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IEEE POWER ENGINEERING SOCIETY
ENERGY DEVELOPMENT AND POWER GENERATING COMMITTEE

PANEL SESSION: HARNESSING UNTAPPED BIOMASS POTENTIAL WORLDWIDE

EXTENDED PANEL SESSION SUMMARIES

IEEE 2004 General Meeting, Denver, 6-12 June 2004
Tuesday June 8, Room Gov Square 16, 2-5 p.m.

INTRODUCTION

Sponsored by: International Practices for Energy Development and Power Generation Subcommittee

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Track 2: Environmental Dimensions
Track 4: Sustainability and Global Change

This Panel Session discussed Harnessing Untapped Biomass Potential Worldwide.

Biomass to electricity power generation is a proven electricity generation option. Biomass includes all kinds of non-fossil organic matter that is available on a renewable basis for conversion to energy. It includes crops and agricultural residues, commercial wood and logging residues, animal wastes, the organic portion of municipal solid waste, and methane gas from landfills. According to the United Nations, biomass accounts for about 14% of world energy use and over one third of energy use in developing nations.

Today in North America, biomass has 10 GW of installed capacity and is the single largest source of non-hydro renewable electricity. More than 500 facilities around the U.S. are currently using wood or wood waste to produce combined heat and power. This installed capacity consists of about 7.0GW from forest products and agricultural wastes, about 2.5 GW of municipal solid wastes (MSW) and 0.5 GW of landfill gas.

Biomass is the only other naturally occurring energy-containing carbon resource known that is large enough to be used as a substitute for fossil fuels. It is estimated that the renewable, aboveground biomass that could be harvested for power production is many times the world's total annual consumption.

This session focused on the potential for power production from woody fuels, municipal solid wastes, anaerobic digestion and landfill gases.

Presenters and Titles of their Presentations were:

(1). Robert C. Brown, Iowa State University, U.S.A. Thermo chemical Technologies for Biomass Energy

(2). Robb Walt, President, and Art Lilley, Community Power Corporation, Littleton, CO, USA. The BioMax^{TM} A New Biopower Option for Distributed Generation and CHP

(3). Ralph Overend, NREL, Golden, CO, USA. Biomass Availability for Biopower Applications (Invited Discussion)

(4) Christian Demeter, Chief Executive Officer, Antares Group Incorporated, Landover, Maryland, USA. Motivating the Power Industry with Biomass Policy and Tax Incentives (Invited Discussion)

(5). Richard L. Bain, Group Manager and Principal Researcher, Thermo chemical Conversion Group, National Renewable Energy Laboratory, Golden, CO, USA. An Overview of Biomass Combined Heat and Power Technologies

(6). Sanako Soungalo, Director, Sonacos, Dakar, Senegal- Biomass Development. Senegal Biomass Exploitation: An Assessment of Applicable Technologies for Rural Development

(7). Greg Tomberlin and M. Kannair, Barlow Projects, Inc., Fort Collins, CO, USA. Energy Generation through the Combustion of Municipal Waste.

Each Presenter spoke for approximately 20 minutes. Each presentation was discussed immediately following the respective presentation. There was a further opportunity for discussion of the presentations following the final presentation.

The Panel Session was organized by Peter Meisen (GENI, CA, USA) and Tom Hammons, (University of Glasgow, UK).

The Panel Session was moderated by Tom Hammons and Peter Meisen.

1). The first presentation was on Thermochemical Technologies for Biomass Energy. Robert C. Brown, Iowa State University, USA, presented it.

Biomass is a renewable resource that can be used for the production of a variety of products currently produced from fossil fuel resources. The concept of “bio-refinery” has been introduced as a means of co-producing electric power and commodity chemicals or fuels. This presentation described how thermo chemical technologies, including combustion, gasification, and pyrolysis, will play important roles in the development of bio-refineries.

Robert C. Brown is Bergles Professor of Thermal Science, Department of Mechanical Engineering, Iowa State University (ISU), USA. He is also Professor in the Departments of Chemical Engineering and Agricultural and Bio-systems Engineering. His research focuses on the thermo chemical processing of biomass into energy, fuels, and chemicals. Dr. Brown received his Ph.D. (1980) and M.S. (1979) degrees in Mechanical Engineering from Michigan State University and a B.A. in Mathematics and a B.S. in Physics from the University of Missouri-Columbia in 1976. He worked for three years as a senior engineer at General Dynamics Corporation He is the director for the Office of Bio-renewables Programs at ISU and helped establish the first graduate program in the United States to offer degrees in bio-renewable resources. He recently published *Bio-renewable Resources: Engineering New Products from Agriculture*, a textbook for students interested in the Bio-economy. Dr. Brown is a Fellow of the American Society of Mechanical Engineering.

2). The second presentation was entitled: The BioMax^{TM}, New Bio-power Option for Distributed Generation and CHP. Robb Walt and Art Lilley, Community Power Corporation, USA prepared it. Robb Walt presented it.

The BioMax line of small modular bio-power systems from Community Power Corporation (CPC), USA offers new options for using a variety of biomass residues to provide power and heat for rural enterprises, homes and small communities.

CPC's BioMax systems are skid-mounted, fully automated, environmentally friendly bio-power systems that consist of an advanced and controllable downdraft gasifier integrated with an engine/generator that produces 5, 20 and 50kW from producer gas. The BioMax systems are fully automated and require less than 30 minutes per day of attendant labor, excluding time to prepare the woody biomass feedstock. The attendant turns the key to start the engine on propane and may then walk away as the "expert" computer-based, control system starts the gasifier, activates the screw feeder as needed, automatically transitions from the start-up fuel (generally propane) to a clean producer gas made from woodchips or many other types of biomass residues and continues to operate and monitor the system until automatic shutdown. The feeder/gasifier system is driven by the load demands of the internal-combustion-spark engine/generator. BioMax systems are configured for combined heat and power applications.

In the presentation, this new bio-power option for distributed generation and CHP was described, discussed and evaluated.

Robb R. Walt is President and CEO, Community Power Corporation, Littleton, CO, USA. He is co-founder and president of Community Power Corporation (CPC), a company focused on the development and supply of bioenergy-based, distributed power generation systems. Over the past 30 years, Mr. Walt has served with the US Government, Westinghouse Electric Corporation, and the World Bank in over 15 countries, including Indonesia, Philippines, Thailand, Malaysia, India, China, Bangladesh, Egypt, Iran, Haiti, Papua New Guinea, and Micronesia.

3) The third presentation is an invited discussion on Biomass Availability for Bio-Power Applications and was given by Ralph P. Overend, National Bioenergy Center, National Renewable Energy Laboratory, Golden, CO, USA.

The majority of biomass used today is a residue produced either in the primary or secondary processing industries, or as post consumer residues. Many of the industries that process wood or sugar cane are themselves significant consumers of energy in the form of process heat and electricity so that this is a sector with a considerable amount of Rankine cycle combined heat and power (CHP) installations. However, many of them underutilize their residues. Post consumer residues, as urban wood and landfill gas, already make a significant power contribution in the United States, Europe and Japan. Large-scale expansion will require increased harvest residue collection and use in the form of forest thinnings, wood slash, straws and stalks from cereal crops, as well as the development of energy crops.

In this presentation, a U.S. supply curve for 2020 was discussed with its approximately 450 million tonne (Mt) potential, as well as a USA. stretch potential for the middle of the century of a Gigatonne (Gt).

Ralph P. Overend trained in physical chemistry and has worked in bioenergy and renewable energy since 1973 as a researcher, research manager, and coordinator of research and development in both Canada and the United States. His nearly 20 years with the National Research Council of Canada was as manager of the Bioenergy program, and advisor to the Department of Energy Mines and Resources on biomass energy. He joined the United States Department of Energy Biomass Power program at the National Renewable Energy Laboratory (NREL) in 1990, and has worked extensively in the development of long-range plans and strategies for biomass power and biofuels since that time. He was the NREL project leader in a joint development activity with industry to develop and demonstrate a 60 MW thermal indirect gasification system attached to the McNeil station in Burlington, Vermont.

His significant recognitions for outstanding scientific contributions in biomass and bioenergy include: Fellow of the Chemical Institute of Canada, 1990; Johannes Linneborn Prize, 1996; H. M. Hubbard Award, 1997; R&D 100 Award, 1998; NREL Research Fellow, 2000; the Thomas R. Miles Award, 2001, and the World Renewable Energy Network, Pioneer Award, 2002.

4). The fourth presentation was an invited discussion on motivating the Power Industry with Biomass Policy and Tax Incentives. It was made by Christian Demeter, Chief Executive Officer, Antares Group Incorporated, Maryland, USA.

Biomass is an abundant, geographically widespread, low sulfur, carbon neutral fuel resource. It is proven in many power-producing applications for base load and intermediate load. However, relative to conventional fossil fuels, biomass has relatively low energy density, requires significant processing, is an unfamiliar fuel among potential customers and is relatively expensive at the burner tip.

In a world driven by calculations of rates of return to capital, biomass fuels are relegated to the position of an opportunity fuel with a large untapped potential in mainstream energy markets. Motivating the power industry to use more biomass fuels – to tap into the biomass energy potential – will require policy interventions from R&D investments to tax and other policy incentives. This discussion focussed on many of the policy interventions existing in the United States and those proposed in the Energy Bill before the US. Congress. By way of comparison, a few examples of the European approach was discussed. Recent US experience on actual biomass demonstration projects illustrated the difference properly targeted policy incentive can have on biomass' ability to meet its untapped potential.

The Antares Group Inc. is participating in several biomass power demonstration projects. These include switch grass co-firing in Iowa, willow and residue co-firing in New York State, and gasification for combined heat and power in Connecticut. It is policy incentives that make all these projects financially viable. An overview of these projects with and without the policy incentives made that point clear.

Christian Demeter has 28 years' energy research and management experience. He currently provides policy, economic and financial analysis support to clients in the electric power and transportation sectors and to several federal agencies and laboratories such as NREL, Sandia and Oak Ridge. His clients also include US AID and members of the World Bank Group. He has authored or co-authored more than 100 papers and reports on the emerging energy technologies markets (fossil, nuclear and renewable) and their potential impacts on the environment and the economy. He has testified before the US. Senate on the current Energy Bill and before State Public Service Commissions on air quality compliance cost issues in electric utility rate cases. He has consulted to the Congressional Research Service, the Joint Tax Committee, the Department of

Treasury, and the Office of Science and Technology Policy on various energy incentive programs. He is past President of the International Association for Energy Economics National Capital Area Chapter. He is currently Vice President of the American Bioenergy Association. He currently is investigating unique financial mechanisms such as green power market insurance to facilitate green power marketing and is advising several consortia of landowners, universities, and power companies on cofiring coal and biomass

5). The fifth presentation was an overview of Biomass Combined Heat and Power Technologies. Richard L. Bain, Group Manager, Thermo chemical Conversion Group, National Renewable Energy Laboratory, Golden, Colorado, USA presented it.

Bio-power (biomass-to-electricity generation), with about 11 GW of installed capacity, is the single largest source of non-hydro renewable electricity. The electricity production from biomass is and is expected to continue to be used as base-load power in the existing electrical distribution system. A series of case studies were discussed for the three conversion routes for Combined Heat and Power applications of biomass—direct combustion, gasification, and co-firing. The cost of electricity and cost of steam as a function of variables such as plant size and feed cost were estimated using a discounted cash flow analysis. This was described.

Environmental considerations was also discussed. Two primary issues that could create a tremendous opportunity for biomass are global warming and the implementation of Phase II of Title IV of the Clean Air Act Amendment of 1990 (CAAA). The environmental benefits of biomass technologies are among its greatest assets. Global warming is gaining greater salience in the scientific community and among the general population. Co-firing biomass and fossil fuels and the use of integrated biomass gasification combined cycle systems can be an effective strategy for electric utilities to reduce their emissions of greenhouse gases. This was discussed

Richard L. Bain has been at NREL since February 1990, and has extensive experience in the thermal conversion of biomass, municipal wastes, coal, and petroleum. He is the manager for NREL in-house research in the area of biomass thermo chemical conversion; technical advisor to DOE on biomass demonstration projects; and coordinator of NREL efforts managing the DOE Small Modular Biopower Initiative. He has been a member of the International Energy Agency Biomass Gasification Working Group for 12 years. He has published more than 60 papers in energy conversion and has 10 patents in coal conversion, heavy oil processing and bioconversion.

6). The penultimate presentation was concerned with Senegal Bio-Mass Exploitation and gave an assessment of applicable technologies for rural development. It was made by Soungalo Sanoko, Technical Director, SONACOS, Republic of Senegal, West Africa

This presentation sought to evaluate the latest technology options for utilizing feedstock from Senegal’s groundnut industry in a mix in with other government initiatives such as waste-to-energy programs. It assessed some of these technologies from the green power sector against local Senegal conditions. The implications for other ECOWAS (Economic Community of West African States) countries with similar rural supply challenges and other fuel source types was evaluated with recommendations.

Soungalo Sanoko is Technical Director, SONACOS, Dakar, Senegal. He received the degrees of MS.EE and PhD from Moscow Energetics Institute in 1979 and 1983, respectively. He specializes in Power Systems, Generation and Industrial Distribution Systems. For the past twenty years Dr.Sanoko has served as the Chief Electrical Engineer at SONACOS, Senegal's prime export industry processing plants. Dr. Sanoko is currently the Technical Director at SONACOS and resides in DAKAR.

7). The final presentation was on energy generation through the combustion of municipal waste and was given by Gregg Tomberlin and M. Kannair, Barlow Projects, Inc., Fort Collins, CO, USA. M. Kannair presented it.

Recovering energy from garbage has evolved over the years from the simple incineration of waste in an uncontrolled, environmentally unfriendly way to the controlled combustion of waste with energy recovery, materials recovery and sophisticated air pollution control equipment insuring that emissions are within US. and EU limits. The waste-to-energy industry has proven itself to be an environmentally friendly solution to the disposal of municipal solid waste and the production of energy. Recovering energy from the waste is still a good idea and Waste-to-Energy is now a clean, renewable, sustainable source of energy, and a common sense alternative to land filling. This presentation highlighted developments in this field at this time.

Gregg Tomberlin has 21 years of experience in the design of power generation facilities having served in various design and design management roles for one of the largest architectural engineering firms in North America. He holds a Bachelor of Science degree in mechanical engineering. He has been responsible for the management of the Aireal™ combustion technology development, including the prototype and commercial installations. He is responsible for the research & development of all new WTE projects for BPI and advances in the Aireal™ Combustion technology.

The final EXTENDED PANEL SESSION SUMMARIES follow.

Rec'd 17 August 2994

1. THERMOCHEMICAL TECHNOLOGIES FOR BIOMASS ENERGY

Robert C. Brown, Iowa State University, U.S.A.

Abstract

Biomass is a renewable resource that can be used for the production of a variety of products currently produced from fossil fuel resources. The concept of "biorefinery" has been introduced as a means of co-producing electric power and commodity chemicals or fuels. This paper describes how thermo chemical technologies, including combustion, gasification, and pyrolysis, will play important roles in the development of biorefineries.

Introduction

Biomass is a renewable resource that can be used for the production of a variety of products currently produced from fossil fuel resources.[1] Among these products are electric power, transportation fuels, and commodity chemicals. This diversity of products has encouraged development of "biorefineries" to replace traditional plants dedicated to the production of either electric power or manufactured products. Thermo chemical technologies, including combustion, gasification, and pyrolysis, will play important roles in the development of biorefineries.

Combustion

Combustion for the generation of electric power is familiar to the utility industry, although fossil resources, especially coal, have been more commonly employed than biomass.

As illustrated in Figure 1, solid-fuel combustion consists of four steps: heating and drying, pyrolysis, flaming combustion, and char combustion.[2] No chemical reaction occurs during heating and drying. Water is driven off the fuel particle as the thermal front advances into the particle. Once water is driven off, particle temperature rises high enough to initiate pyrolysis, a complicated series of thermally driven reactions that decompose organic compounds in the fuel. Pyrolysis proceeds at relatively low temperatures in the range of 225°–500° C to release volatile gases and form char. Oxidation of the volatile gases results in flaming combustion. The ultimate products of volatile combustion are carbon dioxide (CO_2) and water (H_2O) although intermediate products can include carbon monoxide (CO), condensable organic compounds, and soot.

Combustion of biomass in place of coal has several advantages including reduced emissions of sulfur and mercury.[3] Combustion of biomass has almost no net emission of greenhouse gases since the carbon dioxide emitted is recycled to growing biomass. Combustion of biomass, however, can still produce emissions of nitrogen oxides and particulate matter. Some biomass has high concentrations of chlorine, which is a precursor to dioxin emissions under poor combustion conditions. Although co-firing of biomass with coal offers some near-term opportunities for the utility industry, the need for higher efficiencies at smaller scales and the compelling opportunities for biorefineries suggest that gasification or pyrolysis will be better future options for using biomass.

Gasification

Gasification is the partial oxidation of solid fuel at elevated temperatures to produce a flammable mixture of hydrogen (H_2), CO, methane (CH_4), and CO_2 known as producer gas.

Figure 2 illustrates the four steps of gasification: heating and drying, pyrolysis, solid-gas reactions that consume char, and gas-phase reactions that adjust the final chemical composition of the producer gas.[4] Drying and pyrolysis are similar to those processes during direct combustion. Pyrolysis produces char, gases (mainly CO, CO_2, H_2, and light hydrocarbons) and condensable vapor. The amount of these products depends on the chemical composition of the fuel and the heating rate and temperature achieved in the reactor. Gas-solid reactions convert solid carbon into gaseous CO, H_2, and CH_4. Gas phase reactions adjust the final composition of the product gas. Chemical equilibrium is attained for sufficiently high temperatures and long reaction times. Under these circumstances, products are mostly CO, CO_2, H_2, and CH_4. Analysis of the chemical thermodynamics of gasification reveals that low temperatures and high pressures favor the formation of CH_4 whereas high temperatures and low pressures favor the formation of H_2 and CO.

Often gasifier temperatures and reaction times are not sufficient to attain chemical equilibrium and the producer gas contains various amounts of light hydrocarbons such as acetylene (C_2H_2) and ethylene (C_2H_4) as well as up to 10 wt-% heavy hydrocarbons that condense to tar.[5]

Heating and drying, pyrolysis, and some of the solid-gas and gas-phase reactions are endothermic processes, requiring a source of heat to drive them. This heat is usually supplied by admitting a small amount of air or oxygen into the reactor, which burns part of the fuel, releasing sufficient heat to support the endothermic reactions.

Producer gas can be used to fuel high efficiency power cycles like combustion turbines, fuel cells, and various kinds of combined cycles. Producer gas can also be used in chemical synthesis of transportation fuels, commodity chemicals, and even hydrogen fuel.[1] In spite of these advantages; gasification has technical hurdles to overcome before widespread commercialization. Challenges include increasing carbon conversion; eliminating particulate matter, tar, and trace contaminants in the producer gas; and increasing plant availability by developing more reliable fuel feed systems and refractory materials. If producer gas is to be used as fuel in high-pressure combustion turbines, efficient and economical methods for compressing the gas during or after gasification must be developed.

Pyrolysis

Pyrolysis is the heating of solid fuel in the complete absence of oxygen to produce a mixture of char, liquid, and gas. Although practiced for centuries in the production of charcoal, pyrolysis in recent years has been optimized for the production of liquids. In a process known as fast pyrolysis, chemical reaction and quenching proceed so rapidly that thermodynamic equilibrium is not attained, resulting in enhanced liquid yields on the order of 70 wt-% of the original biomass.[6] This mixture of organic compounds and water is known as bio-oil.

Bio-oil is a low viscosity, dark-brown fluid with up to 15 to 20% water, which contrasts with the black, tarry liquid resulting from slow pyrolysis or gasification. Fast pyrolysis liquid is a mixture of many compounds although most can be classified as acids, aldehydes, sugars, and furans, derived from the carbohydrate fraction, and phenolic compounds, aromatic acids, and aldehydes, derived from the lignin fraction. The liquid is highly oxygenated, approximating the elemental composition of the feedstock, which makes it highly unstable.

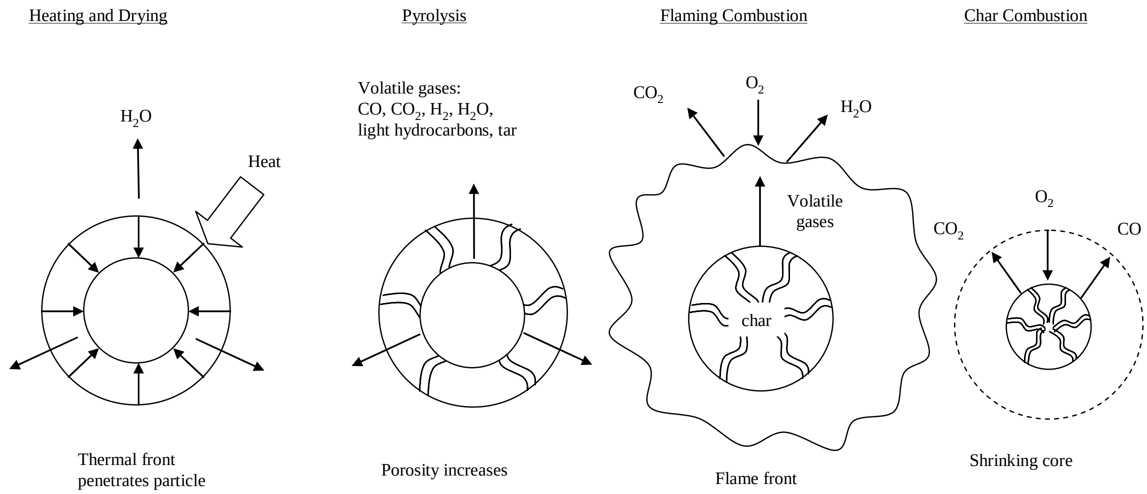

Figure 1. Mechanism of combustion

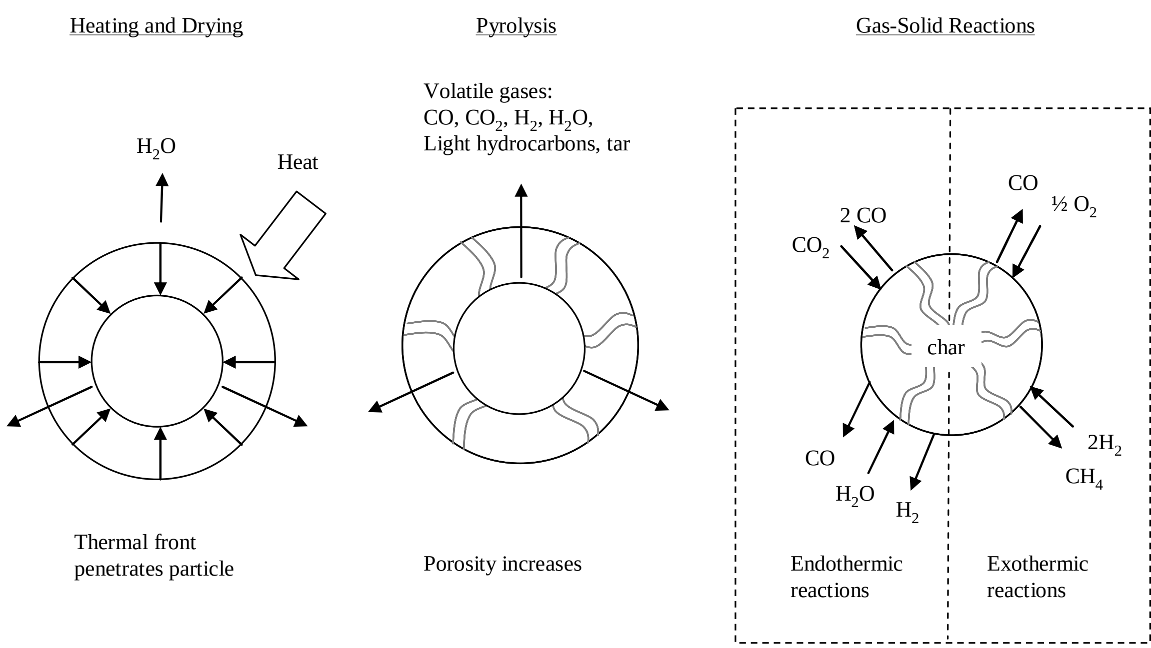

Figure 2. Mechanism of gasification

Figure 3 illustrates the production of bio-oil, which begins with milling of biomass to fine particles of less than 1 mm diameter to promote rapid reaction. The particles are injected into a reactor, such as a fluidized bed, that has high heat transfer rates. The particles are rapidly heated and converted into condensable vapors, non-condensable gases, and solid char. These products are transported out of the reactor into a cyclone operating above the condensation point of pyrolysis vapors where the char is removed. Vapors and gases are transported to a quench vessel or condenser where vapors are cooled to liquid. The non-condensable gases are burned in air to provide heat for the pyrolysis reactor. A number of schemes have been developed for indirectly heating the reactor, including transport of solids into fluidized beds or cyclonic configurations to bring the particles into contact with hot surfaces.

Bio-oil can be used as a substitute for heating oil although its heating value is only about half that of its petroleum-based counterpart. Its handling and storage characteristics are inferior, as well. Nevertheless, the ability to produce liquid fuel from biomass offers opportunities for distributed production of a high-density fuel that can be easily pressurized for injection into combustion turbines. In addition, bio-oil contains a variety of organic compounds that, if they could be economically recovered, offer opportunities for pyrolysis-based biorefineries.[7]

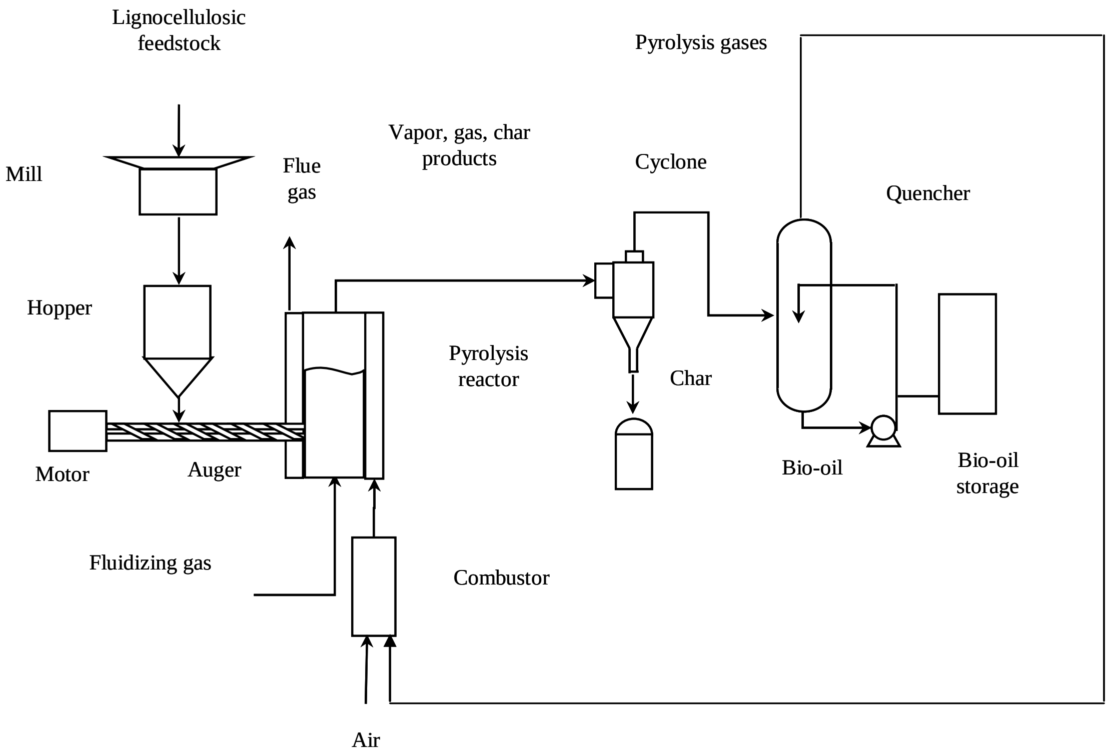

Figure 3. Schematic illustration of a bio-oil production facility

Conclusions

A number of thermo chemical conversion processes are available to meet the growing demand for biomass energy. Biorefineries offer an intriguing future opportunity for the electric utility industry to meet this demand.

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Biography

Robert C. Brown is the Bergles Professor in Thermal Science in the Department of Mechanical Engineering at Iowa State University (ISU). He also holds the rank of Professor in the Chemical Engineering Department. His research focuses on the thermochemical processing of biomass into energy, fuels, and chemicals.

Dr. Brown received his Ph.D. (1980) and M.S. (1979) in Mechanical Engineering from Michigan State University and a B.A. in Mathematics and a B.S. in Physics from the University of Missouri-Columbia in 1976. He worked for three years as a senior engineer at General Dynamics Corporation in Ft. Work Texas before joining Iowa State University as an assistant professor in 1983.

Dr. Brown is the director for the Office of Biorenewables Programs at ISU and helped establish the first graduate program in the United States to offer degrees in biorenewable resources. He recently published Biorenewable Resources: Engineering New Products from Agriculture, a textbook for students interested in the Bioeconomy. Dr. Brown is a Fellow of the American Society of Mechanical Engineering.

Rec'd 24 Jan 04

2. THE BIOMAX™ A NEW BIOPOWER OPTION FOR DISTRIBUTED GENERATION AND CHP

Robb Walt, Art Lilley, Community Power Corporation, USA

Abstract

The BioMax line of small modular bio-power systems from Community Power Corporation (USA) offers new options for using a variety of biomass residues to provide power and heat for rural enterprises, homes and small communities.

CPC's BioMax systems are skid-mounted, fully automated, environmentally friendly bio-power systems that consist of an advanced and controllable down-draft gasifier integrated with an engine/generator that produces 5, 20 and 50kW$_e$ from producer gas. The BioMax systems are fully automated and require less than 30 minutes per day of attendant labor, excluding time to prepare the woody biomass feedstock. The attendant turns the key to start the engine on propane and then may walk away as the "expert" computer-based, control system starts the gasifier, activates the screw feeder as needed, automatically transitions from the start-up fuel (generally propane) to a clean producer gas made from woodchips or many other types of biomass residues and continues to operate and monitor the system until automatic shutdown. The feeder/gasifier system is driven by the load demands of the internal-combustion-spark engine/generator. BioMax systems are configured for combined heat and power applications.

2.1 Introduction

Access to reliable, utility–grade electricity is key to improving the quality and economy of life of many rural communities throughout the world. Conventional approaches to rural electrification such as grid extension or small diesel generators are increasingly prohibitive in cost and often environmentally harmful. CPC's new BioMax small modular biopower systems offer an affordable and environmentally friendly means of using a variety of local forest and agricultural biomass residues to generate on-site the right amount of electricity and thermal energy needed by most rural enterprises, homes, hospitals, clinics, government offices, water pumps and community micro-grids.

2.2 Technology

Beginning in 1999, CPC joined with the US National Renewable Energy Laboratory (NREL) followed by Shell Renewables, the California Energy Commission and the US Forest Service to develop and bring to market a new generation of environmentally friendly small modular bio-power systems. The first BioMax prototypes ranging from 5kW to 20kW are now deployed in the Philippines and six locations in the USA. In January 2004, CPC signed follow-on contracts with the California Energy Commission and the US Forest Service to develop an advanced 50kW BioMax system for prime-power, distributed generation applications.

CPC's fully automated BioMax systems use a variety of biomass fuels to generate electricity and thermal energy. CPC's BioMax system is designed as a "green" alternative to conventional fossil fuel generators and to free the community/user from dependence on the supply and high cost of imported fossil fuels such as gasoline or diesel fuel. By eliminating the need for importing diesel fuel, the community's financial resources are retained in the community and there is no environmental damage from spillage of diesel fuel or exhaust emissions. BioMax users with on-site woody residues avoid the high cost of waste disposal by generating power and heat from that waste.

CPC's new bio-power technology incorporates the latest computer-based control technology and gasifier design to achieve unparalleled levels of clean-gas performance, turn-down flexibility, and environmental friendliness. The "wood gas" is conditioned and fed into a standard internal combustion engine genset for conversion to mechanical, electrical, and thermal power. BioMax systems have also been used to operate a solid oxide fuel cell, a Stirling engine and a microturbine.

CPC's advanced design gasifier with fully integrated controls produces an extremely clean combustible gas from a variety of woody fuels including any kind of wood chips or densified biomass made from switch grass, sawdust, spent hops, grape skins, etc. Most nutshells including coconut, walnut, and pecan have proven to be an excellent fuel for the BioMax.

The small amount of byproduct char is entrained out of the gasifier and is removed from the producer gas stream by inertial separation and filtering. Very low tar levels in the producer gas are a result of automatic control of proper reactor temperatures over the full power range of the generator. The system does not produce condensed water nor does it use any form of liquid scrubbers. The only byproduct of the system is char and fine ash, the amount depending on the original ash content of the biomass feedstock.

Waste heat from the hot producer gas is recovered and used for drying the wood-chip feedstock or for space heating. The moisture content of the feedstock is reduced about 15 percentage points during delivery from the feed hopper to the gasifier. The BioMax gasifiers have been successfully operated with woodchips having between about 5% and 25% moisture. Additional thermal energy is available from the engine coolant and exhaust.

The computer-based control system adjusts the fuel/air ratio in the engine and makes necessary adjustments to the process variables of the gasifier to maintain the desired temperature profile and gasifier bed porosity. The controller remotely alerts the operator if it cannot operate the system within specifications and gives the operator ample time to make corrections. If the operator is not available to refill the feed hopper or if the gasifier or engine/generator system continues to operate improperly, the "expert" controller will automatically (and independently) shut down the gasifier and engine system in a safe manner.

The BioMax line is undergoing a field-based beta testing program with a wide variety of users including a high school, furniture factory, wood shavings company, forest service facility, and a rural enterprise in the Philippines. There are also two BioMax systems at research institutions in the USA.

2.3 Conclusions

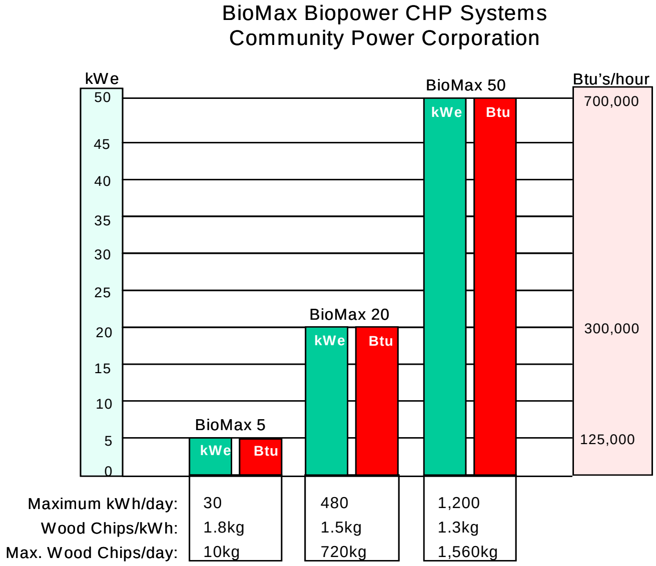
The BioMax line represents a new level of fully automated and environmental friendly bio-power systems designed for the 21st century. On-going R&D at Community Power Corporation's product development facility in Denver, Colorado will continue to achieve upgrades and performance enhancements in the areas of hot-gas filtration, feedstock variety, control systems, and cost reductions to increase the commercial viability of the systems.

Summary of BioMax Features

- Electrical output in blocks from 5kWe to 50kWe; 120 and 240 VAC; 50 and 60 Hz
- Combined heat and power operation for rural electrification and distributed generation applications
- Environmentally friendly, non-condensing system without water scrubbers or liquid effluents
- Fully automatic, closed-loop control of all components including gasifier, gas conditioning and genset
- Dispatch able power within 30 seconds of auto-startup – uses no diesel fuel or gasoline
- Fuel flexible: wood chips, wood pellets, coconut shells, corn, corncobs, nutshells, etc.
- Optional automatic dryer/feeder for wood chips
- Modular, transportable, no need for on-site buildings or waste water disposal, 1 day installation

See below for a comparison of BioMax biopower systems with other power generation technologies.

Comparison of BioMax Bio-power System with Other Power Generation Technologies



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COMPARISON MATRIX	**BIOMAX Community Power Corp.**	PV SYSTEM	DIESEL GENERATOR	FUEL CELL	MICRO-TURBINE	SMALL WIND TURBINE
kW Range	**5-100**	2.5 – 15	5 – 6,000	5 – 3,000	30 – 400	3 – 200
Capacity compared	**20 kW**	15 kW	15 kW	15 kW	30 kW	10 kW
Stand-alone system	**yes**	yes	yes	yes	yes	yes
Dispatchable Power	**yes**	no	yes	yes	yes	no
Installed Capital cost $/kW	**$1,200 - $4,000**	$10,000 – $15,000	$200 - $650	$3,000 – $4,000	$1,200 - $1,700	$2,000 -$3,000
Combined Heat and Power?	**Yes**	No	Yes	Yes	Yes	No
Electrical system efficiency	**20 -22%**	6 - 12%	35%	36 - 50%	14 - 30%	25%
Overall Efficiency	**80-85%**	6 – 12%	80-85%	80-85%	80-85%	25%
Fuels	**Fuel flexible: str biomass or dual with a fossil generator: diese LPG**	None	Diesel fuel	Hydrogen, natural gas or propane	Natural gas or propane	None
Fuel cost	**Biomass: $ 0 –0.04/kWh @ $0.02/kg Diesel: $ 0.10/kWh at $ 1.35/gal**	$0	$0.10/kWh @ $1.35/gal	$0.08/kWh @ $1.35/gal equivalent	$ 0.15/kWh at $1.35/gal equivalent	$0
Variable O&M ($/kWh)	**0.005 – 0.015**	$0.001 – 0.004	$0.005 – 0.015	$0.0019- 0.0153	$0.003 – 0.008	$0.01
Energy density (kW/M2)	**30**	0.02	50	1 – 3	59	.01
Needs battery storage	**No**	Yes	No	No	No	Yes
Needs power conditioning	**No**	Yes	No	Yes	Yes	Yes

Robb R. Walt
President & CEO, Community Power Corporation

Mr. Walt is co-founder and president of Community Power Corporation (CPC) a company with headquarters in Littleton, Colorado, focused on the development and supply of bio-energy-based, distributed power generation systems. Over the past 30 years, Mr. Walt has served with the US Government, Westinghouse Electric Corporation, and the World Bank in over 15 countries, including Indonesia, Philippines, Thailand, Malaysia, India, China, Bangladesh, Egypt, Iran, Haiti, Papua New Guinea, and Micronesia. Community Power is a leader in the development and application of environmentally friendly, small modular bio-power systems to provide on-site, combined heat and power for small communities, enterprises and homes from a variety of biomass residues. CPC's partners to develop and deploy these bio-power systems include the US Department of Energy, the National Renewable Energy Laboratory, the US Forest Service, the California Energy Commission, the Bureau of Indian Affairs, the World Bank, Shell Renewables, USAID, and others. For more information visit: www.gocpc.com.

Rec'd 27 Jan 04

3. BIOMASS AVAILABILITY FOR BIOPOWER APPLICATIONS

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Abstract

The majority of biomass used today is a residue produced either in the primary or secondary processing industries, or as post consumer residues. Many of the industries that process wood or sugar cane are themselves significant consumers of energy in the form of process heat and electricity so that this is a sector with a considerable amount of rankine cycle combined heat and power (CHP) installations. However, many of them underutilize their residues. The advent of export markets for their electricity, due to liberalization and deregulation of electricity supplies, will lead to more efficient CHP installations; the significant energy efficiency measures in the plant operations will result in greater export of electricity. Post consumer residues, as urban wood and landfill gas, already make a significant power contribution in the United States, Europe and Japan. Large scale expansion will require increased harvest residue collection and use in the form of forest thinnings, wood slash, straws and stalks from cereal crops, as well as the development of energy crops. A U.S. supply curve for 2020 will be discussed with its approximately 450 million tonne (Mt) potential, as well as a U.S.A. stretch potential for the middle of the Century of a Gigatonne[1].

Introduction

The estimation of biomass supplies is confounded by the many ways in which biomass is generated and used, especially as today the biomass for energy stream is composed of residues from primarily industrial and societal activities. Thus, the production of biomass feedstocks and bio-energy use is very dependent on the functioning of some other component of the economy, the three major areas being: forestry, agriculture, and the urban environment. While this includes a wide range of resources, ranging from primary residues through to post consumer residues, energy crops also have a significant potential.

To simplify the discussion of biomass it is necessary to provide some definitions and characterization of where in the economy biomass is generated or utilized as bio-energy. One methodology is to identify the stage of processing/utilization since the creation of the biomass by photosynthesis.

It is also necessary to note that there is no biomass currency such as the tonne of oil equivalent (toe). However, the majority of biomass is composed of lignin, cellulose, and hemicellulose polymers in proportions such that most lignocellulosics have a calorific value in the range of 17.5 - 18.6 GJ t^{-1} when measured on a totally dry basis. Each tonne of biomass has •5 MWh_{th} energy content. A gigatonne has 5 PWh equivalent primary energy. The world Total Primary Energy Supply (TPES) in 2001 was about 120 PWh. Current global estimates of future biomass potential are of the same order, though today the world biomass consumption is estimated at about 13 PWH (TPES).

Energy Crops

Energy crops are a primary supply and involve the production and growth of biomass specifically for biomass to energy and fuels applications. This is widespread in developing countries for fuelwood, as well as examples of Eucalypt forestry for charcoal production in iron production in Brazil [1]. Also, in Brazil a significant fraction of the sugar cane crop is dedicated to ethanol production [2], while 9% of the U.S. corn harvest is used in the production of ethanol from starch [3]. Research and development in Europe and the United States is developing the use of woody or straw materials (lignocellulosics) as high yielding non-food energy crops. The impact of energy crops in moving the biomass supply away from what is available as a residue can be seen from the following example. Assuming a 38% efficiency, a 1 Mt annual supply base can support a generating capacity of 225 - 240 MW operating at a 90% capacity. Using an energy crop yielding 15 t ha^{-1} y^{-1} the area planted to the energy crop would need to be about 70 kha, representing less than 4% of the land area inside a circle of 80 km centered on the power plant. Typical ratios of energy out : fossil energy in, for such a plant, would be about 12, while the net carbon dioxide emissions would be < 50 g kWh^{-1}, or even zero if the energy crop accumulates soil carbon at current anticipated rates.

Primary Residues

Primary residues are produced as a by-product of a primary harvest for another material or food use of grown biomass. A representative of this is the use of tops and limbs as well as salvage wood from forestry operations cutting saw-logs or pulpwood. This material along with forest thinning is a developing biomass supply system in Finland, for example [4]. Much of the research in the United States in recent years has focused on corn stover *(Zea mays*) as a large scale opportunity primary residue associated with the harvest of the principal grain crop [5].

Secondary Residues

The majority of biomass used today in the energy system is generated as secondary and tertiary residues. Secondary residues arise during the primary processing of biomass into other material and food products. Sugarcane bagasse is widely used to fuel CHP providing the heat and electricity needs of sugar processing as well as export of electricity to the grid. In the forest industries, black liquor from kraft pulping is a major fuel for CHP and the recovery of process chemicals. The meat, dairy, and egg production in concentrated animal feed operations (CAFO) is a rapidly growing area in which bio-energy production is part of the solution to environmental issues created by this landless food production system.

Tertiary residues: Urban or post consumer residues are a major component of today's bio-energy system. In fact the official statistics of the IEA, for example, describe biomass as combustible renewables and waste, and in many countries the tertiary sector is captured under the title of municipal solid waste or MSW. The tertiary sector generates energy in combustion facilities as well as from the generation of methane as land fill gas (LFG) from properly managed burial of mixed wastes from cities. Methane is also produced in sewage treatment facilities. Individual rates of residue generation are currently about 22 MJ $person^{-1}$ d^{-1} in the United States; this combined with the high population densities of metropolitan areas, results in very high bio-energy potentials in this sector [6].

Biomass Potential for 2020

There is a consensus biomass resource potential estimate for 2020 in the United States, which captures most of the sources described above, other than the CAFO potential [7]. This is described in the form of a supply curve and indicates that there are about 7 - 8 EJ of primary energy at # 4.0 $ GJ^{-1}. This represents about 450 Mt of dry lignocellulosic biomass potential, which can be compared with today's utilization of about 190 Mt. The ultimate technical potential for biomass in the United States is not yet established, however, work is underway on what is called the Gigatonne scenario, which would investigate the effect of seeking double the 2020 projection for say the 2040 - 2050 period.

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Biography:

Ralph P. Overend trained in physical chemistry and has worked in bio-energy and renewable energy since 1973 as a researcher, research manager, and coordinator of research and development in both Canada and the United States. His nearly 20 years with the National Research Council of Canada, was as manager of the Bio=energy program, and advisor to the Department of Energy Mines and Resources on biomass energy. In addition, he served as coordinator of Canadian renewables R&D for several years. He joined the United States Department of Energy Biomass Power program at the National Renewable Energy Laboratory (NREL) in 1990, and has worked extensively in the development of long-range plans and strategies for biomass power and bio-fuels since that time. He was the NREL project leader in a joint development activity with industry, to develop and demonstrate a 60 MW thermal indirect gasification system attached to the McNeil station in Burlington, Vermont.

He was the Chairman of the American Chemical Society Cellulose Division 1993-94. He edits the journal, *Biomass and Bio-energy*, and the biomass section of the Journal, *Solar Energy*, in addition to being a member of several editorial boards. He has also served as a United Nations, World Bank, and FAO lecturer/advisor in the USSR, China, Pakistan, and Mexico. He recently completed the biomass component of a renewable energy atlas for the Government of the Philippines.

Significant recognitions for outstanding scientific contributions in biomass and bio-energy include: Fellow of the Chemical Institute of Canada, 1990; Johannes Linneborn Prize, 1996; H. M. Hubbard Award, 1997; R&D 100 Award, 1998; NREL Research Fellow, 2000; the Thomas R. Miles Award, 2001, and the World Renewable Energy Network, Pioneer Award, 2002.

Rec’d 14-Jan 04

4. INVITED DISCUSSION: MOTIVATING THE POWER INDUSTRY WITH BIOMASS POLICY AND TAX INCENTIVES

Christian Demeter, Chief Executive Officer, Antares Group Incorporated, Maryland, USA

Summary

Biomass is an abundant, geographically widespread, low sulfur, carbon neutral fuel resource. It is proven in many power producing applications for base load and intermediate load. However, relative to conventional fossil fuels, biomass has relatively low energy density, requires significant processing, is an unfamiliar fuel among potential customers and is relatively expensive at the burner tip. In a world driven by calculations of rates of return to capital, biomass fuels are relegated to the position as an opportunity fuel with a large untapped potential in mainstream energy markets. Motivating the power industry to use more biomass fuels – to tap into the biomass energy potential – will require policy interventions from R&D investments to tax and other policy incentives. This discussion will focus on many of the policy interventions existing in the United States and those proposed in the Energy Bill before the U.S. Congress. By way of comparison, a few examples of the European approach will be discussed. Recent U.S experience on actual biomass demonstration projects will illustrate the difference properly targeted policy incentive can have on biomass’ ability to meet its untapped potential.

The Antares Group Inc. is participating in several biomass power demonstration projects. Among them are switchgrass cofiring in Iowa, willow and residue co-firing in New York State, and gasification for combined heat and power in Connecticut. A recent “Healthy Forests” initiative proposed by the Bush Administration, led to a comprehensive review of commercially viable biomass systems for use with forest thinning in rural areas. It is policy incentives which make all these projects financially viable. An overview of these projects with and without the policy incentives will make that point clear.

Christian Demeter, Founding Principal and CEO, Antares Group Incorporated.

Christian Demeter has 28 years’ energy research and management experience. He currently provides policy, economic and financial analysis support to clients in the electric power and transportation sectors and to several federal agencies and laboratories such as NREL, Sandia and Oak Ridge. His clients also include US AID and members of the World Bank Group. He has authored or co-authored more than 100 papers and reports on the emerging energy technologies markets (fossil, nuclear and renewable) and their potential impacts on the environment and the economy. He has testified before the U.S. Senate on the current Energy Bill and before State Public Service Commissions on air quality compliance cost issues in electric utility rate cases. He has consulted to the Congressional Research Service, the Joint Tax Committee, the Department of Treasury, and the Office of Science and Technology Policy on various energy incentive programs. He is past President of the International Association for Energy Economics National Capital Area Chapter. He is currently Vice President of the American Bioenergy Association.

The topic of Biomass for Power, Fuels, and Chemicals has been an area of special interest to Mr. Demeter for over a decade. He has served on many roundtable discussions, review committees, and forums on the topic. He currently is investigating unique financial mechanisms such as green power market insurance to facilitate green power marketing and is advising several consortia of land owners, universities, and power companies on cofiring coal and biomass. He also is advising project developers on biomass combustion and conversion options.

Rec'd 22 Jan 04

5. AN OVERVIEW OF BIOMASS COMBINED HEAT AND POWER TECHNOLOGIES

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Abstract

Bio-power (biomass-to-electricity generation), a proven electricity generating option in the United States and with about 11 GW of installed capacity, is the single largest source of non-hydro renewable electricity. The electricity production from biomass is being used and is expected to continue to be used as base-load power in the existing electrical distribution system. A series of case studies will be discussed for the three conversion routes for Combined Heat and Power (CHP) applications of biomass—direct combustion, gasification, and co-firing. The cost of electricity and cost of steam as a function of variables such as plant size and feed cost are estimated using a discounted cash flow analysis.

Environmental considerations will also be discussed. Two primary issues that could create a tremendous opportunity for biomass are global warming and the implementation of Phase II of Title IV of the Clean Air Act Amendment of 1990 (CAAA). The environmental benefits of biomass technologies are among its greatest assets. Global warming is gaining greater salience in the scientific community and among the general population. Biomass use can play an essential role in reducing greenhouse gases, thus reducing the impact on the atmosphere. Co-firing biomass and fossil fuels and the use of integrated biomass gasification combined cycle systems can be an effective strategy for electric utilities to reduce their emissions of greenhouse gases.

Key Words: Biomass, Combined Heat and Power, Cofiring, Combustion, Gasification, Life Cycle Analysis

Summary

Bio-power is a commercially proven electricity generating option in the United States, and with about 11 GW of installed capacity is the single largest source of non-hydro renewable electricity. The capacity encompasses about 7.5 GW of capacity using forest product and agricultural industry residues, about 3.0 GW of MSW-based generating capacity, and 0.5 GW of other capacity such as landfill gas based production.

Bio-power experienced a dramatic factor-of-three increase in grid-connected capacity after the Public Utilities Regulatory Policy Act (PURPA) of 1978 guaranteed small electricity producers (less than 80 MW) that utilities would purchase their surplus electricity at a price equal to the utilities' avoided cost of producing electricity. In the period 1980-1990, growth resulted in industry investment of $15 billion dollars and the creation of 66,000 jobs

Today's capacity is based on mature, direct combustion boiler/steam turbine technology. The average size of bio-power plants is 20 MW (the largest approaches 75 MW) and the average efficiency is 20%. The small plant sizes (which leads to higher capital cost per kilowatt-hour of power produced) and low efficiencies (which increase sensitivity to fluctuation in feedstock price) has led to electricity costs in the 8-12 ¢/kWh range.

The next generation of stand-alone bio-power production will substantially mitigate the high costs and efficiency disadvantages of today's industry. The industry is expected to dramatically improve process efficiency through biomass co-firing in coal-fired power stations, through the introduction of high-efficiency gasification combined cycle systems, and through efficiency improvements in direct combustion systems made possible by the addition of dryers and more rigorous steam cycles at larger scale of operation. Technologies presently at the research and

development stage, such integrated gasification fuel cell systems, and modular systems are expected to be competitive in the future.

A series of case studies (1) have been performed on the three conversion routes for CHP applications of biomass—direct combustion, gasification, and co-firing. The studies are based on technology characterizations developed by NREL and EPRI (2), and much of the technology descriptions given are excerpted from that report. Variables investigated include plant size and feed cost; and both cost of electricity and cost of steam are estimated using a discounted cash flow analysis.

The nearest term and lowest-cost option for the use of biomass is co-firing with coal in existing boilers. Co-firing refers to the practice of introducing biomass as a supplementary energy source in high efficiency boilers. Boiler technologies where co-firing has been practiced, tested, or evaluated, include wall- and tangentially-fired pulverized coal (PC) boilers, cyclone boilers, fluidized-bed boilers, and spreader stokers. Extensive demonstrations and trials have shown that effective substitutions of biomass energy can be made up to about 15% of the total energy input with little more than burner and feed intake system modifications to existing stations. After tuning the boiler's combustion output, there is little or no loss in total efficiency, implying that the biomass combustion efficiency to electricity would be about 33-37%. Since biomass in general has significantly less sulfur than coal, there is a SO_2 benefit; and early test results suggest that there is also a NO_x reduction potential of up to 20% with woody biomass. Investment levels are very site specific and are affected by the available space for yarding and storing biomass, installation of size reduction and drying facilities, and the nature of the boiler burner modifications. Investments are expected to be in \$100 - 700/kW of biomass capacity, with a median in the \$180 - 200/kW range.

Another potentially attractive bio-power option is based on gasification. Gasification for power production involves the devolatilization and conversion of biomass in an atmosphere of steam or air to produce a medium- or low- calorific gas. This biogas is used as fuel in a combined cycle power generation cycle involving a gas turbine topping cycle and a steam turbine bottoming cycle. A large number of variables influence gasifier design, including gasification medium (oxygen or no oxygen), gasifier operating pressure, and gasifier type. The first generation of biomass GCC systems would realize efficiencies nearly double that of the existing industry. Costs of a first-of-a-kind biomass GCC plant are estimated to be in the \$1800-2000/kW range with the cost dropping rapidly to the \$1400/kW range for a mature plant in the 2010 time frame.

Direct-fired combustion technologies are another option, especially with retrofits of existing facilities to improve process efficiency. Direct combustion involves the oxidation of biomass with excess air, giving hot flue gases that produce steam in the heat exchange sections of boilers. The steam is used to produce electricity in a Rankine cycle. In an electricity-only process, all of the steam is condensed in the turbine cycle, while in CHP a portion of the steam is extracted to provide process heat. The two common boiler designs used for steam generation with biomass are stationary- and traveling-grate combustors (stokers) and atmospheric fluid-bed combustors. The addition of dryers and incorporation of more-rigorous steam cycles is expected to raise the efficiency of direct combustion systems by about 10% over today's efficiency, and to lower the capital investment from the present \$2,000/kW to about \$1275/kW.

Bio-power is unique among renewable energy sources because it involves combustion that releases air pollutants. Major emissions of concern from bio-power plants are particulate matter (PM), carbon monoxide (CO), volatile organic compounds (VOC), and nitrogen oxides (NO_x). Biopower sulfur dioxide emissions are typically low because of the low amount of sulfur usually found in biomass. Actual amounts and the type of air emissions depend on several factors, including the type of biomass combusted, the furnace design, and operating conditions.

Life cycle assessment studies (3) have been conducted on various power generating options in order to better understand the environmental benefits and drawbacks of each technology. Material and energy balances were used to quantify the emissions, energy use, and resource consumption of each process required for the power plant to operate. These include feedstock procurement (mining coal, extracting natural gas, growing dedicated biomass, collecting residue biomass), transportation, manufacture of equipment and intermediate materials (e.g., fertilizers, limestone), construction of the power plant, decommissioning, and any necessary waste disposal.

The life cycle assessment studies have permitted the determination of where biomass power systems reduce the environmental burden associated with power generation. The key comparative results can be summarized as follows:

- ❖ The GWP of generating electricity using a dedicated energy crop in an IGCC system is 4.7% of that of an average U.S. coal system.
- ❖ Cofiring residue biomass at 15% by heat input reduces the greenhouse gas emissions and net energy consumption of the average coal system by 18% and 12%, respectively.

- The life cycle energy balances of the coal and natural gas systems are significantly lower than those of the biomass systems because of the consumption of non-renewable resources.

- ❖ Biomass systems produce very low levels of particulates, NO_x, and SO_x compared to the fossil systems.
- ❖ System methane emissions are negative when residue biomass is used because of avoided decomposition emissions.
- ❖ Biomass systems consume very small quantities of natural resources compared to the fossil systems.

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Biography

Dr. Bain has been at NREL since February 1990, and has extensive experience in the thermal conversion of biomass, municipal wastes, coal, and petroleum. He is the manager for NREL in-house research in the area of biomass thermochemical conversion; technical advisor to DOE on biomass demonstration projects; and coordinator of NREL efforts managing the DOE Small Modular Bio-power Initiative. He has been a member of the International Energy Agency Biomass Gasification Working Group for 12 years. He has published more than 60 papers in energy conversion and has 10 patents in coal conversion, heavy oil processing and bioconversion.

Rec’d Jan 20 2004

6. SENEGAL BIO MASS EXPLOITATION: AN ASSESSMENT OF APPLICABLE TECHNOLOGIES FOR RURAL DEVELOPMENT

Soungalo Sanoko, PhD, **Technical Director, SONACOS, Republic of Senegal, West Africa**

Abstract

This paper seeks to evaluate the latest technology options for utilizing feedstock from Senegal’s groundnut industry in a mix in with other government initiatives such as waste-to-energy programs. The paper will assess some of these technologies from the green power sector against local Senegal conditions. The implications for other ECOWAS (Economic Community of West African States) countries with similar rural supply challenges and other fuel source types are evaluated with recommendations.
Keywords: SMB- Small Modular Bio-power (SMB), C-PUP-Community Productive Use Platform, **NOVASEN-** Nouvelle Valorisation d’Arachide du Sénégal

Introduction

The UNDP report World energy assessment report reference. 1 is comprehensive in addressing the scope of energy options and there implications world wide but it’s importance is the focus it places on the 2 billion people on the planet with no access to electricity.

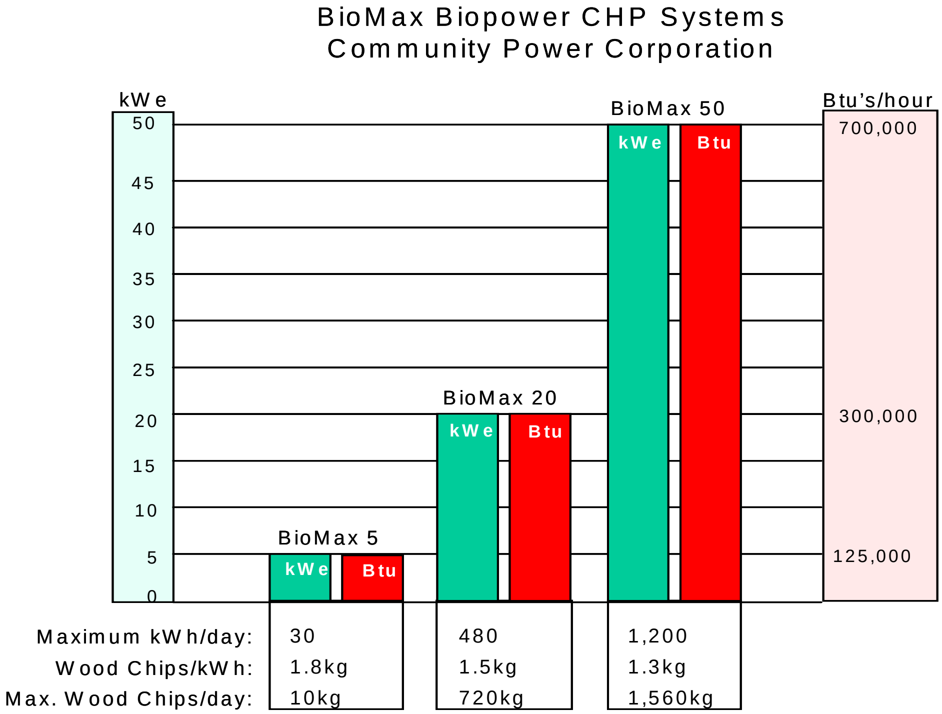
In fact, 2 billion people—one third of the world’s population—rely almost completely on traditional energy sources and so are not able to take advantage of the opportunities made possible by modern forms of energy (World Bank, 1996; WEC-FAO, 1999; UNDP, 1997). Ref.1 Moreover, most current energy generation and use are accompanied by environmental impacts at local, regional, and global levels that threaten human well being now and well into the future. In Agenda 21 the United Nations and its member states have strongly endorsed the goal of sustainable development, which implies meeting the needs of the present without compromising the ability of future generations to meet their needs (WCED, 1987, p. 8). The importance of energy as a tool for meeting this goal was acknowledged at every major United Nations conference in the 1990s, starting with the Rio Earth Summit (UN Conference on Environment and Development) in 1992.REF.4

This paper therefore attempts to illustrate partial solutions to produce sustainable electricity from Senegal’s groundnut industry and the benefits to rural communities in the immediate vicinity of processing facilities.Fig.1

Innovative Renewable Energy Technology for Rural Enterprise

The following excerpt from a recent study illustrates the reality of energy deficiencies and available opportunities:

With a groundnut production of about 1 million t per year, Senegal is one of the most important countries of the world. With 80 % of this production for export, Senegal is the world’s largest groundnut exporting country. Its major export products are groundnuts for eating, groundnut oil and groundnut pellets as a fodder, made from



groundnut cake. The town of Kaolack being the provincial capital of the Kaolack province, lies in the centre of the groundnut growing region and has two groundnut processing plants with a combined capacity of 250,000 t per year. One of these plants is NOVASEN. In 1999, it started production in newly installed plant in the industrial zone at Kaolack harbour. NOVASEN uses a modern press process, which yields 92 % of oil in one go from the groundnut kernel (conventional procedures have a maximum yield of 80 %; therefore, in a second stage another 10 to 15 % has to extracted from the groundnut cake, by chemical means). The new process has quite an increased energy efficiency, thus NOVASEN does not need to burn the groundnut shells to generate the energy needed for the plant, as in conventional groundnut processing. On account of this, the NOVASEN plant in Kaolack produces about 10 to 15.000 t of groundnut shells per year, which are, at present, is not used in other ways. NOVASEN intends to carbonize these groundnut shells in a modern retort and to use all of its by-products (flue gases, pyrolysis oil) as a source of energy in its groundnut processing plant. An industrial briquetting plant is expected to produce about 3,000 to 4,000 t high-quality biocoal per year for the local charcoalmarket at Kaolack or other urban centres in Senegal. At present, about 360.000 t charcoal are consumed each year in Senegal, which are produced locally in traditional earth kilns from Senegal's forest resource. According to official estimates, between 50,000 and 80,000 ha of forest cover are lost annually on account of charcoal production with goes in line with claiming agricultural land. Under this situation, the planned NOVASEN project does not only constitute a very effective rational use of energy measure in industry, but also an important contribution to the protection of natural resources in Senegal. In traditional charcoal kilns with only 17 % efficiency, some 18,000 t of wood would be needed to make 3,000 t of charcoal - this amount of wood could be saved every year through the planned NOVASEN carbonisation and briquetting plant. REF.

5.

Figure 1

The Bio-max System

An advanced small modular bio-power (SMB) system that may be very appropriate for Senegal and other ECOWAS countries has been developed by US-based Community Power corporation (CPC)1 for markets worldwide. The system is known as the *Community Productive Use Platform* (C-PUP), and produces thermal energy, shaft power, and electricity. The C-PUP incorporates a CPC BioMax bio-energy system. *BioMax* is the trade name used by Community Power Corp. for its small modular bio-power (SMB) systems that convert woody biomass residues to electricity, shaft power, and thermal energy. The C-PUP converts locally available biomass into useful mechanical, electrical, and thermal power that can be applied to a myriad of productive use applications. The heart of the CPUP is CPC's Gas Production Module (GPM) that converts coconut shells (and other dry woody biomass) to a product gas for delivery to a spark-ignited engine mounted on a power distribution platform. The gasifier converts biomass by low-oxygen thermal decomposition into a gas mixture that is primarily composed of hydrogen, carbon monoxide, methane, carbon dioxide, and water vapor. The platform can allocate shaft power as needed to various mechanical and electrical loads including motors and compressors.

The peak electrical output of the BioMax 15 unit in the CPUP is 15 kWe from the conversion of about 23 kg of coconut shells per hour. In addition, about 20 kW of thermal energy is available in the form of clean, hot air for drying crops and fish. Ref. 7

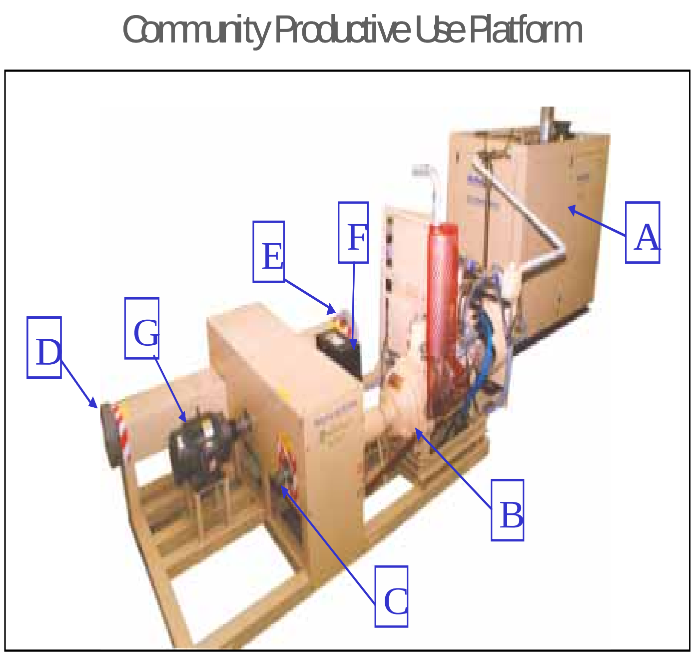


Figure 2. The SMB Community Productive Use Platform

The Gas Production Module (A) converts woody biomass to a fuel gas that is ignited in an engine (B) to turn a shaft. The shaft power is distributed to output (C) to run a small biomass fuel grinder (not shown); to outputs (D) and (E) for powering a variety of larger implements such as flour mills, rice mills, decorticators, composters, water pumps, etc. (not shown). Any combination of these mechanical outputs can be engaged, or disengaged simultaneously. If electrical power is needed, a 15 kW generator (F) can be engaged. If the Gas Production Module or engine are not available, motor (G) can be connected to a backup electrical power source to drive any combination of mechanical outputs (C, D and E). All rotating shafts, belts, pulleys, and heated surfaces are covered for worker safety.

Groundnut Shell Feedstock

Table 1

	BioMax 5	BioMax 20	BioMax 50
Max. kWh/day:	30-50	480	1,200
Shells/kWh (est.):	3.5kg	3kg	2.5kg
Max.Shells/day:	120-175kg	1,440kg	3,000kg

Conclusion

Senegal 's yield in excess of 10,000T (9,071,847kg) groundnut shell feedstock can produce very significant amount of on and off grid electricity per the kWh production yields shown in Table 1.

The secondary use of waste being looked at needs to be evaluated not just as a sources of available electricity supply but as prime movers that can drive 'strategic loads'. Strategic loads in this context implies clusters of strategic entities e.g.**]**. In turn those strategic entities as collective units themselves become 'Prime Movers' in that they have direct evolutionary impacts on society.

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Biography

Soungalo Sanoko PhD, Technical Director, SONACOS, Dakar, Senegal. Dr.Sanoko received the degrees of MS.EE and PhD from Moscow Energetics institute in 1979 and 1983 respectively. Specializing in Power Systems, Generation and Industrial Distribution Systems. His masters Thesis was on the development of a 4x 30 MW Gas and Fossil Fuel Oil Plant. His PhD thesis dealt with 'The Influence of asymmetrical conditions on Supply systems caused by disturbing load fluctuations.e.g arc furnaces and methods for their suppression. For the past twenty years Dr.Sanoko has served as the Chief Electrical Engineer at SONACOS, Senegal's prime export industry processing plants. Dr. Sanoko is currently the Technical Director at SONACOS and resides in DAKAR.

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7. ENERGY GENERATION THROUGH THE COMBUSTION OF MUNICIPAL SOLID WASTE

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Abstract

Recovering energy from our garbage, or (waste-to-energy) as it's called in the U.S., isn't a new idea but it has evolved over the years from the simple incineration of waste in an uncontrolled, environmentally unfriendly way to the controlled combustion of waste with energy recovery, materials recovery and sophisticated air pollution control equipment insuring that emissions are within U.S. and EU limits. The waste-to-energy industry has proven itself to be an environmentally friendly solution to the disposal of municipal solid waste and the production of energy. Recovering energy from the waste we throw away is still a good idea and Waste-to-Energy is now a clean, renewable, sustainable source of energy, and a common sense alternative to landfilling.

The Concept

Recovering energy from waste, or (waste-to-energy) as it's called in the U.S., isn't a new idea but it has evolved over the years from the simple incineration of waste in an uncontrolled, environmentally unfriendly way to the controlled combustion of waste with energy recovery, materials recovery and sophisticated air pollution control equipment insuring that emissions are within U.S. and EU limits. [1] This process took over 50 years of development and many improvements in design and technology, but the waste-to-energy industry has proven itself to be an environmentally friendly solution to the disposal of municipal solid waste and the production of energy. Modern WTE facilities reduce the volume of incoming municipal solid waste (MSW) by 90%-95% creating energy and jobs in the process and extending the life of landfills by generations. Many major metropolitan areas world-wide have facilities capable of processing 1,000, 2,000 and 3,000 tons of MSW a day with energy production in the form of steam and/or electricity.

Barlow Projects has come up with an innovative combustion system and facility design tailor made for those smaller communities with only 100 to 500 tons a day of waste. In some cases this means a collection of communities or districts pooling their waste and bringing it to a central location for processing. This may solve the landfill capacity problem for an entire region while simultaneously providing a predictable waste disposal fee, energy and the creation of new jobs.

Technical Challenges

Municipal solid waste is a difficult fuel to burn. Its non-homogenous nature complicates fuel handling and fuel feeding as well as ash handling. Controlling furnace temperature is critical to managing this process. Additionally, the fuel stream requires sophisticated air pollution control and emissions monitoring equipment to deal with acid gases and metals emissions that result from MSW combustion. Steam generation is accomplished with waterwall or waste heat boilers. In both cases, tube corrosion is an issue due to high combustion temperatures and elevated levels of sulfur oxides and hydrogen chloride. Limiting tube metal temperatures is key to avoiding high temperature corrosion, particularly in superheater tubes. Air pollution control technologies for

MSW combustion have advanced significantly in the last two decades. Stringent emissions standards for a variety of constituents mandate effective control and the industry has risen to these challenges. Most facilities are now equipped with scrubbers, activated carbon injection systems, bag houses and in some cases SNCR systems, but CO must be controlled at the front end by carefully monitoring and controlling the combustion process. Additionally, capital and operating costs must be minimized especially for smaller scale projects. Employing an "all-dry" reagent system provides excellent removal efficiencies without a sizeable increase in costs.

Biomass and Renewable Status

As far as the technology has come, one of the great challenges to WTE today is its status as a renewable fuel. Like any power plant, WTE facilities don't get built unless the economics work. WTE facilities must balance the revenue from accepting the waste, (referred to as the tipping fee) and the price of the energy it is able to sell in the form of steam or electricity, with the debt service and operational expenses of the facility. Because electricity rates are so low in many parts of the country, getting a 1.5 cent per KWh credit for electricity sold can make the difference between the project getting built or not. The DOE has classified MSW as Biomass for years[2] but, although qualifying as Biomass is generally the standard for gaining acceptance as Renewable, many environmental activists object to this notion and are having some success preventing these projects from benefiting from state or federal tax credits. The Energy Bill in Conference Committee as of the writing of this paper currently has sections specifically dealing with energy generated from Biomass, Municipal Solid Waste and a national Renewable Portfolio Standard (RPS).[3] An RPS would require federal agencies to buy a certain percentage of their power from renewable technologies. A tax credit for power generated from new WTE facilities would, perhaps, provide the incentive needed to re-ignite the WTE industry and get more of these facilities built. An RPS would insure there was a client to purchase the power generated by these facilities. Additionally, non-governmental organizations like "Green-E" have set up programs to certify that certain types of energy are "green". Some utilities use this unofficial certification as their standard for marketing that energy as part of their green portfolio. Unfortunately, "Green-E" does not use the same guidelines as the US DOE for deciding what is renewable or "green" and what isn't and WTE is not currently eligible for their certification.

Public Acceptance

Despite the fact that the EPA recently released a report praising the WTE industry as being a "clean, reliable, renewable source of energy",[4] many still have a negative perception of waste-to-energy. This may be due, in part, to the fact that at one time there were over 700 incinerators operating in the United States burning trash without energy recovery or air pollution control equipment.[5] The majority of those chose to shut down when faced with installing the expensive air pollution control equipment mandated by the Clean Air Act, but not enough time has passed to erase these perceptions. Fortunately, the new air pollution control equipment being used is up to the task and modern facilities are meeting new stringent EPA emissions requirements. Additionally, EPA has done exhaustive studies to determine the safe exposure levels of the constituents that could potentially be emitted from a WTE facility and independent studies have determined that the actual amounts emitted do not present a significant threat to human health.[6] There are WTE facilities located in the middle of small communities, in large cities, on college campuses and near hospitals. Those who tour WTE facilities are often amazed that odors are minimal outside the facility and that there is no smoke coming out of the stack. It is those environmentalists that cling to old data and unsound concepts about what could be done with the waste instead that present the challenge to public acceptance. Concepts like "zero waste" which advocate unrealistic recycling levels.

And what about recycling? Can't we just recycle everything so that there isn't anything left for landfilling or incineration? Don't WTE facilities compete with recycling and burn up valuable resources? With all the talk about recycling and the progress that's been made toward source reduction, composting and other forms of diversion, American's still send about 130 million tons of garbage to landfills every year.[7] Even the most efficient recycling programs are only diverting 50% of the waste stream leaving the other 50% to be managed in some other way. The bottom line is that some forms of waste are just not suitable for recycling because it isn't economical to do so. By removing those items from the waste stream that can and should be recycled you improve the quality of the fuel and improve the efficiency of the combustion system. This does not mean that we shouldn't keep trying to manufacture goods in such a way that makes them more amenable to recycling and that we shouldn't continue to work towards higher diversion rates, but at best, only a portion of the problem is addressed. As a species, we are currently entombing millions of tons of fuel in the earth in the form of refuse that could be used to generate heat or electricity through the WTE process. This fuel has a heating value approaching ½ that of coal.[8] Why wouldn't we take advantage of that?

Potential

A Modern 500 Ton/Day Resource Recovery facility will generate approximately 10 MW's of energy. Currently only about 15% of America's municipal solid waste is combusted in 98 WTE facilities.[9] If additional WTE facilities were built to combust the waste we are currently landfilling, the potential for energy generation in America alone is approximately 8700 Megawatts of what can legitimately be called renewable, sustainable energy. The demand overseas is even greater as many European countries are running out of landfill space and outlawing landfilling altogether. Outside the U.S. there have been over 60 new WTE plants built since 1996.[10] Small island nations are also ripe for WTE projects because once their landfill is full, they have no other option than to ship it off island at great cost. Even in the United States, the landfills in rural areas are filling up, leaving many communities with no other option than to long-haul their waste to one of the many mega-landfills built to serve the big cities. This is not only expensive but contributes to the ever growing number of semi-trailers on our roadways. Semi-trailers that are usually traveling empty one way.

Conclusions

The bottom line is that recovering energy from the waste we throw away is still a good idea and, despite some misconceptions, Waste-to-Energy is now a clean, renewable, sustainable source of energy, and a common sense alternative to landfilling. U.S. counties, municipalities, solid waste authorities and energy companies should re-consider this alternative to burying this fuel in a hole.

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Biography:

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