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# Sustainability Plan

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**Sustainability Plan for IPA Blackstone - Background**

International Power (IPA), an independent power company, is motivated by a commitment to deliver the best possible energy solution to every region they serve.  IPA understands the dilemma of growing energy needs and diminishing energy supply.  International Power is one of the leading power generation companies in the world.  With 40 power stations in 17 countries, IPA owns and generates more than 30,000 MW of generating capacity in the United States, the United Kingdom, Europe, Australia, Asia, and the Middle East – enough to provide electricity to 30 million homes.

IPA believes in lasting solutions – not short sighted ones.  IPA has developed some of the cleanest plants in the country using state of the art, proven environmental technology to reduce air emissions and water use to the levels among the lowest in the country.

As a leader in the power industry, IPA brings a broad perspective to power generation, providing our markets with additional services including:

- Being one of the world's largest wind suppliers
- Increased use of hydro electric power
- Gas transportation and supply
- Production of fresh water through seawater desalination

IP understands that its reputation depends on its day to day integrity and continual improvement.  They have made a long standing commitment to both.

IP's Blackstone facility is a 570-MW power plant utilizing two Alstom GT24B Gas Turbines that employ sequential combustion technology to greatly reduce

Nitrogen Oxide (NOx) emissions, compared to traditional power plants. The plant consists of two single-shaft designed, combined cycle units, which each consisting of a Gas Turbine, Heat Recovery Steam Generator, and Steam Turbines that are combined together in a system that produces electric power at a much higher efficiency than is possible with each system operating independently. The Blackstone plant effectively limits its water usage by using Air Cooled Condensers (ACC'S) instead of conventional cooling towers with spray water. This facility began construction in 1999, and has been in successful commercial operation since 2002.

**Plant Milestones**

| | **Unit 1** | **Unit 2** |
|---|---|---|
| **Construction Begins** | **6/1/1999** | **6/1/1999** |
| **First Fire** | **3/24/2001** | **5/14/2001** |
| **Mechanical Completion** | **2/2/2002** | **2/2/2002** |
| **Commercial Operations Achieved** | **2/8/2002** | **4/4/2002** |

IPA is committed to achieving the best practicable environmental performance via the use of modern combustion and abatement technology and to increasing its use of renewables. In addition, the benefits of the latest operation and maintenance practices help to reduce the environmental impact. When generating electricity, the key environmental issues are:

- Emissions to atmosphere of carbon dioxide, oxides of nitrogen, sulphur dioxide and particulates (dust);
- Management of waste materials, including ash, waste oil and other wastes;
- Resource use, including fuel (coal, gas and oil), electricity, water and land;
- Managing our impacts on biodiversity.

A key driver of company policy in the last three years has been to establish a cohesive and consistent approach to health, safety and environmental management. During 2006, the majority of the assets improved their environmental management systems by moving towards full ISO14001 certification, a program that will continue to be promoted and encouraged in 2009.In today's increasingly competitive power markets, combined cycle power plants are expected to cover a wide range of operation regimes. The range reaches from base load engines to peak load engines. Operators tend to maximize the power output when the Spark Spread (gross income from selling a unit of electricity after buying the fuel) is low or negative. During times, when the Spark Spread is low or even negative, every additional generated MWh results in an increase of the financial loss. Without the implementation of a low load operation concept, the lowest possible power production at IPA Blackstone is the GT Minimum load, which is 155MWh. With the low load operation concept the facility would be able to deload to an even lower load, thus reducing the overall financial loss, while staying connected to the grid. The operation concept is uniquely possible with Alstom's sequential combustion technology. The combined cycle load reduces to approximately 15-20% load. The emission requirements typically remain fulfilled, while the steam turbine remains online. While the combined cycle remains online it contributes to keeping plant efficiency relatively high during low load operation. With the ability to operate at low loads the ability to remain connected to the electrical grid may result in increased capacity payments, the reduced risk of missing the generation schedule for the next day are all huge advantages of the low load operation concept. Another huge advantage to the low load operation is increased life cycle for the mechanical parts of the turbine. The life-cycle of gas turbine components is based on the following factors:

1) Start-ups and shut downs.
2) Time differential between start-ups and shut downs (cycling).
3) Running hours.
4) Component protective coatings.
5) Strength of Materials
6) Type of blade cooling.
7) Method of steam/gas injection.
8) Corrosion/erosion.

The degradation of power plant component life occurs with cycling of the turbine, or the starting and stopping of the turbine. Predicting for the interaction of creep and thermal fatigue includes uncertainties and requires the inspection of components for defections.

**Effects of Turbine Cycling**

Creep fatigue interaction is the prominent material degradation in high temperature plants and their components. Elevated temperatures, high temperature gradients, and thermal cyclic loading in power plants are the reason for failures and reduced operating times. Thermal stresses due to expansion and contraction, as the temperature gradients increase and decrease can cause stresses that can induce interferences of metal components and also initiate cracks.

In cyclic service, though the number of "On-Line" hours may be far less, wear and damage can be more severe. Cyclic heating and cooling can turn oxidation into thermal erosion as oxides spall more frequently. While sustained temperature differentials sometimes crack parts in continuous duty, cyclic thermal transients and the stresses they cause can cause component failure. Cracks propagate quickly and blade fracture is not only determined by the amplitude of deformation in the loading cycle, but also by the maximum temperature differential. A sign wave loading cycle inflicts more damage on turbine materials and components, than a constant cycle. In general, turbine component failure can be grouped into two categories: fatigue and creep. Creep is the tendency of solid materials to slowly deform under the influence of stress. It occurs as a result of long term exposure to stress that is below the yield strength of the material. Creep is more severe in materials subjected to heat for long periods. It always increases with temperature. Here, the creep of a turbine blade will cause the blade to contact the casing, resulting in the failure of the blade, more serious; a catastrophic failure.

Thermal fatigue arises from cyclic thermal stresses set-up during start-up and shut down. The large temperature differential causes the materials of the components to expand and contract. The materials can plastically deform and are subject to accelerated oxidation. Here, the fatigue is the repetitious starting and stopping, stressing the material.

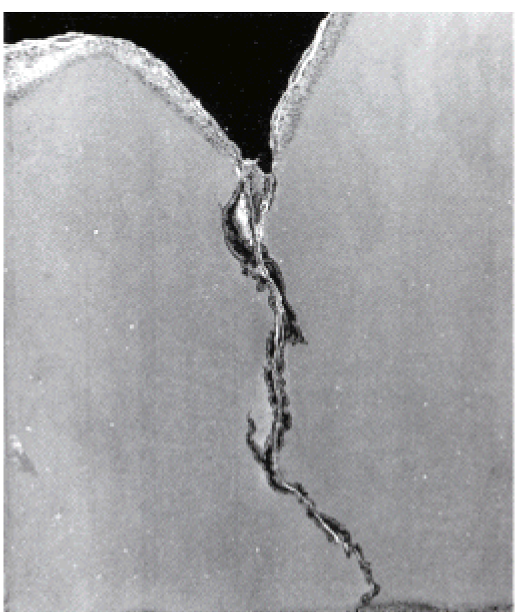
Inspection technology utilizes various tools to detect anomalies in materials. Operational monitoring systems such as temperature, pressure and vibration instruments can give real time indications of the turbine. Variations of readings from these instruments, outside the operating parameters of the turbine, can be beneficial in identifying problems within the system. For instance, a vibration anomaly could indicate distortion of turbine rotors concentricity due to thermal fatigue. Non-destructive testing is often done during preventative maintenance at scheduled shut downs. The following is a list of non-destructive tests:

1) Measurements
2) Ultra-sonic
3) Magna-Flux
4) Acoustic Emission
5) Eddy Current
6) Fluorescent Dye
7) Visual

8) Material Strength Calculations.

Materials can also be analyzed by microscope. Here, inter-crystalline structures are analyzed to see identify inherent or deviations of properties due to outside forces, such as creep. Often times, micro structural analysis of failed component material reveal origins of problem. Such as in creep failure mechanism, the decreasing of ductility and toughness due to carbides precipitation in grain boundaries, degrades the material.

Turbine materials are subjected to extremes of temperature and pressures of gases during the start-up and shut down of the power plant. Distortion and stress interact within component materials and can impact them on the micro-scope level inducing weakened boundaries that can propagate cracks. Frequent extreme conditions can also permanently distort materials causing interference within their calculated boundaries. The repetitive interaction of microscopic fatigue and creep can lead to failure of a gas turbine due to cycling. Crack propagation due to thermal fatigue.



**EOH and Trip Event Risk**

When a combined cycle plant cycles, that transient increases the potential for a trip event to occur due to the pressure and temperature changes inherent in this process. As valves and pumps are required to change position rapidly, which occurs often during a cycle, there is an increased chance to experience an equipment failure. A failure exposes the gas turbine (and other plant equipment, but not to the same degree) to thermal stresses that occur as the unit's load or firing rate goes to zero from some higher value. Gas turbine OEM's have implemented ways in which to monitor the degradation of the internal gas turbine parts. What the GT24 turbines utilize is a counter that weights both events and hours using a quadratic equation to calculate Equivalent Operating Hours or EOH. Depending on the type of event, the counter, or Operational Data Counter – ODC, will accrue "hours" much like an automobile odometer. The exception being that the ODC uses weights for given events where an odometer does not. For example, when a GT24 is started the ODC counts 20 EOH. If this concept were to be adopted in an automobile odometer, then you would accrue 20 miles, or Equivalent Operating "Miles", every time you started your vehicle. The basis is to reflect, in a numerical value, how degraded the gas turbine internal components are at any given time. (See Figure 2)

| Event | | Weight | Cost |
|---|---|---|---|
| **High Load Trip** | **(TH)** | 200 | $137,000 |
| **Low Load Trip** | **(TL)** | 60 | $41,100 |
| **Protective Load Shed** | **(PLS)** | 60 | $41,100 |
| **Emergency Shut Off** | **(ESO)** | 200 | $137,000 |
| **Load Rejection** | **(LR)** | 200 | $137,000 |
| **Start** | **(S)** | 20 | $13,700 |

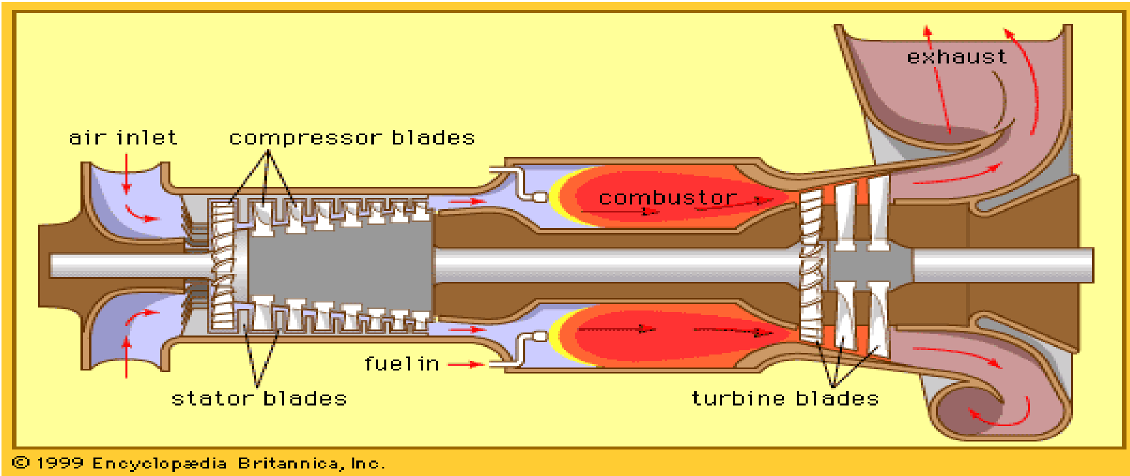
**This chart represents the cost that International Power would accrue given the occurrence of an event listed above. International Power EOH cost is $685 per EOH.**

## Sequential Combustion Gas Turbine Design

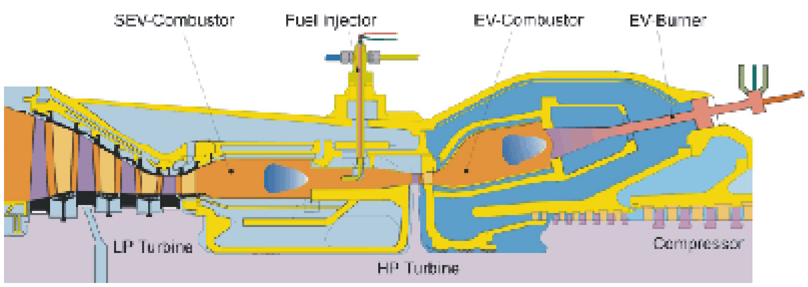
In the power generating field, generators are always modifying operation to gain an advantage over other generators or competitors.  It is important for power generators to position themselves in the market to be flexible in terms of how their units are both dispatched and what loads they are dispatched at.  The Alstom GT24's are uniquely positioned to maximize potential, regarding dispatch range, due to their low part load heat rates and additional operating concepts that can be implemented.

The sequential combustion design of the GT24, as well as the machines ability to control gas turbine outlet temperature allow GT24 users to realize this advantage.  A typical gas turbine engine consists of a compressor, a CAN type combustor, a turbine section, and an exhaust housing.  The GT24 units have all of the same components, and an additional component.  The GT24 units have a compressor, followed by an EV (Environmental) burner in lieu of a CAN type combustor, a single high pressure turbine section, another SEV (Sequential Environmental) burner, a four stage low pressure turbine section, and an exhaust housing.  Figure 3 illustrate the basis differences between a typical gas turbine engine and a GT24.

**Figure 3 - Typical Gat Turbine Engine**

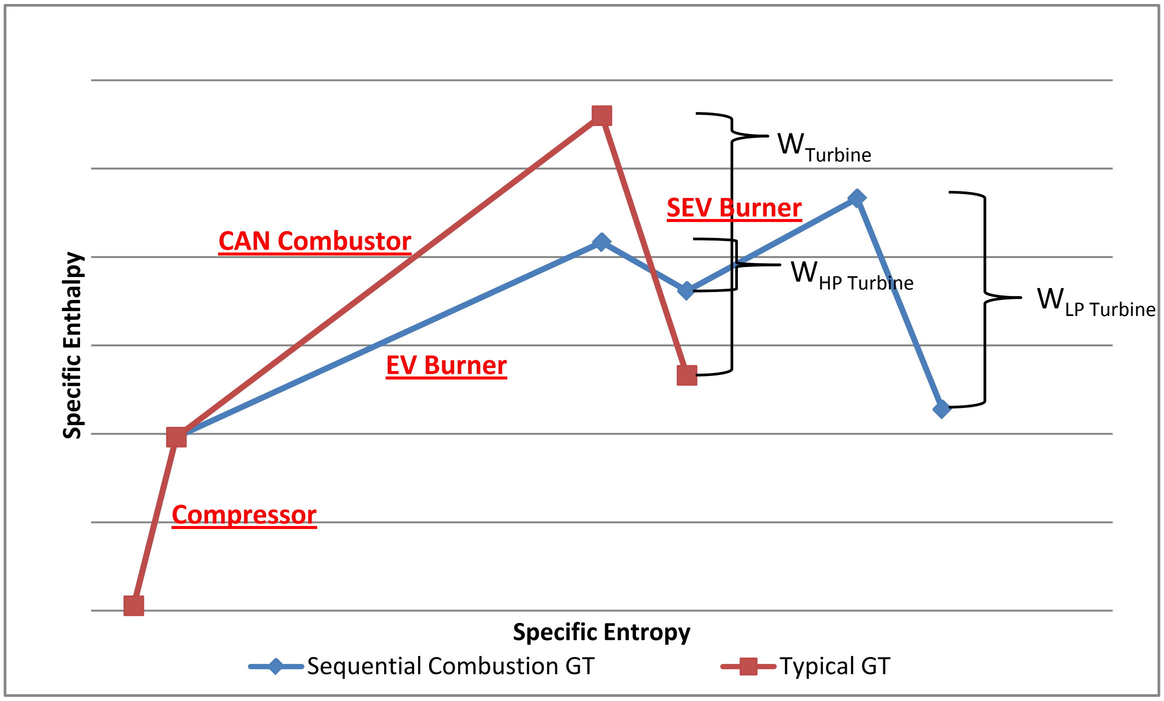



**ALSTOM GT24 Gas Turbine Engine**




The design advantage throughout the entire operating range allows the machine to have lower turbine inlet temperatures without sacrificing output. This allows the internal material and the respective coatings to be less of an issue over the lifetime of the machine, because of the lower firing temperatures that the components are exposed to. Also, from an emissions perspective, as a result of the "reheat" SEV burner, inherent to the sequential design, the GT24 emits fewer pollutants from its combustion process. Figure 4 graphically shows the difference between the typical and sequential design of gas turbine engines.

**Figure 4**




**Enthalpy / Entropy Diagram Illustrating the difference between a Typical Gas Turbine Engine and a GT24 (Sequential Combustion) Engine**

## EV Full Load Operation (low load operation)

Alstom, the GT24 Original Equipment Manufacturer, has approved a concept that would allow the units to cycle down to an operating load much less than nominal economic minimum loads. The design of the operating concept is to take advantage of the two stage combustion process in the sequential type gas turbine, and eliminate the second stage process while the first stage is running at approximately full load. Being that the second stage process converts the bulk of the energy into electrical energy, by removing it you can significantly reduce the total machine output while the first stage is at a relatively high output. This allows the machine to maintain emissions below permit limits at very low loads.

**Benefits**

The EV Full Load concept can provide a number of benefits for IP, both in the energy market and in operating costs.  It can reduce the amount of economical exposure during periods of reduced spark spread hours, and prevent or reduce the amount of cycles on the unit.  The “off peak” hours are typically of little value towards the overall gross margin, but a few of them often hold value and you stand to gain if you can generate during those times.  Flexibility is a key attribute for a unit to have during these periods.  As the value of the off peak hours change, the units with EV Full Load capability can adjust their output with a wider range and position themselves to maximize the value of the entire off peak periods.  Units that cannot operate like this will be forced to either operate at higher loads and be exposed to greater gross margin losses, or even be forced to shut down for those hours.  When a unit comes off line or shuts down, the respective unit creates a number of inefficiencies including excessive emissions, additional water usage, in house electrical consumption, and risk potential to have a trip event occur, all of which have a negative impact to the company. Figure 5 is a chart that illustrates the potential for reducing trip event risk associated with cycling.

**Figure 5**

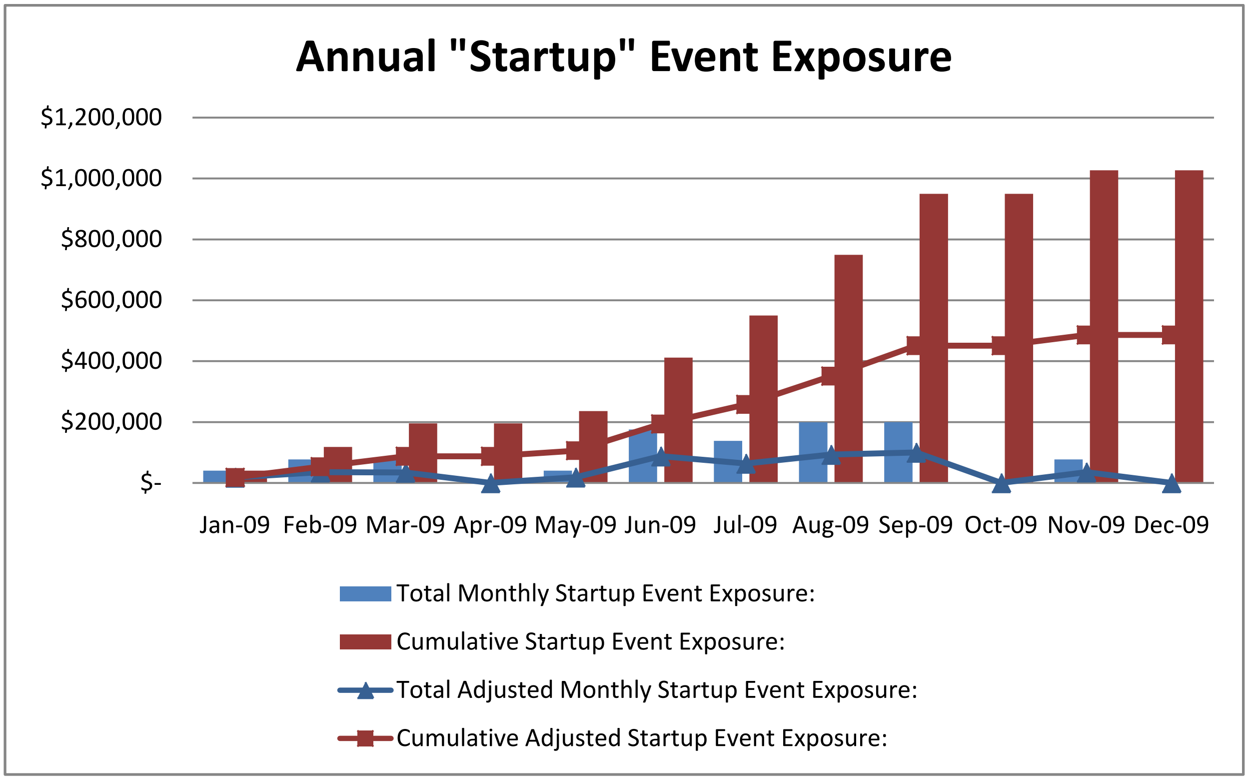



**Figure 5 charts the predicted startup event exposure both with (lines) and without (bars) EV Only Low Load Operation implemented. The assumption is that you can reduce the cycles on the machine by 50%.**

The fast growing demand for clean, fresh water—coupled with the need to protect and enhance the environment—has made many areas of the United States and the rest of the world vulnerable to water shortages for various human uses. As they interact with the electricity industry, these uses encompass agricultural irrigation, thermoelectric generation, municipal water/wastewater treatment and distribution, and industrial processes. The dependency of electricity supply and demand on water availability can impede societal and economic sustainability.

Upon each start up and shut down event IPA – Blackstone consumes a considerably larger amount of water and electricity. If the units were capable of running through the off-peak hours the company would save a significant amount of money through the reduction of water and electricity. The typical water usage for a unit running through the night is 12,000 gpd, if the units were to cycle that numbers drastically increases to 28,000 gpd. This increase in consumption is related to surface and bottom blow downs due to the improper water chemistry related to the disturbances created by cycling. The in house power consumption is also drastically increased due to our static starting device. The Static Starter is an adjustable speed AC drive. It is applied as a starting means for the gas turbine-generator sets by operating the generator as a synchronous motor. Eliminating the need for a separate starting device, such as an electric motor, diesel engine, torque converter, and associated auxiliary equipment, Static Starters require less maintenance and less mounting space, but require much more electricity. If the units were to run through the nights at low load operation, the SSD would not be needed therefore, reducing in house power consumption. (See Figure 6)

**Figure 6**

| Consumable | Cycle | Non-Cycle |
|---|---|---|
| **Electrical Consumption (MWh)** | 12 | 0 |
| **Water Consumption (Gallons/day)** | 28,000 | 12,000 |
| **CO Generation (lb/mmbtu)** | 150 | 0.27 |
| **Nitrogen Oxide Generation (lb/mmbtu)** | 135 | 0.042 |
| **Nitrogen Consumption (lbs)** | 5400 | 0 |

The ability to be within compliance on our emission limits makes it appealing to run through the night. The majority of our emissions to the atmosphere happen at start ups and shutdowns. Without these events our emissions are drastically reduced.

**Vision of Sustainability for International Power of America (IPA)**

IPA is currently taking steps to implement a Sustainability Plan. They are looking to decrease their impact on the environment and are becoming more aware of their use of water and other resources that do not come in an unlimited supply.

IPA's vision of sustainability is to create an operation concept that will provide flexibility, reliability, and allow the company to realize the benefits of reducing their impact on the environment. This vision provides a win-win situation not only for the company but also its employees and the local communities. In addition to the mechanical and economic benefits are many environmental benefits, ranging from a decrease in consumables to reduced noise in the surrounding communities. This broad range allows IPA to highlight the ‘triple bottom line – people, planet and profit and is an excellent way to start connecting every piece of the company to the sustainability vision.

One of the larger challenges to overcome when implementing a companywide initiative is resistance to change, and IPA is taking the challenge head on. Their key to success will be implementing the sustainability initiative at every level of the company starting from the top down. The top of the organization needs to lead by example and show their employees that they are dedicated to sustainability and have adopted it into the company’s culture. Leadership can do this by giving the Operators the support they need to continue to operate the plant. Permits and ISO certifications need to be kept up to date and emissions need to be kept within limits.

A training plan will be set into place for all employees. This new training program will introduce the sustainability initiatives and will help each person see how what they do every day can help the cause. Leadership should see and acknowledge the impact the changes will have on the Operators and the Operators should know what roles the Managers will play to support the new program. This will allow different groups to see how they support the same goal and the different challenges that each group and individual may face on a day to day basis to meet this goal. Every employee should understand the entire process and should know how their task is contributing. Training will also highlight the company’s commitment to the environment and will hopefully empower employees to go back in to their communities and continue to be environmentally conscious at home.

Looking towards the future, as these concepts trickle through employees they will hopefully extend into the community. Power generation companies can get a bad reputation for being bad neighbors. IPA Blackstone has the opportunity to set itself up as a community leader by sponsoring and supporting different events through its employees and local groups in the community. They can reach out to the schools by sponsoring events that educate the young population about the environment and sustainability. This will create a generation of potential future employees that are environmentally aware. Employees can be proud to work for such an environmentally conscious company and Blackstone can be proud to have IPA in their community. Also, IPA Blackstone has had a successful implementation of their sustainability plan they can become the model plant for other IPA plants. IPA is a very large company with multiple plants across multiple countries. In the interest of making sustainability a part of their company culture IPA Blackstone can set the example for other plants to follow.