Cogeneration is the ability to increase the efficiency of any power cycle by using the same fuel source to simultaneously produce electricity and heat. This boost in efficiency can prove itself to be a worthwhile investment opportunity, according to a system’s thermo-economic structure. Cogeneration is a process whereby waste heat energy is recycled to provide heat input to another portion of a power cycle. In a Brayton cycle, heat extracted from the turbine has the capacity to heat the working fluid in another portion of the cycle in an effort to increase thermal efficiency. Modern day power-plants operating on a Brayton cycle require that the turbine stage extract as much work as possible out of the thermal fluid at an elevated pressure, expanding the fluid to a lower pressure (Schmidt et. al, 2006). By optimizing the amount of heat extracted at different stages of the power cycle, the realization is made that power systems increase efficiency and minimize exergy destruction by applying a cogeneration system.

Overall system efficiency is affected by cogeneration in that the system recycles some of the thermal energy it produces from consuming fuel. By using the excess energy exhausted from the turbine in a Brayton Cycle to power another process in the cycle, the operating costs of power the system decrease and thermal pollution is reduced. Questions that arise when implementing a cogeneration system is whether or not to maximize the thermal efficiency of the system, which in turn decreases the profitability of the overall system; or to regulate the temperature of the waste steam to a range that is more profitable. Stable ranges exist between operating cost and thermal efficiency for a cycle, each system is tailored to suit the energy needs of the region it serves.

There are different scenarios that cogeneration is capable of providing an increase in efficiency. These processes include those with no cogeneration, thermal-match cogeneration, electrical-match cogeneration, or maximum cogeneration. “No cogeneration” exists when thermal energy is generated entirely for use by the cycle, meaning that all electrical power is purchased from a utility company and none is generated from heat. “Thermal-match” cogeneration produces thermal energy at temperatures and pressures much higher than that required for the power cycle processes. Electric power is generated by the steam at elevated conditions, afterward recovering the steam for use in generating power. The cogeneration system is sized so that thermal energy generated from the system is just enough to meet the demands of the cycle. In “electrical-match” cogeneration, thermal energy is again produced at elevated temperatures and pressures, similar to the thermally matched case. Electrical power is produced first by the steam, and the recovered steam is then used to power the cycle. The difference in this cogenerative effort is that now the cogeneration system is sized to meet electrical power demands of the cycle. Finally, “maximum cogeneration” exists when thermal energy is produced in excess of the cycle in order to maximize certain output parameters. Once electrical power demand is met from producing excess steam, the remainder of steam is dumped to the heat sink, usually the atmosphere. This cogeneration system is sized for maximum economic gain, such as maximum cash flow, or minimal fuel investment (Hu, 1985). These scenarios are put into practice by incorporating new technology to boost performance in an operational power cycle.

State of the art design and analysis of existing systems has led to development of more efficient technology. Cogenerative systems implemented into existing power-plants take into account various system characteristics. Some generalized parameters include fuel chargeable to electric power, overall system efficiency, electricity per steam flow, minimum process steam required, emission problems, capital costs, gross payback period, unit size and operational lifetime (Hu, 1985). These standards can be critiqued based on a cost/benefit analysis as well as technical inspection with emphasis placed on criteria pertinent to different levels of cogeneration.

There are many factors that contribute to defining the current state of the art cogeneration plant. These deciding elements include political stability, social growth, and economic development. Political stability of a country can affect the current technologies by implementing different regulatory policies. Interpretation of these policies can in turn determine how manufacturers and corporations carry out certain projects. Industries will be forced to follow rules pertaining to many areas, including those for manufacturing and building costs, energy regulations, and environmental laws. The increasing of advancement of society’s can also have a major influence on the designs and definitions of the current state of the art. As more knowledge about different trends in cogeneration is attained, many companies will begin to formulate new ways to implement projects that will utilize the advantages of these concepts, creating technologies that will influence and change the current state of the art. The economic conditions of a society also have a significant influence in what the state of the art of cogeneration plants are decided to be. The economic development at a certain time can determine the costs of certain materials by either increasing or decreasing their prices. This factor will influence the purchase of these materials that could be used to manufacture the different components of the plant (Limaye, 1987).

A state of the art cogeneration plant is one that employs the combined cycle. The simple arrangement of a combined cycle is comprised of gas turbines and steam turbines that recover heat to produce steam for a steam turbine generator. The typical cycle obtains output heat from an open gas circuit and inputs that energy into a heat recovery steam generator that will output the energy back into a combustor or boiler to be reused in the cycle. For the Westinghouse Model 251B Combustion Turbine System the heat recovery steam generator uses the output energy to help adjust the temperatures of the water supply across the university campus, showing the benefit of the utilization of the cogeneration process in the power cycle. The Westinghouse Model 251B Combustion Turbine System is a state of the art technology comprised of multiple components that are used to help generate heating and electrical power to the campus of the University of Texas at Austin. The system is made up of a starting package, an inlet air system, inlet fuel systems, air filters, a combustion turbine assembly, and multiple generators. The starting package uses a general motor to help start the process where the inlet air system and the air filters help to intake and purify air that will be used to drive the combustion turbine system. The fuel system inputs the desired fuel into the combustion turbine assembly, which is composed of a compressor, a combustor, and a turbine, to help generate power for desired processes as well as exhaust gases. The exhaust gases are then relayed either into the atmosphere or through heat exchanging generators. These generators include an open-air cooled generator or a water-cooled generator. These generators use the exhaust gases to heat up other exchanging fluids to help provide the plant more input reactants to increase power output. The thermal performance of this technology based on the use of natural gas fuels shows that approximately 48000kW of power can be generated with the heat exchanging components helping to utilize approximately 11,165kJ/kWh of lost energy, proving again the great impact of cogeneration (Westinghouse, et al).

In addition to heat exchanging generators, multiple pressure boilers, extraction steam turbines, and condensers can be used to better the performance of processes through cogeneration and the combined cycle. A combined cycle can obtain up to 80% utilization of fuel input and an efficiency that varies between 50 to 58% compared to the other cycles that have less than 50% efficiency. Other advantages of the combined cycle are low gas emissions, low capital costs, small space requirements, and easy implementation of machinery (Poullikkas, 2004).

The combined cycle can be applied to many applications, which include those for heating and electricity. In plants that employ the current state of the art to provide heating to inhabited areas, maximum steam outputs are necessary for the fuel inputs that are used. This consideration results in plants having additional boilers. Efficiency of the plant can be increased by inserting extra units. Usually the efficiency required for this heating application requires high energy efficiency and provides the highest economic value (Hu, 1985). For electricity production, condensers are inserted to provide flexibility in the electrical output. The configuration of these types of plants is similar to that of the heating applications but is smaller in size and limited by the consumer demand and rate costs. Thus, the combined cycle will be used to maximize the heat the fuel ration to meet the demands (Hu, 1985).

As of now, the implementation of this current state of the art has provided more benefits than other cycles that have been discovered. Although these benefits are useful for the current societal needs, there are still flaws in efficiency and output production. As knowledge of cogeneration grows and new technologies are created, the current state of the art will be replaced to help overcome these problems.

By implementing cogeneration, fuel is conserved by being recycled back through the system instead of released to the atmosphere. The recycling process also saves energy in areas other than the power cycle system. Cogeneration also outputs a much more dependable amount of energy to the public. Cogeneration has proven to be much more efficient than the conventional fossil steam plant. Approximately 75% of the heat is utilized for power and heat for a cogeneration cycle with only about 25% exhaust steam. But in a fossil steam plant, only 35% of the energy from fuel is obtained as power; the exhaust gases from the condenser and boiler that end up being waste are 48% and 15%, respectively (Boyce, 2002). Not only do cogeneration cycles output more dependable power, but is also a viable means of energy if any kind of emergency such as natural disasters affected a power plant.

By using cogeneration, not only is energy recycled but sources that are under constant worry of depletion, such as fossil fuels and petroleum, are also conserved. Not only are these valuable resources preserved, but the energy required to transport and produce these resources are also conserved. Since waste energy is recycled in a cogeneration power cycle, the vapor waste that was expelled from the system can no longer harm the environment. Many power plants are under constant scrutiny from environmentalist groups about how waste adversely affects animal habitats and causes irreparable damage. Cogeneration power plant cycles help to eliminate unnecessary waste by utilizing it to actually improve system performance, which coincidentally helps the environment.

Cogeneration has proven to save energy that was once thought to be waste. There is a caveat in cogeneration: whether or not to maximize power of the system or to make the system economically friendly. Not only does cogeneration benefit an energy system, but some disadvantages exist as well. Various areas cogenerations affects are overall system efficiency, fuel types, dependability, and environmental modifications.

The final phase of the project extends from the analysis of the Westinghouse Model 251B Combustion Turbine System, which includes incoming air with various moisture levels entering the system through an evaporative cooler. Adding this to our system will simulate realistic humidity of the air, while including a pressure drop across the guide vanes leading to the evaporative cooler will provide a more realistic system that includes losses due to pressure. Also included is combustion modeling and analysis of the fuel entering the combustor. The analysis should produce reasonably accurate values that are comparable to the accuracy of the manufacturer’s specifications. After checking the accuracy of the simulation, a number of case studies will be run to investigate how the performance of the system varies according to changes in weather, pressure losses and effects of the evaporative cooler. Finally, an exergy analysis will be conducted to identify system inefficiencies that aren’t realized with the First and Second Laws of Thermodynamics. Finally, comments will be made to improve the efficiency of the W251B.