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RESIDUALS MANAGEMENT VALIDATION PANEL

Summary of Findings and Recommendations

September 5, 2008

Table of Contents

RESIDUALS MANAGEMENT VALIDATION PANEL

Summary of Findings and Recommendations

INTRODUCTION

The Northeast Ohio Regional Sewer District (District) convened a panel of nationally and internationally renowned biosolids management experts to assess the District's current biosolids handling and incineration project at the Southerly Wastewater Treatment Center (SWTC) in Cuyahoga Heights. The purpose of the panel was to objectively determine if the current plan adopts the most **energy efficient, environmentally friendly and cost-effective technology.** This panel, comprised of the following members, met together August 11-15, 2008, in Independence, Ohio:

- Cecil Lue-Hing, D.Sc., PE, BCEE, NAE
- Terry Logan, Ph.D.
- Scott Harder, PE
- Perry Schafer, PE, BCEE
- Tim Shea, Ph.D., PE, BCEE
- Lori Stone, PE
- Jim Welp, PE

The objectives of the panel included:

- Review the recommendations made in the District's *Long-Term Residuals Management Plan* (January 2005).
- Investigate newer biosolids management technologies.
- Determine the carbon footprint of various biosolids management options.
- Determine if the current incineration plan is still the most viable and cost-effective option for the District.

The District provided background materials, including the *Long-Term Residuals Management Plan*, detailed economic analyses updated to December 2007 costs, regulatory permits, and residuals quality and quantity data, for the panel members to review prior to the workshop. These materials set the foundation for further discussion and were used to validate the District's previous and current work.

In order to fulfill the panel's objectives, the panel members discussed whether there were other viable biosolids technologies for the District. After much dialogue, the panel independently decided upon the following criteria for identifying and evaluating such technologies / systems:

- Provide a proven and sustainable system.
- Produce Class A biosolids.
- Fit on a limited available site at the SWTC (small footprint required).
- Provide renewable energy and reduced greenhouse gas emissions.
- Minimize trucking, odor, and noise impacts.

The technologies/systems selected for further evaluation, and described in the attachments to this report, are:

1. Incineration with co-generation (Green Power).
2. Class A product via Cambi-digestion.

Economic and greenhouse gas emissions assessments of the aforementioned options were also conducted.

Each panel member participated in the workshop discussions and undertook various technology development, evaluation, and reporting assignments. In addition to the Findings and Recommendations contained herein, the following attachments A through G are provided.

Attachments

A. Workshop Agenda

B. Review and Validation of the District's *Long-Term Residuals Management Plan*

C. Technology/System Option: Incineration with Green Power

D. Technology/System Option: Cambi-digestion + Class A Product

E. Carbon Footprint and Economic Comparison of Options

F. Staffing Optimization Opportunities

G. Panel Response to Schmack BioEnergy Presentation

BACKGROUND

In January 2005, the District's Board of Trustees and Senior Staff approved a *Long-Term Residuals Management Plan* that included the replacement of Southerly's four existing multiple hearth incinerators (MHIs) with three new state-of-the-art fluidized bed incinerators (FBIs). The aging MHIs, which are 23 feet in diameter and about four stories high, date back to 1964, with improvements made in the late 1970s. Operating at 1,500 degrees-F, 24 hours per day, seven days per week, the incinerators combust about 80,000 wet tons of biosolids per year. Even though the current equipment consistently meets federal and state regulations, the outdated incinerators are nearing the end of their useful life and must be replaced.

Moreover, the District's Zimpro system, which thermally conditions the biosolids before dewatering and incineration, has reached the end of its useful life. Improvements to extend the Zimpro equipment life for an additional 10 years were made in 1995.

The District is committed to providing efficient management and operation of its wastewater treatment plants. Faced with the challenges of aging equipment, rising operational costs, changing regulations, and increasing energy demands, the District wanted to determine if the current plan is the most viable, cost-effective way to manage biosolids for the future.

To this end, the District gathered a panel of experts to review and validate the District's plan to ensure that biosolids are managed in an environmentally friendly, responsible, reliable, flexible, and cost-effective manner.

FINDINGS AND RECOMMENDATIONS

The panel's findings and recommendations are presented accordingly.

Findings

Energy Efficient

- The planned FBI project will reduce natural gas consumption by 98 percent (about $1 million savings per year) compared to the existing system.
- Opportunities exist to generate electric power from waste heat to offset purchased power (Green Power) resulting in approximate savings of $0.4 to 1.6 million per year.

Environmentally Friendly

- Compared to the existing incineration technology (MHIs), the planned FBI project significantly reduces regulated air emissions.

- The proposed FBI project will reduce greenhouse gas emissions by about 14,000 tons (carbon dioxide equivalent metric tons, mtC02e) per year compared to the existing incineration technology/system.
- The proposed FBI project with Green Power can further reduce greenhouse gas emissions by about 16,000 mtC02e per year.
- The proposed FBI project, with or without Green Power, poses the least odor, noise, and traffic impacts to surrounding communities compared to all of the other options evaluated.

Cost-Effective

- The District's decision to phase out and decommission the Zimpro facilities is correct. The existing facilities are at the end of their useful life and there is increasing risk of serious operational failure.
- The cost and risk of increased operation and maintenance, coupled with the likelihood and magnitude of process equipment failure, are significant (approximately $7,100 each day the proposed FBI construction is delayed).
- The proposed FBI project minimizes uncontrollable costs, including natural gas, purchased power, and diesel fuel.
- The proposed FBI project with Green Power is the most cost-effective solution expressed on a life cycle cost basis.

Recommendations

- Proceed with the proposed FBI design and construction.
- Reconsider the Green Power option.
- Accelerate FBI project implementation, and concurrently evaluate, design and construct the Green Power facilities.
- Develop a contingency plan for unplanned process shut-downs, including the ability to manage biosolids due to Zimpro and MHI failures.
- Review staffing plan for future FBI operating conditions, including construction phasing, start-up, and Green Power operations.
- Develop a comprehensive sampling plan for liquids and solids streams, not only to more accurately quantify percent volatile solids content, but also to aid in process control and operations decision-making.
- Update/develop stakeholder communication plan in light of capital commitments and increased stakeholder interest.

ATTACHMENT A
Workshop Agenda

Northeast Ohio Regional Sewer District Residuals Management Validation Workshop
August 11-15, 2008
Independence, Ohio

Agenda – Monday, August 11th

Topic	Time
WELCOME AND INTRODUCTIONS/ OVERVIEW OF AGENDA (STONE AND NEORSD PERSONNEL)	9:30 – 9:40 am
SESSION 1 – NEORSD LONG-TERM RESIDUALS MANAGEMENT PLAN OVERVIEW AND DISCUSSION (DOMINAK AND JANOSKO) • Review key aspects of the District's Long-Term Residuals Management Plan, Southerly WWTC's Biosolids Handling and Incineration Program and Current Program	9:40 – 10:45 am
Break	10:45 – 11:00 am
SESSION 1 (CONTINUED) – 'WHERE WE'VE BEEN AND WHERE WE ARE…" • Continue presentation • Questions and Answers	11:00 - 12:00 noon
Lunch	12:00 – 1:00 pm
SESSION 2 - TOUR OF SOUTHERLY WWTC • Travel to Southerly to tour facilities	1:15 – 3:15 pm
Break	3:15 – 3:30 pm
SESSION 3 – PANEL DISCUSSION • Q&A with District personnel concerning the issues covered in the Morning Sessions and the tour of the Southerly WWTC.	3:30 – 4:30 pm
SESSION 4 – WRAP-UP DAY 1 • "Top 3 Issues" Survey from Validation Panel Members • Develop Game Plan • Identify Assignments	4:30 – 5:00 pm
Adjourn Day 1	5:00 pm

Agenda – Tuesday, August 12th

Topic	Time
RECAP FROM PREVIOUS DAY AND REVIEW TODAY'S AGENDA (STONE)	9:00 – 9:30 am
SESSION 5 – SCHMACK BIOENERGY PRESENTATION (SCHMACK COMPANY) • Process development background • Experience with municipal solids, including primary-only, biological-only, and blended solids feed streams • Process diagram • Design and operations requirements (sizing, performance, mixing, energy, footprint, staffing) • Summary of installations • Warranties and service support • Questions and Answers	9:30 – 10:30 am
Break	10:30 – 10:45 am
SESSION 6 – DISTRICT RESIDUALS MANAGEMENT COST ANALYSIS (HARDER) • Overview • Cost basis and analysis • Planning and implementation cost tracking • Panel discussion	10:45 – 12:00 pm
Lunch	12:00 – 1:00 pm
SESSION 7 – CARBON FOOTPRINTING (HARDER)	1:00 – 2:15 pm
Break	2:15 – 2:30 pm
SESSION 8 – BRAINSTORMING CONCERNS/IDEAS FOR FURTHER CONSIDERATION • "Round Robin" • Identify key concerns or information gaps • Frame ideas for further consideration	2:30 – 4:30 pm (periodic breaks to be included)
Wrap-Up and Adjourn Day 2	4:30 - 5:00 pm

Agenda – Wednesday and Thursday, August 13-14th

Topic	Time
RECAP FROM PREVIOUS DAY AND REVIEW TODAY'S AGENDA (STONE)[1]	9:00 – 9:30 am
SESSION 9 – "A PROBLEM WELL-DEFINED IS HALF-SOLVED" • Review concerns/opportunities • Determine main themes/options • Develop plan to "drill down"	9:30 – 10:30 am
Break	10:30 – 10:45 am
SESSION 9 - CONTINUED	10:45 – 12:00 noon
Lunch	12:00 – 1:00 pm
SESSION 10 – TAG TEAM OR BREAK-OUT PANEL WORK • Assign members/teams to implement "drill down" plan • Work session	1:00 – 3:00 pm
SESSION 11 – PULSE CHECKS **UPDATE TO DOMINAK, JANOSKO, ET. AL. , WEDNESDAY** • Brief reporting to Dominak, Janosko, et. al. • Update **INFORMATION NEEDS/Q&A** • Recommendations and next-steps plan, Thursday • Summarize main ideas and recommendations • Develop briefing points • Develop report outline • Identify writing assignments and schedule	3:00 – 4:30 pm (periodic breaks to be included)
Wrap-Up and Adjourn Days 3-4	4:30 - 5:00 pm

[1] The agenda for Wednesday and Thursday will depend on the issues identified and discussed in previous work sessions. This agenda is intended to be a guide for time management and is subject to change.

Agenda – Friday, August 15th

Topic	Time
RECAP FROM PREVIOUS DAY AND REVIEW TODAY'S AGENDA (STONE)	9:00 – 9:15 am
SESSION 12 – DEVELOP BRIEFING POINTS AND RECOMMENDATIONS • Develop briefing points • Confirm recommendations • Determine action plan for next steps, with responsibilities and schedule	9:30 – 10:45 am
Break (Travel to the District's EMSC Complex near Southerly)	10:45 – 11:00 am
SESSION 13 – REPORT-OUT PRESENTATION WITH DISTRICT PERSONNEL • Review Validation approach • Discuss findings • Confirm next steps	11:00 – 12:00 pm
Lunch with District [2] ***Additional discussions with District Personnel and Validation Panel Members***	12:00 – 3:00 pm
Wrap-Up and Adjourn Day 5	3:00 pm

[2] Departure to airport will be from the EMSC Complex near Southerly, and times may vary based on participants' travel schedules.

ATTACHMENT B

Review and Validation of the District's Long-Term Residuals Management Plan

The District provided the validation panel with copies of the *Long-Term Residuals Management Plan* approved in January 2005, updated economic analyses of alternatives representing December 2007 costs, residuals quantities and quality data, regulatory permit information, and aerial photographs of the Southerly Wastewater Treatment Plant site. The validation panel members reviewed these resources prior to meeting at the Residence Inn in Independence, Ohio from August 11 – 15, 2008.

District staff gave presentations to the panel, and accompanied them on a tour of the Southerly solids handling facilities. Updates regarding the design status of the proposed FBI project were provided by District staff, and representative design documents were reviewed by panel members throughout the week.

The following comments and findings were discussed by team members:

- The *Long-Term Residuals Management Plan* was exceptionally thorough in its investigation of existing conditions, unit disposal costs, and screening and evaluation of alternatives. The screening and alternatives evaluation was based on site-specific constraints, and economic and non-economic criteria. The economic comparison included a net present value analysis, and the non-economic comparison was made with respect to permittability, product marketability, site availability, odor potential, truck traffic and noise impacts.
- The *Long-Term Residuals Management Plan* and economic evaluation were found to be comprehensive. Further, the economic sensitivity analyses for both the 2005 and 2007 scenarios were robust.
- The relative ranking of alternatives did not change as a result of using updated life cycle costs.
- A comparison of alternatives based on non-economic factors also strongly favored the recommended incineration option.
- A clear separation in rankings between the recommended option (FBI with back-up landfilling) and the other options existed.

The panel held additional discussions regarding the residuals quantities and characteristics.

- **Due to the sensitivity of gas production projections to variations in total solids and volatile solids content, the panel recommends confirmation of the volatile solids content to refine FBI energy projections. It was also emphasized that the District should implement a comprehensive monitoring and measurement plan to verify process performance and to help make operations decisions.**

Panel members commended the District for the level of detail and organization of the plan, and confirmed that it was based on a sound evaluation process.

The FBI design basis was also reviewed and verified. Recognizing the potential risks associated with the aging Zimpro and MHI equipment, the validation panel reviewed the proposed incineration implementation schedule. Panelists explored the risk and cost impacts of not meeting the proposed schedule. Moreover, benefits of accelerating the schedule were also evaluated.

A snapshot of the proposed FBI implementation is provided below.

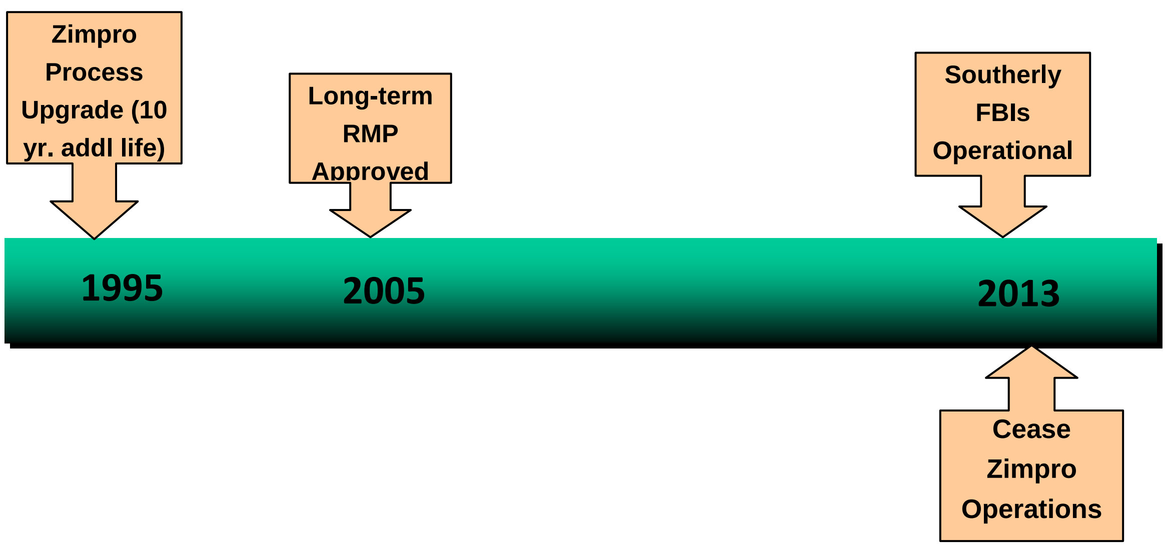


Figure B-1. Proposed FBI Implementation

The Zimpro process upgrade in 1995 extended the equipment life to 2005. Continued operations and maintenance costs are expected to increase until the FBIs are constructed and operational in 2013.

An analysis of the known financial impacts of delay is provided in Table B-1. Other risks associated with delay were discussed and include:

- Increasing costs to maintain Zimpro and MHI operations.
- Unexpected costs from Zimpro and MHI process interruptions.
- Increasing natural gas prices.
- Costs for backup landfilling due to unplanned Zimpro and MHI shutdowns.
- Increased truck traffic and noise due to backup landfilling operations necessitated by Zimpro and MHI process downtime.

Table B-1. Estimated Financial Impacts of FBI Project Delay

Item	Cost
Capital Expenditures	$118,000,000
Less 15% Cash	17,700,000
Net Bond Financing	$100,300,000
Annual Debt Service (4.5%/20 yr)	-$7,700,000
Plus Construction Inflation	$5,850,000
Change in O&M with Project	$4,400,000
Net Annual Cost of Delay	$2,600,000
Cost per Day	***$7,100***
Incremental Rate Increase per MCF per year	$0.55

A snapshot of the potential cost savings – approximately $2.6 million if the schedule is accelerated by one year – is presented below in Figure B-2.

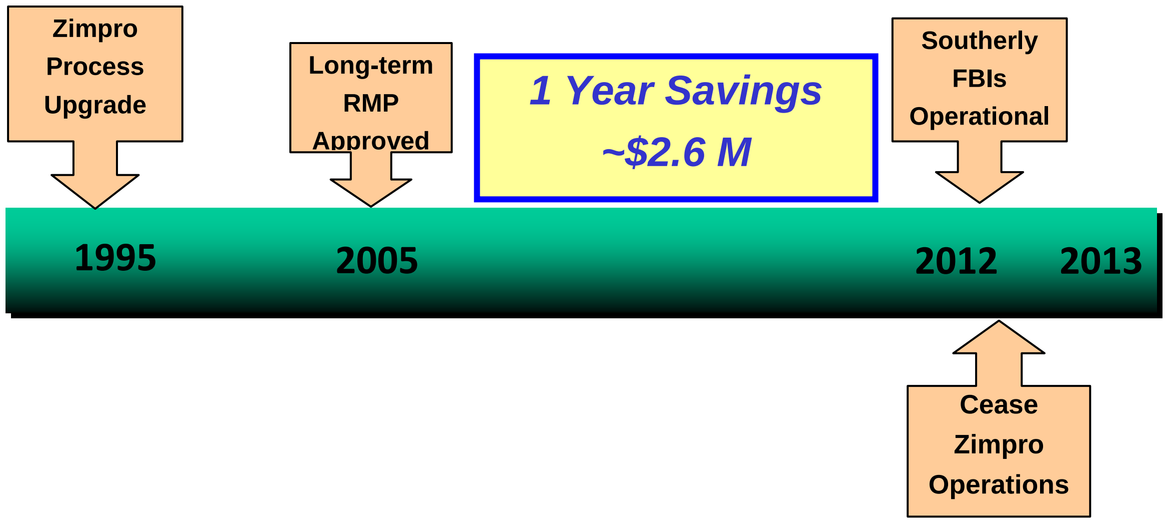


Figure B-2. Accelerated FBI Implementation

Opportunities to accelerate the implementation schedule include, but are not limited to, the following:

- Develop and agree on a procurement strategy.
- Investigate a "site preparation" contract involving demolition of old digesters and construction of new foundation up to grade.
- Coordinate contracts with equipment delivery.
- Accelerate the commissioning of the new dewatering centrifuges to reduce risk.

With the cost of delay over $7,000 per day, the validation team recommends that the District pursue an accelerated FBI implementation schedule.

ATTACHMENT C

Technology/System Option: Incineration with Green Power

INTRODUCTION

The District prepared an evaluation of waste heat boiler and power generation for the planned FBI project. The results were presented in TM 410 dated October 8, 2007. A schematic of the planned incineration project is shown in Figure C-1.

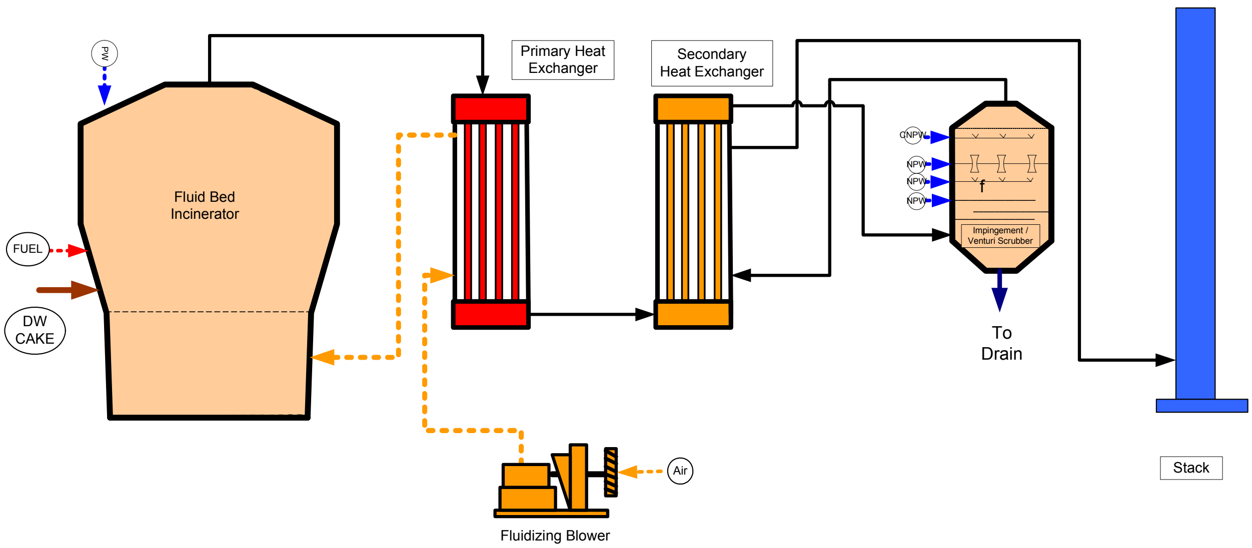


Figure C-1. Heat Recovery Schematic Proposed (similar)

Incineration with Green Power Option

The validation team determined that Incineration with Green Power should be evaluated and considered for the District. A schematic of this option is presented in Figure C-2.

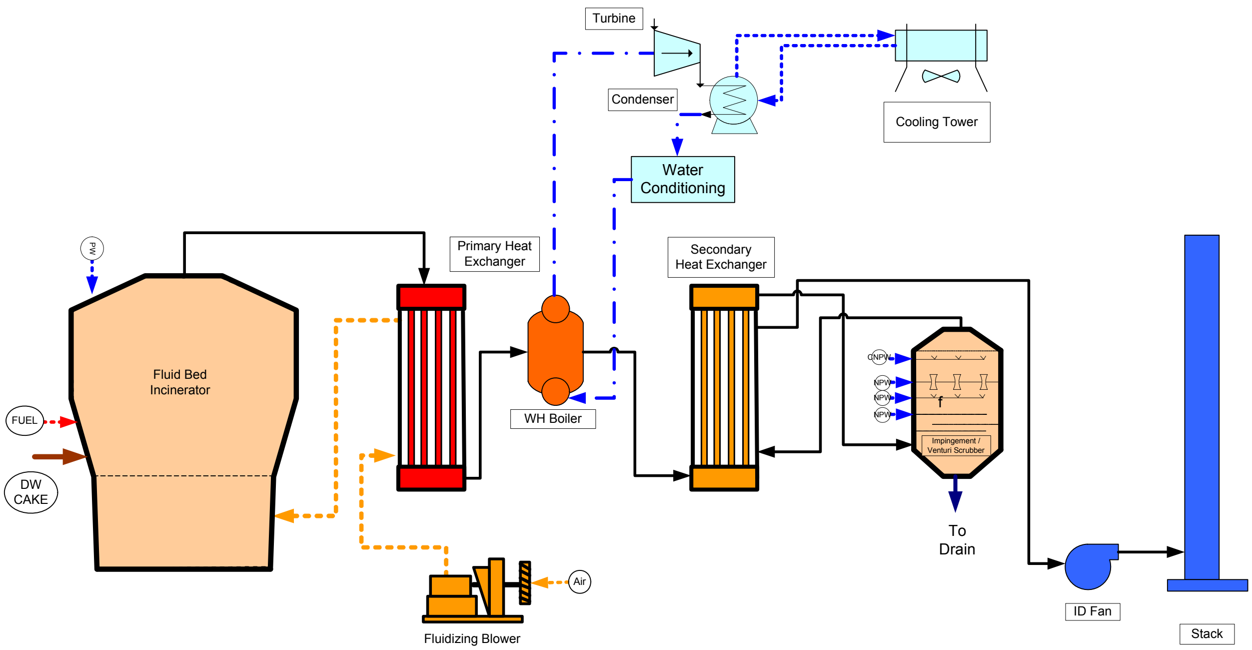


Figure C-2. Incinerator Schematic with Green Power Generation

Energy production was developed for both non-condensing and condensing turbines. Condensing turbines are more efficient but require a better treatment of water quality to avoid maintenance issues in the last stages of the turbine. All the alternatives are on the smaller side of condensing turbines. It is recommended that the District familiarize its staff with issues and opportunities for both types of turbines.

In TM 410, the steam system was complicated with heating loads and interconnection with the building heating system and other process loads. For the comparison, all the steam was used for power generation.

Higher installation costs for the condensing turbines were assumed for this analysis. The electrical system is assumed to be completely used within this building so the power production could be set up to reduce the quantity of purchased power. Since a new substation is part of the project, this can be incorporated into the design. The plant uses approximately 13 MW (average) and this new power supply is 10 to 20 percent of average plant power usage. Jim Welp recommends using the cost of power as the benefit.

The current plan has plume suppression with a secondary heat exchanger. A reheat coil may be needed for plume suppression.

Biosolids Characterization

The analysis in TM 410 was based on incineration of dewatered biosolids at 30 percent total solids (% TS) and 62 percent volatile solids (% VS). This volatile solids content seems fairly low for a typical plant that treats 90 percent residential sewage. The validation team recommends that the District reviews the volatile solids content and confirm that internal recycle streams are not impacting the current sampling locations. For the evaluation of a proposed green power option, Jim Welp conducted a sensitivity analysis using both the reported 62% and a more typical value of 70% VS.

It was noted that the analysis in TM 410 was based on a dewatered cake of 30% TS. We understand that the District has piloted raw sludge dewatering and that this testing indicated that they were able to achieve 30% TS. However, as with the VS discussion, once the Zimpro sludge is removed from the recycle streams, a more conservative value of 28% should be considered. Many utilities are able to reliably dewater to 28% TS with raw wastewater solids. To be conservative, the comparison of options was based on 28% TS and for sizing/costing the equipment. It should be noted that NO_x emissions increase with higher solids content.

Green Power Comparison with TM 410

The costs and sensitivity of power production for various biosolids characteristics are shown below.

Table C-1. Green Power Comparison

Item	TM 410	Green Power Alternative 1	Green Power Alternative 2
Feed Rate, dtpd	162.7	162.7	162.7
Total Solids, %	**30**	**28**	**30**
Volatile Solids, %	**62**	**70**	**70**
Steam Temp, F	700	750	750
Steam Pressure, psig	450	600	600
Steam Capacity, lb/h	19,940	26,000	36,000
Electricity, MW (Non-Condensing Turbine)	**0.65**	**1.4**	**1.8**
Electricity, MW (Condensing Turbine)	**1.14**	**2.6**	**3.6**
Cost	$16,500,000	$22,000,000	$22,000,000

Schedule

The construction schedule of the planned FBI project should be reviewed with respect to cost savings opportunities by accelerating project implementation. The District should consider:

- Timing of equipment delivery with construction contract.
- Potential for a "foundation" contract to install pilings, foundation, base slab, and possibly operation floor at grade if this is on the critical path.
- Provide separate commissioning schedule for dewatering and incineration and determine if there is an advantage to having dewatering and truck loading as a risk contingency to thermal conditioning.

The proposed schedule could be accelerated by one year or more by considering the above factors, as well as other strategic procurement alternatives.

Procurement Alternatives

Based on experience with other projects, it is possible to successfully procure equipment through an equipment procurement process. Issues for consideration include:

- Use of an evaluated bid process with price being approximately a third to half of the evaluation criteria to make sure the proposed equipment met the objectives.
- Require the incinerator supplier to sign a novation agreement with the General Contractor to work under them for the installation of the reactor which the supplier was required to construct.
- Alignment between Supplier and General Contractors goals by giving them a meaningful payment (up to 30%) on substantial completion.
- Allowance of a six month window for equipment delivery to the General Contractor; partial payment was provided for equipment ready to ship and required verifications of storage.
- Change order definition to account for small changes that will occur for the General Contractor (i.e., define basis of bid and how it will be reviewed).
- Define SCADA requirements and coordination points expected from the equipment supplier. Identify and standards they are to follow and require a pre-programming coordination meeting with District, General Contractor, Consultant, and SCADA programmer.

ATTACHMENT D

Technology/System Option: Cambi-Digestion + Class A Product

INTRODUCTION

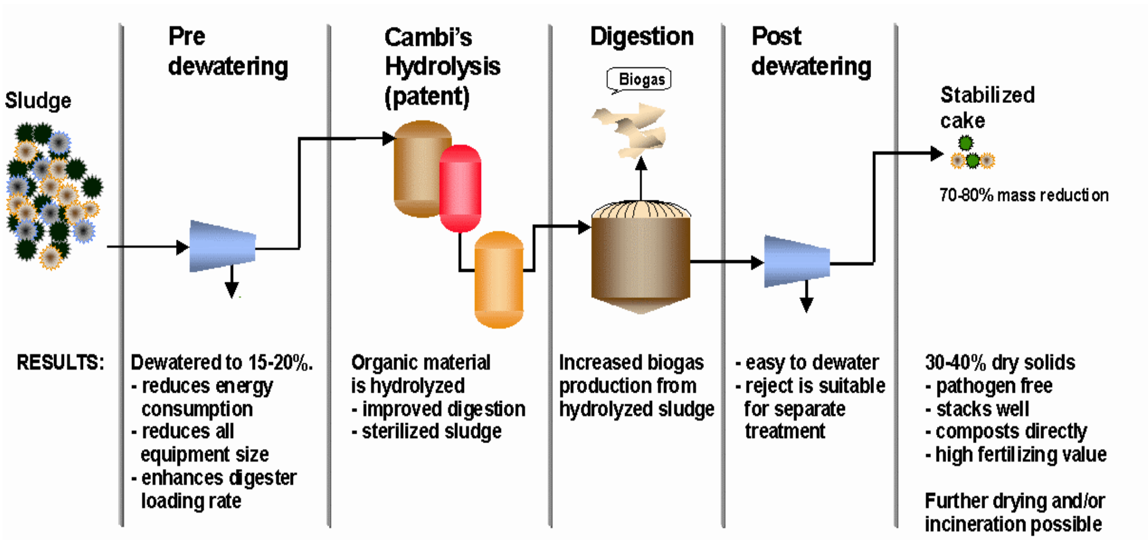
The panel evaluated potential alternative technologies and approaches that could process the Southerly plant solids into a usable beneficial product, to be used in some form of land application program or in fertilizer or soil conditioner production and marketing in Northeast Ohio. The panel felt that the biosolids product needed to be a Class A material and needed to have the capability for utilization during all seasons of the year - i.e., be a sustainable product and program. With very limited usable area available at the Southerly plant site, and the large solids production quantities, the panel felt the approaches and options were highly constrained. By reviewing proven technologies and approaches along with the other constraints and criteria, the team selected the Cambi-Digestion approach as a logical one to evaluate in more detail. Biosolids thermal-drying options were considered, but the panel knew from previous experience these would be high-cost options, requiring more site-area, and have less desirable carbon footprint.

Perry Schafer, Terry Logan, and Tim Shea developed a concept for a solids processing facility that would include Cambi thermal hydrolysis, mesophilic anaerobic digestion facility and a CHP (combined heat and power) system. The effort included the preparation of a cost estimate and a biosolids product analysis as the biological alternative to FBI incineration.

Terry Logan’s biosolids product analysis is presented at the end of this attachment. The facility would produce Class A biosolids for multiple possible outlets to agricultural land application and to topsoil manufacture.

Scott Harder developed a life cycle cost analysis based on the following conceptual design and operations requirements.

Cambi Process Description



Concept for Cambi-Digestion Alternative

- An aerial photograph of the Southerly site was provided to the panel members, with the following locations delineated:
  - 'A' – Center of the plant and current site of the 'A' Digesters
  - 'B' – east side of the plant and site of the Contractor's Parking Lot
  - 'C' – East side of the plant, just north of the Contractor's Parking Lot
- The facilities needed for this alternative will require in the order of 5 acres. The 'A' location at Southerly contains about 2.3 acres and was therefore inadequate in area for the new complex.
- The 'B' and 'C' areas that were available for new facilities contain in excess of five acres and therefore were selected as the site for a Cambi-digestion facility as described below.
- These areas are located about 600 feet easterly of the 'A' area, at the edge of the property, and would allow the development of a solids processing facility that would leave open the central area of the plant for future expansion of the liquid treatment train.
- It was assumed that the new facility would include the following processes and operations:
  - Provide a terminus for a utility corridor from the existing treatment plant for transfer of sludge and reject water streams to and from the new facility.

- Provide a StrainPress facility for treatment of the Easterly sludge flow, the Southerly primary sludge, and the blended skimmings from Easterly before a blending and dewatering operation. The Southerly biological sludges would not require StrainPress treatment. The StrainPress operation would enhance the quality of the Class A products for unlimited distribution and marketing.
- A bay would be required for a dumpster to collect the material removed in the StrainPress facility.
- The streams would be blended and dewatered to 15 to 18% TS as a feed stock to the Cambi process.
- Three Cambi thermal hydrolysis trains would be provided, each interconnected.
- The thermally-hydrolyzed flow would be transferred to three mesophilic anaerobic digesters, followed by a single secondary digester that could also serve as a primary digester. All four digesters would be of the same dimensions and design.
- The digested biosolids would be dewatered and transferred to the truck outloading facility or onsite storage. The onsite storage capacity to be provided was three (3) days of dewatered cake production.
- The outloading facility would have two separate bays, the first for transfer of Class A biosolids cake to beneficial use locations, and the second for transfer of raw cake to tractor trailers for haul to landfill as a back-up system.
- The biogas generated in the process would be used to fuel a combined heat and power system and to satisfy the parasitic heat needs of the Cambi process.

Basis of Concept Design and Cost Estimate

The following basis was used for the concept design:

- Design for peak monthly capacity with 13-day HRT at peak monthly loading rate of 225 DPTD at 11% TS feed to digesters (490,000 gpd), yielding a 18.2-day HRT at average annual loading rate.
- Requires:
  - Strain Press system – sludge flow is 1 mgd or five units; skimming flow to take two units in addition; one spare = 8 eight Parkson strain presses; building to contain skimmings receiving, sludge receiving, truck load-out bay for screenings, odor control, etc. Allow $20 million.

- Dewatering station #1 for Cambi feed – feed at 4% TS; peak weekly at 260 DTPD or 1,555,000 gpd; feed at 18% DS to thermal hydrolysis. Use two Westphalia or Alfa Laval large machines at 600 gpm. Three machines enclosed all in at $15 million.
- Thermal hydrolysis - each train has 125 DTPD of capacity so will need a total of 58,765/125 or 1.28 trains for annual average loading rate, and 2.02 trains per peak week. Use two trains each with six reactors (five duty) at $15 million each or $30 million in total.
- Provide three digesters at 2.15 million gallons each plus one for storage at same size = 8.6 million gallons total. Cost at $7 per gallon = $60.2 million.
- Solids from digester at 62% volatile solids and 50% VSR and 7% TS; this stream will load a belt filter press capable of 630 lbs TS per hour per meter and 155 DTPD of sludge. Operate 24 hours per day, seven days per week. Need seven 3-meter machines plus spares to get to 10 total. Use $ 1.5 million per machine all in or $15 million.
- Post digestion dewatering @ $10 million. Total dewatering both pre and post digestion - use $35 million including building.
- Truck outloading facility for say 500 CY/day average, two separate dedicated bays (one for digested and one for raw), three (3) days of finished cake storage and odor control - $20 million.
- CHP system – 1,600,000 SCFD of biogas at 60% methane and 600 BTU/SCF = 960 MM Btu/day. Assume 3 MW for a Cambi system, net of the parasitic heat use.
- CHP system cost is $15 million all in.
- Utilities and pipeline in a corridor - $10 million.
- Total capital cost before mark-ups: $190 million.

O&M Costs

- 111 DTPD of dry solids or 40,500 DTPY; 317 WTPD or approximately 350 CY as Cambi cake; $5/WT FOB plant to topsoil; $40/WT to agricultural land application.
- 25% to land application; 75% to topsoil.
- Pump-over, strain-pressing, odor control and outloading - $400,000/year.
- All in $1.8 million/year for operation of beneficial use outlets, and includes a biosolids coordinator (topsoil $650,840 @ $7.50/ton for 75%; land application @ $1,157,000 for 25% or total @ $40/WT.
- $2.0 million/year for thermal hydrolysis by Cambi and mesophilic anaerobic digestion except second stage dewatering.

- $2.0 million/year for second stage dewatering ($50/DT x 111 x 365).
- Total $6.2 million/year.

Revenue

- 3,000 kilowatts x $0.069 x 8,640 = $1.8 million/year.
- Assume 95% availability.
- Net revenue = <$1.7 million/year > (first year).
- Net cost is $4.5 million/year (first year).

Beneficial Use of Cambi/Anaerobic Digestion Cake Product

The filter cake product generated by the Cambi/anaerobic digestion (AD) process would be Class A. The Cambi thermal step provides high enough temperatures for disinfection. The temperature in the reactors is 170 ^{0}C for 45 minutes. VAR would be achieved by volatile solids reduction in the AD step (the AD step is estimated to provide about 50% volatile solids reduction).

The Cambi/AD biosolids can be dewatered to 30-35% solids. This material has been shown to be friable, with low odor characteristics, and readily stacked. Work at DCWASA (District of Columbia Water and Sewer Authority) showed that the material could be blended with mineral soil to produce marketable topsoil. The material can also be land applied to agricultural crops or for land reclamation.

The proposed system at Southerly would produce approximately 116,000 wet tons annually at 35% solids. It is proposed that 75% of the annual production will go to topsoil blenders in the area, and 25% to seasonal land application.

Topsoil Blending

Work at DCWASA showed that the Cambi/AD cake could be blended at a ratio of 3:1 mineral soil to Cambi/AD cake. This will require 261,000 tons of mineral soil and will generate 319,000 tons of blended topsoil. There are a number of topsoil blenders in the greater Cleveland area, the biggest of which and the operation closest to Southerly is Kurtz Brothers. The total annual sales of topsoil in the area are not known, but the projected production of Cambi/AD blended topsoil will represent a significant increase in total area topsoil production. This will require firm long-term contracts with area topsoil blenders and market development on their part. There is significant uncertainty as to whether long-term contracts can be developed in advance of plant startup.

Land Application

Approximately 29,000 tons of Cambi/AD cake will be land applied for agriculture, with minor amounts for occasional land reclamation projects. The Long-Term Residuals Management Plan estimated that there are about 446,000 acres of cropland in seven counties in NE Ohio. A more conservative estimate of land within 30-40 miles of Southerly is 374,000 acres. At a nitrogen loading rate, the Cambi/AD cake would be applied at approximately 5 tons/acre. This would require 5,800 acres per year. Although other area municipalities land apply their biosolids, there will be adequate acreage in the area for sustained land application to agriculture. Contracts will have to be negotiated with area land application companies.

The major uncertainty with respect to land application is seasonable weather. Windows for land application are usually August to November for wheat, August to November and April for corn and soybeans, April to November for hay. Early fall rains and late spring rains are common and can prevent land application. More importantly, OEPA has proposed revisions to its land application rules that will prohibit land application of biosolids on snow-covered or frozen land, or on land with a forecast for rainfall. This will greatly lower the opportunity for land application in the period November to May.

Cambi/AD Storage

The proposed design allows three days of storage at Southerly. The assumption is that most of the material will be trucked daily to the soil blending sites, with the remainder trucked to land application sites during seasonable windows. NEORSD will have to apply to Ohio Environmental Protection Agency (OEPA) for a variance on the 120-180 days storage requirement by arguing that blended topsoil is exempt from the storage requirements. A significant increase in storage time at Southerly would require a large increase in capital costs.

ATTACHMENT E

Carbon Footprint and Economic Comparison of Options

INTRODUCTION

A primary objective of the validation workshop was to assess the carbon footprints of the proposed fluidized bed incineration alternative as it compares with that of existing multiple hearth incineration operations and other potential solids management options.

Carbon Footprinting

The carbon footprinting analysis sought to compare and contrast the annual emissions generated through normal operations of: 1) fluidized bed incineration, 2) fluidized bed incineration with co-generation ("Green Power"), 3) multiple hearth incineration, and 4) commercial landfilling. This reconnaissance level analysis will be followed by a more in-depth GHG inventory analysis currently underway.

For purposes of this analysis, carbon footprinting is defined as the annual greenhouse gas ("GHG") emissions due to normal solids processing operations. Emissions related to construction or other "life cycle" emissions are not included in the analysis with the exception of polymer supply chain emissions. Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are the three greenhouse gases of primary interest in wastewater treatment operations. Total emissions are expressed in metric tons of CO_2 equivalents. CH4 emissions are adjusted to equivalent CO_2 emissions by multiplying by a defined Global Warming Potential value of 21. (That is, 1 ton of CH_4 emissions is equivalent to 21 tons of CO_2.) N_2O emissions are similarly adjusted to equivalent CO_2 emissions by multiplying by a defined Global Warming Potential value of 310. One ton of N_2O emissions is equivalent to 310 tons of CO_2.

Emissions estimates rely upon emissions factors established for fossil fuel combustion, generation of electric power in Ohio, and fugitive emissions established for various solids management processes. With the exception of supply chain emissions related to the manufacture and transport of polymer to the Southerly Wastewater Treatment Center, supply chain emissions have been assumed to be negligible.

Climate change mitigation programs in the United States rely on several protocols that have been developed for the accounting of GHG emissions. These include the World Resources Institute and World Business Council for Sustainable Development protocols; ISO 14064; the California Climate Action Registry General Reporting Protocol; the U.S. EPA Climate Leaders Greenhouse Gas Inventory Guidance; and the recently published Climate Registry General Reporting Protocol. The recently published Climate Registry

General Reporting Protocol draws on the other guidance documents, and is the protocol for the largest North American voluntary carbon markets. It is also the registry used by the Regional Greenhouse Gas Initiative (RGGI) and the Western Climate Initiative. It is the primary basis for this analysis.

Most GHG accounting protocols require that boundaries for the analysis be established at the facility or organizational level. These boundaries may be either financial or operational. For purposes of this analysis, the GHG emissions estimates are limited to the solid management processes at SWTC and do not include emissions from the liquids processes.

Based on the Climate Registry General Reporting Protocol, GHG emissions fall into four categories: Scopes 1, 2, and 3, and Biomass CO_2 emissions.

Scope 1. Direct Emissions include all GHG emissions that result from burning of fossil fuels on-site or in company owned vehicles.

Scope 2. Indirect Emissions include those associated with any purchased electricity, steam, heating or cooling.

Scope 3. Indirect Emissions include those emissions not included in Scope 2, and are optional in all reporting schemes. These emissions typically include supply chain operations or other sources outside of the direct control of the District or the SWTC.

Biomass CO_2 Emissions are those generated by the onsite combustion of biomass and are reported separately from the other scopes. For purposes of this analysis, a small amount of fossil carbon is assumed to be present in the biosolids, generating a small amount of reportable Biomass CO_2.

For this analysis, emissions from purchased power would be considered Scope 2; emissions from natural gas combusted in existing incinerators would be considered Scope 1; and emissions from proposed biomass combustion would be both Scope 1 (CH_4 and N_2O) and accounted for outside of the other scopes (CO_2).

Under most voluntary market requirements, the quality of emissions calculations is divided into three tiers based on the method of calculation. Tier A, which is considered the highest quality, is either a direct measurement of waste stream emissions or the measured carbon content (per unit mass or volume) of the fuel. Tier B calculations use measurements of fuel heat content per unit energy, either default or measured carbon content factors, and a default heat value factor. Tier C calculations use default fuel emissions factors. Organizations are encouraged, but not required, to use the highest quality tier that is practical.

Table E-1 below presents the sources of emissions that were examined for this planning level analysis. Table E-2 presents the annual emissions estimates in equivalent metric tons of CO_2. Both the FBI with Green Power and the Cambi-digestion + Class A Product options offer a net reduction in Scope 1 and 2 emissions due to reduced purchased electric power.

Table E-1. Emissions Sources

	SCOPE 1 Direct	SCOPE 2 Indirect	SCOPE 3 Other Indirect	BIOMASS COMBUSTION
Alternative	CO_2, CH_4, N_20	CO_2, CH_4, N_20	Metric tons CO_2 equivalents	CO_2
Baseline MHIs	Natural gas Biosolids transport fuel Ash transport fuel Fugitive emission	Electric power	Polymer supply chain	Biosolids incineration
FBI	Natural gas use Ash transport fuel	Electric power	Polymer supply chain	Biosolids incineration
FBI with Green Power	Natural gas use Ash Transport fuel	Electric power	Polymer supply chain	Biosolids incineration
Cambi-digestion + Class A Product	Topsoil transport Land app. transport Disposal transport	Electric power	Polymer supply chain	
Landfill Disposal	Biosolids transport fuel Decay emissions	Electric power	Polymer supply chain	

Table E-2. Emissions Estimates

	SCOPE 1 Direct	SCOPE 2 Indirect	TOTAL SCOPES 1+2	SCOPE 3 Other Indirect	BIOMASS COMBUSTION
Alternative	CO_2, CH_4, N_20	CO_2, CH_4, N_20	Metric tons CO_2 Equivalents	CO_2, CH_4, N_20	CO_2
Baseline MHIs	13,780	5,500	19,280	6,000	1,570
FBI	500	5,200	5,700	6,000	1,570
FBI with Green Power[2]	500	-11,000	-10,500	6,000	1,570
Cambi-digestion + Class A Product	570	-8,800	-8,230	8,000	n/a
Landfill Disposal	24,525	750	25,275	6,000	n/a

Economic Comparison of Options

Another primary objective of the validation workshop was to re-assess the relative cost-effectiveness of fluidized bed incineration and other potential solids management options.

The workshop participants used life cycle cost analysis methods similar to those used by the District for its Southerly and Easterly Facility Plan projects. Life cycle costs were developed for a forty year analysis period and included upfront capital, annual operating and maintenance, periodic renewals and replacements, and a terminal value at the end of the analysis period. All options were assumed to start operation in 2013. Construction and operating costs were escalated in accordance with inflation factors adopted by the District.

Life cycle cost analysis is standard practice in judging the relative economic benefits of projects that may differ in upfront capital and ongoing operating costs. By employing a “time value of money” approach, the projects are evaluated on an apples-to-apples basis.

Table E-3 presents both life cycle and greenhouse gas emissions for the proposed FBI project, FBI with Green Power, and the Cambi-digestion + Class A Product options.

Table E-3. GHG and Life Cycle Cost Comparison

Option	GHG (mtC02e)	Life Cycle Cost, $M
FBI	5,700	250
FBI with Green Power	-10,500	230
Cambi-digestion + Class A Product	-8,230	370

ATTACHMENT F
Staffing Optimization Opportunities

The major unit processes in the existing residuals treatment train are dewatering, Zimpro, and four multiple hearth incinerators. According to District staff, this complex is currently staffed by 154 full-time employees. The proposed new complex will consist of dewatering and three fluidized bed incinerators (FBIs).

Until the new FBIs are online, construction phasing and the decommissioning of the Zimpro process will require a clear transition and start-up operations plan. Since the Zimpro system will not be needed to provide feedstock to the FBIs, it will be decommissioned as soon as the FBIs are installed and operational. When this occurs, the complex will have one less major system (Zimpro) to operate and maintain.

When this operational status is reached, it is likely that some staff optimization would be feasible via cross-training, transfers, and/or attrition.

The operation and maintenance of additional green power facilities presents opportunities to cross-train, utilize existing staff, and/or contract out operations.

In view of the foregoing, it is recommended that the feasibility of staff optimization be explored for the new incineration operations.

ATTACHMENT G

Panel Response to Schmack BioEnergy Presentation

Representatives from the Schmack BioEnergy Company gave a brief presentation to the panel on August 12, 2008. The representatives in attendance were Annette Burger (from the City of Akron composting facility), Clemens Halene (Vice-President of Engineering), and Mel Kurtz. The presenters gave a professional presentation about the technical aspects of the process. The Schmack BioEnergy process has been developed in response to energy challenges in Germany primarily processing agricultural materials; it was adapted for use in the industrial sector (i.e., food processing). It is currently in the process of being adapted for application in the municipal biosolids processing arena.

Panelists posed a diversity of questions to the representatives, which were responded to in a straight-forward manner. Based on the presentation, the responses to the questions posed during the presentation, and the discussions that followed, panel members arrived at the following conclusions:

- The adaptation of the process from the processing of agricultural materials to municipal biosolids is a work-in-progress.
- The process has very limited operational experience in the United States and worldwide handling biosolids materials. To date, the total extent of their operational experience in the U.S. and worldwide is six months – all of which has been gained at the Akron composting facility. The company is currently in the process of negotiating potential contracts with Columbus and Canton, Ohio.
- With respect to size of operations, their experience with municipal biosolids is attributed to the Akron operation, which handles approximately 15 dry tons per day (about 10 percent of the District's total production).
- The Schmack process requires an input feed concentration of biosolids from the District's Easterly WWTP of five percent total solids, while the District is able to provide only a feed of 0.5 percent solids. An additional cost would be required to meet the increased total solids feed concentration.
- Due to site limitations at the Southerly plant, a separate site would need to be provided by Schmack. The siting and purchase of a separate site would warrant considerable time in project implementation.

- Impacts of sidestreams (i.e., nitrogen concentrations) that would return to the Southerly wastewater treatment plant are unknown; this is a critical consideration as nutrient discharge limits become more stringent.
- During the presentation, it was noted that the Schmack system was presented as proprietary, yet none of the unit processes are patented.
- Technology issues:
  - Technology appears to have merit once biosolids processing adaptations are overcome and more relevant large-scale operational experience is gained.
  - The primary unit processes of the system are well-known and proven for biosolids application in the U.S. (dewatering, equalization, digestion).
  - It is unclear why solids are dewatered to 25 percent, and then diluted again prior to equalization and digestion. This process step is implemented at the Akron facility and is proposed for the District.
  - The “PFRP” (Process to Further Reduce Pathogens) unit process shown in the process train to produce a Class A product is not defined.
  - The overall system does not present any new innovative technology but rather the planned adaptation of existing technologies to wastewater biosolids.
  - The system proposed to the District does not provide for odor control, which represents an unaccounted for cost item.

Based on the information reviewed, it appears that the system proposed by Schmack BioEnergy is simply a privatization project. Alternative project delivery and financing methods proposed by Schmack may not be consistent with District procurement policies and statutory requirements.

In summary, the panel’s comments with respect to the Schmack BioEnergy presentation are:

- The process experience demonstrated in Germany is with animal manures, food and agricultural wastes.
- There is very limited biosolids processing experience in the U.S. or elsewhere.
- This process is not ready for District-scale implementation.