Which is stronger? Executive Summary A or B?

Executive Summary A

Nuclear fission power plants have been providing affordable electricity across the world for over 50 years. Nuclear fission is attractive because the extreme power density of nuclear fuel allows for enormous amounts of power to be produced over long periods of time with no refueling. However, a disadvantage is that the high initial capital costs is a large hurdle to overcome in building a plant. A large amount of electricity must be produced and operating costs must be low in order for the fission power plant to be economically feasible. Therefore it is desirable to extract the maximum amount of power out of each plant to maximize efficiency and return on investment.

To do this, it is proposed that superheating the steam prior to entry into the high pressure turbine of a pressurized water reactor (PWR) will increase overall efficiency. A natural gas combustor is used to provide the enthalpy required to superheat the steam. A cost analysis of the superheated PWR plant is compared to a PWR plant that is not superheated. Both plants have an electrical power out rating of 1000 MW which is the same as the new Westinghouse AP1000 PWR plants.

Cost estimates are prepared for the initial capital costs and recurring operating expenses. The proposed power plants are compared to each other using the internal return on investment (IRR) and the net present value (NPV). The final IRR is then compared to a riskless investment to determine which design is better to pursue or if the money should be invested in a riskless investment.

Adding a superheater to a nuclear power plant cycle after the heat recovery steam generator will not actually increase plant exergy efficiency as thermodynamic theory would indicate because much of the input exergy from the natural gas becomes wasted to the environment. Although the addition of a recouperator improves efficiency, the base case is still more efficient.

The IRR for the proposed plant is lower than the baseline. A lower IRR is less desirable than one with a higher IRR for investors. Therefore if there are other just as risky power plants projects with a higher IRR, our project would be the least favorable as the baseline configuration and less as the proposed configuration. However, in the long run this project might be more promising than a shorter, just as risky project. A longer, larger project could bring higher cash flows in the long run but this is a risk the investor will have to be willing to take.

The net present value of the proposed design decreases with the increase of natural gas costs. To be profitable the price of electricity for the proposed power plant should be more than $87.21/MWh. However, if projections are true, then by 2019 the electricity price will increase to $96.1/MWh. By this point our plant will be profitable.

This project shows that adding a superheater to a PWR is not as promising as expected, but this may be due to some of our simplifying assumptions. Considering this entire design study was conducted by a team of 4 students over several weeks, when in reality the optimization of these plants requires months of many employees working fulltime, these results are promising. In the future to improve the superheated plant efficiency, some of the simplifying assumptions need to be reconsidered

Executive Summary B

According to the International Atomic Energy Agency (IAEA), 63% of commercial operating nuclear fission power plants in 2013 used pressurized water reactors (PWR) to produce electricity. However, these systems suffer from low thermal efficiency because the steam produced in the boiler is produced at low temperature in order to prevent the temperature within the core from reaching the temperature at which boiling would occur. This makes the plant safer than a Boiling Water Reactor (BWR); however, this comes at the expense of decreased power production per unit of used fuel. One possible solution to improving overall efficiency is for nuclear power plants to adopt superheating practices recently implemented in fossil fuel power plants. Superheating is achieved through combusting a fuel to heat the saturated steam prior to it entering the turbine. This report compares a traditional PWR system to one that combusts natural gas to superheat the turbine inlet steam. In addition, this report investigates the effects of adding a second LP turbine to the system, which should minimize exergy destruction.

We used the Westinghouse AP1000 plant as our baseline design since it is the simplest and least expensive PWR design on the market. Our cost estimates for this plant come from the U.S. Energy Information Administration. We determined cost estimates for our superheater system by investigating the costs of natural gas, a superheater, compressor, and the cost of sequestering CO_2 emissions. To determine the fuel saved by the addition a second LP turbine, we used Department of Energy data on fuel savings gained by using preheated combustion air.

After conducting thermodynamic analyses to confirm that the systems can function properly and can physically be produced, we determined the efficiency of the three different configurations by examining their normalized exergy destruction. Surprisingly, our results contradict theory indicating that a superheated cycle should be more efficient: we found that the superheated plant is actually *less* efficient than the base plant with an efficiency of 26.18% for the base plant but only 19.75% for the superheated plant. While adding the second turbine mitigated these effects, the superheated plant was still less efficient than the baseline.

Our economic analyses found that the internal rate of return (IRR) for the base PWR power plant was 4.34% compared to 3.26% for the proposed plant, suggesting that the baseline plant is a more attractive investment opportunity. Moreover the net present values (NPV) of both the base system and the redesigned system are negative. To be profitable, the electricity revenue for the base system would need to be $80.0/MWh and the electricity revenue for the proposed system would need to be $87.21/MWh.

In conclusion, our results show that adding a superheated cycle makes the PWR plant less efficient than the baseline plant and consequently it is a less profitable investment at the moment. However, this was an initial-scoping investigation completed using limited resources. Our results depended on several simplifying assumptions about acceptable system inlet/outlet temperatures and did not fully consider how our initial parameters could be optimized. As such, a more thorough analysis would need to be conducted to obtain a more accurate analysis of the potential benefits of a superheated cycle.