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Cogeneration and Climate Change

By Robert Farmer, President of Third Planet, Inc.

From a carbon dioxide emissions perspective, the current economic opportunity and business challenge facing the U.S. On-Site Power industry is to develop near-term markets for highly efficient cogeneration.

There is great urgency attached to this challenge. The largest source of carbon dioxide (CO_2) emissions in the U.S.–greater than all transportation emissions combined –is baseload coal power generation.

The numbers tell the story: The EPA's *2009 U.S. Greenhouse Gas Inventory Report* reveals that fully 82% of all CO_2 emissions in the electricity sector come from baseload coal plants. These in turn account for 32% of all CO_2 emissions from all sources and are 5% greater than all the CO_2 emissions from the transportation sector alone. In the global context, emissions from U.S. coal plants are 6.6% of the world's total CO_2 emissions from all sources, and they are growing. Since 1990, CO_2 emissions from U.S. baseload coal plants have increased by 28.5%.

Thanks to the fuel's CO_2 emissions and the struggling economy, coal finds itself in uneasy hiatus while long-term (25+ years) research and development continues in the quest to find geological and technical solutions to carbon capture and storage (CCS). At some point in the near future the economy, population, and housing starts will begin to recover. When they do, new baseload power will eventually be required and pressures will mount to build new coal-based central power plants with their incumbent emissions.

Given the unlikely possibility of delivering near-term renewable baseload at scale, I propose that the electrical generating systems industry must counter new coal developments with natural gas and gasified biomass-powered cogeneration in district heating and cooling applications. The reasons are simple enough.

Cogeneration is highly efficient and cleaner than any other fossil-fuel based technology. It is eminently viable in the near-term (5-25 years) as a low-carbon solution for baseload, especially when integrated with renewable energy resources in district energy systems. And absent long-term (25+ years) carbon capture and storage and advanced nuclear power, it can have an immediate impact on CO_2 emissions reductions. Equally important, cogeneration is the key enabling technology for the transition to sustainable gasified biomass – the ideal renewable fuel of combined heat and power generation.

Federal and state rulemakers are already working to reduce power plant and other carbon emissions, thus leading to the active role cogeneration must play in our energy security and climate change future. Now the On-Site Power Generating Industry needs to lend its vision, leadership and voice in an effort to champion cogeneration, to promote big picture visionary district energy applications, and to partner in the development of the domestic and international markets for these applications.

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Meanwhile, global climate change waits for no-one.

The Enhanced Greenhouse Effect

Beyond the science and international negotiations, the anecdotal evidence of global climate change appears irrefutable. Looking at snow and ice data alone, 30 years ago Mounts Fuji and Kilimanjaro were covered in snow year round, glaciers were intact and slow-moving, and polar ice was permanent. Not anymore.

What has caused the climate to change? In 1860 the Irish physicist John Tyndall demonstrated and measured the absorption of infra-red radiation by CO_2 and water vapor. In 1896 the Swedish chemist and Nobel laureate Svante Arrhenius took the work a step further. He pointed out that CO_2 in the atmosphere served as a "heat trap" because it allowed high-frequency sunlight to penetrate freely to the Earth's surface but was opaque to the low-frequency infra-red radiation that the Earth re-radiated at night. His CO_2 model also included what later became known as a "feedback loop": the effect of increasing temperature on water vapor, which, in turn, would increase atmospheric absorption. Arrhenius suggested that even a slight rise in CO_2 levels would raise the Earth's temperature markedly.

Measurements of atmospheric CO_2 began in 1956 at the Mauna Loa Observatory in Hawaii, situated 11,000 feet high and far away from any man-made sources of pollution. In 1956 the mean CO_2 concentration was found to be 315 parts per million (PPM), 12% above the pre-industrial (1750s) level of 280 PPM recently determined from ice-core records. In 2008 the concentration was 387 PPM, a 23% increase in the last 50 years alone. CO_2 emissions are now accumulating approximately 2 PPM annually.

You may think that "parts per million" doesn't sound onerous until you discover that Chlorofluorocarbon compounds (CFCs), the principal cause of ozone depletion, are measured in parts per trillion!

This continual build up of greenhouse gases in the atmosphere is known as the "enhanced greenhouse effect." Accepting that natural variability and solar cycles may have some cyclical effect on the melting of the planet's ice and mountain snow caps it is nonetheless accepted that the enhanced greenhouse effect, in addition to any natural variability, is the real culprit in the global climate change problem.

While current scientific work and international negotiations leading up to the Copenhagen climate talks in December are based on measures to limit CO_2 equivalent stabilization to 450 PPM, the global mean temperature is still expected to increase a dangerous 2°C. Barring serious change we will reach 450 PPM long before long-term carbon capture and storage (CCS) research and development yields solutions at scale, or advanced nuclear reactors can be built.

Yet we ***must*** slow and eventually reverse the accumulation of greenhouse gas in the atmosphere. Baseload carbon emissions must be reduced immediately. There is no time to wait for long-term nuclear and carbon capture and storage for coal.

Cogeneration is a core technology for this effort, and it is a major growth opportunity for the electrical generating systems industry.

Cogeneration is the highly efficient simultaneous production of electricity, heating and cooling services from the same power source.

Known today as combined heat and power (CHP), it is a decades-old approach to power engineering used most recently in industrial and campus applications, where both electricity and large amounts of supplementary heat are required for their operations. The generation of electricity, combined with the simultaneous recovery of heat from engine cooling systems and exhausts to produce hot air and/or hot water, offers very high fuel efficiency and reduces overall production and operating costs. In turn, fuel savings from cogeneration present key competitive advantages to manufacturers and effective budget management for educational institutions.

In the last decade CHP has been increasingly viewed as a core technology for fighting global climate change and for meeting Federal Clean Air Act requirements.

Engines emit CO_2 in direct proportion to the type and quantity of fuel they use, and because less fuel is combusted in a cogeneration system, greenhouse gas emissions, such as CO_2 and criteria air pollutants like NO_x and SO_2 can be reduced by the maximum possible. Energy efficiency is therefore a key not only in competitive and energy security considerations, but also in any strategy to reduce baseload greenhouse gas emissions.

Cogeneration power plants are attractive because they are often applied at thermal efficiencies as high as 85% with few line losses due to their close proximity to the loads they serve. The fleet national average for central coal plants is 26% on a BTU-to-BTU basis after transmission losses and 50% for combined cycle natural gas turbines. But when comparing the carbon content of coal to natural gas, the primary fuel of cogeneration, the advantage swings more markedly in favor of cogeneration. EPA CO_2 emission factors are 207 lbs/million BTU for coal and 117 lbs/million BTU for natural gas. Natural gas is 43% cleaner than coal.

Many more natural gas and gasified biomass-fired cogeneration applications are needed for baseload carbon emissions reductions. The opportunities are many.

An American Opportunity

When a CHP system is further integrated with absorption chillers, a commercial technology from the 1970s, it produces chilled water from engine heat sources in addition to providing heat services. Air conditioning and chilling is required throughout much of the United States and offers an unprecedented opportunity to greatly expand CHP applications. These systems are known as trigeneration applications or simply as combined cooling, heat, and power (CCHP).

District heating and cooling (DHC) is the conduit for new cogeneration applications. Denmark elevated cogeneration applications to a whole new level as part of its response to the 1973-74 oil crisis. At the time, Denmark already had over 60 years of experience with district heating, where by-product steam and hot water are distributed to homes, businesses, and other buildings through local heating networks.

Starting with the Danish Energy Policy 1976, Denmark passed a series of far-reaching national energy policies that provided local governments with incentives to develop local district heating systems as core components of Denmark's national energy strategy. That work continues to grow and evolve. Today, cogeneration systems are not only connected to stand-alone heat loads but also to local heating transmission and distribution networks to provide heat services "on demand." These have become the centerpiece of Denmark's journey toward energy independence. By 2004, 60% of the total heated floor space in Denmark was serviced by district heating networks.

There is a lot of interest in the United States for these kinds of applications and systems are now operating but the momentum needed to make CHP-driven DHC a core power consideration across the country does not exist. The question is, "How do we make district heating and cooling work in the U.S.?"

A national energy policy might help, but there are too many state and local institutional barriers at the moment to put teeth into any federal policy. It also serves no useful purpose to review the litany of barriers other than to say that electric utilities own and operate baseload coal plants. Electric utilities are the primary target market for CHP systems.

A more practical approach is to "act locally, think globally." If real barriers to cogeneration exist at the local and state levels, begin there. However, I suggest the entire process begins by considering the bigger regional and local picture.

What are the elements of big picture planning? New baseload power plants are planned to either meet the demands of new growth or to replace older units. In new growth scenarios the plants are planned by electric utilities many years ahead of the growth itself in response to local development plans. State and local planners are the focal point for developing new district heating and cooling cogeneration applications. How we connect with them is the key.

Visionary applications are required. Denmark is a district heating and cooling and CHP pioneer. Strong leadership is now coming from the UK and Germany. Their examples show the emphasis placed on spatial planning—where the spatial relationship of the entire built environment to energy infrastructure needs is considered in each community and throughout regions.

In this energy planning approach, several interconnected cogeneration applications requiring sophisticated controls provide energy services to a common DHC network to serve a wide diversity of electricity, heating and cooling loads. Supply reliability and security can be readily appreciated in this kind of design. Heating and cooling services are dispatched based on demand, similar to the U.S. electricity grid. It is interesting to note that Denmark's transmission networks can distribute hot water at distances of up to 10 miles.

A very high premium is placed on future-proofing – the process of anticipating future development on existing DHC networks. It provides the network with the flexibility to be adapted and expanded Lego-style (Lego is a Danish company) when needed. In this way new resources such as heat transmission expansion and future biomass-powered cogeneration systems can be added as required. How might we imagine a community or region built entirely on CHP and district heating and cooling systems for energy services?

Pieces Of A Big Picture Vision

City-to-rural in scope, spatial planning integrates urban and rural energy infrastructure into one whole. Carefully planned integrated resources serve many different dedicated electric and thermal loads in addition to being able to provide backup service for the DHC network. Coordinated resources and maximum flexibility are fundamental for the control systems necessary to provide reliable, on-demand thermal and electrical services.

Rural biomass resources are processed into biogas fuels for CHP systems serving an entire region of urban and rural electric, heat, and cooling loads. Landfill, digester, and natural gas CHP power plants and such sources as deep-water cooling systems serve similar loads. But all energy sources are interconnected into a local DHC grid network.

Businesses requiring steam heat, cooling or refrigeration services are located in industrial parks built close to combined-cycle gas turbines repowered to serve these district heating and cooling applications.

> The big picture is all about how one area or neighborhood interconnects with its built environment and others.

Local government, especially those with municipal utilities, plan their urban facilities to take advantage of CHP systems to provide electricity, heating and cooling to downtown office buildings and shopping centers. Rural cultural facilities are planned to provide thermal services to rural businesses and residences.

Examples of large local government needs that can be serviced by CHP installations while integrated with other community thermal loads include airports, hospitals, desalination plants, libraries, convention centers, recreational facilities, and office buildings spatially connected to residential, commercial, and industrial loads.

Developments also utilize micro-turbine and fuel cell-based CHP integrated with solar PV and wind resources as pieces of comprehensive, integrated, city/region-wide solutions. The big picture is all about how one area or neighborhood interconnects with its built environment and others. The possibilities are endless.

Education as Business Development

The tools exist to execute this level of energy planning. State and local government must be willing to seek the best solutions and have the will to implement them. And it all begins with education.

We should also look to Europe for best practices. There is no cookie-cutter approach; what works for them may not work for us but they can guide us and assist us if required. The value lies in the practical experience.

Non-professionals can have difficulty grasping the concept of cogeneration. Many essential collaborators don't know how CHP works and how the applications may work for them. The possibilities may be endless in the minds of practitioners but they are only possible in practice with an informed and willing audience.

Decision-makers must be educated. Without them, planning and projects cannot be developed. Here the educational process becomes the act of new business development. The large audience is made up of state and local policymakers; electric and gas utilities; state Public Service Commissions (PSCs); energy and climate commissions; state and local government including economic development and planning agencies, large consumers of heating and cooling energy services, builders, developers and others.

Many partners are needed to develop the projects. These include members of the American Planning Association (APA) and the American Institute of Architects (AIA), engineers, state and regional departments of environmental protection, the banking and insurance communities and citizen groups. The group process is best facilitated by creating partnership forums to create community conversation. The key is to get the community and partnership conversations going.

Many points of entry exist to initiate the education and market development process. For example, Florida statutory law grants utilities franchises to sell electricity. There is no similar provision for heating and cooling services. This could open the possibility for local government and large commercial entities to partner with utilities to deliver heating and cooling services. In another example, electricity production competes with residential heating and commercial uses for natural gas supplies. We can show local government and developers that some of these competing demands for natural gas can be obviated by cogenerating electricity and heating with less fuel consumption and fewer carbon emissions. These local issue examples and 'opening' recommendations can be brought before

Public Service Commissions, utilities, and local government to begin the conversation on combined heat and power.

The education and business development process can be aided by existing financial incentives. The economic stimulus package and existing policies provide incentives for district heating and cooling and cogeneration. A regulatory regime to control greenhouse gas emissions is also emerging to draw further attention and incentives toward the development of these strategically important assets.

U.S. Economic Stimulus

H.R.1, the American Recovery and Reinvestment Act of 2009 (ARRA) contains $3.2 billion for Energy Efficiency and Conservation Block Grants to state and local governments. The Department of Energy`s National Energy Technology Laboratory has specifically stated that eligible activities include district heating and cooling systems, combined heat and power systems, cogeneration systems, and absorption chillers, among others.

$3.1 billion is also available as additional funds for the State Energy Program. Twelve states currently have Energy Portfolio Standards that include CHP systems. Interestingly, ARRA contains language that would seem to assist these states in particular as funds will be made available "only if the governor of the recipient State notifies the Secretary of Energy in writing that the governor has obtained necessary assurances" that: 1) the state's Public Utility Commission will seek to initiate rulemaking proceedings related to energy efficiency incentives and utility ratemaking issues; 2) certain building codes will be met; and 3) the state will "prioritize the grants toward funding energy efficiency and renewable energy."

Federal energy policy has been in place since before ARRA to encourage district heating and cooling systems development. In one example, IRS Code allows tax-exempt bonds for DHC networks – but not for power plants themselves. This will change but gives a clear upfront indication of the importance that the federal government places on the development of DHC systems.

The Emerging Greenhouse Regime

Attempts are underway to regulate carbon emissions from coal plants in response to the threat of global climate change.

Europe's Emissions Trading Scheme (EU-ETS) and the Northeastern U.S. Regional Greenhouse Gas Initiative (RGGI) foreshadow the Obama Administration's goal of establishing a national carbon cap-and-trade system. Despite the best of intentions, the road ahead is very difficult; I find it unlikely that such a program could soon be presented in the U.S. Senate.

However, the U.S. Supreme Court has ruled that CO_2 is a pollutant to be regulated under the Clean Air Act. This has presented the U.S. Environmental Protection Agency (EPA) with a mandate to take a regulatory approach to reducing CO_2 emissions. In anticipation of EPA rules and oversight, several states have already initiated rulemaking to reduce carbon dioxide emissions from coal-fired power plants.

Indications are that CO_2 emissions rulemaking will be founded on output-based regulations. In this approach, power plant output is regulated based on the pounds (lbs) of carbon emitted per mega-watt hour (mWh) of production. In this context only the electric output of CHP systems is currently considered. The EPA and states agencies are moving quickly to set output-based regulations that include thermal output to take full advantage of the environmental benefits of cogeneration.

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Federal and state efforts to create Renewable Portfolio Standards (RPS) have an even greater, positive effect on CHP development. CHP systems fueled with a qualifying renewable resource, such as biomass, are eligible under RPS. Typically only the electric output of a CHP system is eligible, but states can also include the thermal output of these systems in their RPS to fully value the benefits of CHP.

As noted earlier, 12 states currently have EPS (Energy Portfolio Standard) programs (defined as RPS and/or Energy Efficiency Portfolio Standard-EEPS) in place while more EPS programs are unfolding across the U.S. Of these 12 states, seven include clean fossil-fueled CHP, five include waste heat CHP, and one includes renewably fueled CHP.

Cogeneration's future looks very bright. In a further testimonial, the Energy Information Administration (EIA) notes that in a 20% RPS scenario, biomass gasification for CHP is seen as growing substantially over solid biomass used in coal co-firing applications.

Utilities

Whether through cap-and-trade, RPS or regulatory schemes, these all will have a profound effect on the way utilities generate their revenues. In order to produce energy services with the minimum carbon footprint, they will have to sell both electric and thermal energy services, produced from the same amount of fuel, to maximize their profits. This scenario is currently unfolding. California's Air Resources Board (CARB) is modeling small-scale CHP into their CO_2 control plans with the agreement and cooperation of electric utilities.

These effects on utility planning and operations will induce local governments to integrate the CO_2 reduction measures into their own greenhouse gas reduction plans.

Local Government

In many states, initiatives are underway to hold cities and counties accountable for their carbon emissions. Organizations such as the U.S. Conference of Mayors with the assistance of ICLEI (Local Governments for Sustainability) are creating greenhouse gas management plans beginning first with an inventory and then developing action plans. In parallel, local and state rulemakers are placing greater emphasis on the role that local and regional jurisdictions must play.

In the U.S., state governments use local comprehensive development plans to direct urban planning. In Florida for example, development may not proceed without state approval of local comprehensive development plans. Florida law requires the plans to address, among other things, electric power plants and transmission as well as greenhouse gas reduction strategies.

This convergence of legislation, regulation, voluntary initiatives, and the impact of new low-carbon power plants on regional and local development is reshaping how communities plan infrastructure. It will also promote local economic development and higher education research on energy infrastructure, make their cities more attractive to newcomers, and increase the community's tax base.

Public Service Commissions

Strategic electricity and natural gas planning is the purview of state regulators and the utilities. Local government now joins that exclusive group and brings with it the demand for new thermal energy services. State public service commissions must be empowered to regulate these thermal energy services to the benefit of the consumer. In addition to hot water and cooling services, their mandate will include energy efficiency portfolio standards; biomass requirements for renewable portfolio standards; ratepayer investments in local economic development; and local gasified biomass production among others.

Action Plan

Significant profit-making opportunities exist for the On-Site Power industry in developing near-term markets for district heating and cooling and cogeneration applications. But the industry must rise to the challenge with urgency. Applications are needed today to replace coal power plants—the leading source of carbon dioxide emissions produced by the U.S. electric power sector.

The work begins by educating policymakers, local government, electric utilities and Public Service Commissions. However care must be taken in crafting the message, because cogeneration concepts may be difficult for lay audiences to understand.

While this article covers many aspects of the process, there are a few points upon which to focus:

- Educating your market *is* business development.
- Start in communities where coal plants are either being postponed or proposed.
- Your initial target audience for education should be the Public Service Commissions, electric utilities and local governments and planners.
- Think big picture instead of individual applications.
- Do everything in your power to help enact a national natural gas energy strategy that ensures the fuel's viability for the near-to-long term.
- Make your own community sustainable.

About the Author

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