling. Not once during the past summer or winter, did we lack for service from [them]. That is what I count on. That's what my guests need."

—*Ed Rudzinski,* General Manager,
Long Island Marriott Hotel,
Long Island, New York, 1994

"We're very happy with the quality of service… My overall impression of our district energy provider] is that they are quality people and they really care about what they do… We look forward to continued savings and dependable heating and cooling through our arrangement."

—*Harry L. Walder,* Senior Development Manager,
Chicago Metropolitan Pier and Exposition Authority,
Chicago, Illinois, 1994 and 1997

"We were looking at replacing our centrifugal chillers. This way we were able to avoid the expense of new chillers and ongoing Operation & Maintenance costs. No more refrigerant issues. [Our district energy provider] also provides us with colder water so we can provide our tenants with better temperature and humidity control."

—*William Nooney,* Operations Manager,
U.S. General Services Administration,
Cincinnati, Ohio, 1997

"We were faced with aging inefficient chillers, which utilized CFC refrigerants and whose reliability was increasingly questionable. We were also facing either a major cost for tube replacement, or the purchase of costly new chillers, or opting for district cooling service. DC service solved all our problems and avoided any up-front capital costs. It got us out of the business of dealing with the day-to-day risks associated with chillers, cooling towers, water treatment, etc. DC also allows us to downsize our work force via attrition. And the colder water temperatures enable us to get enhanced capacity and comfort from our HVAC system."

—*Gary F. Carver,* Senior Engineer,
Orlando Utilities Commission,
Orlando, Florida, 1999

"This recent [district energy] development at Blue Lake is a continuation of the commitment we have made to offer our tenants improvements which represent the latest in cutting edge technology…. Our goal is to offer standards of service which are unequaled in this industry."

—*Michael D. Masanoff,*
Director, Blue Lake Corporate Center,
Boca Raton, Florida, 1998

"The joint efforts of The City, The County and the GSA helped make this [district energy/CHP] project happen and reflect their commitment to the continued growth of downtown Kansas City. We believe that this new energy infrastructure makes our downtown more competitive than other options developers may have in the metropolitan area."

—*George Blackwood,* Mayor Pro-tem,
Kansas City, Missouri, 1998

"… the whole community is in this together. We share the cold winters, we share the problems, and we're going to share the solution… to install district heating to help stabilize the economic development of our nation. I think it can make that kind of a difference in our future… district heating is one of the greatest gifts we can bestow on future generations."

—*George Latimer,* Mayor,
St. Paul, Minnesota, 1983

"We, at the Department of Energy and the [White House] Administration, are absolutely convinced that it is possible for us to do responsible things for our environment at the same time we do things that are positive for the economy. Projects such as this particular [Grays Ferry Philadelphia] cogeneration project are proof positive that the two can go hand-in-hand."

—*Elizabeth Moler,* Deputy Secretary,
United States Department of Energy, 1998

"The future across Europe looks bright for combined heat and power. CHP can play a significant role in helping the EU meet its carbon emission reduction targets because it delivers both environmental benefits and energy efficiency gains. The European Commission has proposed a strategy with a view to doubling the share of CHP in the community as a whole by 2010. In the UK, we have already been actively promoting CHP. We now have some 1,300 CHP schemes accounting for 4,000 megawatts of capacity, in a whole range of applications."

—*John Battle,* Energy Minister,
United Kingdom, 1998

"District energy can provide environmental, energy efficiency, and socio-economic benefits to society, communities, and district energy customers … There is still a need for more action to realize the opportunities provided by district energy and to address current obstacles … We challenge these stakeholder groups … to identify what action they should take so that those benefits may be realized."

—*The District Energy Option in Canada,*
Natural Resources Canada Handbook, 1996

BARRIERS

Barriers to the widespread implementation of distributed CHP/ district energy systems have been identified. The U.S. electric power generation industry has an average energy conversion efficiency in the low 30 percents. There has been virtually no improvement in the industry's average efficiency during the last half of the 20th century, in spite of the many technological advances actually achieved. Over two-thirds of U.S. generating capacity was built before 1972 (i.e. over 28 years old) and these plants employ outmoded, inefficient polluting technology.

Among the key barriers to efficiency improvements have been the entrenched system of monopoly utility regulation and the well-intentioned but often self-defeating environmental regulations. Some of the key barriers to improved efficiency via CHP are briefly introduced below.

Laws and Regulations That Protect Some

Monopoly utilities are protected from competition, and insulated from incentives to innovate and to improve efficiency, in numerous ways.

- *Lack of Incentives for Efficiency*: Regulated monopolies lack the incentives to be efficient. Regulators focus on limiting profits, rather than focusing on reducing costs. Notably, little if any attention is paid to fuel efficiency, even though fuel cost typically represents 45 to 55% of total price[1].

- *Retail Electric Sale Prohibitions*: The retail sale of electricity by potential competitors of the local monopoly utilities has been prohibited. Even as the industry moves slowly toward retail access, additional barriers and delays are being imposed.

- *Laws Banning Transmission Competition*: Even when the time comes that both generation and the retail sale of electric power are open, control of transmission lines will continue to impede competition.

- *Interconnection Rules*: The rules and regulations regarding the electric power interconnection between independent power plants or on-site cogenerators and the grid are usually controlled by the local electric utility. In some cases, requirements can be arbitrary and abusive to the potential competitor of the utility.

- *Back-up Power Access*: Sometimes access to back-up power for on-site cogenerators is available only from the local electric utility. Once again, pricing can be arbitrary and abusive to the potential competitor of the utility.

Condoned Anti-competitive Practices of Monopolies

In spite of the spirit and the letter of the Sherman and the Clayton Antitrust Acts, by and large, some utilities have been allowed to function outside the antitrust rules. Such condoned practices have included those noted below.

- *Bundling Heat and Power*: e.g. lower electric rates for customers employing all-electric facilities.

- *Buying-out Cogenerators*: Utilities are sometimes allowed to consummate secret deals involving payments or lower rates that are unavailable to other customers, in exchange for customers not implementing a new cogeneration system.

- *Manipulation of Pilot Programs*: Various pilot programs incorporating special electric rates and/or special demand-side management (DSM) cash incentives can be selectively started and stopped, penalizing potential competitors and even directly subsidizing unregulated companies affiliated with the local monopoly utility.

- *Percent-of-Load Rate Ratchets*: In some cases, punitive rates can be utilized in which a potential cogenerator would pay an exorbitant price for power purchased from the utility in the event that cogeneration was utilized for a substantial portion, but not all, of the customer's electric load.

Environmental Laws That Ignore Efficiency or Assume That Central Generation is Optimum

Environmental regulations, though well-intentioned, are often self-defeating to the extent that they fail to motivate, and often penalize, efficient new technologies.

- *Input-Based Rules Ignore Efficiency*: Typical regulations limit the quantity of pollutant emissions as a function of the power plant exhaust. This ignores the fact that the exhaust is itself a function of the fuel consumed. Thus a doubly inefficient plant, burning double the fuel, is permitted double the emissions of a more efficient plant.

- *Present Regulatory Approach Extends Use of Inefficient Plants*: Ever tightening requirements on new plants create an economic incentive to keep old, inefficient, and heavily polluting plants in service.

- *Permits Required to Start Construction Delay Efficient Plants*: The Clean Air Act of 1972 forbade even starting new power plant construction until after the granting of an air permit. This process is unlike that employed in general building construction and is even unlike that employed when applying power plant engines or gas turbines to other uses such as transportation or industrial drives.

Lack of Pollution Offsets

Although a typical CHP/district energy system will eliminate the use of dozens or even hundreds of individual in-building boilers, the avoided pollutant emissions from those boilers are not credited to the system development.

Regulations That Prohibit Optimizing Plant Operations

New, efficient, clean power plants, if operated at off-design conditions such as part-load, are forced to shutdown due to increased emissions at those conditions, even though the result is that old, inefficient, polluting power plants must make up the lost capacity, often at an order of magnitude higher pollution[1].

Tax Policies Penalize Efficiency

New and efficient power plant equipment is burdened with an inequitably long tax depreciation life. When used in different applications such as transportation, the same equipment is granted a depreciation period only half or even a third as long[1].

Federal Reimbursement and Reward Structures

Federal subsidies (e.g. those typically provided to low income housing) fail to recognize the economic value of efficiency improvements. A reduction in energy costs, achieved by a more efficient energy system to serve the subsidized facilities, simply results in a similar reduction in the subsidy. Accordingly, the facility operators have no incentive to opt for the more efficient energy approach.

Obsolete State and Local Laws

Existing state and local laws are often based on obsolete technology assumptions, often passed originally to protect public safety or union jobs. One of many examples is the Massachusetts requirement for dedicated local operators for steam turbines, effectively precluding the economic deployment of efficient back-pressure steam turbines in district energy customer buildings.

ELIMINATING BARRIERS

Methods to eliminate or overcome those barriers, and to realize the available energy, environmental and economic benefits of CHP/district energy, have been proposed:

1. Deregulate all electric generation and sales and modernize regulatory laws impacting energy.

2. Modernize environmental regulation of power plants.

3. Change taxation to encourage efficiency.

4. Include energy efficiency in all federal activity and funding.

5. Take miscellaneous federal actions to promote energy conservation

Further details of these proposals are presented in Thomas Casten's book, *Turning Off the Heat*[1]. With the implementation of these recommended actions, it is projected that within a 20-year period:

- the efficiency of the nation's electric power generation industry can be doubled,

- the resultant emissions of criteria pollutants and greenhouse gas can be halved, and

- the nation's consumers will save 30% or more in their electricity costs.

CONCLUSIONS AND RECOMMENDATIONS

Clearly, distributed generation configured as CHP district energy systems can fulfill a significant role in reducing energy use, reducing pollutant emissions and reducing the emission of greenhouse gas (carbon dioxide). It is practical to achieve reductions of half or more in all these areas, relative to conventional means of independent generation of electricity and thermal energy.

Just as clearly, CHP/district energy systems have been demonstrated to provide economic and other benefits to customers and communities.

The widespread deployment of the technology and its benefits are severely hindered by numerous barriers.

Notable among the barriers are those associated with the continuing monopoly regulation of electric power and the well-intentioned but often self-defeating environmental regulations.

It is recommended that these barriers be systematically eliminated. This will allow the marketplace to provide choice and savings to consumers as well as efficiency and emission reductions to the energy industry.

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