California Integrated Waste Management Board
Session Summary:
Emerging Technology Forum
17-18 April 2006
Thermal Technologies—Session 1B

The purpose of this session was to provide some technical background and detail to the different types of non-combustion thermal conversion technology processes.

Brief summary of presentation by Bryan M. Jenkins & Robert B. Williams, University of California, Davis provided by presenter

Bryan Jenkins is a professor at University of California, Davis, teaching graduate and undergraduate courses in energy systems and power and energy conservation. He is also the Executive Director of the California Biomass Collaborative, a joint industry, governmental, environmental, and academic coordinating organization for biomass technology and policy in California.

Robert Williams is a Research Engineer in the Department of Biological and Agricultural Engineering at University of California, Davis. He is also a staff member for the California Biomass Collaborative. Mr. Williams' presentation was entitled, "Resource Potential of California Landfill Stream (and some options to pursue).

There are three principal pathways for conversion of biomass and waste. These pathways are thermochemical conversion, bioconversion, and physicochemical conversion. These pathways can yield energy in the form of heat and electricity, alternative fuels, and products. Thermochemical conversion includes processes such as pyrolysis, gasification, and combustion. These processes can use a variety a feedstocks and produce a number of fuels including methanol, ethanol, liquified biomethane, biodiesel, synthesis gas, and hydrogen.

Worldwide, waste-to-energy combustion is used to process an estimated 150 million tons per year of MSW in 600 WTE facilities. Over 1 billion tons per year is landfilled. Since 1995, 164 new WTE facilities have been constructed but none in the U.S. There are a number of perceptions/concerns with incineration of MSW including competition with reduction, reuse, and recycling; dioxin emissions; and mercury emissions. Maximum available control technology has reduced dioxin emissions by 99% and mercury emissions have lowered by approximately 90%.

Gasification is the conversion of solids or liquids to fuel or synthesis gas through gas-forming reactions. Pyrolysis is similar to gasification but without the addition of air or oxygen. Pyrolysis can be optimized for the production of fuel liquids (pyrolysis oils) with fewer gas products. Pyrolysis oils can be used for liquid fuels, chemicals, adhesives, and other products. Plasma arc systems use an electric arc for combustion, pyrolysis, gasification, and metal processing. Power consumption for plasma arc ranges from 200-400 kWh/ton of feedstock. Gasification can be classified by reactor type (fixed/moving bed, fluidized bed, entrained bed) or reactor media (air, oxygen, steam, CO_2, hydrogen). There are a number of reactions that yield a number of gases in different percentages including carbon monoxide, nitrogen, methane, and hydrogen.

Gasification has a number of advantages including more versatile application of fuel gas for power generation and chemical synthesis, potential for higher conversion efficiency, lower temperatures than direct combustion, lower volume of gas needing treatment, and power generation can occur at smaller scale than direct combustion.

There are a number of constraints with gasification as well. These include the need for gas cleaning, generation of char, limited scale, and need for feedstock drying.

Development of gasification has occurred for 30 years with about 20 processes having been investigated and tested at varying capacities. Early designs did not envision such things as feedstock separation and heterogeneity of feedstock. Others issues not envisioned included too rapid a scale-up, lack of regard for chemical complexity, and not adequately addressing gas cleanup.

Combustion remains the predominant thermal technology for MSW conversion. Gasification and pyrolysis are now at commercial scale but industry is still emerging. Improved environmental data on operating systems is needed and comprehensive environmental or lifecycle assessments should be completed.

Brief summary of presentation by William Welch provided by presenter

William Welch is a Principal Development Engineer at the University of California, Riverside College of Engineering, Center for Environmental Research and Technology (CE-CERT).

Thermochemical Conversion Technologies – Gas Cleanup

Thermochemical conversion is characterized by higher temperatures and conversion rates than most other processes. Thermochemical conversion includes a continuum of processes ranging from thermal decomposition in a primarily non-reactive environment (commonly called pyrolysis) to decomposition in a chemically reactive environment (usually called gasification if the products are primarily fuel gases or complete combustion if the products are fully oxidized). Pyrolysis can be considered an incomplete gasification process, in which a mixture of gaseous, liquid and solid products is produced, each of which may have some immediate use to sustain the process. The characteristics of each of these processes can also vary depending on the oxidizing or reducing media, process temperature and process pressure.

Gasification of solids with subsequent combustion of the gasification-derived fuel gases generates the same categories of products as direct combustion of solids, but pollution control and conversion efficiencies may be improved. Alternatively, the produced synthesis gases can be used directly for liquid fuel or chemical synthesis, eliminating or delaying the combustion process and the emission of resulting effluent.

Pyrolysis and combustion of pyrolysis-derived fuel liquids and gases also produce the same categories of end products as direct combustion of solids. Like gasification, their pollution control and conversion efficiencies may be improved. Where fuel liquids are produced, the eventual emission of combustion products may be considerably displaced from the source of fuel production (e.g., vehicle emissions). Non-combustion thermochemical conversion differs from incineration in two key respects:

1) The desired product gases in thermochemical conversion are low-molecular weight hydrocarbons, carbon monoxide, and/or hydrogen. Incineration involves complete combustion to carbon dioxide and water.

2) The volume of gas produced by thermochemical conversion per ton of material processed is much less than incineration (typically 10%). The lower volume makes gas cleanup/air pollution control far easier and less costly than that required for incineration.

Emissions from thermochemical conversion to energy processes can include air pollutants such as oxides of nitrogen and sulfur (NOx and SOx), hydrocarbons,

carbon monoxide (CO), particulate matter (PM), volatile heavy metals, greenhouse gas emissions such as CO2, and dioxins/furans.

NOx and hydrocarbons are precursors to photochemical smog. Exposure to PM, CO, and toxic emissions has been associated with a number of acute and chronic health effects.
Dioxins and furans are of particular concern in terms of potential environmental consequences. These compounds are formed under high temperatures when chlorine and complex mixtures containing carbon are present, and they can be found in the gas and liquid phases. However, existing data from facilities in Japan and Europe indicate that thermochemical conversion technologies can operate within constraints established by their local regulatory agencies. During the past decade, considerable technological progress in emissions controls has occurred that can be directly applied to conversion technologies.

This is corroborated by data from the U.S. Environmental Protection Agency (U.S.EPA) showing more than a 99 percent reduction in the release of dioxins and more than 90 percent reduction in the release of heavy metals such as lead and mercury from MSW incinerators. Although this data is from MSW incinerators, these factors indicate that it is very likely that conversion technologies with the most advanced environmental controls would be able to meet regulatory requirements in California.