California Integrated Waste Management Board
Session Summary:
Emerging Technology Forum
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Session 1A Biological Technologies

Summary of presentation by Dr. Melvin Finstein provided by presenter

Dr. Finstein is a Professor Emeritus of New Jersey State University and former professor in the Department of Environmental Sciences at Rutgers University, and Represents ArrowBio Ecology, Ltd. in the United States.

The ArrowBio Process

Power Point Panel 1. This morning Colonel Zadik introduced the ArrowBio process and described its unusual effectiveness in terms of recovering recyclables, generating energy, and "environmental friendliness." Now, I wish to explain the underlying logic of the system: That is, the science and technology that accounts for this effectiveness. To do this we must dig down to certain general fundamentals, and to describe their particular application in the ArrowBio process.

Panel 2. All anaerobic digestion technologies have three major functions.

2a. The usual term for operations prior to digestion is "pre-processing." But the term pre- implies operations unconnected to the central action – that of digestion per se. That is, a one-way arrow →. But in ArrowBio the separation and preparation functions are inseparable from the digestion functions. The system is highly integrated. Separation for materials recovery (recyclables) and the preparation of the organic feed for digestion are inseparably linked, as part of overall system integration. Thus, we prefer the term sep/prep. The return dashed arrow (**<**- - -) applies only to ArrowBio (the only integrated technology I know of), and hints at the thoroughgoing system integration.

2b. If a facility is termed "anaerobic digestion," then its centerpiece has to be -- *anaerobic digestion*. That is, the microbial transformation of biodegradable organic matter to methane. So we will spend some time here.

A characteristic of MSW often neglected is its moisture content, nominally around 30%. That is, a ton of MSW contains around 70 gallons of waster. Anaerobic digestion liberates some of the moisture content - to the extent of the intensity of the digestion. In ArrowBio, some of the freed liquid water is returned as makeup water to the sep/prep vat. As noted before, this return arrow represents the nuts and bolts of system integration.

2c. The amount of digestate produced in ArrowBio is relatively small and well stabilized. Both characteristics stem from sep/prep in water (2a) and *advanced* anaerobic digestion (We'll revisit 2c. later and point out the regulatory significance of stabilization.)

Panel 3. The microbiological work (transformation organics to biogas) is not done in one fell swoop. Rather, it is done through the action of different populations (types) of microbes; each population performs a specialized biochemical reaction. One organism's metabolic product is the next one's substrate.. [Transitory intermediates include compounds such as acetic acid and ethanol (alcohol); however, the system is

naturally poised to go all the way to completion - CH_4 and CO_2.] The consortium of the individual microbial types makes up a microbial community.

Important question: Is that community in an organized, or a disorganized, state?

Panel 4. If you were to "Google" UASB (Upflow Anaerobic Sludge Blanket digestion) you'd find the following:

4a. UASB is an *advanced* form of anaerobic digestion developed in the 1980's, now widely applied in the treatment of strong wastewaters (COD 10,000 – 20,000 mg/L). UASB is preferred over conventional anaerobic digestion for its more rapid and complete transformation of organics to methane, the high quality of its digestate, and other desirable performance characteristics.

4b. The genius of UASB digestion is in how it leads to the self-organization of the microbial sequence, analogous to a bucket brigade. With UASB there is a straight-line bucket brigade, with efficient sequential transferal of compounds from specialist to specialist. In conventional high solids digestion the bucket brigade in a chaotic jumble. This is a crude representation of events, but it is a valid representation.

4c. The causation: UASB: SRT>>>HRT (80/1); Conventional: SRT = HRT (14/14).

4d. Google, if asked, would also tell you that UASB is intolerant of particulate organic matter; UASB likes its organics in dissolved form, though can tolerate fine particulates. If MSW is anything, it is particulate! So, how does ArrowBio get around UASB's finicky ness, to reap the benefits of UASB? Let's keep Panel 4 in mind, while revisiting Panel 2.

Panel 2. revisited. In the course of gravitational separation in water (recovery of recyclables), the organics get dissolved or sufficiently size-reduced in preparation for UASB digestion. In effect, the organics in MSW are converted to strong wastewater – thereby taking advantage of UASB's many desirable performance characteristics. The centerpiece of the system thus functions with great efficiency, and this radiates out to the other functions.

One other point about the digestate. It is well stabilized – because SRT>>>HRT. Therefore, it's potential to vent Volatile Organic Compounds (VOCs), ammonia, or generate nitrous oxides during any polishing step (composting) is extremely small. The significance of this is that the South Coast Air Quality Management District is leading the way toward strict regulation of composting based on gaseous emissions. This is a significant switch in how composting is viewed, and ArrowBio is well disposed to accommodate that switch.

Panel 5. Overall, ArrowBio can be seen as a "refinery" of MSW. The products are secondary recyclables, energy in considerable excess of that needed to run the plant, and like other refineries, or factories, some biologically inert waste needing to be landfilled.

Panels 6 and 7. We've covered a lot of basic stuff. The rest is commentary.

Summary of presentation by Gary Yowell provided by presenter

Gary Yowell is employee of the California Energy Commission specializing in transportation.

Potential Renewable Transportation Fuels for California

The California Energy Commission (Commission) is the state's primary energy policy agency. California Public Resources Code (PRC 25000.5) directs the Commission to evaluate and exploit all practical and cost-effective conservation and improvements in the efficiency of energy used in California. This directive compels the evaluation of the competitiveness of transportation energy markets based on the least environmental and economic cost.

The prerequisites for a sustainable transportation renewable fuel include the following properties; liquid at room temperature and pressure, compatible with existing petroleum-based infrastructure, compatible with old and future engines and vehicles, economically competitive with petroleum based fuels.

Doomsday accounts that the world is running out of oil or energy thus compelling the need to move to more exotic or non liquid fuels are not well supported when one evaluates the remaining world supply of energy. Today there are world-scale plants that convert unconventional resources (tar sands, coal, and natural gas) into liquid transportation fuels. World energy supplies are abundant but there are no guarantees that low and stable energy prices will be maintained. Renewable energy is a prudent and now perhaps even competitive energy source worth exploiting.

The future vehicles and fuels are not envisioned to change radically from today's vehicles. However, the feed source used to make the "gasoline or diesel" fuel may change significantly. Today there are several renewable diesel and gasoline fuel processes reaching sufficient maturity to move into commercial scale especially if crude oil prices are sustained above $50 and $70 dollars a barrel. The Commission and California Air Resources Board are evaluating all renewable options and are preparing a plan to use greater amounts of all practical alternative fuel options. Liquid renewable fuels that are compatible with the existing transportation fuel infrastructure and vehicles are strong viable options. You are welcome to help by following and participating in the Commissions AB 1007 Alternative Fuel plant development at, http://www.energy.ca.gov/ab1007/index.html.

Summary of presentation by Dr. Bin Yang provided by presenter
Dr. Yang is an associate researcher at the University of California, Riverside Center for Environmental Research and Technology (CE-CERT).

Cellulosic Ethanol for Sustainable Transportation

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Petroleum provides the single largest energy source in the United States, and while supply and demand are nearly balanced for other options, we now import almost two thirds of our petroleum, the highest percentage ever. This extremely high dependence on petroleum presents important environmental, economic, and

strategic issues. Furthermore, about two thirds of petroleum is used for transportation which in turn is almost totally dependent on oil. On the other hand, cellulosic biomass materials such as agricultural and forestry residues, portions of municipal solid waste, and grassy and woody crops are inexpensive and abundant domestically and provide a uniquely sustainable and low cost approach to solar energy collection and storage. The challenge is to convert this low cost solid into fuels that better fit into our infrastructure, and breakdown of a major portion of biomass to fermentation sugars for biological conversion to fuel ethanol as well as a variety of chemicals and materials is particularly promising. The energy balance of such processes is very favorable, and the net release of carbon dioxide that could lead to global climate change is very low.

Over the last 20 years, these and other technical advances have dropped the cost of making cellulosic ethanol from more than $4.00/gallon to only about $1.20/gallon for biomass costing $42 per ton. At this cost, ethanol is competitive for blending with gasoline, and several companies are working to build the first commercial cellulosic ethanol plants. Although these initial facilities will be relatively small to capitalize on niche opportunities and manage risk, economies of scale appear to favor larger plants even though delivered biomass costs increase with demand, and coproduction of ethanol, chemicals, and electric power can provide important synergies. Advances in overcoming the recalcitrance of cellulosics are still needed to achieve competitive costs without subsidies, and strategic opportunities have been defined to reduce the cost of cellulosic ethanol sufficiently to become a low-cost pure liquid transportation fuel. Furthermore, it has been shown that development of advanced processes could reduce the cost of ethanol production to less than $0.60/gallon at the plant gate. Our research is directed at better understanding the key steps involved in sugar release with the goal of developing a stronger foundation that accelerates commercialization and facilitates advancing the technology to significantly reduce costs.