The eco/Tech Sludge Recycling System:
New Waste Streams, New Revenues

Submitted by:

eco/Technologies, LLC
An EnergyAnswers Company
79 North Pearl Street
Albany, New York

Presented at:
NAWTEC 10
Philadelphia, PA
May 5-8, 2002

ABSTRACT

The patented eco/Technologies Sludge Recycling System (eco/Tech SRS) is a commercially proven technology that provides resource recovery facilities with a new revenue source *and* the potential for reduced emissions of nitrogen oxides (NOx). The eco/Tech SRS offers an environmentally sound, cost-effective disposal option for sludge and liquid waste producers and an additional revenue source for municipal waste combustor facilities. As the wastewater treatment and other industries face increasing regulatory scrutiny that will result in more expensive sludge disposal practices, the resource recovery industry, which has already met the regulatory challenge and has taken the lead in compliance and corporate citizenship, can provide the answer.

INTRODUCTION

One industry's trash is another industry's treasure. This variation on an old saying can be applied to the cross-pollination of industries that have not been linked historically. For example, who could have predicted that increasingly stringent environmental regulations facing the wastewater treatment industry would lead to *reduced* sludge disposal costs, while simultaneously achieving lower-cost air pollution control for solid fuel power plants struggling for survival?

This paper describes the success of the eco/Tech Sludge Recycling System (SRS), patented (U.S. Patent No. 6,279,493 - August 28, 2001), and operating commercially at the Pioneer Valley Resource Recovery Facility (PVRRF) located in Agawam, Massachusetts.

As available options for communities and industries for sludge disposal decline because of increasing environmental constraints and rapidly rising disposal costs, an environmentally sound, cost effective method of sludge disposal is desperately needed. Since the 1950s, sludge has often been incinerated in multiple hearth incinerators. However, most of those installations experienced poor combustion and generated adverse air emissions. Accordingly, this approach was either abandoned in favor of non-combustion disposal technologies or forced to install expensive air pollution control retrofits. Other sludge combustion technologies often involve energy-intensive thermal drying systems that are expensive and even dangerous, because of potential health hazards related to inhalation of fugitive dust and dust explosions. Still other approaches involved injection of wet sludge into more modern combustion processes, but failed to achieve commercial viability because of limited applicability and economic or technical disadvantages.

Non-combustion technologies including landfilling, land application, composting, and ocean dumping all have the potential for significant detrimental environmental impacts because of the bio-accumulation of heavy metals and other chemical compounds. These technologies are coming under increasingly focused regulatory scrutiny and face the very real threat of being banned or significantly altered with increased disposal costs as a result.

Because of its involvement with numerous projects where co-disposal of sludge with other fuels could be environmentally and economically sound, EnergyAnswers Corporation (EAC) embarked on a technology development program to substantially reduce or eliminate the shortcomings that historically prevented commercial viability of earlier co-combustion techniques. This program evolved during six years of studies, testing, design, and operation, and culminated in the commercial success of the newly patented eco/Tech SRS.

INITIAL TEST PROGRAM

In late 1999, EAC completed a test program to evaluate the efficacy of a new approach to sludge co-combustion and concurrently the environmental performance of EAC's Pittsfield Resource Recovery Facility (PRRF) located in Pittsfield, Massachusetts. The PRRF employs the Enercon combustion technology. The test program compared emission results while co-combusting sludge and municipal solid waste (MSW) against combustion of MSW only. The primary purpose of the program was to determine if sludge could successfully be co-combusted with MSW at commercially viable levels in a safe and environmentally sound manner. Activities completed included SRS evaluation, air emissions testing, ash sampling, and an evaluation of PRRF process operations, all under the watchful eye of the Massachusetts Department of Environmental Protection (MADEP).

Following is a discussion of the results of the SRS demonstration test program:

Sludge Solids Content

Solids contents from 2% to 12% were evaluated. As expected, sludges with lower solids content were easier to pump, but added excessive moisture in the combustor. Higher solids content sludges offered less heat loss in the combustor due to reduced moisture, but were more difficult to store, mix, and pump. Subsequent comprehensive testing focused on sludges in the range of 10% solids.

Sludge Injection Rate

Sludge flow rates from 4 gpm to 20 gpm (15 to 75 L/min) were tested initially. Good flow characteristics and quality of particle atomization were achieved at all flow rates, using a specially crafted dual-fluid nozzle. The selected flow rate for further testing was 10 gpm (38 L/min) at 10% solids, which represents a sludge disposal ratio of approximately 5% by weight dry sludge solids to MSW disposal capacity at the PRRF.

Sludge Nozzle Atomizing Parameters

A wide range of sludge and steam pressures at the atomizing nozzle were tested. Sludge pressure in the range of 15 to 25 psig (1.05 to 1.76 kg/sq. cm.) at the nozzle, with steam pressure running in a similar range, worked well. Atomization worked better as the amount of steam superheat increased.

Primary Combustor Temperature

Operators learned quickly to anticipate the onset of sludge injection by slightly increasing primary combustor temperature or slightly increasing MSW feed rate.

Recirculating Flue Gas (RFG) Damper Position

As expected, the RFG damper, which automatically controls primary combustor temperature in the Enercon technology by adding cooled flue gas, further closed in response to sludge injection. This indicated that primary combustor temperature could be used to modulate sludge flow in a commercial automatic control mode. This observation was also helpful in judging that the impact of moisture in the sludge was not excessive, because of the relatively low ratio of sludge to MSW.

Furnace Draft

Sludge injection had no noticeable effect on furnace draft. It was observed that less excess air was demanded by the control system during sludge injection because turbulence in the furnace from sludge injection utilized combustion air more efficiently. This suggests that there are balancing effects of sludge injection that may offset some of the heat lost to evaporating moisture in the sludge.

Sulfur Dioxide, Carbon Monoxide, and Opacity Emissions

There was no difference in these parameters between co-combustion of sludge with MSW and combustion of MSW only.

Nitrous Oxide Emissions

Significant NOx reductions ranging from 5% to 37% were achieved with the SRS. Therefore, the SRS demonstrated the potential to replace existing costly reduction systems with a revenue-generating alternative for solid fuel boilers. To the extent that NOx emission tradeoffs and credits become a marketable commodity, this discovery could lead to dramatic improvements in power plant economics.

Particulate Emissions

Measured particulate emissions were slightly greater during the co-combustion tests than during the MSW-only test, but the results of all tests were within the range of historical test results at PRRF and well below permitted levels.

Metal Emissions

The only metal showing emissions higher than for combusting only MSW was zinc, a known additive in many wastewater treatment processes. EAC believes it will be possible to work with sludge suppliers to reduce zinc concentrations in commercial applications.

Dioxins/Furans Emissions

Measured emissions were slightly greater during the co-combustion tests than during the MSW-only test, but again the results of all tests were not only within the range of historical test results at PRRF but also well below permitted levels.

Ash Analysis

Six combined ash samples were tested using the Toxicity Characteristic Leaching Procedure (TCLP). The results showed that only two of the 48 data points tested were within 30% of the regulatory limit, while all others were less than 2% of the limit.

Conclusions

The demonstration test program was successful and showed that:

- Sludge having maximum solids content below 15% eliminates many of the previous barriers to commercial development of sludge recycling technology
- Sludge recycling ratios of approximately 5% (by weight) dry solids to MSW disposal capacity can be achieved
- A wide variety of sludge types can be handled successfully
- A wide variety of sludge types and liquid wastes can be handled successfully
- Superheated steam helps achieve good sludge particle atomization and good sludge solids combustion
- No significant adverse effects were observed with respect to air emissions or ash quality. In fact, a reduction in NOx emissions was achieved when combusting sludge
- No adverse impacts were observed with respect to combustor operations as determined by carbon monoxide concentrations and primary combustor temperature

- No odors were evident from the SRS, except in connection with the temporary nature of the test apparatus. However, such odors can be eliminated in commercial application.

As a result of the extremely successful testing program at PRRF, MADEP issued permits to construct commercial SRS installations at the PRRF and PVRRF, the first permits of their kind in the United States.

FIRST COMMERCIAL INSTALLATION AT PVRRF

Based on the success of the initial testing program, EAC established the following goals for its first commercial installation at PVRRF:

- Maximize the efficiency of a receiving and processing system that handles sludge and liquid wastes with a wide range of characteristics, including variable solids content; delivers a consistent flow of sludge to the injection system; and eliminates odor control problems typical of other sludge management systems

- Allow continuity of combustor fuel input by balancing the heating value of sludge solids with the loss in heating presented by moisture in the sludge

- Avoid the material handling difficulties with sludge having solids content greater than 15% by adding liquid waste and agitating to produce a mixture of flowable sludge

- Minimize sludge particle size to achieve no impact on ash quality and air emissions

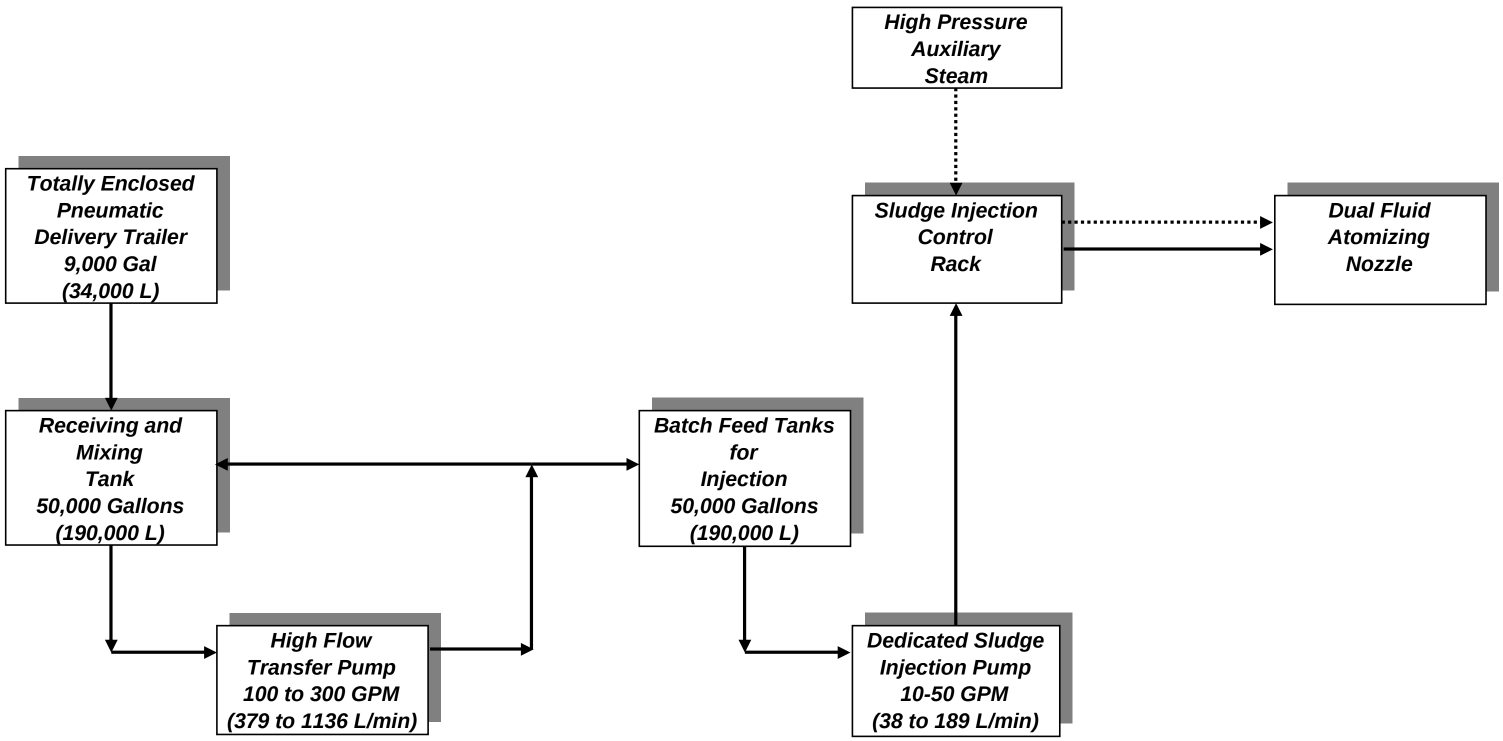
- Inject sludge at a ratio of up to 5% by weight of dry sludge solids to as-fired MSW

- Design modular components applicable in multiples to future projects of any size

- Achieve complete integration with PVRRF combustion control system for automatic operation of the SRS

Shown on ***Figure 1*** is a simplified schematic diagram of the PVRRF eco/Tech SRS. The system is divided into three modules: SRS bulk transportation module, SRS receiving and mixing module, and SRS injection module.

Figure 1
eco/Tech Sludge Recycling System
Simplified Flow Diagram



eco/Technologies, LLC
An EnergyAnswers Company

SRS Bulk Transportation Module

An integral part of the SRS is the specially designed bulk trailer for receiving loads of sludge at a customer's facility, transporting to the power plant, and using pneumatic unloading for fast and odor-free transfer to the receiving and mixing module. The trailer features an innovative air diffusion system designed to both mix sludge on board and to manage odor by ensuring aerobic conditions inside the tanker. Air for mixing, odor control, and unloading is provided by an on-board Power Takeoff (PTO)-driven positive displacement blower. Alternatively, air can be provided by stationary air compressors at the power plant. The mixing system allows for maximum flexibility to enable mixing of a partial load of high-solids content material with a partial load of low-solids content material.

In addition to primary odor control by the addition of air, an activated carbon cannister is mounted on each trailer, so that all air vented from the trailer passes through the cannister to provide secondary positive odor control. In the initial commercial operation at PVRRF, this system has performed beyond expectations, and there has never been an odor emanating from the trailer.

For customers who prefer to pump directly from their trailer to the combustor one load at a time, valves and connections are provided for recirculation back to the trailer from the injection pump.

The bulk transportation system delivers loads of 7,000 or 9,000 gallons, depending on road restrictions, that can be unloaded either pneumatically or pumped in less than one hour.

SRS Receiving and Mixing Module

To enable maximum flexibility, continuous feed to the combustors, and storage capacity for uneven deliveries, a minimum of three storage tanks is recommended, each sized for the maximum daily delivery rate. One tank is used for receiving and mixing, one for on-line delivery to the combustors, and one as a spare or overflow for combustor outages. All tanks are vented through a common header through an activated carbon odor control system sized for the maximum air flow from bulk trailer unloading. However, since all tanks are connected to a common header, the amount of air vented is reduced by the amount of displacement from the tank actively feeding the combustors. When trailers are not being unloaded, air is actually drawn into the system. Each tank is aerated and mixed by a positive displacement air diffusion system that adds heat to the sludge and reduces viscosity.

The receiving and mixing tank is piped to a high-capacity sludge transfer pump that allows continuous recirculation from the bottom of the tank to the top during unloading of trailers and batch preparation. The sludge transfer pump discharges through a large Moyno Pipeliner, specially selected to reduce sludge particle size below the size of the injection nozzle opening. The Pipeliner chops up fibrous material to protect against nozzle plugs. When the receiving and mixing tank is full and the material has been checked for proper solids content, the sludge transfer pump transfers sludge to the on-line combustor feed tank.

The combustor feed tank provides suction to each sludge injection pump, which then delivers sludge to the SRS Sludge Injection Module. One injection pump is provided for each 10-GPM nozzle. This arrangement allows for maximum operational flexibility and automatic integration with the power plant combustion control system. The sludge injection pumps are variable speed and respond to demand signals from the SRS control system, which is an integral part of the injection module.

SRS Injection Module

Each 10-GPM injection nozzle is provided with a fully instrumented injection rack for fully automated control of sludge and atomizing steam flows, temperatures, and pressures. The instrumentation package provides data input to the SRS programmable controller. The controller includes input/output ports for important combustor operating parameters, such as furnace temperature, furnace draft, and permissive signals from the burner management system. Each controller is engineered to specifically meet requirements for full, safe integration with the plant's combustion control system.

The nozzle is inserted and retracted automatically by an externally supported mechanism according to commands from the control system. An opening of only three inches in diameter in the combustor is necessary, and this opening can be provided with an automatic-closing cover door if desired. In the inserted position, the nozzle extends less than two feet into the furnace to minimize its exposure to radiant heat and corrosive gases. The nozzle and lance are constructed with Hastelloy to ensure long service life.

Sludge pressure at the nozzle is typically 25 to 50 psig, as delivered by the sludge injection pump. Atomizing steam pressure is set by the operator to follow a set differential pressure above or below sludge pressure. This set point is fully adjustable and capable of automatic operation to allow for maximum flexibility in optimizing atomization of varying sludge products and consistencies.

An automatic steam purge system is included to momentarily stop sludge injection and apply line steam directly to the nozzle whenever sludge pressure begins to rise to a predetermined set point. In most cases, plugs can be avoided in this manner, because plugs tend to build up over time rather than suddenly. The purge cycle is also used as part of the automatic shut-down sequence to clean the nozzle before a combustor outage.

EMISSION RESULTS FROM THE FIRST COMMERCIAL INSTALLATION

Shown on ***Table 1*** are the results of stack emission testing at PVRRF in March 2002 for MSW combustion only and MSW/sludge co-combustion. Permits limits, where applicable are also shown.

Table 1
eco/Tech Sludge Recycling System
Emission Test Results
March, 2002

Independent Stack Testing by AirRECON	Permit Limits	Stack[1] 21H	Unit 3 ONLY[2] Sludge
Total Particulate (gr/dscf x 10^{-2} @ 12% CO_2)	1.7	0.4	0.2
Beryllium (lb/MMbtu x 10^{-7})	6.3	0.5	0.6
Cadmium (lb/MMbtu x 10^{-6})	(No Limit)	6.7	2.9
Lead (lb/MMbtu x 10^{-3})	1	0.02	0.01
Mercury (lb/MMbtu x 10^{-4})	2.4	1.0	1.7
PCDD/PCDF tetra-octa (lb/hr x 10^{-6})	6.1	1.5	1.6[3]
HCl unit 3 (ppmv @ 12% CO_2)	48	15	33

CEM Data for Test Days

	Permit Limits	Stack 21H	Unit 3 Co-Combustion[4]
SO_2 (lb/MMbtu)	0.075	0.053	0.055
NO_x (lb/MMbtu)	0.291	0.236	0.199
CO (lb/MMbtu)	0.11	0.01	0.03

Notes

1. Facility 21H Test - 3 Units, MSW, No Sludge, Common Stack
2. Sludge Co-combustion Test - Results for Unit 3 Only, Except Dioxin/Furans - see Note 3
3. Result Multiplied by 3 for Comparison with Common Stack Limit
4. Results for Common Stack - Units 1 & 2 MSW only, Unit 3 with Sludge
5. Metric Conversions:
   - 1 gr/dscf = 2,250 mg/dscm
   - 1 lb/hr = 0.454 kg/hr
   - 1 lb/MMbtu = 0.4286 kg/MMKJ

Because all three combustion units at PVRRF utilize a common stack, some interpretation of the results is necessary. The Facility 21H test was conducted with all three units combusting MSW only. During the Unit 3 sludge test, only Unit 3 was co-combusting sludge and MSW, while the remaining two units continued to combust MSW. Particulate, metals, dioxins/furans, and HCl for Unit 3 on sludge were measured in the Unit 3 discharge duct prior to mixing with flue gas from the other two units, but continuous emission monitoring (CEM) results were for the combined stack.

No correction to the results for particulate, metals, and HCl was necessary, because the permit limits for these parameters were expressed in units of concentration. However, the permit limit for dioxins/furans is in pounds per hour; therefore, the result in Table 1 has been multiplied by three to represent the equivalent emission if all three units had been co-combusting sludge.

Table 1 shows significant reductions in NOx, particulate, and metals other than mercury. Only HCl, mercury, and CO were higher, but all were well below permit limits. Chemical analysis of the sludge verifies that chlorides and mercury were negligible in comparison to MSW. Therefore, these results were due to normal variations in solid waste composition. The higher CO emissions are attributed to the relatively low 3.5% sludge solids content during the test. Since the test, the CO increase has been eliminated through minor variations in standard operating conditions with low-solids and higher-solids content material. It is expected that results will be even better with higher solids content material.

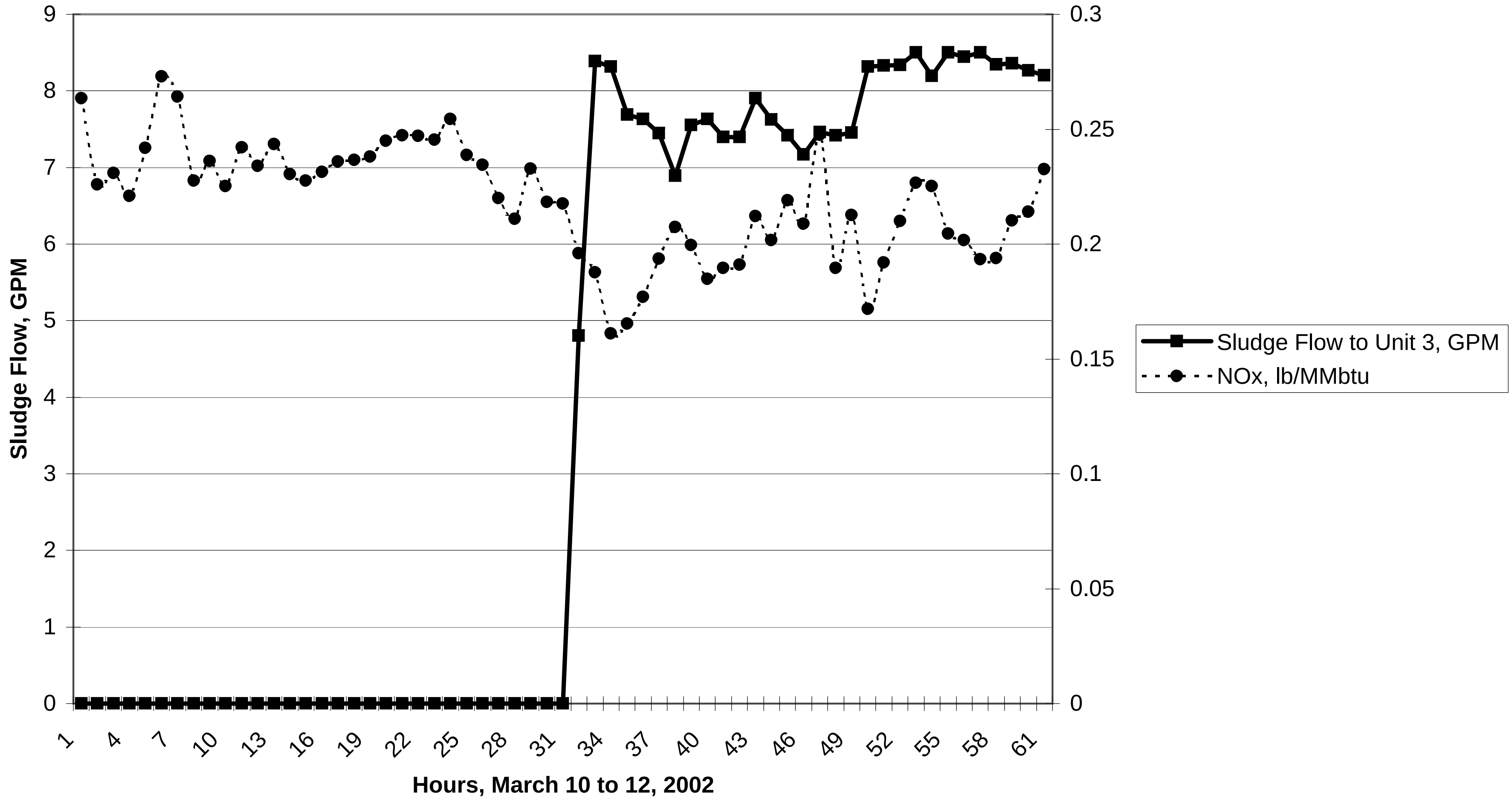
The CEM emissions results are additionally striking when considering the effect on total stack emissions for only one unit co-combusting sludge. ***Figure 2*** shows a real-time plot of sludge flow to Unit 3 versus NOx emissions for the combined stack. The immediate effect of sludge injection is clear and would be much more dramatic with all three units injecting sludge. NOx reductions of more than 30% are achievable on a repeatable basis.

IMPLICATIONS AND APPLICATIONS

The eco/Tech SRS provides exciting new environmentally sound business opportunities both for sludge producers seeking lower disposal costs and solid fuel power plants seeking new revenue opportunities and enhanced air pollution control.

On average, the SRS is applicable to any solid fuel boiler with primary fuel heat input of 50 Million Btu/hr or greater. Each nozzle applied to multiples of this base amount of primary fuel input can deliver 6 dry tons per day of sludge solids at 10% solids content. From this basis, local sludge producers can quickly determine potential matches with local solid fuel power plants for mutual benefit. For example, any solid fuel plant greater than approximately 3 MW electrical generating capacity or steam generation capacity of about 35,000 pounds per hour is a candidate for SRS savings and environmental improvements.

Figure 2
CEM Data - All 3 Units
One Unit SRS Co-Combustion, Two Units MSW Only



eco/Technologies, LLC

Environmental benefits of the SRS include elimination of odor in disposal practices, reduction in power plant air emissions, possible air pollution control credits for future trading, and potential classification as a renewable energy source. Many states may have special funding to support this type of project.