FUELING DISTRICT ENERGY AND CHP WITH LOCAL BIOMASS: U.S. POLICY CONSIDERATIONS

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ABSTRACT

District energy is the production and distribution of energy from a central plant to serve multiple buildings. When the same central plant equipment is used to produce both thermal and electrical energy, the process is referred to as combined heat and power (CHP). Using biomass to fuel central district energy or CHP plants is a unique and powerful application of renewable energy for heating community downtown areas and supplying "green" electricity at the same time. The primary policy benefit of biomass district energy is the replacement of large quantities of fossil fuels for heating aggregations of buildings in communities and small cities. This public benefit can be further divided into two broad categories: environmental (air quality, climate change, clean solid waste disposal and sustainable forest management) and economic development (community retention of energy dollars, job creation and enhanced state and local tax revenues). This paper examines the technology and applications of biomass district energy, discusses the benefits and barriers, and suggests public policy initiatives to overcome those barriers and promote the creation of biomass-fueled community energy systems.

Keywords: biomass, district energy, CHP, climate change, economic development

I. INTRODUCTION TO THE TECHNOLOGY

In the context of this paper, *biomass* refers to any organic material that can be used as a combustion fuel and can be burned for energy. Included are wood chips, sawmill residues, sawdust, bark, chipped plantation wood, herbaceous energy crops, clean municipal solid waste, urban tree thinnings, crop residues, food processing wastes, landfill gas, agricultural waste digester gas, and more.

District Energy

District energy is a mature technology that involves the distribution of heating (and sometimes cooling) energy to a number of buildings in relatively close proximity, sourced from one or more central plants. The technology can be used to supply heat to buildings in urban or town settings, to campuses of buildings (such as colleges or medical facilities), to industrial parks, or to other small or large clusters of existing or new buildings.

The most common type of district energy system in the North America uses buried steam mains to distribute thermal energy from the central plant to the connected buildings. These systems have been in use in cities and college campuses for over 100 years. District heating technology in Europe, however, has taken a different form over the last thirty years, with the development of more efficient systems using pre-insulated pipes and hot water distribution. Some European countries use district heating to supply as much as 50 percent of all space heating nationwide, compared to 2-3 percent in the U.S. and Canada (Maker, 1999).

Biomass Combustion Systems for District Energy

The concept of using low-grade waste biomass (low-grade forestry and mill residues, plantation wood, crop residues, etc.) as fuel is a very attractive enhancement to the district energy concept, from a policy perspective. While it is very difficult, if not impossible, to implement renewable fuel heating for individual urban buildings, district energy makes it possible to bring the sustainability benefits of biomass use to many buildings in urban or campus settings.

Industrial-scale biomass combustion, like district energy, is a mature technology, in use for more than a century. A central biomass plant includes large-volume fuel storage, automated fuel handling equipment, biomass combustion equipment and emissions control devices. Like district energy, biomass combustion technology spans a range from conventional to advanced. Conventional systems burn biomass directly to create steam, which can be used for heat or in steam-driven turbine/generator sets. Advanced systems gasify biomass to produce a gas that can be used in very much the same kinds of equipment used for natural gas, at considerably higher efficiencies than those of direct biomass combustion. Gasifiers are inherently cleaner-burning than direct combustion burners. Biomass gasifier technology, while promising in the near term, is not fully commercialized at this time.

A further advantage of central biomass heating plants is that it is easier and more cost-effective to install state-of-the-art emissions controls, compared to smaller biomass plants sized to provide thermal energy for a single building. While emissions control equipment for smaller biomass plants may be prohibitively expensive, for large central plants it is possible to install emissions control technology to meet virtually any regulatory standard.

Biomass CHP

Cogeneration is a highly regarded technological development because it permits the use of one set of equipment to produce thermal and electrical energy concurrently from the combustion of a single fuel. Cogeneration is also called *combined heat and power* or

CHP. CHP allows the capture of waste energy with the result that net efficiencies as high as 80% can be realized when fueled with natural gas.

Adding electric production to the central plant of a biomass district energy system is an attractive enhancement because it brings together a high-efficiency energy conversion technology and a renewable combustion fuel. Because electricity is a much more valuable form of energy than thermal energy, CHP operation can significantly enhance project economics for a biomass district energy system.

<u>Biomass CHP Applications</u>

The potential for CHP to optimize a biomass project's economic viability depends in large part on achieving an optimal balance of thermal and electrical outputs. Optimization also increases the net efficiency of the energy conversion process and gets the most work done while using the least biomass fuel.

Biomass District Energy. There are a number of ways in which a biomass-fired district energy system with both thermal and electrical outputs can be established. One way is to use the waste energy in the turbine exhaust steam from an existing wood-fired power plant to provide thermal energy to meet the heating needs of nearby buildings. This may be a very small niche. The municipal utility in Burlington, Vermont has studied the potential for converting its 50 MW wood-fired power plant (located within the city limits) to CHP operation, connected to a proposed district heating system that would serve the city's largest institutional and commercial buildings.

Another way to implement biomass CHP in a district heating application is to retrofit an existing fossil-fired district heating system plant with a biomass boiler (or gasifier) and electric generator. This approach could be used in many existing campus heating plants or in the smaller number of cases where there is an existing community district heating system. There is good potential for system optimization because the energy conversion equipment can be sized to match the existing, aggregated thermal load. District Energy St. Paul, a fifteen year-old system with hot water distribution and coal and gas-fired boilers, is an excellent example. DE St. Paul is building a new biomass CHP plant to handle most of its thermal load and produce electricity.

Arguably the best way to create an optimized biomass CHP system in a district energy setting is in the creation of new systems. The simultaneous creation of a new thermal distribution system (hot water) and a new central plant allows for optimal design and some cost savings compared to retrofitting existing plants and distribution networks.

Other Biomass CHP. Biomass CHP can be used in applications other than district energy. In industrial settings where biomass is used to fire high-pressure steam boilers to meet process loads (e.g. in the forest products industry), backpressure turbines can sometimes be added to produce a modest amount of electricity. Overall efficiency is not improved, but displacing the purchase of some electricity from the utility may make the conversion cost-effective.

II. BENEFITS OF BIOMASS DISTRICT ENERGY

From the standpoint of public policy, the main reason to encourage the use of biomass energy is to replace fossil fuel combustion. There are five important reasons, related to public benefits, why policy should promote locally-supplied biomass in substitution for fossil fuels, particularly in optimized district energy systems.

1. Use of Renewable, Sustainable Fuels

The promotion of biomass as an energy source is premised on the use of sustainably-produced biomass. The supply of fossil fuels is extractive, since they are removed from the terrestrial store, combusted and cannot be used again. Biomass, however, comes from regenerative processes that can be sustained indefinitely, if properly managed.

2. Large Reductions in Emissions of Climate Change Gases

The combustion of fossil fuels, whether coal, oil or gas, results in large additions to the CO_2 content of the atmosphere because carbon that was sequestered underground is extracted, combined with oxygen and deposited in the atmosphere as CO_2. The combustion of sustainably-produced biomass, on the other hand, adds no net CO_2 to the atmosphere because it represents a recycling of carbon that is already in the global carbon cycle (McLain, 1998).

The climate change impact of heating buildings with fossil fuels is usually seen as a problem that can be dealt with only through building energy efficiency measures. Aggressive energy efficiency efforts may be able to reduce building heating fuel use and CO_2 emissions by about 20 percent. Connecting the buildings to a biomass-fired district energy system, on the other hand, can reduce CO_2 emissions from heating by 90-100 percent (depending on the level of fossil fuel use for backup).

Not only does biomass district energy reduce heating CO_2 emissions sharply on a per-building basis, it also allows the aggregation of these savings across many buildings to deliver very large reductions in climate change gas emissions for a whole community. DE St. Paul's new biomass plant (due for completion in 2002) will reduce annual CO_2 emissions by 280,000 tons, meeting the city's entire CO_2 reduction goal.

3. Low Overall Air Emissions

Considered from the standpoint of all components of stack emissions, a central biomass-fired district energy plant can have lower overall stack emissions compared to heating individual buildings with fossil fuels (natural gas and fuel oil). A central plant is likely to run more efficiently than the many individual building plants it replaces, so that net fuel input is reduced. Another advantage of a large central plant is that economies of scale allow the central plant to afford the cleanest-burning biomass combustion and emissions cleaning technologies. The 50 MW biomass-fired McNeil Generating Station in Burlington, Vermont, for example, regularly keeps its stack emissions to a fraction of the allowable limits of its state permit.

Another advantage is that professionally managed district energy plants can provide much higher levels of attention to proper combustion and daily oversight, compared to smaller oil and gas-fired heating plants found in individual buildings. The result is better-tuned combustion equipment and improved emissions at large central plants.

In terms of specific emissions components, the combustion of woody biomass in industrial/utility-sized plants has the potential to have lower emissions than natural gas in NOx, N_2O and net CO_2 (EPA, AP-42). Wood and natural gas both have very low SOx emissions. Wood emissions are generally lower than fuel oil in SOx, NOx, N_2O and net CO_2. The criteria pollutants of major concern for wood are particulates and CO. Particulates are generally controlled to within regulatory limits using such devices as multi-cyclones, baghouses and electrostatic precipitators. The best particulate-removal systems for wood combustion have emissions rates comparable to or even lower than natural gas and oil. CO control is generally achieved through proper plant operation.

In areas where sulfur pollutants from burning oil must be controlled (most of the eastern U.S.), the cost of complying with air quality regulations for sulfur emissions can be significant. Wood, in substitution for oil, offers an important environmental and cost advantage through the virtual elimination of SOx emissions and the elimination of the capital cost of sulfur controls. However, the cost of sulfur control is traded off against higher costs for particulate control necessitated by the use of wood.

4. Solving Environmental Problems and Nurturing the Forest Resource

In many areas there are significant volumes of biomass waste materials that are causing environmental problems: forest products industry wastes, new construction wood waste, urban and suburban tree thinnings, wood from land clearing disposed of by open burning, food-processing and agricultural wastes and the burnable fraction of municipal solid wastes. The associated problems include the cost of disposal, limited landfill capacity and the production of methane (a potent greenhouse gas) from anaerobic decomposition of biological wastes in landfills. Clean biomass wastes (i.e. those not contaminated with chemicals or treatments) can be used as fuel in district energy systems, turning a waste problem into a renewable energy solution.

One tool of sustainable forest management is the removal of diseased and mal-formed trees and limbs, to make space for healthier trees and increase the overall vigor of the forest, including its ability to sequester carbon. The low-grade wood, chipped and removed as part of a harvest operation, can be used as a fuel in district energy, CHP and power production. This "weeding of the forest garden" is considered to be beneficial to forest health when part of a responsible, sustainably-managed harvest.

Another sustainable source of forest wood for energy is from sawmill residues. Every mill produces a large volume of wood (as well as sawdust and bark) that is not of commercial quality and must be chipped and disposed of. Some mills burn these wastes for their own space-heating or kiln-drying operations, but most must sell them to fuel users or to the pulp and paper industry. The use of these low-grade mill wastes for energy is consistent with sound environmental and ecological principals, as long as the forest resource from which they come is managed sustainably.

5. Increased Community Wealth

The use of biomass fuels generated within the region surrounding a district energy system is an effective stimulus to local economic development. Most energy dollars spent on fossil fuels leave the local economy, while most dollars spent on local biomass fuel stay within the local and regional economies. A study by the Northeast Regional Biomass Program (Resource Systems Group, 1994) found that in the eleven northeastern states, every 1000 tons of wood used in industrial and commercial applications each year created a net increase in community wealth of about $57,000. A biomass district energy project studied for Burlington, Vermont in was projected to use 55,000 tons of biomass, with a net annual community income benefit of over $3.75 million in current year dollars.

Beyond the retention of wealth in the community, there are other economic development benefits associated with large-scale wood energy. The same 1994 study showed that in the northeast, approximately one job was created for every 1000 tons of wood used. The Burlington biomass district energy project referenced above would create about 55 jobs in the regional economy. State and local tax revenues for the Burlington project would increase by $200,000 annually.

III. BARRIERS TO BIOMASS DISTRICT ENERGY

There are a number of barriers that make it difficult to establish biomass-fueled district energy systems. Some of the most significant are discussed below.

Unfamiliar Technology

District energy is hardly a household term. By those policy makers who have some knowledge of the subject, district energy is usually considered to be equivalent to old-style urban district heating systems or campus steam distribution systems. The more enlightened know about the recent trend toward urban district cooling systems. Few are likely to equate district energy with a state-of-the-art technology for optimal production of heating and electrical energy and for the creation of thermal energy networks that can accept inputs of low-level waste energy as well as energy from combustion plants while at the same time distributing that energy to points of use throughout a community.

Neither is *biomass* a household word. The term is unfamiliar or poorly understood except by those in the field. For this reason, the idea of linking "biomass" and "district energy" is not in the conceptual framework of the kinds of people who make decisions about community infrastructure. Many policy makers are engaged in the task of making buildings more efficient but few are thinking about innovative ways to supply heat to buildings, particularly heat from renewable sources.

The result is that energy policy makers and program planners, on both the state and federal level, do not consider district energy as a field needing attention. Nor do they consider the possibility of heating existing urban buildings with renewable energy. From the R&D and implementation perspectives, biomass is typically seen only as a fuel for utility power generation. Urban planners and municipal decision makers rarely hear about district energy as a viable element of city infrastructure, and they certainly get no messages about using biomass or other renewables to heat large buildings.

<u>High Capital Cost</u>

Biomass energy systems carry higher capital costs than do gas and oil systems. Biomass fuel takes up more storage space than fluid fuels, is harder and more expensive to move from storage to point of combustion, and often requires more expensive combustion and emissions control systems. In addition, operating and maintenance costs are usually higher than for fluid fuel systems.

District energy systems, like municipal sewer and water systems, are expensive municipal infrastructure. Projects are large, costly and difficult to organize. Unlike other forms of municipal infrastructure, however, there are no federal or state subsidies for district energy.

<u>Low Fossil Fuel Prices</u>

Until very recently, oil and gas prices have been off the radar screen as something for most people to worry about. With low prices for conventional fuels, there is little general sense of urgency or need to address building heating costs.

Low prices for fossil fuels also make it difficult for biomass and other renewable energy sources to compete directly. In conventional economic analysis, when renewables are studied as an alternative to fossil fuels, there are few instances where renewables are shown to be clear winners. This analysis rarely factors in community benefits that are difficult to quantify: greenhouse gas reductions, use of renewable resources, better air quality, economic development, retention of community wealth, etc.

When studies are done to compare biomass energy to fossil energy for particular applications, biomass fuel is usually less expensive on a dollars-per-million-Btu basis. However, this is often insufficient to tip the balance in favor of biomass when capital and O&M costs are factored in.

Uncertainty About Environmental Impact

There is a general perception, based on history, that wood burning is environmentally "dirty." This perception is grounded in fact. Industrial boilers have been burning wood poorly for over one hundred years (although modern air quality regulation has greatly improved their emissions). For most people, the experience of burning wood is the experience of residential wood stoves. Until EPA certification of new wood stoves became mandatory, odor and visible smoke from residential wood burning was a well-known fact of life in rural areas.

There is a carry-over of these perceptions, among air quality regulators, environmentalists and the general public, even though today's wood-burning technology is significantly cleaner-burning than older technology. One result is that regulators are hesitant about biomass combustion systems in sizes or settings that are unfamiliar, i.e. district energy, institutional-sized heating plants and CHP plants of less than utility scale. The lack of emissions test data in this size and type of application is a barrier. Potential system owners do not want to go ahead with projects without assurance that the systems will be permitted and regulators do not want to offer any assurances until they have adequate test data.

Environmentalists have a tendency to see only "smoke and trees" when they think about proposed biomass energy projects. Biomass brings up the specter of dirty wood burning as well as a fear that any wood energy project means irresponsible logging and long-term damage to the forest resource. There are few mechanisms in place to educate the public about modern, state-of-the-art biomass energy systems, nor about the benefits of using low-grade waste wood from responsible forest management to supplant fossil fuels and reduce emissions of climate change gases.

Inadequate Policy Support

Public policy and energy program planning for biomass focus on such technologies as utility-scale wood gasification and the industrial-scale conversion of biomass to ethanol or bio-chemicals. Little attention is given to the use of biomass for space heating, district energy or mid-sized biomass CHP.

While biomass energy R&D funding has historically lagged far behind fossil and nuclear programs, funding to support community-scale biomass energy has been non-existent. Consequently, the competing fuels continue to enjoy subsidies while mid-sized biomass applications do not. In addition, there are no funds generally available to do comprehensive emissions testing of new biomass energy technologies, particularly in smaller sizes.

IV. POLICIES TO SUPPORT BIOMASS DISTRICT ENERGY AND CHP

Educate Decision Makers About Biomass District Energy and CHP

Provide education about modern district energy systems and the potential for biomass use to planners and other municipal decision makers, through workshops, written materials and contact through professional organizations. Target decision makers at universities and colleges with campus district heating systems with information about the benefits of converting to biomass firing. Work to integrate district energy and biomass use technologies into undergraduate engineering curricula. Educate state energy offices in biomass CHP technology and its applications.

Create a Biomass Energy Services Company (BESCO)

Assist and support the creation of a regional or national non-profit center that would be organized to initiate and do feasibility studies of new biomass CHP projects, including district energy, and to assist with financing and project management to bring projects to fruition.

Provide Financial Incentives

Work with federal and state governments to put in place financial incentives that will support the establishment of biomass district energy systems and other biomass CHP uses. Incentives may include: accelerated depreciation for biomass district energy and CHP systems to make financing of systems more attractive to financiers; investment tax credits tailored to biomass CHP systems that meet certain minimum net efficiencies; and municipal financing mechanisms (such as bonds and municipal leasing) that are specifically tailored for the creation of community district energy systems.

Stimulate Demonstration Projects

Work with federal officials and the U.S. Congress to establish a cost-share grant program to stimulate the creation of a small number of new biomass-fired district energy systems in certain types of settings, including small communities (less than 20,000 population) and mid-size cities, as well as retrofits of existing college campus district heating systems to replace old steam distribution with new hot water distribution and to add biomass CHP equipment. The projects would be organized to use state-of-the-art technologies, to document and disseminate costs, savings and project histories, to address environmental factors aggressively, and to provide a thorough documentation of community and regional benefits from converting from fossil fuel use to biomass.

Focus on Biomass District Energy as Community Infrastructure

Create an initiative to elevate district energy, and biomass CHP in particular, to become a commonly understood option for municipal infrastructure. Disseminate information to community planners, city councils and other municipal decision makers on: the application of district energy technology and the use of biomass as a large-scale heating fuel; the identification and responsible use of biomass resources; financing district energy projects; project development success stories and case studies; and community benefits deriving from the replacement of fossil fuel use with local biomass.

Provide Regional/National Leadership on Air Quality Issues

Develop an initiative to provide definitive leadership on the issues of emissions from small and mid-sized biomass boilers, gasifiers and CHP systems, including appropriate and cost-effective emission control technologies. Develop region-wide expedited air quality permitting procedures (as well as ash disposal and overall permitting) for biomass CHP systems and high-efficiency boiler applications in sizes smaller than industrial and utility scale.

ACKNOWLEDGMENTS

This paper grew out of previous work done by the author under contract to the following: Community Renewable Energy (CORE) at the Chittenden County Regional Planning Commission; Vermont Department of Public Service; and the Renewable Energy Policy Project (REPP). Particular thanks to Paul Wishinski of the Vermont Air Pollution Control Division, John Irving of the McNeil Generating Station and consultant Jeffrey Fehrs, P.E.

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