Final Report

Unique Enzergy™ Bioenzymatic Coal Treatment Will Reduce CO_2 5.2% at All Alberta Coal-fired Plants at a Net Cost that Could Go Below $0.00/tonne CO_2e while also Cutting NO_x and SO_2

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Legal Disclaimer

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Executive Summary

An 18-day field trial with the patented Enzergy™ bio-enzymatic coal treatment application (Enzergy™ application) was conducted at two coal fired Units.

The results from the short trials and tests have been summarized as follows:

- Under the tested units' combined high, mid and low load conditions, approximately at 320 MW, 240 MW, and 120 MW gross generations, respectively, Enzergy™ application was observed to produce approximately 16% reduction on the stack sulfur dioxide emissions (SO_2), for the mid load (~240 MW gross) conditions, the SO_2 reduction was observed to be as high as 19%.
- The Enzergy™ application was observed to produce repeated effects stabilizing the boiler conditions such as more consistent and less variable heat rate than the baseline combustion conditions which applied the US EPA Method 19 standard calculation. Furthermore, under the high load condition, there was approximately 1% boiler efficiency improvement (heat rate reduction) for a short period of the 18 day of continuous application
- The ASME standard calculation was consistent with the Method 19 heat rate reduction calculation for the boiler efficiency improvements. Under the high load conditions, the input-output method was applied for calculation for the tested units' furnace and economizer efficiency and the efficiency improvement was determined at 1.58%. Applying the evaporation ratio, the boiler efficiency improvement was determined at 1.68%.
- This boiler efficiency improvement, in turn, would resulted in an approximate 1% carbon dioxide (CO_2) emission reduction which was consistent with the CO_2 continuous emission monitor installed at the stack. For the high load conditions, the CO_2 emission was observed to increase by 1.15%; for the mid load conditions, the CO_2 emission was observed to decrease by 1.49%; and for the low load conditions, the CO_2 emission was observed to decrease by 1.90%; therefore, the overall CO_2 emission reduction during this Enzergy™ trial was averaged at 0.93%.
- The Enzergy™ application was observed to create no impact on the fly ash marketability, according to the fly ash analysis, and there was approximately a 10%-15% increase in fly ash volume
- Although there might have been increase in fly ash volume, the Enzergy™ application was observed to create no negative impact on the stack opacity and particulate matters (PM) emissions.
- On 9/5/2014, the ACI operation was suspended, on that particulate date, the Hg content in coal was averaged to be 24.6 ppb by a third party laboratory which was approximately 5.11 µg/dscm as the total stack Hg emission. However, the stack Hg emission was not observed to fully recovered back to 5.11 µg/dscm, it was determined to be at 3.52 µg/dscm by EPA Method 30B, and measured to be at 2.41 µg/dscm. Take it as Hg removal efficiency, the Enzergy™ application actually produced approximately 31% which could mean that in the continuous Enzergy™ application, the tested plant could save around 30% worth of activated carbon consumption a year.

However, there were issues that were identified in this trial resulting in shortfall of Enzergy performance:

- The use of raw river water (the first 7 days of Enzergy™ application) for enzyme dilution was observed to impact the enzyme performance, probably because the enzyme was consumed digesting algae in the river water. A significant improvement in performance occurred when the dilution water was changed to deionized water. Because of the dilution water problem, a huge quantity of Enzergy™ material was not applied under the optimal conditions.

- The use of raw river water also impacted the required time (7 days) for Enzergy™ coal treatment to condition the boiler system. Proper Enzergy™ application for the full test period would have resulted in reduced boiler slagging and fouling, which improves the unit's heat-transfer rate and thermal efficiency.
- During the last 3 days of the Enzergy™ trial, it was observed that the overall boiler efficiency was reduced by 1% to 2%. This was due to the plant operation's improper control on of the tested units' excess air (caused by a broken O2 probe). A potential 2% to 3% overall boiler efficiency improvement would have been observed. Certainly, this would have also produced additional 2% to 3% CO_2 emission reduction.
- One critical evidence that indicated this ineffective economizer O_2 control was creating negative impacts rather than just bad data on the screen was that none of these two units were equipped with boiler NOx emission control devices (like over fire air), so the additional excess air input was turned into the obvious stack NOx emission increase by between 10% and 20%
- From this field trial, it had been suspected that only 20% to 40% of coal on the coal belt was treated with the Enzergy™ solution. Improvements on spraying location with future re-arrangement of spray nozzles have been identified that can optimize the Enzergy™ spraying operation to enhance even distribution.
- Although there was approximately 31% Hg emission reduction observed, this could have been contributed by the accumulated activated carbon deposited in the system. There was only approximately 12 hours of ACI suspension. A longer term of testing would be required to see if this 31% Hg reduction could be reproduced.
- To solve and address the above issues and questions, Coalvation is proposing to conduct a long-term (three months) commercial-scale demonstration. After implementing a modified and optimized spraying system/procedure to apply Enzergy™ to the Alberta subbituminous coal, this proposal is expected to achieve the optimum Enzergy™ performances that will maximize the boiler efficiency improvements, and reduce stack emissions of NOx, SO_2, and CO_2
- To reduce the stack nitrogen oxides (NO_x) by between 10% and 20% with a more precise control on the plant excess air. (It is recommended that the excess oxygen be reduced until the CO emissions begin to increase).
- To quantify how much Enzergy™ improves the existing electrostatic precipitator performance on a long term basis and the impact on stack opacity. Particulate matter (PM) emissions testing is recommended to be performed at the stack.
- During the winter time in Alberta, the surrounding temperature gets below water freezing point, although Enzergy™ will not freeze, the carrier water will. This could reduce the Enzergy™ reactivity. Coalvation proposes to use heating elements to bring up the Enzergy™ solution temperature to above 22^o C. When the solution is sprayed onto the coal particles, this will at least get the reaction initiated. After coal is piled up in the coal yard, the internal temperature will then kick-in to reactivate the enzymatic process. This internal temperature within the coal pile exists because the Alberta subbituminous coal would self-ignite in the stockpile. However, this winter modification will require further testing.

1. Project Overview

B&C ES Field Services Team was contracted to perform Enzergy™ coal treatment on Alberta Subbituminous coal between 8/24/2014 and 9/29/2014 at the tested two Units. Based on the previous testing data from the commercial application of Enzergy™ in Taiwan, the main objective of the project was to determine whether the following observations could be repeated:

1. To reduce the stack SO_2 emission by ~30%
2. To reduce unit heat rate (Btu/KWh) and improve the boiler efficiency by ~5%
3. With consistent excess air control, to reduce the stack NOx emission by ~20%
4. To achieve ~5% CO_2 emission reduction based on the ~5% boiler efficiency improvement

Specific field operations include:

1. Enzergy™ Spraying Systems (ESS) set-up, test run, and operations: the ESS set-up was finished on 8/20, and the systems were fully operational at all the conveyors.
2. Enzergy™ solutions preparation based on the pre-determined concentration.
3. CO2 continuous emission monitoring.
4. Stack PM measurements/samples analysis under various boiler conditions applying US EPA Method 5B and
5. Stack mercury emission measurement/sample analysis applying US EPA Method 30B

1.1 Technological Background

Billions of dollars have been invested in developing technologies to remove criteria pollutants (such as SO_2, NOx, Hg, etc), and more recently, CO_2, from the emissions of coal-fired power plants and other facilities. Research and development have been conducted to prevent greenhouse gases and other emissions by enhancing coal prior to combustion, however, is not nearly as mature. Research and developments on enzymatic pretreatment of coal is at an even earlier stage although several commercial applications have shown positive results repeatedly.

Enzymes are proteins produced by microscopic organisms that serve as biocatalysts to accelerate and sustain a host of biochemical reactions. For substrates, a microorganism can activate its gene and make it excrete bio-catalytic enzymes that reduce the potential energy barrier required for biochemical reactions. This has the unique virtue of initiating specific chemical reactions at ambient temperature and pressure, rather than elevated temperatures/pressures commonly required in most other major chemical and combustion processes. Enzymes also complete these reactions extremely quickly – less than one millionth of a second in many cases.

For years, enzymes have been used to turn starch into sugar for making wine and other beverages and foods. The pulp and paper industry has long-employed esterases to break down an unneeded component of wood into smaller compounds, facilitating their removal from pulp. More recently, the biotech industry has modified numerous enzymes to improve their productivity in many industries, most notably to convert corn, switch grass, and other plant matter into ethanol.

1.2 Enzymatic Process on Oil-fired Application

Oil-fired combustion application is rather common in south-east Asia which consists a few problems for the system. First, the long carbon chain in the oil is not broken down prior to the combustion process, thus, it is common to observe heavy carbon deposit around the oil nozzles which signifies incomplete combustion. Further the impurity in the oil can get melted onto the boiler tubes and becomes slagging when there is accumulated heat inside the boiler. These problems associated with the oil-fired application are the opportunity for the early Enzergy™ application developments.

As shown in Figures 1 and 2, after applying Enzergy™ in the oil, it is obvious that the carbon deposit has been reduced and boiler slagging issues were improved. After a few successful commercial applications have been implemented, a question as how effective it is to implement Enzergy™ onto coal-fired applications has been raised.

Figure 1: A Typical Oil-fired Application (left: Slagging Inside of the Furnace, right: Carbon deposit on the Oil-spraying Nozzles)

Figure 2: Enzergy™ treated Oil-fired Application (left: Inside of the Furnace, right: Oil-spraying Nozzles)

Compared to oil, coal is a more complex and non-homogeneous mixture of hydrocarbons (primarily aromatic chains), that contains sulfur and nitrogen, and inert materials including iron and other metals. The complex mix of chemicals and the mechanical structure (as is shown by example below in Figure 3) make it more difficult to handle, process, and burn than natural gas.

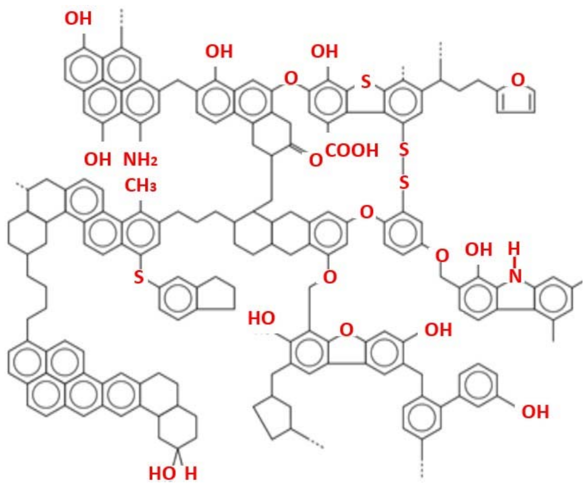


Figure 3: Typical coal structure

In 2011, Coalvation and its technical team completed development of Enzergy™, a specially formulated mixture of bioenzyme in a diluted liquid solution that is sprayed onto and mixed with coal. Coalvation designed it to initiate numerous biocatalytic reactions and depolymerize (break up) the long chains of coal molecules into smaller groups as well as oxygenate the coal This improves combustibility and effective Btu yield, which extracts more energy per unit of fuel. The bioenzyme also alters several other key characteristics of the coal:

- Weakens and/or breaks down the bonds between the aromatic molecules, which “frees-up” the hydrogen atoms to bond with oxygen atoms;
- Increases the oxygen content in the fuel, which consequently requires less excess air to support its combustion;
- Modifies the ash left over from combustion into a fleecy, solid-state matter that does not stick as easily to furnace walls/tubes, thereby reducing slag and soot buildup, which improves the unit’s heat-transfer rate and thermal efficiency; and
- Catalyzes the reaction of sulfur and nitrogen to form sulfate and nitrate salts which are collected in the bottom and fly ash.

The bioenzymatic process is hard to visualize because the chemical changes occur at the molecular level, but it can be illustrated in simple terms (Figure 4):

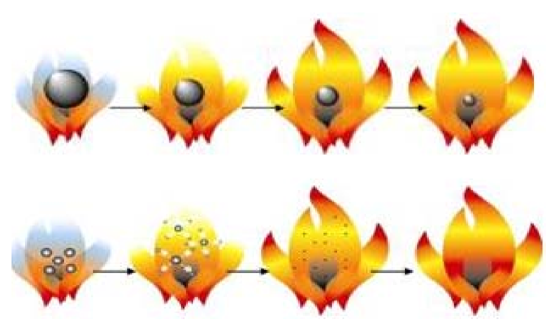


Figure 4: Coal combustion with (top) /without (bottom) Enzergy™

A sample of Alberta subbituminous coal was pretreated with Enzergy™ and tested though a series of thermal gravimetric analysis (TGA). The TGA was conducted with nitrogen as a carrier gas instead of oxygen to simulate the combustion environment. As the temperature increased, there was corresponding weight-loss on the sample which would reveal the combustibility difference between the untreated coal and the Enzergy™ treated coal.

Specifically, the test results indicated that the Enzergy™ treated coal was much easier to dry, pyrolyze and combust, with lower excess combustion air and O_2 requirements. The Enzergy™ treated coal samples lost 3% more of their weight at 72.8% weight remained when heated to 149° C compared to 75.8% weight remained for untreated coal heated to a higher temperature at 153° C, see Figure 5.

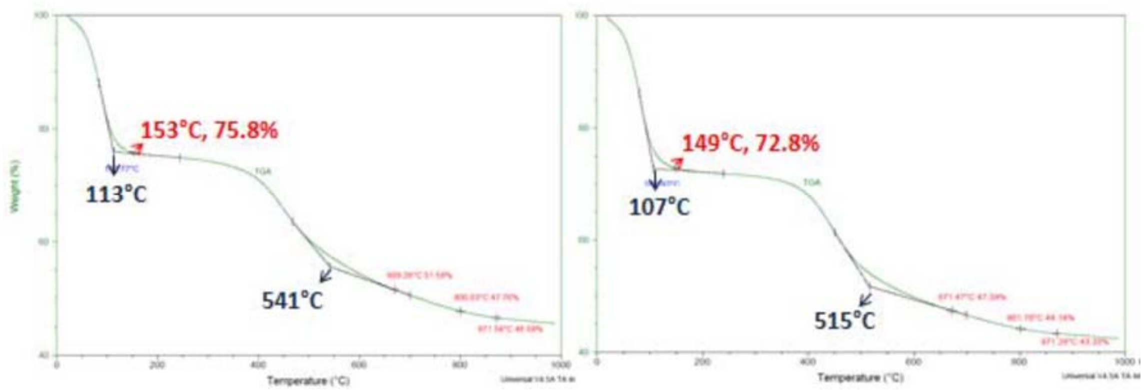


Figure 5: TGA analysis between the untreated coal (left) and Enzergy™ treated coal (right)

As also showed in Figure 5, when the untreated samples were heated to 541°C, the TGA curve was turning flat which indicated that after 541°C, all the combustible volatile matters have been released into the combustion environment. The Enzergy™ treated coal TGA curve showed the turning point at 515°C which was lower than 541°C. This could signify that under the combustion conditions, the Enzergy™ treated coal would initiate complete combustion to occur at the lower temperature.

Enzergy™ was formed by adapting a combination of selected enzymes that are naturally occurring, nontoxic, nonhazardous, and environmentally friendly, both during transportation and when used to treat the coal. Lab testing and verification used to produce Enzergy™'s Material Safety Data Sheet show:

- Toxicity Test: LD50 > 15,000 ppm (nontoxic)
- Corrosion Test: ASTM D130 – 1A (noncorrosive)
- Lead (Pb) Test: CNS 12221 – Not detectable
- Density (15° C): CNS 12017 – 0.842 g/ml
- Ash Content: CNS 3576 – 0.01%

Enzergy™ is both a patented and a proprietary process. Nothing like it has ever been demonstrated in North America. It can process coal from any seam from any Canadian or U.S. mine, despite variations in quality and non-carbon constituents, and still produce a more consistent fuel that will provide a more efficient and cleaner burn. The bioenzyme's composition, spray patterns, application rates, residence times, and other variables can be adjusted to accommodate the largest and oldest coal-fired boiler systems in Alberta. In a sense, we can now "tune" the coal itself to its highest potential for energy release, CO_2 reduction, and control of other emissions.

1.3 25-Month Demonstration at a 204 MW-Equivalent CHP Pulverized-Coal Boiler Plant:

For the past 25 months, Enzergy™ has been commercially applied onto coal fed into three pulverized coal-fired boilers at a combined heat-and-power (CHP) plant in Taiwan (Figure 6). This plant consumes about 1,500 tonnes of high Btu coal per day – approximately 500,000 tonnes per year – and generates power and steam equivalent to a 204 gross-MW coal-fired generation unit.

Figure 6: Three boilers (left); Enzergy™ containers, storage tanks and pumps at coal shed (right).

This process was begun by laboratory-testing on the coal treated with Enzergy™. This bioenzyme's chemical composition and residence time have been varied on the fuel to determine their optimal levels using thermal gravimetric analysis. Then, over four weeks, some critical spraying system components were designed, packaged, and shipped the bioenzyme solution to the plant. A system was then assembled and installed (Figure 7, left) that sprays each tonne of coal with 3 liters of solution (100 ml of Enzergy™ diluted 30x) over three phases: 1) when trucks arrive (Figure 7, center); 2) during unloading; and 3) on the conveyor as the coal makes its way to the silo (Figure 7, right).

Figure 7: Enzergy™ concentrate and storage tanks (left), truckload sprayers (center), and conveyer spraying system (right) at Taiwan CHP plant

The infrastructure to apply the bioenzyme is comprised of top-quality, off-the-shelf hardware that was locally sourced. It consists of two large storage tanks and automatically controlled pumps (Figure 7, left) connected by pipes to three sets of spray rails with spray heads to disperse the diluted solution evenly on the coal (Figure 7, center and right). This spraying system was assembled and commissioned, which occupies a very small footprint, in four weeks.

The concentrated Enzergy™ solution is shipped to the plant in 200-liter blue plastic drums (Figure 7, left), where plant staff dilute it 30 times with water to produce 6,000 liters of solution, which can treat 2,000 tonnes of coal. Each application takes only a few seconds per tonne. Thus, the plant's 1,500 tonnes/day of coal require 150 liters of the (pre-diluted) enzyme, or about ¾ of one barrel daily. All of the storage, application, and control hardware is completely customizable and can be configured to meet the needs of any size plant.

The blend of Chinese subbituminous and Indonesian bituminous coal used at this CHP plant shares some similar properties to the subbituminous coal burned in Alberta. (It averages 12,212 BTUs, 12.41% moisture, 35.55% volatile matter, and 14.07% ash.) Over the last 25 months, all of the plant's coal have been treated and the following boiler efficiency improvements were observed:

- Boiler Evaporation Ratio: +5.62%
- GCV_{AR} (ASME PTC 4.1 Input-Output Method): +5.79%
- GCV_{AR} (ASME PTC 4.1 Heat-Loss Method): +4.18%

Average: **+5.20%**

The Enzergy™ system has produced numerous related improvements during this commercial-scale pilot: less unburned carbon (improving the quality of the ash for recycle and improved plant efficiency), less excess air and oxygen, less fouling, and less slag and scale. That, in turn, reduced the frequency of soot-blowing from 5-6 times/day at 232° C (450° F) to 2-3 times/day at 204° C (400° F). It also significantly reduced SO_2 and NO_x emissions, with correlative drops in NO_x-control chemicals (e.g., urea, ammonia) and SO_2-control consumables, e.g., lime, limestone and/or magnesium oxide (MgO). It is confirmed that PM emission was reduced by the system duct inspection, but not yet tested with an EPA approved method at that time. The overall testing results have been summarized in Table 1:

Table 1: Enzergy™ Results at 204 MW (equiv.) Taiwanese CHP Plant

Characteristic	Untreated Coal	Coal Treatedby Enzergy™	Enzergy™ Benefit
Boiler Efficiency	0.8	0.852	5.20%
Coal Consumption	~1,500 tonnes/day	~1,425 tonnes/day	-5.20%
Excess O_2	3.5% ~ 4.0%	2.5% ~ 3.0%	↓ ~27%
Boiler-exit-Gas Temp.	232°C /450°F	204°C/400°F	↓ 11.1%
Soot-Blowing Intervals	6-May	3-Feb	↓ ~50%
Soot-Blowing Heat Loss	1.47%	0.88%	↓ 40.1%
NO_x Emissions	0.49 lbs/MMBtu	0.38 lbs/MMBtu	↓ 22.4%
NO_x-control consumables	NA	NA	↓ ~90%
SO_2	1.18 lbs/MMBtu	0.81 lbs/MMBtu	↓ 31.7%
MgO to Control SO_2	93.3 lbs/coal ton	122.0 lbs/coal ton	↓ 30.8%
CO_2 Emissions	2.5 tonnes/coal ton	2.32 tonnes/coal ton	↓ 5.2%

At baseline, this plant produces about 2.5 tonnes of CO_2 per tonne of coal. At its current consumption of 500,000 tonnes/year, Enzergy™ cuts coal use by about 25,000 tonnes of coal per year. That, in turn, reduces annual CO_2 emissions by about 62,500 tonnes. Equally important to the plant owner, the cost of the bioenzyme and related equipment has shown to be *less* than the amount the plant is saving in reduced coal use (5.2%) because coal is very expensive: $100 - $120 (U.S.) /tonne. The plant also saves approximately 30% in reduction of expensive Magnesium oxide (MgO) for dry sorbent injection downstream of the economizer to reduce SO_2 emissions.

At the current Enzergy™ pricing, the system has a *negative* cost of approximately -$2.71/tonne of coal, which will produce an annual net *savings* of about $1.7 million. Given the 2.5:1 ratio of coal to CO_2e, that translates to a negative cost (net savings) of $1.11 (U.S.)/tonne CO_2 removed. These results prompted the plant owner to sign a three-year contract extending the treatment process.

2. Tested Units Description and Results

2.1 Tested Units configuration

The objective of this demonstration project was to treat all of the subbituminous coal consumed at two coal-fired units with Enzergy™ continuously between 8/24/2014 and 9/29/2014.

The targeted units' generating capacity is approximately 160 MW gross per unit (320 MW total). Both units are equipped with electrostatic precipitator (ESP), and share with one common stack, see Figure 8.

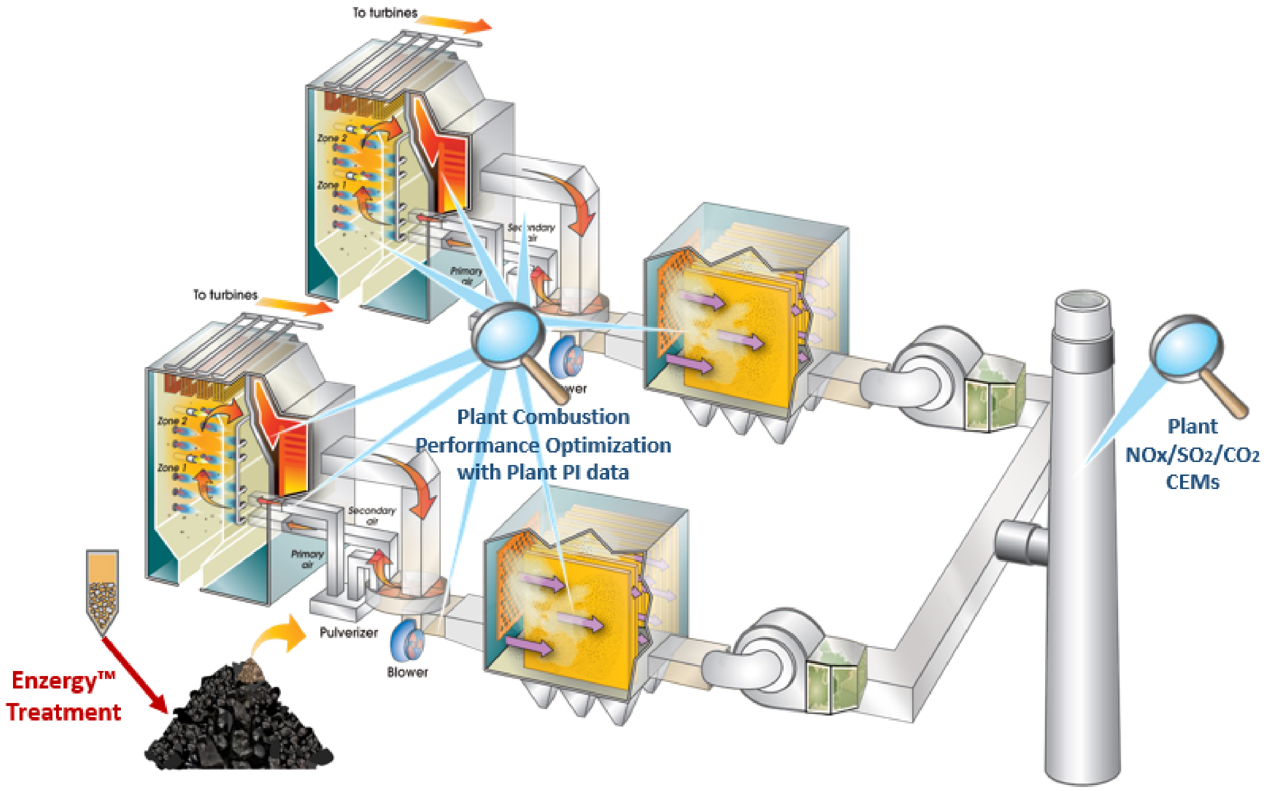


Figure 8: Tested Generating Station Units Configurations

2.2 Testing Arrangements

As shown in Figure 8, diluted Enzergy was sprayed continuously onto coal and the treated coal was left outside for 72 hours in the stock pile before combustion took place. The treatment was also applied on the conveyor inside as the coal was moved to the bunker/storage silos and would have had 8 hours contact time before being combusted. This was to ensure that the Enzergy™ penetrated the coal surface area and broke the coal carbon structure. The original proposed Enzergy™ spraying concentration and preparation has been summarized in Table 2, the strength "1.1" shown in Table 2 means that the concentrated Enzergy™ solution was prepared 10% higher the original specification. Specifically, the 100% Enzergy™ solution was diluted 10 times down to inactivate the enzyme during the transportation. 10% extra was ordered for contingency, so the strength is higher.

Table 2: Enzergy™ Preparation/Dilution

Tank (Actual)			750	Total Volume in gallons
Coal			947	Treated coal in tonne
Tank (Calculated)			2,840	Enzergy C3001 in liter
Enzergy C11			300	Ratio of water needed to dilute Enzergy C11
Strength	High	Mid	Low	
Enzergy C11 Mixing Strength				
1.1	12.91	8.61	4.30	Enzergy C11 needed in liters
	0.65	0.43	0.22	Enzergy C11needed in container (20L)
Ammonia Acetate Mixing Strength				
1.1	16.14	10.76	5.38	Ammonia Acetate needed in Kg
	13.79	9.19	4.60	Ammonia Acetate needed in container (l)

The targeted high, mid and low concentrations were defined by the field results from the on-going commercial Taiwanese application mentioned above. The spraying rate at the mid concentration has been in operation in Taiwan for 25 months which was 1 part of pure (100%) Enzergy™ C11 and 1.25 part of ammonia acetate mixed with ~2800 liters of plant potable water. For example, the high concentration Enzergy™ required mixing 12.91 liters of Enzergy™ C11 and 16.14 Kg of ammonia acetate into 750 gallon of plant potable or deionized water. After mixing and recirculation, this tank of diluted Enzergy™ could treat ~ 947 tonne of coal.

The role of ammonia acetate was serving as an activator. During the transportation from the upstream enzyme production plant to the testing site, Enzergy™ C11 was normally stored in an unreactive form to ensure the product quality. At the testing site during the Enzergy preparation, ammonia acetate was added to bring up the pH of the Enzergy™ mixture and thus re-activated Enzergy™ C11.

The ESS operations were performed at the upstream locations of the primary crusher and secondary crusher. The typical ESS operations are illustrated in Figure9. The ESS operation and flow in gallon per minute (GPM) has been precisely calculated and controlled by the reading on the scales installed at each conveyor in tones per hour (TPH). Throughout the entire project, total treated coal was approximately 100,000 tonnes.

Figure 9: Typical ESS Operation Locations

Other than the ESS operations, B&CES field service team had also been contracted to perform stack testing on CO_2 continuous monitoring, 14 sets of particulate matter (PM) measurement that applied EPA Method 5 and 14 sets of mercury emission measurement that applied EPA Method 30B. The stack testing arrangements are shown in Figure 10.

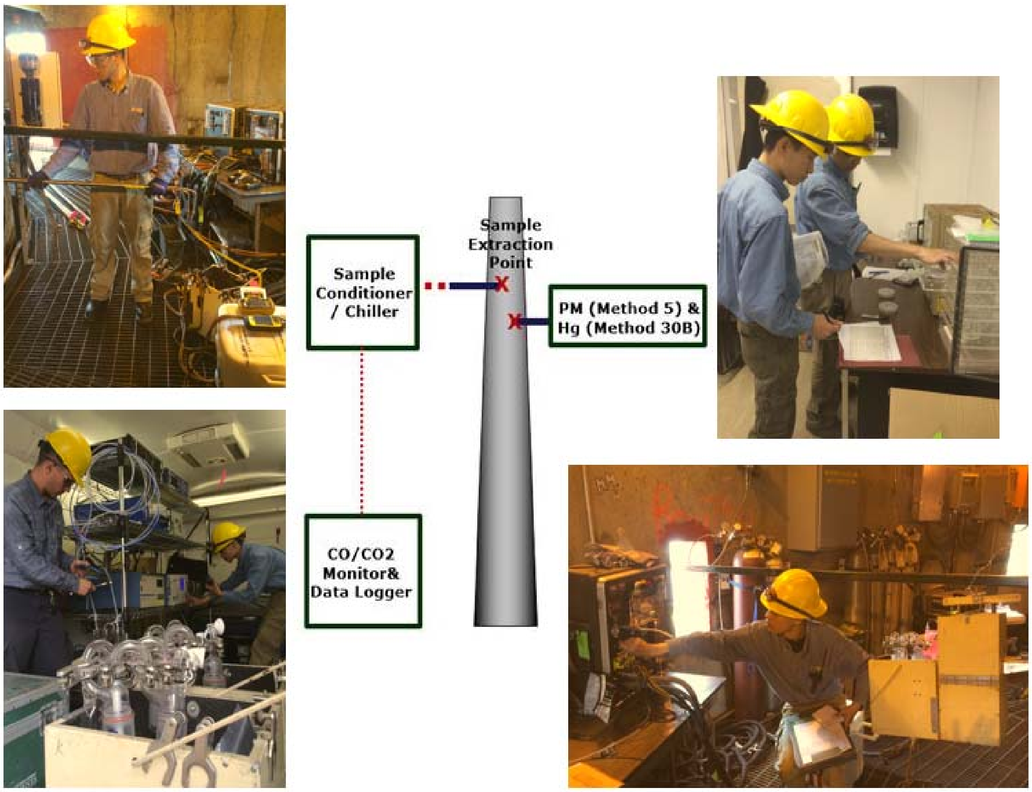


Figure 10: Stack Testing/Analysis Arrangements

3. Testing Observations and Data Analysis

3.1 Enzergy™ Application Stack SO_2 Removal Efficiency

The daily coal sulfur analysis data (% and the coal flow in tonnes per hour) was used to calculated the total SO_2 generation input to the post-combustion system; and the stack SO_2 measured by the plant certified continuous emission monitor (in tonnes per hour) was used to compare to the total SO_2 generation input to the output SO_2 determine the stack SO_2 emission reduction. This process and calculation was done and validated by the tested plant personnel.

The stack SO_2 has been closely monitored with the plant certified continuous emission monitor along with the daily coal sulfur analysis to determine the overall stack SO_2 reduction while under the Enzergy™ coal treatment. Results were measured when the two tested units were operated at high load (averaged at 321 MW gross), mid load (between 164 MW gross and 260 MW gross) and low load (averaged at 127 MW gross). Between 8/25/2014 and 8/28/2014, a series of baseline tests were performed to determine the baseline emission conditions.

3.1.1 Enzergy™ Application Stack SO_2 Removal Efficiency at High Load (~320MW)

Between 8/25/2014 and 8/28/2014, a series of baseline tests were performed to determine the baseline emission conditions. Specifically, the high load baseline test on 8/25/2014 with 1.1% native SO_2 removal efficiency; the mid load baseline test on 8/26/2014 and 8/27/2014 with 0.6% and -0.5% native SO_2 removal efficiency; and the low load baseline test on 8/28/2014 with 10.9% native SO_2 removal efficiency. However, the low load baseline test results was found contradictory to the historical data, so it was considered an outliner and discarded as heighted in red in Table 3. The other three sets of SO_2 removal efficiencies were averaged at 0.4% as the baseline SO_2 removal efficiency, and applied to compare against the testing results throughout the entire Enzergy™ trial.

All of the high load Enzergy™ testing results have been summarized in Table 3.

Table 3. High Load SO_2 Enzergy™ Resting Results Summary

Date	Test time	Unit A MW	Unit B MW	Combined	Sulfur received	Sulfur received	STK SO2 T/HR ORIG REPORT	Unit A COAL Mass	Unit B COAL Mass	Calculated STK (TPH)	STK SO2 Reduction	Actual Calculated Reduction	Enzergy Dosing Test Description	Water Quality
25/Aug/14	7:45-5:45	158	165	322	0.42	0.44	1.74	103.3	101.2	1.758	1.1%			
26/Aug/14	7:15-14:45	130	130	260	0.43	0.45	1.41	84.9	76.5	1.419	0.6%	Baseline Average		
27/Aug/14	7:15-14:45	98	99	197	0.41	0.43	1.06	61.1	63.8	1.050	-0.5%			
28/Aug/14	7:45-14:45	58	59	117	0.41	0.42	0.63	44.1	41.3	0.708	10.9%	0.4%		
29/Aug/14	11:15-17:00	157	164	321	0.42	0.43	1.65	108.3	108.7	1.844	10.6%	10.2%	BL Coal/8Hr-High Conc.	Fire/Domestic Water
29/Aug/14	17:15-23:30	156	164	319	0.42	0.43	1.67	106.1	107.4	1.815	8.1%	7.7%	8Hr-High Conc.	Fire/Domestic Water
30/Aug/14	3:45-9:45	156	161	317	0.4	0.4	1.65	116.3	113.8	1.841	10.3%	9.9%	72Hr/8Hr-High Conc.	Fire/Domestic Water
5/Sep/14	7:45-15:30	152	165	316	0.44	0.45	1.75	101.3	101.8	1.808	3.5%	3.0%	72Hr-High Conc.	Fire Water
8/Sep/14	7:30-7:00	158	165	322	0.43	0.44	1.72	109.1	113.9	1.941	11.4%	11.0%	72Hr/8Hr-Mid Conc.	Fire/DI Water
9/Sep/14	7:00-7:00	158	164	322	0.42	0.42	1.69	111.7	117.6	1.926	12.3%	11.9%	72Hr/8Hr-Mid Conc.	Fire/DI Water
15/Sep/14	7:45-7:00	157	165	322	0.42	0.42	1.79	121.4	122.1	2.045	12.4%	12.0%	72Hr Mid-Conc.	DI Water
16/Sep/14	7:00-16:45	158	164	322	0.42	0.42	1.74	123.0	125.5	2.087	16.7%	16.2%	72Hr/8Hr-Mid Conc.	DI Water
23/Sep/14	7:00-7:00	158	166	323	0.42	0.42	1.70	103.3	100.6	1.713	0.7%	0.3%	8Hr-Mid Conc.	DI Water

The baseline stack SO_2 reduction between 8/25/2014 and 8/28/2014 calculated to be 0.4%. Starting on 8/28/2014, Enzergy™ spraying operation at the high concentration was initiated at the conveyors to fill the both units' bunkers with treated coal which would provide an 8 hour soaking time. The Enzergy solution was prepared with the slightly chlorinated domestic water.

On 8/29/2014, the SO_2 reduction was determined to be between 7.7% and 10.2%. On 8/30/2014, the Enzergy™ pre-treated coal in the stock pile with at soaking time of 72 hours was fed into both units' boilers and the SO_2 reduction was determined to be 9.9%.

Starting on 8/30/2014, the slightly chlorinated domestic water supply was changed to unfiltered river water as shown in Figure 11.

Figure 11: Unfiltered River Water Used for Enzergy™ Application between 8/29/2014 and 9/7/2014

The high load test on 9/5/2014 indicated the SO_2 reduction was only 3.0% which was only one-third of efficiency observed on 8/30/2014, and the mid load and low load tests also showed less than anticipated results. The quality of water supply was questioned. On 9/8/2014, the unfiltered river water was switched to the plant deionized water, the stack SO_2 removal efficiency started to show improvements. According **t**o Table 3, the stack SO_2 removal efficiency was determined to be 11.0% on 9/8/2014, 11.9% on 9/9/2014, 12.0% on 9/15/2014, and 16.2% on 9/16/2014.

We believe the SO_2 reduction was observed because Enzergy™ fundamentally improved the combustion conditions in the boiler. The improved combustion causes more complete oxidization to convert more SO_2 to SO_4^{2-}. The fly ash alkalinity (CaO, MgO, etc.) captured this converted SO_4^{2-} and formed sulfate salt. The sulfate salts are collected in both the fly ash and bottom ash, therefore, reducing the flue gas SO_2 emissions. Based on onsite observations at the on-going commercial implementation in the Taiwanese boiler systems, it would take approximately two weeks to a month for the system to reach its equilibrium for optimal Enzergy™ performance. The problems with dilution water make it difficult to project the final SO_2 reduction possible with continuous Enzergy™ application.

It was suspected that algae in the unfiltered river water caused the reduced performance of Enzergy™. Conditions in the ESS also promoted growth of the river water algae. The ultraviolet radiation blocking storage tank, solution recirculation and slightly increased temperatures all provided for increased algae growth thus it was suspected that much of the Enzergy™ materials were consumed by the river algae. However, it was difficult to quantify the exact impact, it was only observed that after 9/8/2014, when the water supply was changed to deionized water, the stack SO_2 removal efficiency improved drastically.

The use of river water not only caused waste of Enzergy™ materials, but also reduced the system cleaning/conditioning effects by a whole week.

Enzergy™ materials were essentially consumed and depleted by on 9/17/2014, so the continuous ESS operation was suspended, and resumed on 9/23/2014 after four days of normal operations with untreated coal. The stack SO_2 removal efficiency was measured on 9/23/2014 at 0.3% this was primarily due to the fact one day of Enzergy™ application was simply not sufficient to produce any noticeable change on the stack emissions. According to the site observations of the on-going commercial implementation in the Taiwanese boiler systems, giving it more time for the system conditioning, the optimal Enzergy™ performances would most likely be repeated.

3.1.2 Enzergy™ Application Stack SO_2 Removal Efficiency at Mid Load (between 164MW and 260MW)

Between 9/3/2014 and 9/6/2014, the stack SO_2 removal efficiency was determined to be between 4.0% and 11.4%, but mostly less than 8%. This was the period when the unfiltered river water was used for Enzergy™ solution preparation and with low removals most likely caused by the river algae consuming Enzergy™. As the deionized water was replaced in the ESS operations on 9/8/2014, the stack SO_2 removal efficiency was observed to gradually improve. The mid load Enzergy™ testing results between 164 MW and 260 MW gross have been summarized in Table 4.

Table 4. Mid Load SO_2 Enzergy™ Resting Results Summary

Date	Test time	Unit A MW	Unit B MW	Combined	Sulfur received	Sulfur received	STK SO2 T/HR ORIG REPORT	Unit A COAL Mass	Unit B COAL Mass	Calculated STK (TPH)	STK SO2 Reduction	Actual Calculated Reduction	Enzergy Dosing Test Description	Water Quality
25/Aug/14	7:45-5:45	158	165	322	0.42	0.44	1.74	103.3	101.2	1.758	1.1%	Baseline Average		
26/Aug/14	7:15-14:45	130	130	260	0.43	0.45	1.41	84.9	76.5	1.419	0.6%			
27/Aug/14	7:15-14:45	98	99	197	0.41	0.43	1.06	61.1	63.8	1.050	-0.5%			
28/Aug/14	7:45-14:45	58	59	117	0.41	0.42	0.63	44.1	41.3	0.708	10.9%	0.4%		
3/Sep/14	7:30-14:45	99	100	199	0.44	0.44	1.09	65.9	63.6	1.140	4.5%	4.0%	72Hr -High Conc.	Fire Water
3/Sep/14	17:30-1:30	130	130	260	0.44	0.45	1.42	84.5	84.3	1.503	5.9%	5.4%	72Hr -High Conc.	Fire Water
4/Sep/14	7:00-7:00	75	107	182	0.44	0.44	0.97	47.1	69.4	1.026	5.2%	4.8%	72Hr -High Conc.	Fire Water
6/Sep/14	7:00-7:00	68	104	172	0.45	0.45	0.95	48.4	70.7	1.072	11.4%	11.0%	72Hr -High Conc.	Fire Water
10/Sep/14	7:30-14:45	98	100	198	0.41	0.41	1.00	68.6	67.9	1.120	10.5%	10.1%	72Hr/8Hr -Mid Conc.	Fire/DI Water
10/Sep/14	7:00-7:00	74	90	164	0.41	0.41	0.84	54.1	62.9	0.959	12.7%	12.3%	72Hr/8Hr -Mid Conc.	Fire/DI Water
11/Sep/14	7:30-14:45	129	131	260	0.4	0.42	1.30	96.9	93.1	1.557	16.7%	16.3%	72Hr/8Hr -Mid Conc.	Fire/DI Water
11/Sep/14	7:00-7:00	81	99	180	0.4	0.42	0.93	62.9	72.6	1.113	16.5%	16.1%	72Hr Mid - Conc.	DI Water
13/Sep/14	7:00-7:00	78	100	178	0.42	0.43	0.95	63.0	76.2	1.184	19.7%	19.2%	72Hr Mid - Conc.	DI Water
14/Sep/14	7:00-7:00	72	116	188	0.42	0.43	1.00	58.3	87.9	1.245	19.4%	19.0%	72Hr Mid - Conc.	DI Water
16/Sep/14	7:00-7:00	107	121	228	0.42	0.42	1.22	82.8	91.6	1.465	17.0%	16.6%	72Hr/8Hr -Mid Conc.	DI Water
17/Sep/14	7:45-14:45	130	130	260	0.42	0.42	1.38	94.6	92.3	1.569	11.8%	11.4%	72Hr/8Hr -Mid Conc.	DI Water
17/Sep/14	7:00-7_00	98	109	207	0.42	0.42	1.10	72.2	75.8	1.243	11.6%	11.2%	72Hr/8Hr -Mid Conc.	DI Water
18/Sep/14	7:45-14:30	100	100	199	0.42	0.42	1.07	74.2	63.6	1.157	7.2%	6.8%	72Hr/8Hr -Mid Conc.	No Water
20/Sep/14	7:00-7:00	67	105	173	0.41	0.41	0.89	46.3	68.7	0.943	5.9%	5.5%	Baseline	No Water
21/Sep/14	7:00-7:00	76	97	173	0.42	0.42	0.89	49.5	57.7	0.900	1.6%	1.3%	Baseline	No Water
22/Sep/14		83	89	172	0.41	0.42	0.87	51.2	50.3	0.842	-3.8%	-4.2%	Baseline	No Water
23/Sep/14	7:00-7:00	106	112	219	0.42	0.42	1.15	70.6	69.2	1.174	1.8%	1.4%	Baseline	No Water
23/Sep/14		97	98	195	0.42	0.42	1.02	64.7	57.4	1.025	0.6%	0.2%	8Hr -Mid Conc.	DI Water

Between 9/10/2014 and 9/17/2014, the stack SO_2 removal efficiency was determined to be between 10.1% and 19.2% with an average of 15.3%. The replacement of river water with deionized water was observed to improve the stack SO_2 removal efficiency by approximately 11%. However, the optimal Enzergy™ performance on the stack SO_2 emission reduction remained uncertain due to the waste of one whole week of system conditioning.

As mentioned, the continuous ESS operation was suspended on 9/17/2014 due to the low Enzergy™ materials inventory. However, the Enzergy™ residual effects were still observed until 9/20/2014, and on 9/22/2014, the stack SO_2 removal efficiency fell down to -4.2% back to the baseline conditions where there was no SO_2 reduction across the post combustion system. On 9/23/3014, the Enzergy™ spraying operation was resumed under the units mid load condition for the final test.

However, prior to the Enzergy™ testing on 9/23/3014, the Units A and B operation was having trouble making the required loads which might be due to the heavy slagging build-ups which might have been due to the heavy ash content in coal. This was a clear indication that the boiler condition was restored back to the pre- Enzergy™ conditions. In this case, it would have required a few more days of continuous Enzergy™ spraying for the boiler clean up. One day was simply not enough to see the obvious SO2 reduction results.

3.1.3 Enzergy™ Application Stack SO_2 Removal Efficiency at Low Load (~127MW)

During the low load tests between 9/1/2014 and 9/7/2014, the stack SO_2 removal efficiency was determined to be between -1.9% and 7.6%, the stack SO_2 removal efficiency was observed to be minimal, averaged at 4.5%. After the river water was replaced by deionized water on 9/8/2014, the stack SO_2 removal efficiency was observed to improve to 17.8%. The low load Enzergy™ testing results have been summarized in Table 5.

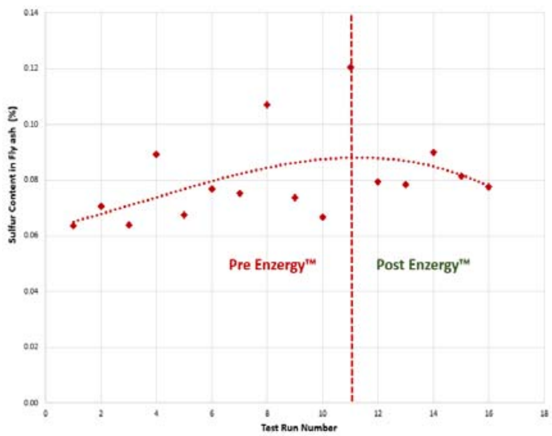
Table 5. Low Load SO_2 Enzergy™ Resting Results Summary

Date	Test time	Unit A MW	Unit B MW	Combined	Sulfur received	Sulfur received	STK SO2 T/HR ORIG REPORT	Unit A Mass	Unit B Mass	Calculated STK (TPH)	STK SO2 Reduction	Actual Calculated Reduction	Enzergy Dosing Test Description	Water Quality
25/Aug/14	7:45-5:45	158	165	322	0.42	0.44	1.74	103.3	101.2	1.758	1.1%	Baseline Average		
26/Aug/14	7:15-14:45	130	130	260	0.43	0.45	1.41	84.9	76.5	1.419	0.6%			
27/Aug/14	7:15-14:45	98	99	197	0.41	0.43	1.06	61.1	63.8	1.050	-0.5%			
28/Aug/14	7:45-14:45	58	59	117	0.41	0.42	0.63	44.1	41.3	0.708	10.9%	0.4%		
1/Sep/14	1:45-6:30	59	62	121	0.42	0.42	0.66	43.7	41.7	0.718	8.0%	7.6%	72Hr-High Conc.	Fire Water
2/Sep/14	7:45:14:45	60	62	122	0.43	0.43	0.68	41.3	39.9	0.699	2.2%	1.8%	72Hr -High Conc.	Fire Water
4/Sep/14	22:30-7:00	61	62	123	0.44	0.44	0.70	38.7	40.1	0.693	-1.5%	-1.9%	72Hr -High Conc.	Fire Water
7/Sep/14	7:00-7:00	60	62	122	0.45	0.45	0.72	40.5	41.6	0.739	2.9%	2.4%	72Hr -High Conc.	Fire Water
12/Sep/14	7:00-7:00	60	78	139	0.43	0.44	0.77	49.7	57.9	0.937	18.2%	17.8%	72Hr Mid - Conc.	DI Water
19/Sep/14	7:00-7:00	59	74	133	0.42	0.42	0.73771	45.8	50.9	0.812	9.1%	8.7%	Baseline	DI Water

The replacement with deionized water was observed to improve the stack SO_2 removal efficiency by approximately 13% under the both units' low load conditions. As the continuous ESS operation was suspended on 9/17/2014, the Enzergy™ residual effects were still observed on 9/19/2014, the stack SO_2 removal efficiency was determined to be 8.7%.

3.2 Enzergy™ Application Stack Particulate Matters (PM) and Opacity Control Efficiency

Results of the fly ash analysis between 9/8/2014 and 9/14/2014, showed the sulfur content increased by 18.9% (from 0.07% to 0.09%) while the fly ash loss on ignition was reduced by 8.2% (from 0.35% to 0.32% indicating more complete combustion of the coal), the trends of sulfur content in coal and fly ash loss on ignition (LOI) have been charted in Figures 12 and 13, respectively. The Fly ash analysis conducted by a local laboratory has been summarized in Table 6 for the two tested units' fly ash samples analysis. In Table 6, the fly ash analysis hightlted in green (the first section) was under the baseline conditions; the fly ash hightlighted in pink (the second section) was when the lake water was used, and the portion with no highlight (the third section) was the normal Enzergy™ treatment fly ash sample analysis.



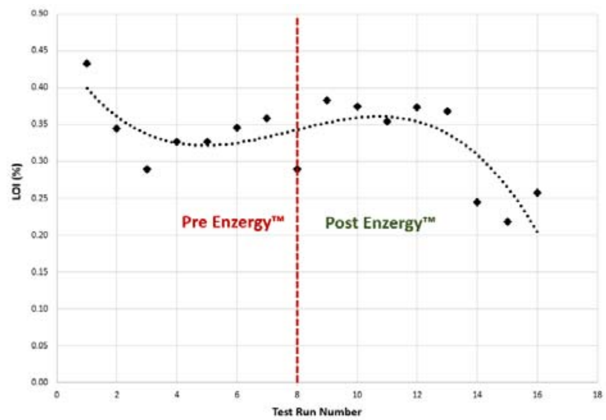


Figure 12: Fly Ash Sulfur Analysis

Figure 13: Fly ash LOI analysis

The increasing trend of sulfur in the fly ash indicated that the fly ash adsorbed more sulfur after the Enzergy™ coal treatment and there was a clear indication that some of the converted SO_4^{2-} was captured by the fly ash. Moreover, this could have caused a 10%-15% increase in fly ash volume because the SO_4^{2-} had bonded with the fly ash alkalinity to form stable salt. The decreasing trend of the fly ash LOI was the indication that the boiler efficiency was improved. It was also observed that there was no change on both the chemical or physical property on the fly ash that would have afftected the resuability of the fly ash.

Table 6. Fly Ash Analysis Summary

ID	%MOISTURE	%LOI	%SULFUR	ID	%MOISTURE	%LOI	%SULFUR	Average LOI (%)	Average Sulfur (%)
B24-150	0.04	0.543	0.06	B24-150	0.03	0.323	0.06	**0.43**	**0.06**
B8-120+AUG26N	0.04	0.366	0.07	B8-120+AUG26N	0.04	0.323	0.07	**0.34**	**0.07**
B8-90	0.05	0.246	0.06	B8-90	0.06	0.332	0.07	**0.29**	**0.06**
B8-50	0.07	0.315	0.08	B8-50	0.06	0.339	0.10	**0.33**	**0.09**
AUG27N	0.07	0.351	0.08	AUG27N	0.06	0.301	0.05	**0.33**	**0.07**
AUG28N	0.06	0.323	0.09	AUG28N	0.05	0.369	0.07	**0.35**	**0.08**
(2)B8-90	0.01	0.277	0.09	(2)B8-90	0.03	0.44	0.06	**0.36**	**0.08**
H24-150-8	0.04	0.45	0.07	H24-150-8	0.03	0.39	0.07	**0.42**	**0.07**
H-Aug30	0.04	0.35	0.06	H-Aug30-31	0.03	0.31	0.07	**0.33**	**0.07**
H24-150-72	0.03	0.50	0.06	H24-150-72	0.03	0.40	0.05	**0.45**	**0.06**
H8-50-72	0.03	0.41	0.08	H8-50-72	0.01	0.15	0.10	**0.28**	**0.09**
H-SEPT2N	0.03	0.38	0.09	H-SEPT2N	0.03	0.41	0.07	**0.39**	**0.08**
H8-90-72	0.04	0.38	0.07	H8-90-72	0.03	0.37	0.07	**0.38**	**0.07**
H8-120-72	0.02	0.40	0.08	H8-120-72	0.03	0.41	0.08	**0.41**	**0.08**
H8-150-72 (NOACI)	0.02	0.18	0.08	H8-150-72 (NOACI)	0.02	0.26	0.08	**0.22**	**0.08**
H-SEPT5N	0.02	0.21	0.07	H-SEPT5N	0.03	0.41	0.08	**0.31**	**0.08**
H-SEPT6N	0.02	0.29	0.09	H-SEPT6N	0.02	0.38	0.08	**0.33**	**0.08**
H-SEPT7N	0.00	0.19	0.09	H-SEPT7N	0.02	0.39	0.13	**0.29**	**0.11**
(2)H24-150-72	0.01	0.35	0.08	(2)H24-150-72	0.02	0.41	0.07	**0.38**	**0.07**
(3)H24-150-72	0.01	0.34	0.07	(3)H24-150-72	0.01	0.40	0.07	**0.37**	**0.07**
H-SEPT10N	0.01	0.29	0.13	H-SEPT10N	0.01	0.42	0.11	**0.35**	**0.12**
(2)H8-90-72	0.02	0.30	0.09	(2)H8-90-72	0.02	0.45	0.07	**0.37**	**0.08**
(2)H8-120-72	0.03	0.34	0.09	(2)H8-120-72	0.04	0.40	0.06	**0.37**	**0.08**
H-SEPT12	0.03	0.18	0.09	H-SEPT12	0.04	0.31	0.09	**0.25**	**0.09**
H-SEPT13	0.03	0.17	0.10	H-SEPT13	0.03	0.27	0.07	**0.22**	**0.08**
H-SEPT14	0.03	0.23	0.08	H-SEPT14	0.03	0.29	0.07	**0.26**	**0.08**

Although there was a potential increase in volume on the fly ash, there was no negative impact on the stack PM and opacity observed. The testing results have been summarized in Table 7.

Table 7. Stack PM/Opacity Testing Results Summary

Date	8/25/14	8/25/14	8/26/14	8/26/14	8/29/14	8/29/14	9/1/14	9/1/14	9/6/14	9/6/14	9/8/14	9/8/14	9/11/14	9/11/14
Start Time	12:10	14:05	9:30	11:00	14:30	15:52	10:25	12:00	10:00	11:20	10:00	11:40	10:00	12:10
End Time	13:25	15:05	10:30	12:00	15:30	16:52	11:25	13:30	11:00	12:25	10:45	12:25	11:00	13:10
Total Run Time (min)	75	60	60	60	60	60	60	90	60	65	45	45	60	60
Stack Parameters														
Gas Moisture, % by volume, as measured	10.3%	8.7%	10.3%	10.1%	12.2%	12.4%	14.1%	8.7%	11.6%	13.6%	14.5%	11.8%	10.0%	9.8%
%CO2 by volume, dry basis	13.5	13.5	13.5	13.9	13.5	13.9	13.5	13.5	13.5	13.9	13.5	13.9	13.5	13.9
Dry Molecular Wt. of Gas, lb/lb-mole	30.38	30.38	30.38	30.43	30.38	30.43	30.38	30.38	30.38	30.43	30.38	30.43	30.38	30.43
% Excess Air	35%	35%	35%	32%	35%	32%	35%	35%	35%	32%	35%	32%	35%	32%
Isokinetic Variance	101.6%	80.5%	86.8%	87.7%	99.9%	101.4%	101.8%	112.3%	97.3%	107.6%	101.7%	100.1%	98.1%	96.8%
Total Filterable PM														
PM Conc. (gr/dscf	0.026	0.014	0.009	0.017	0.029	0.020	0.042	0.021	0.022	0.024	0.022	0.019	0.016	0.021
lb/MMBtu (Fd Factor)	0.049	0.026	0.018	0.031	0.055	0.038	0.080	0.039	0.042	0.044	0.041	0.034	0.030	0.040
Average (lb/MMBtu)	0.038		0.025		0.046		0.059		0.043		0.038		0.035	
STKB OPACITY REPORT(%)	14.464	15.224	11.652	11.280	14.907	14.565	15.577	16.500	8.879	11.700	12.640	15.740	9.254	11.201
Average Opacity	14.8		11.5		14.7		16.0		10.3		14.2		10.2	

As indicated in Table 7, during the high load testing, the averaged baseline stack PM and opacity were 0.042 lb/MMBtu and 14.7%. The first set of PM test conducted on 9/1/2014 showed 0.059 lb/MMBtu for the stack PM and 16.3% for the opacity. Both measurements were observed to decrease down to 0.038 lb/MMBtu for the stack PM and 14.2% for the opacity with a slight improvement on 9/8/2014.

We hypothesize that the reason both the PM and opacity became worse before they got better was because the Enzergy™ coal treatment makes the coal particle more porous, which weakened the binding between the coal particle surface area and the moisture. The moisture was then vaporized more quickly, so no heat was accumulated to cook the moisture. When there was less accumulated heat, there was also fewer chances for the slagging to form in the boiler. So the hot flue gas would flash all the existing slag material inside the boiler out to the back end electrostatic precipitators (ESPs). This was the repeated observation from the Taiwanese commercial application.

The baseline PM/opacity testing under the mid load conditions were measured at 0.025 lb/MMBtu and 11.5% on 8/26/2014, respectively. Under the Enzergy™ coal treatment the averaged stack PM and opacity were 0.039 lb/MMBtu and 10.3%. Although the results showed an increase in PM, the stack opacity decreased implying that the resistivity of the ash was reduced due to mechanisms that still required more studies to be conclusive.

For the ESP performance evaluation, it was determined that there was 18% increase in the ESP total power, and corresponding spark rate reduction. The improvements on the ESP performances were the main reason that explained there was a potential increase in volume on the fly ash, but there was no negative impact on the stack PM and opacity observed, shown in Figures 14 and 15.

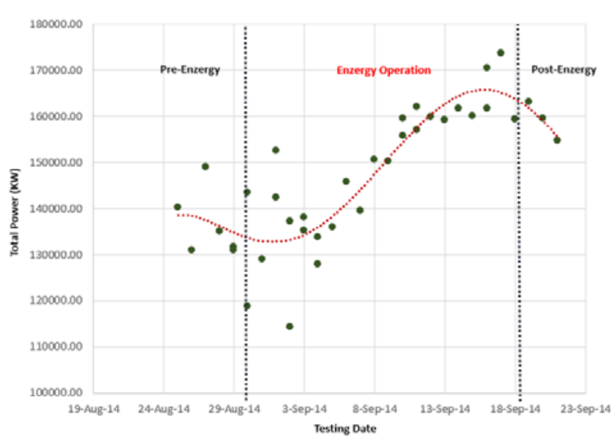


Figure 14: ESP Total Power Improvement

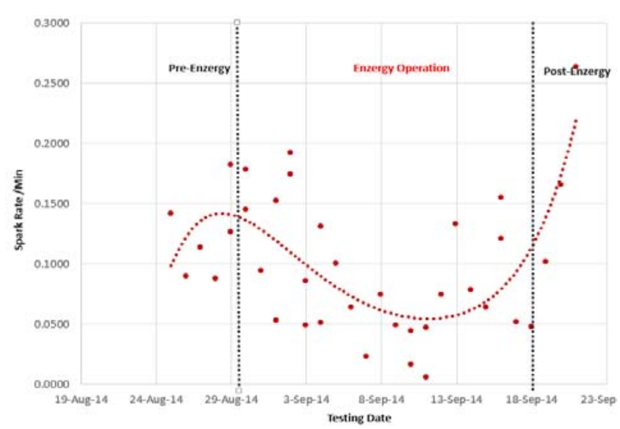


Figure 15: ESP Spark Rate Reduction

3.3 Enzergy™ Application Heat Rate (Btu/KWh) Reduction and Boiler Efficiency improvements

All the high load (~320 MW) data points in July and August 2014 were documented to calculate the heat rate generation for both units to compare to the heat rate generation under the Enzergy™ coal treatment in September 2014. The heat rate calculation was based on US EPA Method 19 which was first used to determine the total heat input based on the stack moisture content (in the case of these two tested units, approximately 10% moisture) and the certified flow and oxygen continuous monitors, and then divide the calculated heat input by the total MW generation to come up with the heat rate in Btu/KWh. The higher the heat rate, the less efficient the boiler. The heat rates under the units' high load generating capacity at approximately 320MW in July, August and September 2014 have been summarized in Table 8.

As indicated in Table 8, all the high load heat rate data points in July and August 2014 were averaged at 11,654Btu/KWh with a relative deviation of 6.21 before Enzergy™ treatments. The highest heat rate in these two-month period was determined at 12,559 Btu/KWh and the lowest heat rate was 11,090 Btu/KWh. Compared to the maximum heat rate at 12,559 Btu/KWh and the minimum heat rate at 11,090 Btu/KWh, the minimum heat rate (11,090 Btu/KWh) output obviously yielded the most efficient combustion condition because less coal was consumed to generate the same required power (MW). Therefore, the lower the heat rate, the higher the boiler efficiency and vice versa.

Table 8. Tested Units Heat Rate (High Load) Summary in July (Pre-Enzergy™), August and September (under Enzergy™) in 2014

Date/Time	Rate (Btu/KW	Date/Time	Rate (Btu/KW	Date/Time	Heat Rate (Btu/KWh)
7/2/14 13:15	11,176	7/28/14 20:30	12,559	8/19/14 15:00	11,859
7/4/14 14:00	11,254	8/1/14 18:00	11,476	8/25/14 7:45	11,536
7/8/14 1:00	11,216	8/6/14 12:00	11,835	8/29/14 11:15	11,560
7/12/14 1:45	11,166	8/7/14 13:45	11,670	8/29/14 17:15	11,645
7/12/14 18:00	11,575	8/8/14 13:15	11,740	8/30/14 3:45	11,633
7/13/14 1:15	11,369	8/9/14 18:00	11,417		
7/15/14 18:45	11,379	8/10/14 23:30	11,515		
7/18/14 16:00	11,090	8/11/14 17:45	11,509		
7/21/14 13:00	11,591	8/14/14 14:45	11,583		
7/22/14 20:00	11,474	8/14/14 23:15	11,771		
7/23/14 22:30	11,518	8/15/14 15:30	11,741	Max	12,559
7/25/14 14:15	11,587	8/16/14 13:00	11,774	Min	11,090
7/25/14 23:30	11,763	8/17/14 22:15	11,736	Average	11,654
7/27/14 23:30	12,149	8/18/14 13:30	11,764	Varation	6.21%

Date/Time	Heat Rate (Btu/KWh)	Heat Rate Reduction
9/1/14 8:45	11,479	1.5%
9/2/14 0:15	11,515	1.2%
9/5/14 7:30	11,490	1.4%
9/6/14 12:00	11,534	1.0%
9/8/14 7:30	11,602	0.4%
9/9/14 0:00	11,552	0.9%
9/10/14 0:00	11,507	1.3%
9/15/14 7:30	11,561	0.8%
9/16/14 0:00	11,598	0.5%
9/16/14 7:00	11,548	0.9%
Max	11,602	
Min	11,479	
Average	11,539	1.0%
Varation	0.53%	

Ideally, the plant operation would want to maintain the boiler heat rate consistently at 11,090 Btu/KWh to minimize the coal consumption and CO_2 production while maximizing electricity generation. As indicated in Table 8, the heat rate fluctuation have been observed at 6.21. Generally speaking, this heat rate fluctuation could have been caused by the following reasons:

1. The variation of moisture content in coal: Neither the coal surface moisture nor inherent moisture in the coal served a positive role during the coal combustion process. The trouble could have been too much moisture or the bond between coal and moisture was too strong. Either case, the heat generated from coal combustion would have been accumulated to vaporize ("cook") the water before the volatile matters or carbon content became fully combustible.

2. The variation of ash content in coal: This accumulated heat could quickly have melted the sodium content in the fly ash to form boiler slagging, which would have blocked the contact between the heat and the boiler tubes, thus inhibited the heat transfer efficiency which in turn, cased the heat rate to increase.
3. The boiler operation access air input: if the required excess air input for coal combustion was 15%, 30% excess air input would have resulted in a 15% increase. This would mean that the heat generated to produce steam would have been utilized to heat up this 15% additional air input. From a combustion efficiency stand point, it has been a common practice to eliminate the unnecessary excess air input to prevent increase and heat rate, and decrease in boiler efficiency.

There could have been more factors affecting the heat rate. Some of the most obvious factors would be any combination of the above three factors that cased the heat rate fluctuation at 6.21.

Enzergy™ spraying operation was initiated on 8/29/2014. All the heat rate data points under the high load Enzergy™ application between 9/1/2014 and 9/16/2014 have also been summarized in Table 8. As indicated in Table 8, all the Enzergy™ application high load heat rate data points were averaged at 11,539 Btu/KWh with a relative deviation of 0.53. The highest heat rate during this period was determined at 11,602 Btu/KWh and the lowest heat rate was 11,479 Btu/KWh.

Comparing the Enzergy treated coal heat rate to the two month baseline heat rate average of 11,654Btu/KWh to every data high load point under Enzergy™ application, the heat rate reductions (boiler efficiency improvements) have been observed between 0.4% and 1.5 % with an average of 1.0%. All the high load heat rate data points in July, August and September 2014 have been plotted in Figure 16 for comparison. It is obvious from figure 16 that there was a dramatic reduction in variation, and plant heat rate after the Enzergy treatment and application.

In July and August 2014, the high load heat rates have been observed to fluctuate. Soon after the Enzergy™ application was initiated, the heat rate was gradually stabilized shown in Figure 16 (relative deviation 6.21 vs. 0.53) with 1 % positive gain in boiler efficiency (heat rate reduction).

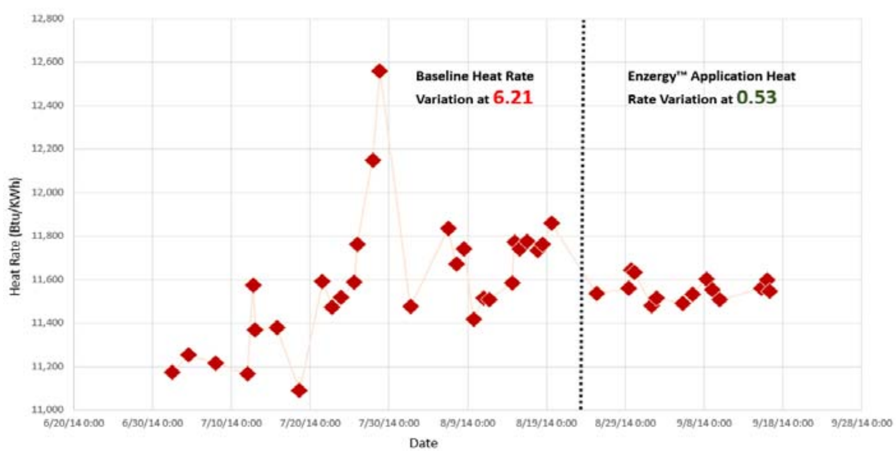


Figure 16: Tested Units High Load Heat Rate Overview, July, August, September 2014

All the Units A and B low load (~130 MW) data points in July and August 2014 were also calculated for the heat rate for both tested units to compare to the heat rate under the Enzergy™ coal treatment in September 2014. The heat rates under the units' low load generating capacity at approximately 130 MW in July, August and September 2014 have been summarized in Table 9.

As indicated in Table 9, all the low load heat rate data points in July and August 2014 were averaged at 12,438 Btu/KWh with a relative deviation of 6.21. The highest baseline heat rate in these two-month period was determined at 12,884 Btu/KWh and the lowest heat rate was 11,823 Btu/KWh. Comparatively, the minimum heat rate at 11,823 Btu/KWh output yielded the most efficient combustion condition because less coal was consumed to generate the same required power (MW) under the Units low load conditions. Therefore, the lower the heat rate, the higher the boiler efficiency and vice versa.

Table 9. Tested Units Heat Rate (Low Load) Summary in July, August (Pre-Enzergy™) and September (under Enzergy™) in 2014

Date/Time	Heat Rate (Btu/KWh)	Date/Time	Heat Rate (Btu/KWh)	Date/Time	Heat Rate (Btu/KWh)
7/4/14 8:00	11,873	8/2/14 23:45	12,564	8/23/14 11:15	12,255
7/5/14 9:45	11,941	8/3/14 23:45	12,594	8/24/14 11:30	11,836
7/14/14 2:45	12,111	8/4/14 23:45	12,638	8/25/14 6:45	12,017
7/14/14 13:15	12,082	8/5/14 6:30	12,884	8/28/14 7:45	12,436
7/15/14 3:00	11,792	8/6/14 5:15	12,156	8/30/14 0:45	12,366
7/17/14 6:00	12,270	8/7/14 18:45	12,347		
7/19/14 8:15	12,021	8/9/14 3:00	12,479		
7/20/14 2:15	12,116	8/12/14 6:45	12,620		
7/20/14 8:15	12,166	8/13/14 5:45	12,600		
7/21/14 6:00	12,200	8/13/14 16:45	12,180		
7/23/14 6:30	12,157	8/16/14 8:15	12,769		
7/24/14 7:45	12,089	8/18/14 5:15	12,608	Max	12,884
7/25/14 5:00	11,912	8/20/14 5:00	12,231	Min	11,823
7/26/14 7:45	11,908	8/21/14 6:45	12,084	Average	12,438
7/27/14 8:45	12,358	8/22/14 7:45	11,823	Varation	4.30%

Date/Time	Heat Rate (Btu/KWh)	Heat Rate Reduction
9/1/14 1:45	12,191	1.5%
9/2/14 7:45	12,266	0.9%
9/3/14 0:45	12,371	0.0%
9/4/14 2:30	12,022	2.8%
9/5/14 22:30	12,213	1.3%
9/5/14 16:45	12,202	1.4%
9/6/14 22:00	12,177	1.6%
9/7/14 0:00	12,375	0.0%
9/8/14 0:00	12,511	-1.1%
9/11/14 21:30	12,420	-0.4%
9/12/14 7:00	12,616	-2.0%
9/12/14 14:15	12,459	-0.7%
9/13/14 22:15	12,403	-0.2%
9/14/14 7:00	12,459	-0.7%
9/15/14 0:00	12,264	0.9%
Max	12,616	
Min	12,022	
Average	12,330	0.4%
Varation	2.41%	

Just like under the Unit high load conditions, plant operation would want to maintain the boiler heat rate consistently at 11,823 Btu/KWh to minimize the coal consumption thus maximizing electricity generation. However, boiler condition heat rate fluctuation have been observed at 4.30 during this two-month baseline period.

All the heat rate data points under the low load Enzergy™ application between 9/1/2014 and 9/16/2014 have also been summarized in Table 9. As indicated, all the Enzergy™ application low load heat rate data points were averaged at 12,330 Btu/KWh with a relative deviation of 2.41. The highest heat rate during this period with Enzergy™ coal treatment was determined at 12,616 Btu/KWh and the lowest heat rate was 12,022 Btu/KWh.

Compared to the two month baseline heat rate average of 12,438 Btu/KWh to every data low load point under Enzergy™ application, the heat rate reductions (boiler efficiency improvements) have been observed between -0.7% and 2.8 % with an average of 0.4%. All the low load heat rate data points in July, August and September 2014 have been plotted in Figure 17 for comparison.

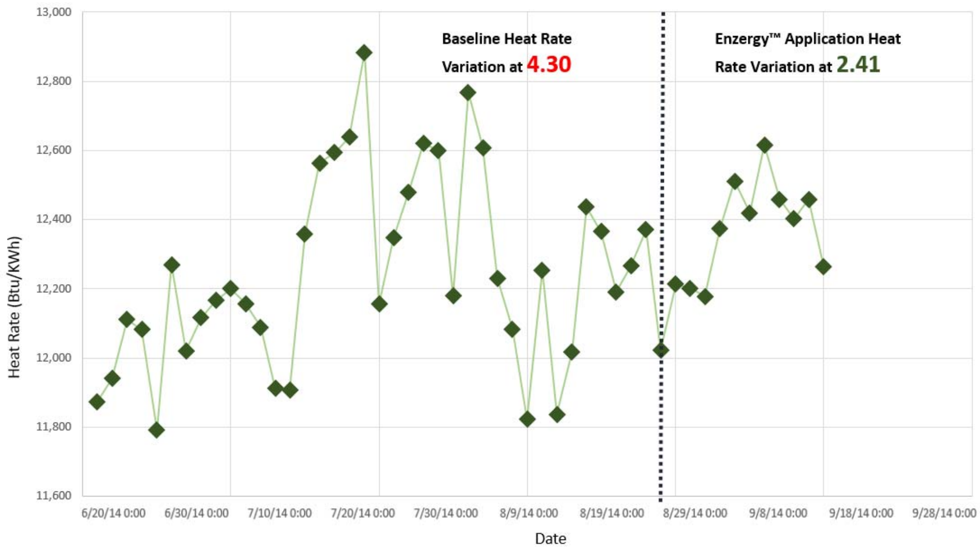


Figure 17: Low Load Heat Rate Overview, July, August, September 2014

An onsite observation was found repeated. In July and August 2014, the low load heat rates have been observed to fluctuate at the relative deviation of 4.30. Soon after the Enzergy™ application was initiated, the heat rate was gradually stabilized shown in Figure 17 (relative deviation 4.30 vs. 2.41) with 0.4 % positive gain in boiler efficiency (heat rate reduction).

Under both high load and low load conditions, the Enzergy™ application was observed to produce similar effects stabilizing the boiler conditions to produce more consistent heat rate than the un-treated combustion conditions. Furthermore, there has been combustion efficiency improvement reflected by system heat rate reduction 1% under the high load conditions and 0.4% under the low load conditions. This process produced by Enzergy™ treatment has also been known as “system cleaning” as has been observed by the test and commercial operation at the Taiwan CHP over the last 2 years.

As mentioned previously, when the diluted Enzergy™ was sprayed onto crushed coal, its unique bio-catalytic capabilities weakened and/or broke down the bonds between the aromatic molecules, which not only made coal particles more porous, but also “freed up” the hydrogen atoms to bond with oxygen atoms. When this happened, both the surface and inner moisture would be vaporized and released into the flue gas stream more quickly than the untreated coal combustion environment. Thus there would be less heat accumulated in the boiler and due to the lower temperature, sodium content in the ash would be less likely to cause slagging problem. The existing slag formed from the previous combustion environment without Enzergy™ coal treatment would gradually be flushed out and carried to the backend ESP.

The ASME (American Society of Mechanical Engineers) standard calculation was found consistent with the Method 19 heat rate reduction calculation for the boiler efficiency improvements. Under the high load conditions, the input-output method was applied for calculation for the two units’ furnaces and economizers’ efficiency, and the efficiency improvement was determined at 1.58%. Applying the evaporation ratio, the boiler efficiency improvement was determined at 1.68%, summarized in Table 10

Table 10. High Load Enzergy™ Boiler Efficiency Summary with ASME Calculations

DATE	TEST MODE	O2	EXCESS AIR	FURNACE	ECONOMIZER	FURN + ECON	EVAP RATIO	EVAP RATIO	HEAT RATE	PLANT EFFICIENCY
		%	%	%	%	%	T/T	Correlated	MJ/KWH	
8/25/2014	Unit A BASELINE	2.06	10.90	49.46	11.44	60.90	4.27	4.27	11,912	30.22%
9/1/2014	Unit A ENZERGY	2.27	12.20	51.57	11.11	62.68	4.29	4.39	12,008	29.98%
		10.19%	11.93%	4.27%	-2.88%	2.92%	0.31%	2.77%	-0.79%	
DATE	TEST MODE	O2	EXCESS AIR	FURNACE	ECONOMIZER	FURN + ECON	EVAP RATIO	EVAP RATIO	HEAT RATE	PLANT EFFICIENCY
		%	%	%	%	%	T/T	Correlated	MJ/KWH	
8/25/2014	Unit A BASELINE	2.06	10.90	49.46	11.44	60.90	4.27	4.27	11,912	30.22%
9/2/2014	Unit A ENZERGY	2.12	11.20	51.15	11.15	62.30	4.32	4.42	11,500	31.30%
		2.91%	2.75%	3.42%	-2.53%	2.30%	0.98%	3.46%	3.58%	
DATE	TEST MODE	O2	EXCESS AIR	FURNACE	ECONOMIZER	FURN + ECON	EVAP RATIO	EVAP RATIO	HEAT RATE	PLANT EFFICIENCY
		%	%	%	%	%	T/T	Correlated	MJ/KWH	
8/25/2014	Unit A BASELINE	2.06	10.90	49.46	11.44	60.90	4.27	4.27	11,912	30.22%
9/5/2014	Unit A ENZERGY	2.33	12.50	52.34	11.09	63.43	4.38	4.42	12,015	29.96%
		13.11%	14.68%	5.82%	-3.06%	4.15%	2.50%	3.51%	-0.86%	

DATE	TEST MODE	O2	EXCESS AIR	FURNACE	ECONOMIZER	FURN + ECON	EVAP RATIO	EVAP RATIO	HEAT RATE	PLANT EFFICIENCY
		%	%	%	%	%	T/T	Correlated	MJ/KWH	
8/25/2014	Unit B BASELINE	1.98	10.40	64.88	7.60	72.48	5.47	5.47	11,265.20	0.32
9/5/2014	Unit B ENZERGY	2.10	11.10	64.95	7.55	72.50	5.46	5.48	11,272.88	0.32
		6.06%	6.73%	0.11%	-0.66%	0.03%	-0.17%	0.12%	-0.07%	
		Averaged Efficiency Improvements		1.58%			1.68%		2.30%	

However, this process would take somewhere between 3 weeks to 1 month to reach equilibrium conditions that produce a cleaner boiler. To speed up this "system cleaning" process, the initial Enzergy™ dosing was set to high concentration for the ESS operations. Although the positive boiler combustion improvement was identified from the 18-day Enzergy™ trial, it was difficult to quantify the exact impact because of the use of the river water for dilution of the bio enzymes. The question that remained was "what happened if the deionized water had been used since the beginning of the trial, would the boiler efficiency improve further?"

3.4 Enzergy™ Application Stack CO_2 Reduction at Various Loads

The tested plant is not equipped with a CO_2 continuous emission monitoring system (CO_2 CEM), to report its annual CO_2 emission and comply with the Alberta greenhouse gases (GHG) regulation. The plant has been calculating the CO_2 emission based on the carbon content in coal as the maximum CO_2 emission throughput at the stack in intensity CO_2. This intensity is defined by tonne per hour CO_2 generation divided by the total megawatts (MW) electricity generation

Throughout the Enzergy™ trial, one set of continuous CO_2 emission monitor (CO_2 CEM) has been installed at the stack for continuous monitoring. The CO_2 CEM data has been summarized in Tables 11, 12, and 13 under the units combined high load, mid load and low load conditions.

As indicated in Tables 11, 12, and 13, the relative deviations of CO_2 density calculation between the coal carbon content basis and the CO_2 CEM data basis have been observed to be within 10% (from -4.1% to 6.6%). This indicated that the two sets of data agreed with each other. For the stack CO_2 emission reduction, the CO_2 CEM data have been adopted because it was more accurate and representative. Coal samples have been collected once a day during the trial, there has been concerns to represent the whole day of CO_2 emission generation based on one set of coal analysis. The CO_2 CEM system, on the other hand, has been calibrated everyday with CO_2 standard gases at high and zero concentrations and the CO_2 data has been collected continuously, thus the run averaged CO_2 CEM data represent a more accurate picture of stack CO_2 throughput.

Table 11. High Load CO_2 Enzergy™ Resting Results Summary

Unit A Test Name	Date	SO2 Reduction (%)	Intensity Nox	Intensity CO2 Unit A	Intensity CO2 Unit B	Heat rate Unit A (Kj/KWh)	Heat rate Unit B (Kj/KWh)	Averaged CO2 Intensity from Coal	Intensity CO2 Stack	Unit A Relative Variation	Stack CO2 Reduciton	Unit A BLR temp	Unit A Econo temp	Unit B BLR temp	Unit B Econo temp
B24-150	25/Aug/14	0.99	2.03	1.13	1.11	11.91	11.26	1.12	1.16	-1.8%		2361	973	2155	850
H24-150-8HR	29/Aug/14	8.07	1.94	1.17	1.17	12.31	11.85	1.17	1.18	-0.4%	1.7%	2365	977	2233	854
H24-150-72HR	1/Sep/14	8.16	2.02	1.16	1.16	12.00	11.93	1.16	1.16	0.0%	0.0%	2373	971	2209	854
H24-150-72HR	2/Sep/14	3.90	1.96	1.11	1.16	11.50	11.96	1.14	1.16	-1.1%	0.0%	2360	967	2179	853
H8-150-72HR/No ACI	5/Sep/14	3.46	1.97	1.14	1.10	12.01	11.28	1.12	1.16	-1.8%	0.0%	2346	973	2103	849
H24--150-72HR+8HR	8/Sep/14	11.39	2.24	1.18	1.19	12.53	12.59	1.19	1.18	0.2%	1.7%	2371	983	2097	860
H24--150-72HR	9/Sep/14	12.30	2.28	1.26	1.28	12.83	13.09	1.27	1.17	4.1%	0.9%	2358	983	2099	863
M24-150-72HR	15/Sep/14	14.44	2.22	1.31	1.21	13.32	13.12	1.26	1.17	3.7%	0.9%	2321	971	2116	851
M8-150-72HR+8HR	16/Sep/14	16.66	2.27	1.29	1.21	13.27	13.08	1.25	1.17	3.3%	0.9%	2318	971	2144	854
M8-150-K1/K2	23/Sep/14	0.70	1.71	1.17	1.06	12.06	11.35	1.12	1.21	-4.1%	4.3%	2434	973	2257	852

During the high load Enzergy™ test at approximately 320 MW gross electricity generation, the stack CO_2 emission has been determined to increase by 1.15% on average under the Enzergy™ coal treatment compared to the baseline condition. This was the only CO_2 increase observed during the testing, for the mid low and low load, CO_2 reduction was observed, this could be due to that all the high load tests occurred in the beginning of the test when the system cleaning process was still on-going, also. The misuse of river water between 9/1/2014 and 9/8/2014 could have reduced the Enzergy performances as well

Table 12. Mid Load CO_2 Enzergy™ Resting Results Summary

Test Name	Date	SO2 Reduction (%)	Intensity Nox	Intensity CO2 Unit A	Intensity CO2 Unit B	Heat rate Unit A (Kj/KWh)	Heat rate Unit B (Kj/KWh)	Averaged CO2 Intensity from Coal	Intensity CO2 Stack	Relative Variation	Stack CO2 Reduciton	Unit A BLR temp	Unit A Econo temp	Unit B BLR temp	Unit B Econo temp
B8-120	26/Aug/14	0.62	1.93	1.17	1.08	11.90	11.02	1.13	1.17	-2.0%		2273	928	2053	794
H8-120-72HR	3/Sep/14	5.86	2.17	1.12	1.16	11.85	11.89	1.14	1.14	0.0%	2.6%	2274	937	1936	806
H8-120-72HR	11/Sep/14	16.74	2.31	1.31	1.27	13.40	12.73	1.29	1.13	6.6%	3.4%	2182	936	1948	802
M8-120-72HR	17/Sep/14	11.77	2.07	1.24	1.14	12.65	12.40	1.19	1.17	0.8%	0.0%	2222	933	2010	801

Test Name	Date	SO2 Reduction (%)	Intensity Nox	Intensity CO2 Unit A	Intensity CO2 Unit B	Heat rate Unit A (Kj/KWh)	Heat rate Unit B (Kj/KWh)	Averaged CO2 Intensity from Coal	Intensity CO2 Stack	Relative Variation	Stack CO2 Reduciton	Unit A BLR temp	Unit A Econo temp	Unit B BLR temp	Unit B Econo temp
B8-90	27/Aug/14	-0.49	2.31	1.12	1.16	11.37	11.74	1.14	1.22	-3.2%		2148	877	1917	742
H8-90-72HR	3/Sep/14	4.46	2.29	1.20	1.17	12.15	11.67	1.19	1.22	-1.3%	0.4%	2102	886	1885	756
H8-90-72HR	10/Sep/14	10.52	2.47	1.24	1.19	12.55	12.37	1.22	1.20	0.7%	1.9%	2191	901	1838	763
M8-90-72HR	18/Sep/14	7.18	2.54	1.25	1.09	12.93	11.28	1.17	1.22	-2.1%	0.0%	2058	899	1856	743
M8-90-8HR	23/Sep/14	0.56	2.30	1.21	1.01	12.02	10.76	1.11	1.20	-4.0%	1.6%	2229	879	1987	745

During the mid-load Enzergy™ test between 180 MW and 240 MW gross electricity generation, the stack CO_2 emission has been determined to reduce by 1.49% on average under the Enzergy™ coal treatment compared to the baseline condition.

Table 13. Low Load CO_2 Enzergy™ Resting Results Summary

Test Name	Date	SO2 Reduction (%)	Intensitv CO2 Unit B	Heatrate Unit A (Kj/MWh)	Heat rate Unit B (Kj/MWh)	Intensity CO2 Stack	Stack CO2 Reduciton	Unit A BLR temp	Unit A Econo temp	Unit B BLR temp	Unit B Econo temp	Intensity Nox
B8-50	28/Aug/14	10.93	1.35	13.44	12.83	1.40		1816	791	1603	696	3.52
H-50-72HR	30/Aug/14	8.53	0.00	12.32	13.20	1.38	1.4%	1859	783	1620	699	2.44
H8-50-72HR	2/Sep/14	2.23	1.21	12.68	11.86	1.36	2.9%	1896	789	1630	710	3.27
H-50-72HR	7/Sep/14	2.85		12.54	12.60	1.38	1.4%	1943	803	1639	704	3.05

During the low load Enzergy™ test at approximately 110 MW gross electricity generation, the stack CO_2 emission has been determined to decrease by 1.90% on average under the Enzergy™ coal treatment compared to the baseline condition.

The overall average for the CO_2 emission reduction has been determined to be 0.93% which was on each load condition being operated 33% in any given year. This 0.93% CO_2 emission reduction was found consistent to the boiler efficiency improvement, and the heat rate reduction calculation.

3.5 Excess Air Issues Discovered during the Enzergy™ Application

Other than the use of river water, there were operational issues associated with the boiler excess air control that prevented Enzergy™ treatment providing increased boiler efficiency improvements. From data collected from the commercial Enzergy™ application in Taiwan, the excess air could be reduced by at least 30%. We believe this was because the treated coal became more porous and chemically more reactive as the coal was depolymerized and also oxygenated, it simply did not take more air for complete combustion than the untreated coal.

According the plant PI report, all the oxygen and excess air data were documented for further analysis, summarized in Table 14. The initial agreement was to control both units' economizer outlets O_2 at close to 2% consistently throughout the entire trial.

Table 14. Tested Units O_2 and Excess Air (High Load) Summary

Baseline	1.98%	2.00%	12.8%	11.0%	Observed	O2 Calculated	E.A. Calculated
	Increased Boiler **A** %O2	Increased Boiler **B** %O2	Increased Boiler **A** Excess Air	Increased Boiler **B** Excess Air	Boiler Efficiency	Boiler Efficiency	Boiler Efficiency
8-Sep	60.9%	6.1%	36.0%	-0.4%	0.44%	0.59%	0.52%
9-Sep	60.9%	1.7%	36.0%	-4.9%	0.88%	1.15%	1.01%
15-Sep	176.6%	4.2%	167.4%	-2.3%	0.80%	1.52%	1.45%
16-Sep	151.9%	6.1%	136.3%	-0.3%	0.48%	0.86%	0.81%
16-Sep	193.0%	5.5%	189.1%	-0.9%	0.91%	1.81%	1.77%

Under the high load conditions, on one of the tested units, there were more O_2 control issues due to a malfunctioned O_2 probe at the economizer outlet.

As indicated in Table 14, from the baseline condition at 1.98% O_2, it was increased by 60.9% on 9/8/2014 and 9/9/2014. The economizer O_2 was increased again by 176.6% on 9/15/2014, and increased an average of 172.5% on 9/16/2014. This economizer O_2 increase resulted in unnecessary waste of heat because it took energy to heat up the additional combustible air. Certainly, this increase in the economizer O_2 corresponded perfectly to the calculated boiler excess air.

According to ABB's Engineers' hand book, a 1% increase in excess air would result in a 0.05% decrease in boiler efficiency. Therefore, going from 2.0% O_2 (~12% Excess Air) to 5.5% O_2 (~32% Excess Air) would have resulted in a decrease in boiler efficiency by approximately 1%. However, this does not take into account the increase in Furnace Exit-Gas Temperature (FEGT) that normally results in operating at higher excess air levels. A 35F to 40F increase in FEGT will reduce boiler efficiency by another 1%.

Therefore, during the 18-day Enzergy continuous application, the heat rate reduction (boiler efficiency) could have been between 2.0% and 3.0% under the boilers high load condition. This left another question as "what will happen if the economizer O_2 had been precisely controlled since the beginning of the trial, would the boiler efficiency improve further?" It is recommended for future tests that O_2 be incrementally reduced until there is an increase in CO.

One critical evidence that indicated this ineffective economizer O_2 control was creating negative impacts rather than just bad data on the screen was that none of these two units were equipped with boiler NOx emission control devices (over fire air), so the additional excess air input resulted in an obvious stack NOx emission increase from 0.46 lb/MMBtu to 0.51lb/MMBtu.

3.6 Enzergy™ Application Impacts on Stack Mercury Emission

Throughout the project, EPA Method 30B (sorbent traps) was used as the reference method to compare against the plant stack Hg CEMS. The results have been summarized in Table 15.

The stack Hg CEMs and the Method 30B data have been observe to follow the same trend, shown in Figure 18. Most of the results comparison between the two methods would have passed RATA (relative accuracy test audit) except for the test on 9/5/2014 while the activated carbon injection (ACI) was shut down to determine the impact of Enzergy™ application on the stack Hg emission.

Table 15. Units A & B Stack Hg Testing Results Summary

Test Run Number	1	1	1	1	1	1	1
Combined Loads in MW	323.3	259.9	321.2	322.9	316.6	322.6	259.9
Date	8/25/14	8/26/14	8/29/14	9/1/14	9/5/14	9/8/14	9/11/14
Start Time	15:15	13:25	16:24	9:30	9:30	10:00	9:30
End Time	15:58	14:45	16:59	13:27	11:50	11:30	11:20
Total Run Time (min)	43	85	35	237	140	90	110
Stack Parameters							
Gas Moisture, % by volume, as measured	10.3%	10.3%	12.2%	14.1%	11.6%	14.5%	10.0%
%CO2 by volume, dry basis	13.5	13.5	13.5	13.5	13.5	13.5	13.5
Dry Molecular Wt. of Gas, lb/lb-mole	30.38	30.38	30.38	30.38	30.38	30.38	30.38
Total Filterable PM							
Elemental Hg (µg/dscm)	0.30	0.40	0.17	0.19	2.81	0.15	0.60
Total Hg (µg/dscm)	0.51	0.42	0.37	0.47	3.52	0.26	0.77
STKB Hg CEM (µg/dscm)	0.09	0.08	0.06	0.19	2.41	0.12	0.08

According to the RATA guidelines, when the background mercury concentration was below 5 µg/dscm, a difference less than 1 µg/dscm between the reference method and stationary Hg emission monitoring source could was acceptable. However, the test on 9/5/2014, the difference between the two methods was 1.11 µg/dscm.

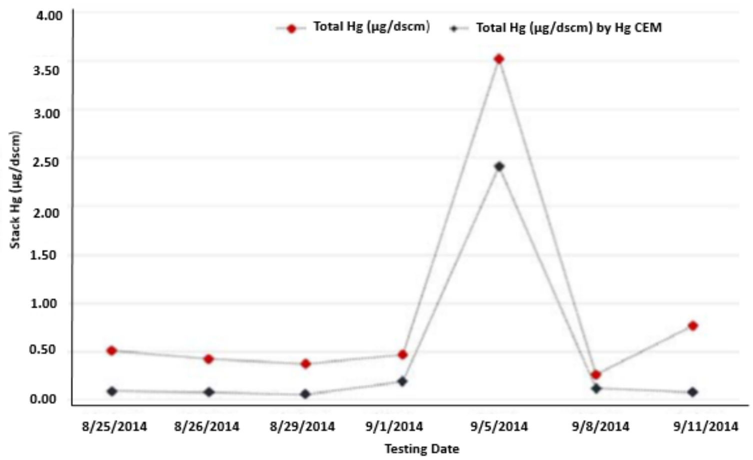


Figure 18: Comparison between EPA Method 30B and Existing Hg CEMs

As mentioned, on 9/5/2014, the ACI operation was suspended, on that particulate date, the Hg content in coal was averaged to be 24.6 ppb. To convert this Hg content in coal from ppb to the 100% vapor phase Hg at the stack, the as determined (dry) analytical data of heating value at 7616 Kj/Kg, carbon content at 57.51%, hydrogen content at 3.57%, oxygen content at 15.61%, nitrogen content at 1.30%, sulfur content at 0.62%, moisture content at 24.87%, and ash content at 21.40% were calculated. The calculated stack Hg emission was 5.11 μg/dscm. However, the stack Hg emission was not observed to fully recovered back to 5.11 μg/dscm, it was determined to be at 3.52 μg/dscm by EPA Method 30B, and measured to be at 2.41 μg/dscm. Take it as Hg removal efficiency, the Enzergy™ application actually produced approximately 31% which could mean that in the continuous Enzergy™ application, the tested plant could save around 30% worth of activated carbon consumption a year.

However, this 31% Hg reduction could have been contributed by the accumulated activated carbon deposited in the system. After all, there was only approximately 12 hours of ACI suspension. A longer term of testing would be required to see if this 31% Hg reduction could be reproduced stably.

3.7 Issues associated during the Enzergy™ Spraying Operations

If the coal on the conveyor belt was not treated (sprayed) with Enzergy™, it remained untreated. From this field trial, it had been suspected that only 20% to 40% of coal on the coal belt was treated with the Enzergy™ solution.

Figure 19: ESS Operations at the 1st set Conveyors

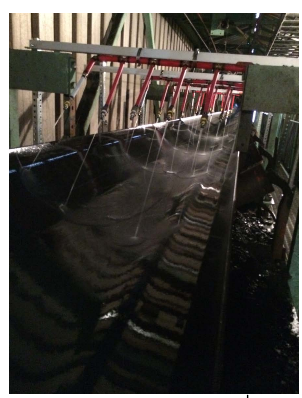


Figure 20: ESS Operations at the 2nd set Conveyors

The speed on the 1st set of conveyor was approximately 500 to 700 tonne per hour (TPH) whereas the speed on the 2nd set of conveyor was approximately 200 to 300 tonne per hour (TPH). As shown in Figures 19 and 20, the mist that was created from the Enzergy™ spray at 1st set of conveyor was carried forward due to the high velocity. The 2nd set of conveyor, on the other hand, the Enzergy™ spray was allowed to penetrate more deeply because the lower high velocity. Either case, the coal that was close to the belt could have remained untreated which would be a partial explanation of why there was only 16% SO_2 reduction and 1% boiler efficiency observed, shown in figure 21.

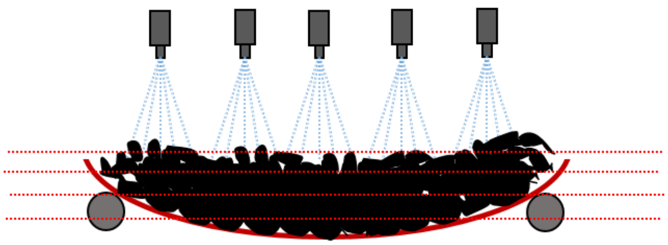


Figure 21: Schematic Enzergy™ Spray: the Bottom two Layers could have remained untreated

Improvements on spraying location re-arrangements have been identified that can further optimize the Enzergy™ spraying operation to enhance even distribution. This would allow the Enzergy™ spray on coal from 360^{o} angle, shown in Figure 22.

Figure 22: Proposed Improvements on Enzergy™ Spray

4 Summary and Conclusions:

The results from the short trials and tests have been summarized as follows:

- Under the units A&B combined high, mid and low load conditions. There was approximately 16% reduction on the stack sulfur dioxide emissions (SO_2). On 9/13/2014 and 9/14/2014 under the mid conditions, the Enzergy™ application was observed to produce stack SO_2 reduction for as high as 19%.
- The Enzergy™ application was observed to produce repeated effects stabilizing the boiler conditions such as more consistent and less variable heat rate than the baseline combustion conditions. Furthermore, under the high load condition, there was 1% boiler efficiency improvement (heat rate reduction) for a short period of the 18 day of continuous application
- The Enzergy™ application was observed to produce repeated effects stabilizing the boiler conditions such as more consistent and less variable heat rate than the baseline combustion conditions which applied the US EPA Method 19 standard calculation. Furthermore, under the high load condition, there was 1% boiler efficiency improvement (heat rate reduction) for a short period of the 18 day of continuous application
- The ASME standard calculation was consistent with the Method 19 heat rate reduction calculation for the boiler efficiency improvements. Under the high load conditions, the input-output method was applied for calculation for the tested units' furnace and economizer efficiency and the efficiency improvement was determined at 1.58%. Applying the evaporation ratio, the boiler efficiency improvement was determined at 1.68%.
- This boiler efficiency improvement, in turn, would resulted in an approximate 1% carbon dioxide (CO_2) emission reduction which was consistent with the CO_2 continuous emission monitor installed at the stack. For the high load conditions, the CO_2 emission was observed to increase by 1.15%; for the mid load conditions, the CO_2 emission was observed to decrease by 1.49%; and for the low load conditions, the CO_2 emission was observed to decrease by 1.90%; therefore, the overall CO2 emission reduction during this Enzergy™ trial was averaged at 0.93%.
- The Enzergy™ application was observed to create no impact on the fly ash marketability, according to the fly ash analysis, and there was approximately a 10%-15% increase in fly ash volume
- Although there was an increase in fly ash volume, the Enzergy™ application was observed to create no negative impact on the stack opacity and particulate matters (PM) emissions.
- The ACI operation was suspended on 9/5/2014. On that particulate date, the Hg content in coal was averaged to be 24.6 ppb by a third party laboratory which was approximately 5.11 µg/dscm as the total stack Hg emission. However, the stack Hg emission was not observed to fully recovered back to 5.11 µg/dscm, it was determined to be at 3.52 µg/dscm by EPA Method 30B, and measured to be at 2.41 µg/dscm. Take it as Hg removal efficiency, the Enzergy™ application actually produced approximately 31% which could mean that in the continuous Enzergy™ application, the tested plant could save around 30% worth of activated carbon consumption a year.

However, there were issues that were identified in this trial resulting in shortfall of Enzergy performance:

- The use of raw river water (the first 7 days of Enzergy™ application) for enzyme dilution was observed to impact the enzyme performance, probably because the enzyme was consumed digesting algae in the river water. A significant improvement in performance occurred when the dilution water was changed to deionized water. Because of the dilution water problem, a huge quantity of Enzergy™ material was not applied under the optimal conditions.

- The use of raw river water also impacted the required time (7 days) for Enzergy™ coal treatment to condition the boiler system. Proper Enzergy™ application for the full test period would have resulted in reduced boiler slagging and fouling, which improves the unit's heat-transfer rate and thermal efficiency.
- During the last 3 days of the Enzergy™ trial, it was observed that the overall boiler efficiency was reduced by 1% to 2%. This was due to the plant operation's improper control on of the tested units' excess air (caused by a broken O2 probe). A potential 2% to 3% overall boiler efficiency improvement would have been observed. Certainly, this would have also produced additional 2% to 3% CO_2 emission reduction.
- One critical evidence that indicated this ineffective economizer O_2 control was creating negative impacts rather than just bad data on the screen was that none of these two units were equipped with boiler NOx emission control devices (like over fire air), so the additional excess air input was turned into the obvious stack NOx emission increase by between 10% and 20%
- From this field trial, it had been suspected that only 20% to 40% of coal on the coal belt was treated with the Enzergy™ solution. Improvements on spraying location with future re-arrangement of spray nozzles have been identified that can optimize the Enzergy™ spraying operation to enhance even distribution.
- Although there was approximately 31% Hg emission reduction observed, this could have been contributed by the accumulated activated carbon deposited in the system. There was only approximately 12 hours of ACI suspension. A longer term of testing would be required to see if this 31% Hg reduction could be reproduced stably.
- To solve and address the above issues and questions, Coalvation is proposing to conduct a long-term (three months) commercial-scale demonstration. After implementing a modified and optimized spraying system/procedure to apply Enzergy™ to the Alberta subbituminous coal, this proposal is expected to achieve the optimum Enzergy™ performances that will maximize the boiler efficiency improvements, and reduce stack emissions of NOx, SO2, and CO2
- To reduce the stack nitrogen oxides (NO_x) by between 10% and 20% with a more precise control on the plant excess air. (It is recommended that the excess oxygen be reduced until the CO emissions begin to increase).
- To quantify how much Enzergy™ improves the existing electrostatic precipitator performance on a long term basis and the impact on stack opacity. Particulate matter (PM) emissions will also be measured at the stack.
- During the winter time in Alberta, the surrounding temperature gets below water freezing point, although Enzergy™ will not freeze, the carrier water will. This could reduce the Enzergy™ reactivity. Coalvation proposes to use heating elements to bring up the Enzergy™ solution temperature to above 22^{o} C. When the solution is sprayed onto the coal particles, this will at least get the reaction initiated. After coal is piled up in the coal yard, the internal temperature will then kick-in to reactivate the enzymatic process. This internal temperature within the coal pile exists because the Alberta subbituminous coal would self-ignite in the stockpile. However, this winter modification will require further testing.

5 <u>Next Steps and Communication Plan:</u>

Enzergy™ has been commercialized in Taiwan and is in the final stage of commercialization in North America. During this Enzergy commercial-scale demonstration at this tested plant, some critical spraying process modifications, physical requirements and logistics of deployment have been identified.

The final step to commercialization will be to deploy and implement Enzergy™ application technology at all coal-fired plants in Alberta. The pre-engineering needed to bring an Enzergy™ system online at any power plant is relatively simple. It includes fuel analysis, bioenzyme modification, site evaluation, system design, permitting, resolution of any other regulatory matters, and creating a deployment schedule. The total process should take 2-3 months, depending on the site-specific variables.

The Enzergy™ system is at Technology Readiness Level of 8 out of 9, as defined by the U.S. Department of Energy: "Integrated Pilot System Demonstrated – System/process prototype demonstration in an operational environment ([i.e.,] integrated pilot-system level."

5.1 <u>Communication Plan</u>

B&CES will also work closely with its main partner in the United States, the **National Rural Electric Cooperative Association** (NRECA), to disseminate the results of this project and the possible U.S. demonstrations at the two NRECA-member co-ops, to all NRECA members, with a focus on generation-and-transmission (G&T) electric cooperatives. NRECA hosts several conference targeting utility generation and environmental issues annually, and B&CES has been invited to present the Enzergy™ trial results.

Two U.S. electric cooperative (co-op) utilities, **Associated Electric Cooperative, Inc.** and **Southern Illinois Power Cooperative**, have expressed strong interest in performing field demonstrations of the Enzergy™ bioenzyme at each of their plants. Three other co-ops, **Deseret Electric Cooperative, Arizona Electric Power Cooperative**, and **East Kentucky Power** Cooperative, have also expressed strong interest in evaluating the results of the demonstration of Enzergy™ bioenzyme. We foresee a realistic possibility that if these demonstrations are successful, one or more utilities will pursue discussions about installing an Enzergy™ system at their facility.

The Assistant Project Director, Dale Bradshaw, is the chairman of the **Centre for Energy Advancement through Technology Innovation**'s Thermal Generation Interest Group (CEATI TGIG). He will likewise disseminate the results of the CCEMC project and U.S. demonstrations to all CEATI TGIG members, with a focus on all Canadian utilities that burn coal.

The Enzergy™ bioenzyme was engineered and is produced by **Simpert Technology**, an engineering company and system integrator. B&CES will continue partnering with Simpert to refine the product and expand its production as the market grows.