Biosolids Technology Forum

September 17, 2008, Richmond Virginia

Summary Report

Submitted by Caroline G. Hemenway, President, Hemenway Inc., chemenway@hemenwayinc.com

It is early morning, hours before sunrise, and the first of that day's 60 trucks pull up to the loading dock at the District of Columbia Water and Sewer Authority's Blue Plains Advanced Wastewater Treatment Plant. They draw up under the silos and cranes and fill up with material more valuable than gold to hundreds of farmers in Virginia: biosolids. These growers rely on this organic fertilizer for vigorous crops, improved production, healthy livestock, and savings worth $300 an acre. Many could not survive without this reliable, safe, and recycled alternative to costly chemical fertilizers.

At the field, spreaders and tillers wait for daylight to incorporate it into the land; monitors are checking permits, measuring buffers, and gathering soil samples to make sure nutrient limits are not exceeded; and flags mark the boundaries. In a few weeks, the fields are lush with feedstock corn, soybeans, hay, mullet, sod, and other products that keep Virginia's economy going. At the land-applier's office, there is a waiting list for biosolids. Back at the plant, the agency is preparing for a third-party audit after updating its biosolids management plan to reflect best management practices.

Opening Session

Rhonda Bowen, vice-chair of the Virginia Biosolids Council, and Chris Peot, PE, DC-WASA'S Biosolids Division manager opened the general session of the Biosolids Technology Forum in Richmond, attended by more than 85 members of the public, government agencies, biosolids-related organizations, and others. The forum, an open and free event sponsored by the Virginia Biosolids Council, was in response to a mandate by the Virginia General Assembly to the Department of Environmental Quality's Biosolids Expert Panel that it look at various aspects of biosolids, including alternative technologies.

Mr. Peot noted that biosolids land application provides well-established benefits to the agricultural community, to urban centers that rely on its products, and to the global ecology because of carbon sequestration. This forum, he said, offered an opportunity to present options for biosolids production and use, to ask questions about their reliability and costs, and to explore whether they are worth piloting on a large scale.

Following is a summary of presentation highlights, with the title of the presentations, brief descriptions of the presenting organization and speakers, and their websites.

Environmental Credit Corporation. *Integrating Carbon Sequestration Models into Biosolids Management Decisions*, Scott Subler, PhD. ECC creates environmental assets from greenhouse gas (GHG) reduction projects by implementing long-term projects that reduce GHGs so these projects can become reliable sources of carbon credits. ECC has agricultural, waste management, and renewable energy projects in the US, Brazil, and Mexico. Ithaca, NY, www.envcc.com

- Of the three largest current greenhouse gas sources – carbon dioxide, methane, and nitrous oxide – the latter has the greatest potential for global warming and deserves the most attention. Sources of N_2O include transportation, industry, livestock and feed, and biomass burning.

- In the US, wastewater treatment contributes 32 million metric tons of CO_2 equivalents, as methane and nitrous oxide, or 2.8% of the total. Agriculture and forestry together account for more than 30%. These sectors are among the unregulated GHG sectors, compared with "capped" sectors like industry and energy, which have imposed GHG emissions limits.
- These unregulated sectors can participate in carbon offset programs, allowing them to voluntarily reduce their carbon emissions, create certified "credits," and trade them for money from regulated and other sectors to give the latter time to come into compliance with standards or regulatory limits. Only a subset of offset credits can be used for trading; you can't get offset credits for business-as-usual practices.
- Existing "cap-and-trade" systems include the Chicago Climate Exchange and the Kyoto Protocol. A federal bill and some 28 states and Puerto Rico have developed or are developing plans to reduce net GHG emissions. Regional GHG activities exist in California and the Northeast / Mid-Atlantic regions. GHG standards have been created.
- Wastewater treatment plants can participate in GHG initiatives by adopting practices that reduce emissions. There is a natural alignment between agricultural coalitions and waste management corporations. Food waste can go to lagoons or even landfills where methane can be captured. Biosolids on farm fields sequester soil carbon and displaces nitrogen fertilizers. Anaerobic treatment captures methane for energy use. Land like afforested areas and mines is being restored using biosolids, also sequestering carbon.
- Example: ECC's lagoon cover program covers lagoons at farm sites, then captures the gas, destroys the methane, and thus reduces carbon emissions. ECC owns, manages, and insures the lagoons and farmers receive payments based on these offsets.
- Potential for biosolids: 8 million dry tons x 60% currently not land applied = 4.8 million tons / yr; @ 0.2 – 0.5 metric tons CO_2e per ton, = ~1.0 – 2.4 million tons CO_2e; @ $5.00 per metric dry ton CO_2e = $5 – $12 million annually. A ballpark calculation of biosolids credit value: $1.50 per wet ton.
- US cropland overall potential: ~ 433 million acres @ 2 metric tons CO_2e / acre = 1.6 billion tons per year CO_2 sequestration potential overall. Eight million tons of biosolids could contribute to 1.6 million tons of CO_2 sequestration / year (at above rates)
- The fate of the carbon market hinges on future legislation and incentives. Carbon trading is one of the fastest growing markets in the world. Over the last five years, it went from nearly $0 to $60 billion and by 2015 it could top $1 trillion a year, especially if the US participates in earnest.

Water Environment Research Foundation (WERF). *Research and Innovative Technology – An Overview*; Lauren Fillmore, PE (lfillmore@werf.org). Dedicated to water quality research since 1989. Alexandria, VA, www.werf.org

- WERF has conducted nearly 400 research projects, valued at more than $85 million. Research has led to more than a billion dollars in industry savings; regulations based on scientifically defensible facts, leading to greater protection of human health and the environment; improvements in testing, processing, treatment, and management of wastewater and stormwater; more effective methods for maintaining or rehabilitating aging infrastructure; additional intellectual resources to help subscribers meet their public obligations.

- After consulting with subscribers, WERF chose several issues for concentrated research:
  - Biosolids – Providing pathogen risk assessment and risk communication methodologies to support evaluations of biosolids land application practices.
  - Climate change – Evaluating the likely effects of climate change on wastewater services and assessing mitigation and adaptation options. Top research issues: Provide a solid understanding of the likely impacts of climate change including impacts on water quality, wastewater services and costs; provide planning tools and operational management to cost-effectively mitigate and adapt to climate change.
  - Operations optimization – including energy management, resource recovery, and solids volume reduction with the following longterm goals: Facilitate breakthroughs of innovative and emerging technologies; improve resource recovery, including energy; reduce environmental footprint; minimize energy use and shift from energy consumption to a renewable energy production. New projects: Case study demo on energy efficiency best practices; life-cycle tool for green energy options; assessment of carbon footprint of biosolids management options; evaluate sludge gasification/syngas technologies. More than $2M in new research funds approved.

- The State of the Science (SOS) Report, developed with the Global Water Research Coalition (GWRC) and published in February 2008, provided a status of knowledge on energy and resource recovery from sludge and identified research needs and knowledge gaps.

- National average for energy use in wastewater = 1200 kWh/MG, or approximately 0.62 kWh/capita/day. Source: Global Energy Partners. The US uses only 1/3 of the current production of biogas for energy. Wastewater treatment facilities are major energy users. These statistics raise concerns in a world facing global warming but also present opportunity.

WWTP with Anaerobic Digester	Potential Electric Capacity (kW) per day
Alexandria Sanitation Authority	818
Arlington County Pollution Control Plant	498
Northside/Southside STP Danville	357
Martinsville STP	119
Rockingham	167
Richmond STP	1323
Falling Creek STP Chesterfield	167
So. Central Regional STP Petersburg	444
Moores Creek STP Charlottesville	230
Hopewell STP	749
James River WRCF, HRSD	311
York River WRCF, HRSD	148
Army Base WPCF, HRSD	315
Virginia Initiative Plant, HRSD	623
Nasemond WPCF	378
Total Daily Electric Generating/ Energy Demand Reduction	6,306
Source: USEPA Combined Heat and Power Partnership. April 2007. Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities EPA-430-R-07-003	Source: USEPA Combined Heat and Power Partnership. April 2007. Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities EPA-430-R-07-003

- The SoS report looked at new sludge processes relative to recovery of resources such as phosphorus and nitrogen or to be reused as a building material. Various volatile acids (i.e. formic acid) with industrial uses, can be produced from sludge. Many of these technologies are very new, emerging technologies with little or no full-scale applications, but have potential.

- Emerging energy recovery processes:
  - Sludge to biogas (MH_4) (anaerobic digestions, thermal hydrolysis, cell destruction)
  - Sludge to syngas ($CO+H_2$) (gasification, incineration)
  - Sludge to oil (pryolysis, hydrothermal)
  - Sludge to liquid

- Emerging sludge resource recovery processes:
  - Phosphorus recovery (chemical, crystallization)
  - Building materials (thermal solidification, incineration)
  - Nitrogen recovery (Chemio-process)
  - Volatile acid production (microbial fermentation, hydrothermal wet air oxidation)

- Case studies reviewed in the SoS report included two each from The Netherlands, UK, and US, including GlassPack vitrification, Cambi thermal hydrolysis pretreatment, and combined heat and power (CHP) processes. Recommendations from the SoS report:
  - Apply a new framework for cradle-to-grave (cradle-to-cradle) optimization for overall net environmental benefits
  - Promote recovery of energy, elements and water
  - Agree upon standard metrics and calculations for carbon footprint, carbon offsets, greenhouse gases, etc.

- Other WERF initiatives:
  - The life-cycle assessment manager for energy recovery (LCAMER) tool, a spreadsheet that enables users to assess the life-cycle costs and benefits of modifying anaerobic digesters to enhance biogas production for heat recovery and energy co-generation.
  - A resource recovery project on co-digestion of organic waste with wastewater solids.
  - A benchmarking demonstration project at the Strass WWTF in Austria. Strass is one of a few 100% sustainable WWTPS, producing more energy than it consumes.
  - A long-term (2040) energy recovery project on nitrifying fuel cells for sustainable wastewater treatment
  - Energy management research projects in New York and Wisconsin
  - A sustainability best practices technology roadmap for WWTPS.

Virginia Department of Environmental Quality. *Virginia's Perspective*; Jeff Corbin, Assistant Secretary of Natural Resources; also worked for Chesapeake Bay Foundation and serves as staff for the Biosolids Expert Panel. Appointed by Governor Tim Kaine to help formulate environmental policy in Virginia. Richmond, VA, www.deq.state.va.us

- This is an opportune time to look at several options related to biosolids use. There is no silver bullet, and many opportunities. DEQ is revising regulations for land application. The governor has formed a commission on climate change to come up with recommendations on reducing environmental impacts. The Biosolids Expert Panel is charged with reporting to DEQ before the end of the year.

- Every year there are several pieces of legislation at the state level that deal with biosolids, except last year, when the legislature created the Biosolids Expert Panel to address biosolids issues. Most of the bills have a few vocal, educated constituents. The question not being asked, however, is "If not land application, then what?"
- There used to be three ways to get rid of solids: burn, bury, or land apply. There is a need to look at alternative technologies that have the capacity for beneficial biosolids use, exploring whether they are available, what the capital and operation costs are, the relative environmental and human health impacts, their public acceptability, and what institutional and financial alternatives there are.
- Interest from legislators means there is potential for money to implement some of these. Costs are critical! Can we put these on the ground in Virginia? Public acceptability is a key consideration.

Afternoon Session 1: Innovative Technology

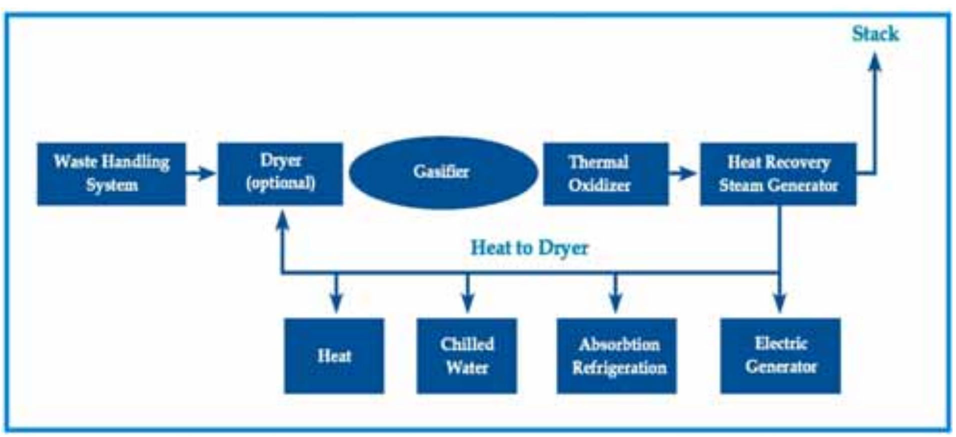
MaxWest Environmental Systems Inc. *Biosolids Management and Energy Generation Through Gasification*; Richard Heien, President (rheien@MaxWestEnergy.com). MaxWest designs, builds, owns, and operates waste-to-energy gasification facilities. Houston, TX, www.maxwestenergy.com

- Gasification converts energy contained in biomass or biosolids into a combustible gas in an oxygen-starved environment. It is a modern adaptation of a technology that is more than 200 years old. It provides renewable "green" energy systems for wastewater treatment industry outputs, wood wastes, agriculture (animal wastes, crop residue), municipal solid waste, industrial wastes.

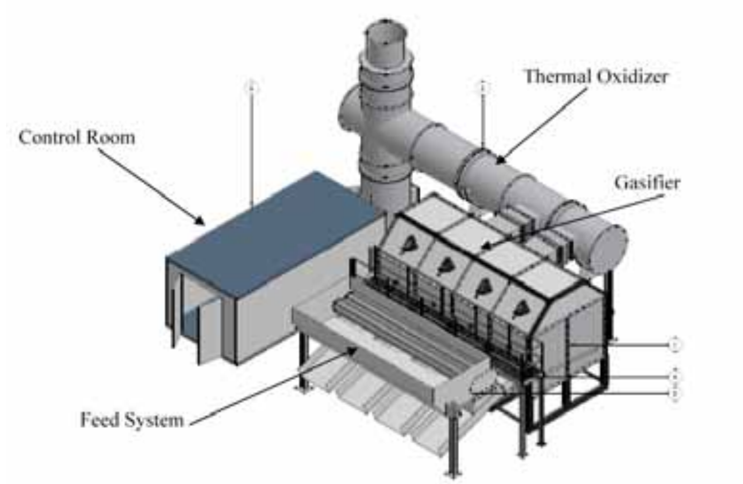
- Gasification produces renewable green "Syngas" (CO, H2, CH4) energy, and inert, inorganic residual ash. It produces minimal air emissions and little water, which can be returned to treatment plant. The high temperatures eliminate pathogens.

- The MaxWest gasification/thermal oxidation process systems are located at the customer's site and integrated into existing operations to lower costs. Each project is engineered for specific customer requirements.

- The systems are automated (locally and via SCADA), modular, and scalable. The process dynamics and products vary considerably depending upon the type of feeds. The system can take digested biosolids, FOG, screenings, and grit. It is continuous and not batch-processing. There is no need for a complete shutdown for maintenance. It can use methane from anaerobic systems (digester, landfill, etc.).



- Economic benefits include reduced cost of management and minimized cost volatility.
- Process flow: Waste is delivered to the gasifier via hydraulic rams, one per cell. Ceramic-lined primary gasification chambers (1–4) handle up to 28 $x10^6$ Btu/hr and produce syngas. Hot exhaust gases are fed into a heat recovery steam generator to produce steam that can be used to generate electricity and provide thermal heat
- The system can handle 400 tons per day with 3 MW power. Ash is 2% inert. May be used like mulch, with nutrient value. Typical cost per unit: $12M cash on cash. Typically needs to go to 60-65% moisture. Belt press isn't enough, so need dryer. Could blend with other materials so no drier may be needed.

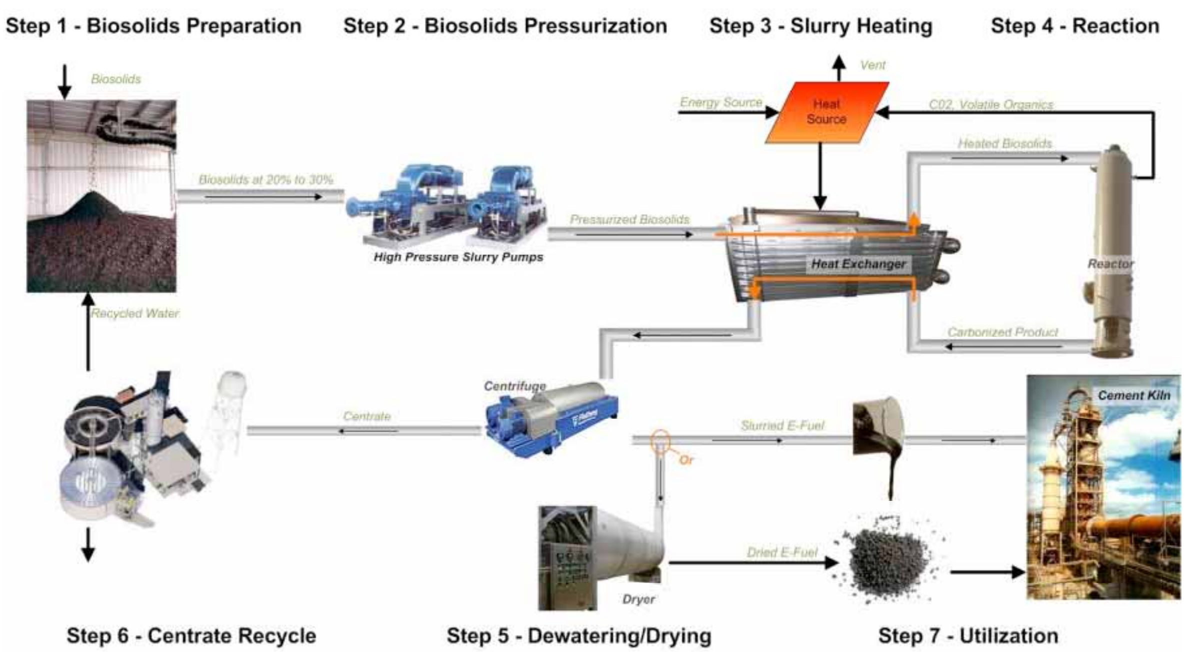


Westwood Model 144 Gasifier Section

- MaxWest will finance, build, own and operate (BOO) the gasification system, with no "upfront" capital costs; assume responsibility for design, permitting, financing, construction and operation; contract to receive a waste stream for a 15-year period for a fixed price per ton; lease land for the facilities from the customer for installing the gasification facilities; and deliver electric power and/or other commodities to the host or a third-party via PPA.
- 3rd-generation commercial gasifier installations completed: Six wood-fired systems in Canada and one chicken litter system is in West Virginia. Four wastewater sludge operations are scheduled for Florida in the next year. Several are under discussion in MA, NC, MD, DC, MN, and CA. Systems using biosolids from animal waste also are being discussed.

EnerTech Environmental Inc. *The SlurryCarb Process Energy Efficiently Converts Biosolids to a Renewable Fuel;* Raymond J. Kearney, PE, BCEE, Vice President. EnerTech is a renewable energy company that develops and commercializes clean combustion technologies for biosolids and other organic wastes. Atlanta, GA, www.enertech.com

- The SlurryCarb™ process is a net energy producer, generating 98% more thermal energy than it consumes. Traditional drying requires 160 million Btus to produce 20% solids from 100 wet tons. SlurryCarb requires 64 million Btus to produce the same percent solids, with lower CO_2 emissions. It also captures 64 tons of water that might otherwise evaporate. The resulting E-fuel has 5,800 to 8,000 Btus/lb in dry form, and can be used in multiple coal applications. It is certified as a renewable fuel in California.



- Process flow: High-pressure slurry pumps avoid losing heat and keep the solids moist. Solids go into a heat exchanger, then into a reactor (a large pipe), which maintains the biosolids at the same temperature and pressure. The resulting high BoD centrate is dewatered / dried so it can be turned into fuel. Discharge water recirculates for treatment.

- In 2009, the Rialto Regional Biosolids Processing Facility will be processing 683 wtpd of biosolids from Orange County, Los Angeles County, and the cities of Rialto, Riverside, and San Bernardino in CA. It will produce 167 tpd of e-fuel for a cement kiln.

- The site has a 30-year lease and the customer contracts are for 25 years (the length of the bonds). The price for each agency differs. Excess capacity is being sold for $72 per wet ton (not fixed), there are escalators for CPI and O&M, and indexes for natural gas and electricity pricing.

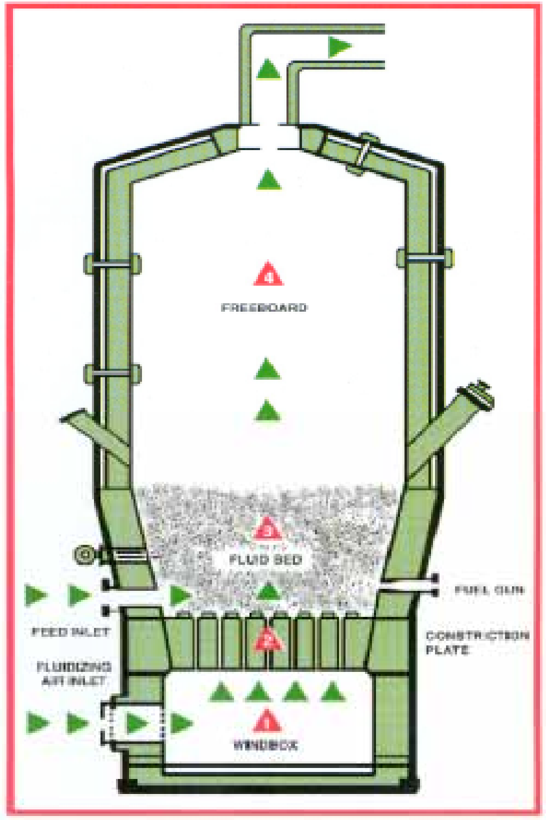
- Of note: The Rialto project did not require capital funding from the clients and had local community support. The process had no trouble getting permitted since it is not combusting anything except natural gas.

Infilco Degremont Inc. *Fluidized Bed Thermal Oxidation: A Sustainable Approach To Wastewater Biosolids Disposal*; Richard Ubaldi, Vice President. Infilco is a full-service water and wastewater treatment equipment and system provider. It is a member of the Degremont Group, part of SUEZ Environment, an international multi-utility provider of drinking water, wastewater, and sludge treatment services. Richmond, VA, www.infilcodegremont.com

- Although land application is a cost-effective and beneficial use of biosolids, it poses challenges (land availability, nutrient loading, and transportation).

- Fluid bed incineration is becoming widely accepted for sludge and biosolids disposal. In a fluid bed incinerator, water is evaporated and organic materials are combusted, eliminating odors and reducing the sludge to a much smaller quantity of inert ash (as low as 7% by weight). Typical reduction of sludge volume is 93%. Land requirements and air pollution are reduced, protecting the environment.

- Process flow:
  - Wastewater treatment produces sludge, which goes into the high-temperature fluid bed (HTFB) incinerator. The resultant exhaust gas leaves the fluid bed and enters the heat recovery and air pollution control systems, and the energy can be put to use.
  - The incinerator contains sand, and the term “fluid bed” refers to the violent boiling action of the sand bed, which occurs when air is blown through from below and fine solids are transformed into a fluid like state. To ensure that the air passes evenly through the sand, it must first pass through the windbox and a refractory arch distributor.
  - Dewatered sludge and auxiliary fuel (if required) are introduced directly into the bed, where they are instantly combusted at 1250°F. In the next stage, combustion gas and evaporated water flow upward into the teardrop-shaped freeboard, where the bed material is disengaged. Operating at 1550°F, the freeboard provides sufficient residence time to polish the gas and to complete the combustion.



- Depending on sludge characteristics, the heat recovery system can be composed of heat exchangers to preheat the combustion and the plume suppression air, or a waste heat boiler for steam generation. Both methods of heat recovery reuse energy for maximum cost savings.

- Uniform bed temperature, the result of steady turbulence, simplifies PLC / PC automation and logic control systems. Data gathering for compliance reports becomes much easier. Gaseous and particulate emissions, and heavy metals comply with all regulatory requirements; the highest emission characteristics are during startup and shutdown

- In a 200-tpd dry solids case, 2.5 MW of electricity are produced, 1.15 MW are used, with a green energy net of 1.35 MW. Two trains can handle 200 dtpd. Steady-state operating temperature: 650 degrees. Will self-sustain reaction indefinitely.

- By co-locating waste to energy (WTE) with biosolids HTFB, upfront capital cost can be avoided, footprint is reduced, NIMBY issues are eliminated, lime stabilization and long-haul transport is minimized; economies of scale and are possible, shared equipment between HTFB and WTE are possible, and energy recovery offsets tip fees.

- Infilco experience:

  Pfizer, CT – 18 dry TPD 1995
  Bayshore, NJ – 27 dry TPD 1995
  Morton International, MS – 76 dry TPD 1996
  Greensboro, NC – 60 dry TPD 1996
  Camden County, NJ – 10 dry TPD 1996

Northwest Bergen, NJ – 27 dry TPD 1999
Little Miami, OH – 72 dry TPD 2000
District d'Elbeuf, France – 11 dry TPD 2003
Valence, France – 14 dry TPD 2003
Puerto Nuovo, PR – 64 dry TPD 2004
Ypsilanti, MI – 76 dry TPD 2005
Lakeview I, ON – 110 dry TPD 2006
Cobb County I and II, GA – 53 dry TPD, each 2007
Lakeview II, III, IV, ON – 110 dry TPD, each 2008
Tripoli, Lebanon I and II – 31 dry TPD, each 2008
Le Havre, FR – 30 dry TPD 2010
Mill Creek, I, II, III, OH – 96 dry TPD, each 2010
Duffin Creek, I and II, ON – 115 dry TPD, each 2010

- New incinerators have been difficult to build so past strategies have been to upgrade existing facilities, but since the US EPA has designated HTFIs as a "green technology," there have been several inquiries from agencies in CA.

New Planet Energy/INEOS Bio. *Back to the Future: Converting Carbon to Ethanol*, Ray Crabbs. NPE Florida works with INEOS Bio, a division of INEOS Technologies, to convert carbonaceous feedstock into bioethanol. Los Angeles CA (NPE); Lisle, IL, www.ineosbio.com

- "We believe very strongly in the magic of heat."
- The INEOS Bio Ethanol technology efficiently converts a wide range of low-cost, organic materials, including household and commercial wastes, into bioethanol for use as a renewable road transport fuel or petrochemical intermediate.
- INEOS uses a thermal gasification process to "crack" complex carbon molecules and re-form them into simple carbon monoxide and carbon dioxide. The bioreactor looks like a huge blender on high. Patented bacteria used to catalyze the process are in an aqueous solution, and take a two-minute trip through reactor, where they consume 85% of CO and 45% of H, giving off ethanol. The waste is ash, which can be land-applied. There is nothing in the technology that isn't off the shelf. The only thing new is the colony of bacteria in bioreactor.
- Process flow: The INEOS Bio process is a combined thermochemical and biochemical processes in the following steps:

  1. Flexible feed handling, where organic materials are economically dried using heat from the process before being fed into the gasifier. The process is fully compatible with high recycling rates.

  2. Organic material gasification, with oxygen at high temperature under controlled conditions to produce synthesis gas, or syngas, a mixture of principally carbon monoxide and hydrogen. Syngas has valuable chemical energy.

  3. Energy recovery, where the hot syngas is cooled and cleaned before being introduced to the fermenter. The heat recovered from the hot syngas is used to generate renewable power for use in the process.

  4. Fermentation: The cool, clean syngas is introduced to patented active bacteria, which ingest it and convert it quickly and selectively to ethanol. The bacteria biocatalyst is far more effective than all known conventional catalysts for syngas conversion to fuels.

  5. Bacteria: The naturally occurring bacteria are at the heart of the process. They are found in nature where they have evolved to efficiently convert carbon monoxide and hydrogen to

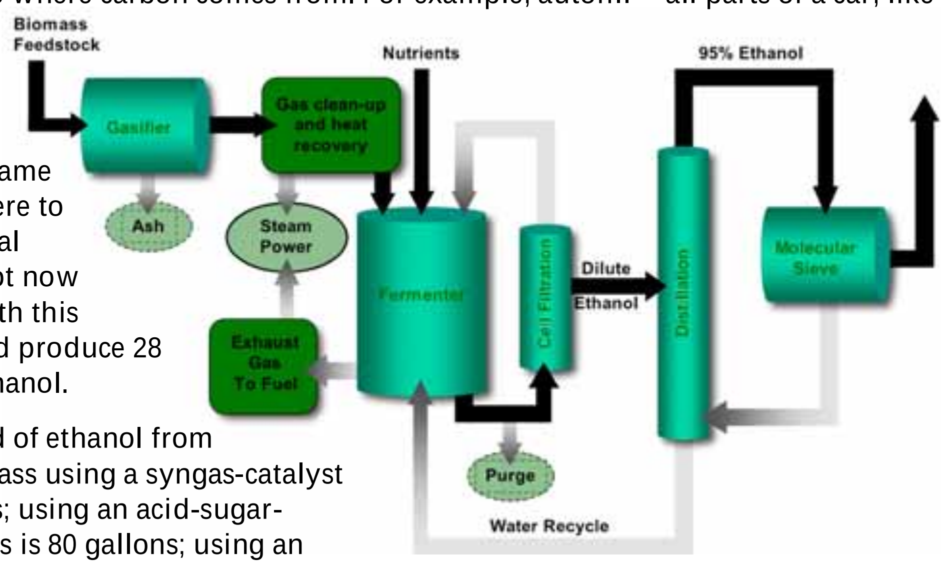
ethanol. They are maintained in a healthy state with the help of small amounts of essential nutrients to achieve a high yield of ethanol. At processing temperatures of 2,300 degrees, these bacteria have no natural predators in this environment.

6. Ethanol purification: Most of the water is removed from the ethanol to produce hydrous ethanol, which is around 96% ethanol in 4% water. The water is returned to the fermenter.

7. Ethanol drying: Finally, the ethanol product is refined to produce anhydrous ethanol (>99.7% ethanol), which can be used as a clean, green transport fuel or as a renewable chemical intermediate for the production of a variety of plastics.

8. INEOS bioethanol use: The INEOS bioethanol delivers 90% greenhouse gas savings compared with burning petrol (gasoline) in a car and it is potentially cheaper than petrol. The INEOS bioethanol process can convert wastes generated locally into clean, renewable, cost-competitive transport fuel for use locally.

- Gas fire doesn't care where carbon comes from. For example, autofill -- all parts of a car, like the chassis, dashboard, seats, etc., that are left when metal is removed – has the same Btu as coal. If we were to take all the municipal solid waste that's not now being converted, with this technology we could produce 28 billion gallons of ethanol.



- The theoretical yield of ethanol from one dry ton of biomass using a syngas-catalyst process is 77 gallons; using an acid-sugar-fermentation process is 80 gallons; using an enzyme-sugar-fermentation process is 85 gallons; and using a syngas-biocatalyst (INEOS) process is 145 gallons.
- Byproducts: Solids from ash for the gasifier are handled by a landfill; liquids from the cell purge are recycled to the gasifier; liquid from the gas scrubber is handled by wastewater treatment; gas form the fermenter and exhaust are combusted for energy.
- Key points: Different feedstocks can be blended; the process handles up to 30% moisture content; dry feedstock (tires & plastics) can be blended with wet feedstock to achieve the 30% moisture limit; the process is odorless; it can alternatively produce hydrogen.
- Plans are modular. A single plant module will process 50,000 tons of carbon and biomass annually, produce 4,000,000 gallons of bioethanol annually, and generate 1.5 MW of excess electricity for sale to the grid. Processing time is about two hours on the plant; corn ethanol takes 48 to 55 hours to produce.
- One plant has been operational since 2000 with a full gasifier in place. It uses steam-blown gasification (moisture with feedstock used to release water). The other portion is O-blown,

90%, which promotes additional CO. Bacteria will consume twice the CO as H and create CO_2 and ethanol.

- New Planet Energy soon will have the first commercial site on the coast of FL, a brownfields site that was a citrus juice farm. It shares a common boundary with landfill. It is expected to produce 8 million gallons of ethanol/yr, costing about $47 million to produce, at less than 60 cents/gallon. New Planet Energy will get the wholesale price plus a hosting fee and in return will pay the company for not landfilling.
- New Planet Energy has submitted a proposal to Roanoke VA (pop. 100K), which treats 8 mgd, enough for five bioreactors that can process a total of 750 tons per day, producing 20 million gallons of ethanol per year. Feedstock can include coal, for clean coal technology, and municipal solid waste.
- We've shorted universities of R&D money to help keep this country on the cutting edge. We cannot rest on the laurels of the past.

Biological Systems Engineering, Virginia Tech. *Thermal Depolymerization That Converts Organic Matter to Oil*, Dr. Foster A. Agblevor (fagblevo@vt.edu). Presented by Kristen Hughes, Staff Scientist for the Chesapeake Bay Foundation. The Department of Biological Systems Engineering develops and disseminates engineering knowledge and practices that protect natural resources and improve sustainable production, processing, and utilization of biological materials. Blacksburg, VA, www.cals.vt.edu/departments/bse.html

- The Waste Solutions Forum, held April 28 & 29, 2005, in Roanoke, VA, hosted 80 stakeholders from Virginia and across the nation to develop a waste solutions strategy (a detailed action plan) for identifying, researching, and implementing economically and environmentally viable solutions for manure and litter management in the Shenandoah Valley of Virginia. 40% of Virginia's dairy industry and 76% of Virginia's poultry industry is in the Shenandoah Valley.
- As a result of this initiative, Virginia Tech, with support from the Virginia Poultry Federation, Chesapeake Bay Foundation, Shenandoah RC & Council, and the National Fish and Wildlife Federation, developed a portable pyrolysis unit for turning poultry litter into bio-fuel and synthetic gas for energy, and ash into a slow-release fertilizer. This is the first unit of its kind, and is being tested and analyzed in the Harrisonburg, VA area (Shenandoah Valley). It uses a modified traditional boiler to run bio-oil for a radiant heating system in the floor of a poultry shed.
- Pyrolysis is an endothermic reaction (i.e., you must add heat) in the absence of oxidizing agents (oxygen) that converts organic matter into gas. Pyrolysis always occurs before any combustion process. In gasification, the end product usually is synthetic gas, but it can produce bio-oil.
- Process flow: The feedstock is air-dried poultry litter from neighboring farms, put through a fluidized-bed pyrolysis reactor where it is heated to 450 to 500^{o}C. It then goes through a hot filtration cyclone filter system and a pyrolysis oil condensation system that produces raw oil. Nitrogen or other gas that is produced goes to the re-heat burner, and excess gas can be used to heat the dryer. The feed rate is 200 gallons per hour.
- Traditionally, poultry litter is used in land application and as cattle feed. Disposal of poultry litter in the US is becoming a major problem because it can create excess nutrients in the soil

from land application, contaminated drinking water, eutrophication (excess plant growth because of too many nutrients) in surface waters, ammonia emissions from poultry houses, oil acidification through nitrification and leaching, and biosecurity concerns. Biosecurity concerns drove development of this system because instead of taking chicken litter to a central facility, it can be processed onsite, then moved to the next one.

- One advantage of this system is that many members of the thriving Mennonite community in Virginia are not on the power grid, so they face large costs to heat and cool poultry houses with diesel-run generators. Bio-oil can be used in a boiler instead.
- Pyrolysis is brand new for VA so regulators don't know how to regulate it. The question: Is it an incinerator? But nothing burns. It has no category.
- Right now, it costs several hundred thousand dollars because it is a pilot unit, and Virginia Tech is looking for companies that can manufacture it, perhaps in a public/private partnership.

Afternoon Session 2: Alternative Management Options

Environmental Solutions Inc. *Changing Conditions for Compost Manufacturing*, Brenda Robinson, President (Brenda.Robinson@envirsol.com). ESI develops innovative, patented green products derived from wastes and has been composting for municipalities since 1995. Richmond, VA, www.envirsol.com

- Composting is facing a changing landscape. It is focused more on the manufacturer and less on the seller, there are larger facilities involved, it faces higher production rates because of population growth, there is a greater emphasis on product quality – it must meet higher regulatory standards and public expectations, and there are competing alternative management options.
- Windrow composting is low-tech but can have hidden operating costs and odor management challenges. Aerated static pile (ASP) systems have upfront investment requirements and a higher learning curve, but they provide better management practices if the right approach is used. Composting partnerships with biosolids generators can produce some of the best benefits when used with AST systems. Modern indoor facilities that meet permit requirements can be better financed and can maintain manufacturing integrity.

- Market shifts include greater acceptance of compost (it is more mainstream), “green” environmental movements that are looking for recycling opportunities, nutrient management concerns that can open markets to quality compost, expanding markets, and new and more credible product certifications.
- Challenges for municipalities include lack of integral support by government officials to manage permitting programs, reduced public outreach resources to address vocal local activists who can drown out messages about the benefits of compost to the community, and justifying upfront costs of building indoor AST systems that may be superior and cost-beneficial technologies in the long-run.
- In sum, composting is a viable, sustainable option for municipalities. Modern AST processing provides benefits to product quality, odor management, permitting challenges. What is needed is assistance from government to ensure composting is seen as a viable management option. There is proven desire for the product among citizens.

Brown and Caldwell. *Anaerobic Digestion*, Perry L. Schafer, PE, BCEE. Brown and Caldwell is a full-service environmental engineering and consulting firm with 45 offices and 1,500+ professionals across the country. Walnut Creek, CA, www.brownandcaldwell.com

- Anaerobic digestion is a naturally occurring biological process in which large numbers of anaerobic bacteria convert organic matter into methane and carbon dioxide (a mixture called biogas) in the absence of air. It is a widely used biological process for treating wastewater solids.
- This process stabilizes organic matter in wastewater solids, reduces pathogens and odors, and reduces the total solids/sludge quantity by converting part of the volatile solids (VS) fraction to biogas. Anaerobic digestion results in a product that contains stabilized solids, as well as some available forms of nutrients such as ammonia-nitrogen. In short, anaerobic digestion destroys solids, produces methane (biogas), destroys pathogens (Class A/B), stabilizes sludge, and provides a product suitable for beneficial use.
- (The next two paragraphs were adopted by the editor of this summary from the EPA document, *Biosolids Technology Fact Sheet, Multi-Stage Anaerobic Digestion* (www.epa.gov/owm/mtb/multi-stage.pdf))
- Process flow: Anaerobic digestion can take three separate steps, each of which is performed by a different group of microorganisms: 1) hydrolysis, during which proteins, cellulose, lipids, and other complex organics are broken down into smaller molecules and become soluble by using water to split the chemical bonds of the substances; 2) volatile acid fermentation, during which the products of hydrolysis are converted into organic acids through the biochemical processes; and 3) methane formation, during which the organic acids produced during fermentation are converted to methane and carbon dioxide.
- The standard multi-stage anaerobic digestion system is a two-stage acid/gas (AG)-phased system, in which the acid-forming steps (hydrolysis and volatile acid fermentation) are physically separated from the gas-forming step (methane formation) by being conducted in separate digestion tanks. An alternative method is to separate the stages over time by adding different levels of heating at different times in the process by a process called temperature-phased anaerobic digestion, or TPAD.

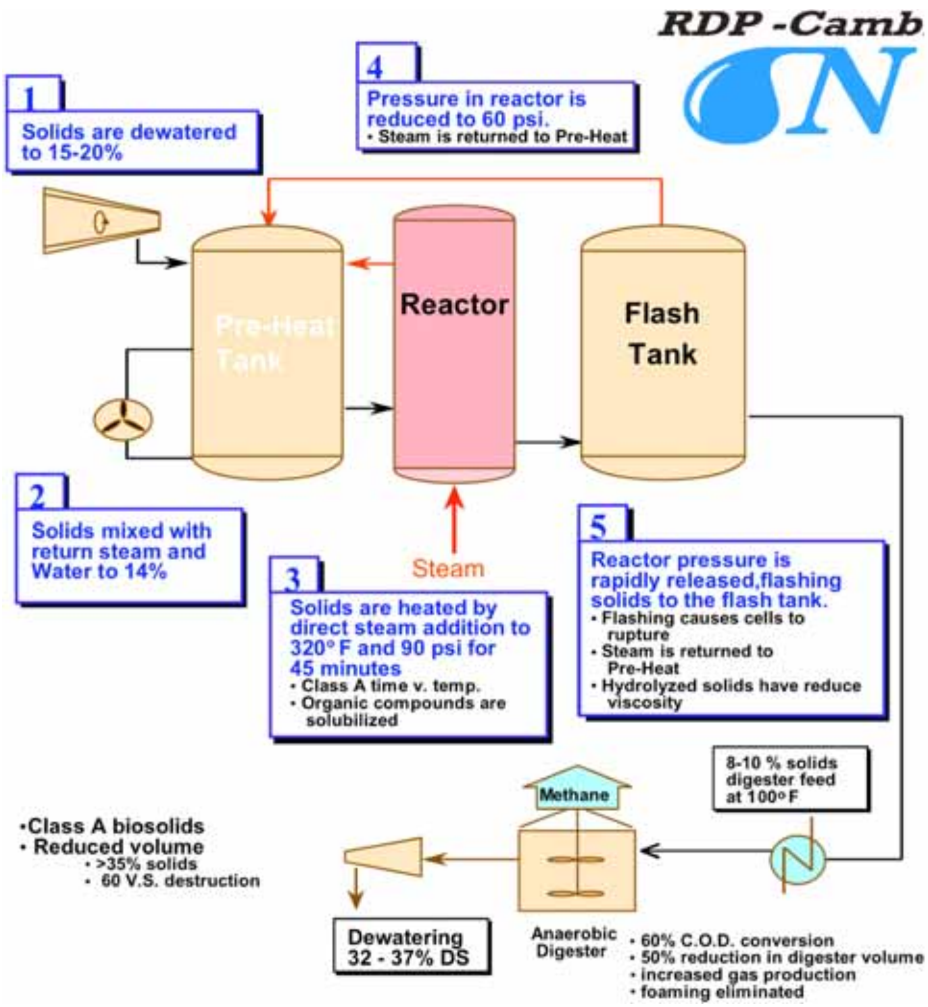
- A renaissance is occurring in anaerobic digestion driven by improved performance requirements (volatile solids reduction, biogas production, Class A needs, product stability, odor management), reduced costs (systems are more efficient and require less tankage), and desire for renewable energy and reduced carbon footprints. Research on impacts by chemicals such as ammonia has created process innovations and has quantified benefits, such as beneficial nutrient recycling outcomes. Digestion-related R&D is expected to continue.

- Digestion processes have evolved from use of lagoons and tanks and psychrophilic / mesophilic digestion in the early 1900s, to industrial waste digestion 60 years ago, to sector-specific digestion just ten years ago. Major digestion advances include thermophilic digestion, 2 / 3 phase, Class A, the Cambi process, co-digestion enhancements, and biogas use options.

- There are five basic causes of digestion instability / failure that must be monitored and controlled: hydraulic overload, organic overload, temperature stress, toxic overload, foaming situations

- Digesters come in many shapes and sizes, from cylindrical shapes with fixed, floating, or submerged covers, to single-component piece egg-shaped digesters that don't need covers.

- Process modifications and enhancements include physical, chemical or biological sludge disintegration to destroy volatile solids; pre-pasteurization; pre-digestion thermal hydrolysis systems; batch digestion at pressure and elevated temperatures; flow-through vs. batch thermophilic tanks; heat recovery systems; methane gas recovery systems; and co-digestion that allows two different waste streams to be processed simultaneously.



- There is a growing body of data on ROIs, life-cycle analysis, energy efficiency and recovery, greenhouse gas reduction, fertilizer and other end-use benefits, costs, etc. that are providing utilities with decisionmaking tools as they improve and upgrade their systems.

Department of Crop and Soil Environmental Sciences (CSES), Virginia Tech. *Biosolids Utilization for Disturbed Land Rehabilitation*, Dr. W. Lee Daniels (with other scientists, support staff, and graduate students). CSES's combined research, teaching, and outreach programs focus on development of new techniques and strategies for rehabilitating drastically disturbed soils and landscapes. Blacksburg, VA, www.cses.vt.edu/revegetation

- The research program originally focused on coal-mined land reclamation and associated water quality issues, and has been continuously supported by the Powell River Project since 1979. In addition, researchers worked cooperatively with Iluka Resources on mineral sands mining reclamation since 1989.
- Over the past decade, they have significantly expanded their research base into wetland creation and restoration, acid sulfate soil remediation, roadside revegetation, dredge spoil use, manufactured soil production, by-product screening, and an array of related programs based in environmental soil science. The combined research program employs six to nine scientists, support staff and graduate students and maintains two support laboratories and two greenhouse facilities at Virginia Tech that offer complete physical and chemical analytical capability for soils, sediments, and mine spoils. It also offers greenhouse experimental and bioassay support.
- Biosolids have been used at higher-than-agronomic rates on coal-surface mined lands in the Appalachians since the 1970s. To test the effects of this practice, Penn State University and Virginia Tech launched a controlled overburden placement (COP) experiment in 1982, which ultimately confirmed the benefits of this practice and indicated a general lack of ground and surface-water impacts.
- The pictures above show the course of a typical study, this one of an Appalachian haul-back contour mine in Virginia. Over a five-year period, a 300 acre application of 65 T/ac of

Left: During this surface treatment experiment begun in April 1982, biosolids were applied at 10, 25, 50 and 100 T/ac vs. topsoil and sawdust plots *Center:* COP in early June, 1982, after seeding and rainfall. *Right:* COP Plot (50 T/Ac) in 2005. Red oak in foreground; fescue etc. in background. These are the oldest continuously monitored mine soil research plots in the world.

biosolids + woodchips (C:N = 30) had no effect on ground water NO_3 levels. In fact, NO_3 levels were highest before application due to the use of NH_4NO_3 explosives used in the mine.

- In 1995, the State of Virginia Department of Mines, Minerals, and Energy developed guidelines for the application of biosolids on coal-mined lands. These guidelines capped loading rates at 35 T/ac (dry) for biosolids cake and at 50 T/ac when the C:N ratio of the applied product was 25:1 or greater. However, use and application of these rates on non-coal mined lands in eastern Virginia was questioned by DCR and a number of follow-up studies ensued.

Tailings revegetation species trial with/without biosolids. Both areas received conventional lime/fertilizer/seeding. Not much more to say?

- Conclusions: Application of biosolids at higher than agronomic loading rates is an important and very effective disturbed land reclamation alternative. Benefits of this application include establishment of long-term organic matter and nutrient pools, improved water holding capacity, and long-term mine soil resilience and quality. Higher-than-agronomic rates are used on a one-time basis only with appropriate setbacks, buffers, water table separation etc.

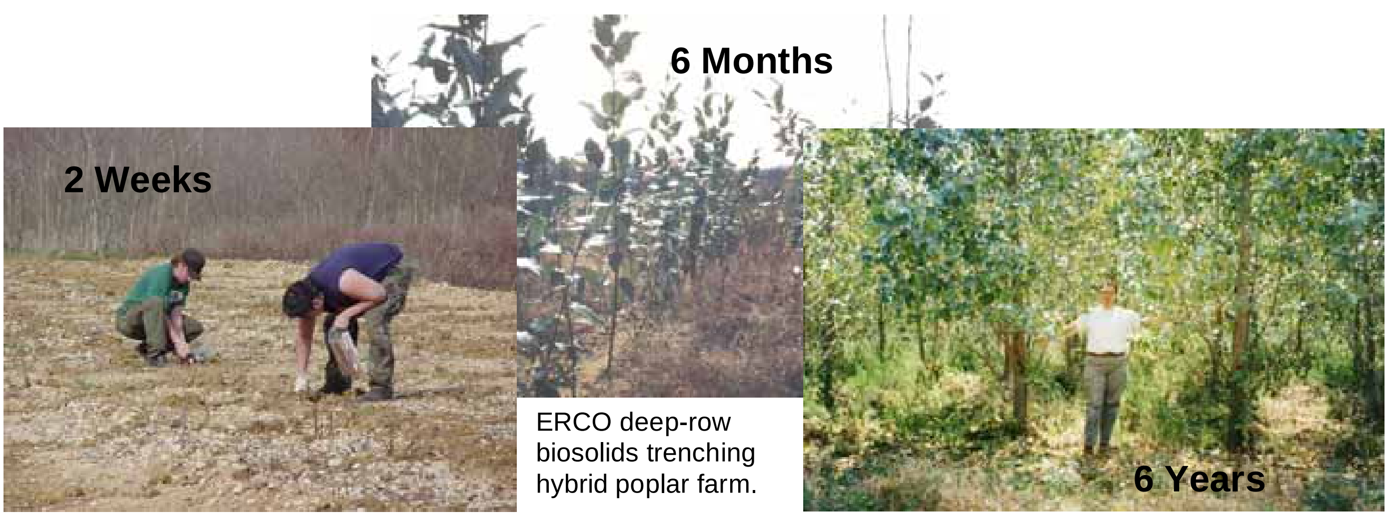
ERCO Inc. *The Use of Biosolids to Grow Forest Crops: A Private-Public Success Story,* Eric Flamino, ERCO Inc. (eflamino@erco-inc.com) (with Jonathan Kays and Gary Felton of Maryland Cooperative Extension). ERCO owns a tree farm and specializes in growing sustainable crops at reclamation sites and other locations using biosolids. Glen Burnie, MD.

- ERCO Inc. has operated a 120-acre tree farm on a sand gravel mine reclamation site in southern Maryland since 1983. The company uses deep-row trenching to incorporate biosolids for fertilizer. This involves one-time application of biosolids in a wide and shallow trench that is covered with overburden and planted with hybrid poplar cuttings that use the nutrients over a seven-to-nine year rotation.

- Environmental benefits: Reduces or eliminates energy used to generate nitrogen (compared with ethanol production from corn, hybrid poplar production using fertigation); high rate reduces energy use per ton for application (compared with land application for crops); maintains and increases green space, even in suburban settings in close proximity to housing; produces wildlife habitat; gives the landowner a reason to keep the land rather than sell it for development; carbon sequestration; increased infiltration / decreased storm runoff impact; extended life of landfills.

- The biomass from the forestry operation can be used for energy and fertilizer production along with imported biosolids. Fore example, at least one on-site wastewater treatment plant is necessary to get the effluent (water) that makes the trees survive (income source). It could process biomass and biosolids to create Class A compost.

- Compost can be sold, and biomass from the forestry operation can be used to created useful products like paper, dimensional products, and biofuel energy via cellulosic ethanol feedstock or palletizing.
- The system can adapt to the markets and to biosolids input availability, which is likely to increase. Once started, a forestry crop goes on without additional biosolids input. However, additional biosolids can be surface-applied. Biofuels from hybrid poplar and switchgrass can use spent sand and gravel mine spoils and marginal agricultural land without negatively affecting Maryland’s agricultural land base.
- Energy values for various biomass crops: Acre corn = 233 gal. gasoline; acre switchgrass = 530 gal. fuel oil; Acre 6-year old hybrid poplars = 1,023 gal. fuel oil.
- If corn ethanol were used to replace gasoline as E85 (as in Brazil) it would require more farmland than exists in the US. Biomass energy can be a component of a system with flexibility, but in the current state of science and technology, it is not a practical replacement for transport fuels. The energy gain is small, the water requirement is 4-5 gal/gal ethanol, the energy content = 2/3 gasoline energy content (therefore reduced mileage), one gallon of gasoline equivalent costs $3.99 for E85.
- Research: ERCO has been working with the University of Maryland, the Washington Suburban Sanitary Commission, and DC-WASA to analyze groundwater samples to study the fate and transport of nitrogen and other nutrients in the deep-row trenching-tree planting system. The researchers also have been studying the impact on tree growth of different fertilizer and spacing rates and the overall economics of the system.
- It also has launched several projects to explore the use of biosolids and poultry litter to grow hybrid poplars without contributing to water pollution. One of the projects was to be conducted by Dr. Gary Felton at the Beltsville Agricultural Research Center and another at the university’s Wye research farm on the Eastern Shore. In both cases, the trees are planted conventionally and biosolids or other soil amendments are surface-applied.
- In addition, trials of using different hybrid poplar clones are helping select clones best adapted to different sites.



ERCO deep-row biosolids trenching hybrid poplar farm.

College of Natural Resources, Virginia Tech. *Land Application of Biosolids to Forests*, Dr. Thomas R. Fox, Associate Professor of Forestry (trfox@vt.edu). As part of the program at Va Tech, researchers are studying the impact of biosolids application on forested sites to water quality and tree growth. Blacksburg, VA.

- The growth of most pine plantations in the south is limited, but following are the effects of biosolids on two-year growth of young loblolly pine in Florida (showing treatment, height, and growth in feet): Check -- 4.8a – 0.6a; N+P fertilizer – 5.6b – 0.9b; biosolids – 6.0b – 1.1b.
- Researches wanted to answer the following questions: Do trees grow faster after application of biosolids? What are the effects of biosolids on nutrient dynamics in forest soils? What is the potential for offsite movement of nutrients following biosolids application in forest ecosystems? Are there differences among the various types of biosolids?
- They launched two studies: 1) Soil Nutrient Dynamics and Growth Response of Loblolly Pine Following Biosolids Application; 2) SMZ Effectiveness and Water Quality Following Biosolids Application (where biosolids were applied to paired stream segments with 50 ft SMZs)
- At the first study site in Amelia County, VA, they applied different levels of biosolids to a loblolly pine plantation and measured the flux of nutrients leaving the site in ground and surface water. The project was designed to identify the maximum level of biosolids amendment that would benefit the trees without compromising water quality. Nitrogen availability increased after biosolids and conventional fertilizer applications. Results from this study indicate that biosolids, applied at low rates, may be a good alternative as a source of nutrients. Biosolids and conventional fertilization increase nitrogen availability. With allowed 215 kg/ha PAN there is no sign of nitrogen leaching.
- The second study evaluated forestry best management practices (BMPs) at streamside management zones (SMZs) to maintain water quality. It is indicating that water quality shows no significant declines when SMZs are retained adjacent to biosolids-applied forestland. Forestland soils applied with biosolids have elevated N & P availability.