Introduction

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Turbines are among the most indispensable engineering components ~~at present~~. The first patent for a gas turbine was received by John Barber, which dates back to the year 1791 ("Early gas turbine history," 2020). Although this patent took place during the late 70~~'~~s, the first attempt to launch a gas turbine was by Franz Stolze in 1904, which was unsuccessful ~~nonetheless~~. It was only ~~until~~ in 1939 ~~when~~that the Brown Boveri Company developed the world's first gas turbine for power generation in Switzerland ("Early Gas Turbine History," 2020). Steam turbines however have been around prior to the existence of gas turbines, and the first steam turbine was built by Charles Parsons in 1884 ("Steam Turbines," 2020), 55 years before the gas turbine.

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A number of different types of turbines have been developed, but the two most heavily used turbines are gas turbines and steam turbines. The main difference between ~~both~~ these ~~types of~~ turbines is the type of flowing fluid each one uses. Many working fluids could be used in turbines, but the two most popular fluids are fossil fuels and steam. Gas turbines are known to use fuel while steam turbines use pressurized heated water vapor. In this paper, I argue that gas turbines are more efficient than steam turbines.

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I support my position on gas turbines being more efficient than steam turbines with the following arguments. First, I argue that the power to weight ratio in gas turbines is much higher compared to that of steam turbines. Power to weight ratio is important in the case of mobility. Engines and mobile power sources require minimal weight in order to attain maximum speed and propulsion and so maximum efficiency. Second, I argue that the cost of installation is less for gas turbines than it is for steam turbines. As a result, the overall cost required for a system to run on gas turbines would be less compared to that of a system that runs on steam turbines. Third, I ~~briefly introduce~~explain how steam turbines have longer startup periods than gas turbines. These longer startup periods usually cause complications in

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I also consider alternative positions towards steam turbines being more efficient than gas turbines. These positions include how steam turbines have a longer life span compared to that of gas turbines, and how gas turbines are more prone to deterioration than steam turbines. These deteriorations cause the maintenance of gas turbines to be critical. As mentioned by Araner (2020), the high temperatures in a turbine demands extremely high maintenance and repair methods, and therefore reduc~~eing~~ ~~its~~ the average lifespan. I also consider how steam turbines can be made more ecofriendly. Millien (2020) has introduced a working prototype of solar energy powered steam turbines. Nuclear energy is in fact considered as a renewable energy source and can be used to power steam turbines as well. Such systems are known as nuclear power plants, where nuclear fission is used to generate power (Afework et al., 2020). I refute the initial claim by stating how the majority of modern day steam turbines indirectly run on fossil fuels.

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This paper is important to engineering students with an interest in the topic of turbines. My position is that, it is necessary for those who want to pursue a career in engineering to be able to differentiate systems that suit the same function at an early stage. Specifically, those who wish to study mechanical engineering, since their path mainly includes the study of complex systems such as engines, turbines, compressors and many more. It is important for them to be able to know the differences between gas turbines and steam turbines, as turbines are used in almost any application.

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I also suggest the use of combined cycles in power plants. Combined cycles are cycles that include both gas turbines and steam turbines. A combined-cycle power plant usually uses a gas turbine to drive an electrical generator, which then recovers waste heat from the turbine exhaust in order to generate steam. The steam from waste heat is then guided to a steam turbine to provide electricity (IPECA, 2013). IPECA (2013) also states that the overall efficiency of a combined cycle is around 60 ~~percent~~%, which is much higher compared to the efficiency of a simple turbine power plant of around 28.6% (Rovense et al., 2017).

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Gas Turbines ~~are~~ Are More Efficient ~~than~~ Than Steam Turbines

How Turbines Function

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It is important to note the energy generation mechanism by which power plants follow. Power plants are composed of three to four main components, and these include the compressor, the boiler, the turbine, and the condenser. The system runs as follows. The compressor or pump increases the pressure of the fluid exponentially, this high-pressurized fluid is then directed into a turbine. Turbines are assigned the function of converting fluid flow into shaft work, which is a form of mechanical energy. The blades of the turbine are designed and manufactured at a specific angle in order to obtain maximum torque. This torque allows it to rotate at a high speed once the highly pressurized gas strikes the turbine blades. At the other end of the turbine, there exists a rod, also known as a shaft, which rotates with the turbine. The shaft in question can then be attached to various different mechanical components to suit various different applications.

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Turbines have proven their importance in the energy extraction industry. They are heavily used for electricity generation in power plants, and almost all electricity is generated by turbines (Afework et al., 2020). Power plants are facilities that produce electricity from fundamental energy and available fuel reservoirs (Afework et al., 2020). Other major applications of turbines include heat engines, hydropower, wind power, and propulsion in jet engines.

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Power to Weight Ratio

Gas turbines have a higher power to weight ratio compared to steam turbines. Power to weight ratio is simply the power generated by a system divided by its overall mass

("Power-to-weight ratio," 2020). One way to determine the efficiency of a system is to judge assess it by its power to weight ratio. The higher the ratio, the more efficient the system is (Cengel and Boles, 2011). That This is because the less mass required the less material that is needed for manufacturing. Therefore, the pound volume costs are substantially reduced. Not to mention, reducing the mass minimizes the transportation costs. The main issue with transportation is that usually turbines are imported and are not locally manufactured, and so the expenses are is quite higher compared to those of local transport.

Another major advantage of weight reduction is that lighter systems are able to displace more freely and therefore the forward propulsion rates are much higher. For example, in the case of jet engines, forward propulsion is the most important criterion that should be focused on during design. For this reason, aircraft manufacturing companies pay particular attention to weight reduction. A similar parameter to the power to weight ratio, is the thrust to weight ratio of aircrafts and airplanes. This ratio is directly proportional to the aircraft's acceleration (Hall, 2015), which means acceleration multiplies as the weight is reduced. An aircraft that obtains a high thrust to weight ratio acquires a high value of excess thrust. As a result of excess thrust and acceleration, the vehicle's efficiency amplifies as it propels forward with high velocities. For this reason, gas turbines are the preferred candidate because they have a higher power to weight ratio compared to steam turbines.

Cost of Installation

Cost analysis studies carried out during the period of 2008-2009 have shown that the average funds required to run simple gas turbine cycles are less than half the expenses required to run coal-fired steam turbine cycles (Pauschert, 2009). According to the referenced report, in 2008, the total running costs of a simple gas turbine cycle plant estimated to $860 dollars per kilowatt of energy produced by the plant. While that of a coal-fired steam plant varied between 1960 dollars to 2730 dollars per kilowatt of energy generated. The variation

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depended on the overall power produced by the plant, measured in Megawatts. These estimations took account of the funds for earthwork, concrete, structural steels used as well as plant equipment. Plant equipment includes each of turbines, compressors, pumps, boilers and condensers. The analysis also incorporated piping and electrical expense, along with painting, insulation, building and architectural costs (Pauschert, 2009).

Gas turbines were seen to be more cost effective for the same range of power produced by both gas turbine and steam turbine power plants. The statistics are all relative to calculations that were carried out in the United States, which were considered as benchmark numerals throughout the report. Another study has showed that the capital cost of a gas turbine cycle plant is around 825 dollars per kilowatt while that of a steam turbine cycle plant is between 1041-1100 dollars per kilowatt of energy (Rovense et al., 2017). Additionally, oddly enough, even transportation costs vary between gas and steam turbine cycle plants. This additional cost stems from the fact that steam turbines are considered relatively heavier and larger in size compared to gas turbines. Turbine weight usually depends on the model used as well as the amount of power produced by the turbine. For example, the weight of a reheat marine propulsion steam turbine ranges from 330 to 370 tons for output power ranges of 20,600 and 33,100 kW ("Marine Steam Turbine," 2018). Therefore, the added weight requires more fuel for transportation, and thus transportation costs are increased for steam turbines.

Various benefits arise with the reduced costs associated with gas turbines. First, reduced power plant expenses translate into reduced electricity prices. This reduction allows the average individual to benefit economically. Second, the pollution levels emitted from non-renewable energy sources are also being reduced as a result of the lower demand for electricity ("Reducing Electricity Use and Costs," 2020). Indeed, most households already attempt to reduce their average electricity consumption for the same two reasons mentioned previously. Lastly, reduced costs for gas turbine power plants allow easier implementation in

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Commented [cp23]: cute language but not for a formal paper developing countries, provided it is considered as an economic advantage to them. Subsequently, maintaining the required expenses to install and run power plants at a minimum saves the country a substantial amount of money. This difference in funds can therefore be implemented into projects that are necessary for the country's development.

Complications of Turbines

Engineers measure the overall efficiency of any plant using what is known as Temperature vs entropy (T-s) diagrams. These diagrams are also extremely important for the energy analysis of any system. In order to understand the complications associated with increasing the efficiency of steam turbines, one must be familiar with these diagrams. By definition, the area enclosed by the cycle of a power plant on a T-s diagram provides the calculation of the shaft work produced by the turbine, and thus could be used to spin a generator and obtain electricity.

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Ideally, multiple efforts are being made to increase the enclosed area on T-s diagrams in order to obtain more useful energy output. This enclosed area could be increased by either increasing the average inlet temperature that transfers heat to steam in the boiler, superheating the steam to high temperatures or decrease the average temperature at which heat is rejected from steam in the condenser (Cengel and Boles, 2011). By increasing the area under the graph, the efficiency of the plant ~~also~~ has a corresponding increase~~s respectively~~.

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Steam turbines function poorly at temperatures that are higher than the optimum temperature of the power plant. That is, the plant has an upper cap on the maximum allowable temperature. Increasing the maximum temperature at the inlet of the turbine indeed causes it to produce more shaft power; however, more steam will condense towards the outlet of the turbine. This condensation happens at the expense of decreasing the vapor quality. Vapor quality is defined as the mass fraction of vapor in a saturated mixture ("Vapor Quality," 2020). This fall in quality causes the moisture content of the working fluid to

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increase, which is considered a problem. Steam turbines are not designed to work with water as a working fluid as it causes them to deteriorate. Erosion at the blade tips is known to be the major mechanical problem associated with an increased moisture content in steam turbines (Hesketh, J. A., & Walker, P. J., 2005). In the case of gas turbines, erosion is not considered an issue since they do not work with steam as a working fluid. Additionally, the material from which turbines are manufactured also restricts the temperature up to a temperature that these materials can withstand. Exceeding this temperature would result in the loss of function of the turbine blades. Consequently, there will exist a limitation on the maximum temperature of the plant, which causes a substantial reduction in the overall plant efficiency.

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It is important to note that the materials from which turbines are engineered differ for each of gas turbines and steam turbines. Designers are provided with an estimate of the maximum recorded temperature in the turbine such that they will be able to specify the most suitable material with an appropriate melting point. The same procedure is followed for each of steam turbines as well as gas turbines, but the only noticeable difference is the estimated maximum temperature, which is relatively less for steam turbines compared to that of gas turbines. Subsequently, these exaggerated temperatures give rise to complications in gas turbines, as they demand much more maintenance than steam turbines.

Steam turbines are known to have a longer lifespan than gas turbines. This shorter lifespan is a result of gas turbines working at extremely high internal temperatures. These high internal temperatures have a negative effect on the durability of the turbine blades, where the majority of gas turbine failures take place at the components that are in direct contact with combustion chambers (Pelaseyed, S. S., Attarian, M., Kermajani, M., & Abdi, A., 2019). The temperature of the superheated gas in combustion chambers reaches up to 1300 degrees Celsius (Pelaseyed et al., 2019). The components of the combustion chamber are designed and expected to withstand several conditions such as airflow, fuel flow, discharge temperature, rapid acceleration and deceleration, and variation in fuel properties. In

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addition, other factors encourage a loss of function in the form of erosion, corrosion, fracture, hot oxidation. These factors are high temperature, fuel and air contaminations, and thermal stresses induced by user usage. (Pelaseyed et al., 2019).

Jet Engines

Jet engines are an example of a direct application of gas turbines. In addition to all the complications associated with gas turbines, jet engines struggle with even more fatal issues. For example, they are susceptible to encountering bird strikes on flight. The collisions are usually deadly to the birds. Additionally, these accidents require average repair costs of around 1.2 billion dollars annually (Moskvitch, 2020). Jet engines also require frequent test runs, including “hot and cold” tests that ensure the materials are working properly under extremely hot and/or cold conditions at high altitudes. Other tests include “lightning” tests, which ensure that lightning strikes can be dealt with and are not fatal for the passengers. Although these issues demand extremely high levels of maintenance, steam turbines cannot compensate for gas turbines and therefore gas turbines are the ideal candidate for jet engines.

In addition to the damages caused by high internal gas temperatures, high internal gas pressures also pose threats on material life overtime. User misuse should also be considered among the factors concerning the failure of each of gas turbines and steam turbines. By taking all of the above into consideration, it becomes quite evident that gas turbines are more prone to deteriorations than steam turbines. Not to mention that they also require more frequent maintenance. However, it is important to mention, as previously discussed, that steam turbines also face similar hindrances. Whereas statistically speaking, gas turbines still managed to grasp higher numbers of efficiency even with all the difficulties associated with them. Rovense et al. (2017) have shown that a simple gas turbine power plant managed to obtain a thermal efficiency of 33.1% with a net power output value of 441.4 Megawatts. Whereas a simple steam turbine power plant with ambient air cooled steam with thermal

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efficiency of 28.6% and a net power output of 200.2 Megawatts. Similarly, a simple steam turbine power plant with a water-cooled steam condenser and a wet cooling tower also had a thermal efficiency of 28.6% and a net power output of 200.2 Megawatts. Comparing these values to those obtained for a simple gas turbine power plant shows that gas turbine plants are 4.5% more efficient than either steam turbine power plants.

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The Demand for Renewable Energy

Switching to renewable energy is more necessary than it is desired. In addition to the dreadful environmental effects they bring, fossil fuel reservoirs may run out in the near future. Fossil fuels are favored as a main energy source because they have relatively higher energy densities compared to those of alternative energy resources. Energy density is the energy per unit volume that is stored in a substance (Cengel and Boles, 2011), and so the higher the energy density the more energy that is obtained per unit volume. Nowadays, most steam turbines and gas turbines obtain their energy from fossil fuels. The dependence on these fuels is a growing issue as the fuel supplies are constantly being exhausted. in turn This exhaustion ~~in turn~~ enforces a need to begin diverting to more environmentally friendly solutions.

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Climate change is a global crisis that the world is currently facing. So far, it has resulted in imperiled ecosystems, warmer and more acidic oceans, rising sea levels, dirty air, health risks, and extreme weather such as hurricanes and floods (Denchak, 2017). Global warming is a major contributor to climate change and is known to be the biggest environmental threat yet to be faced. This threat is a direct consequence of the increased levels of greenhouse gasses in the atmosphere, specifically the carbon oxide gasses. That is, moderating the average percentage of carbon dioxide emissions is crucial to the environment. Burning fossil fuels such as coal and oil acts as the primary source of such emissions (Denchak, 2017). Jackson et al. (2018) have detected that the burning of fossil fuels, in addition to cement manufacturing, releases about 90% of all carbon (IV) oxide emissions

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from human activities. There has been an ongoing quest on using renewable energy as an energy source to run modern-day systems. At last, de-carbonization by using solar energy was suggested as the only effective way to manage environmental and economic challenges that are caused by climate change (Millien, 2020).

Ideal Renewable Energy Alternative

Without a doubt, the initial cost of installation of solar power is relatively high~~er~~ compared to other energy extraction mechanisms. However, Kalogirou (2019) stated that among alternative energy sources, solar energy investment should indeed be prioritized. In addition, the International Renewable Energy Association (IRENA) has estimated that the cost of electricity from renewable energy sources such as solar and wind power technologies could be reduced by at least 26% and as much as 59% between the years 2015 and 2025. Similar studies by IRENA have also shown that the global funds for renewables totaled to USD 241.6 billion in 2016. Additionally, 2017 was noted as the fifth year in a row for new investments in renewables to be almost double that of fossils in terms of power generation capacity ("The Power to Change: Solar and Wind Cost Reduction," 2016).

Some argue that steam turbines could be made more ecofriendly. Clearly, plenty of funds have been assigned solely for research on how to integrate renewable energy sources into modern day systems. A specific study by Kawira Millien took place in 2020, where she integrated her knowledge in the field of renewable energy to propose a steam turbine prototype that runs mainly on solar power. The turbine operation conditions have shown that it is possible to utilize the steam turbine in Millien's study to produce small scale industrial power and process heat. The study has shown that the average cycle power output calculated was 450.8 watts, with a maximum power output of 498.2 watts. Moreover, the highest turbine efficiency came to be 61.6% (Millien, 2020). The average steam turbine efficiency is usually between 65% for small turbines and 90% for bigger commercial ones (A. Schetz & A. E. Fuhs, 1996). The efficiency obtained is quite close to the normal range of efficiencies and is

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not considered as a total outlier, which proves that solar power can most definitely be integrated for turbine processing. However, this solar powered steam turbine is just a prototype and most functioning steam turbines are still operating on fossil fuels.

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Gas turbines in fact can also use solar power as a main energy source. Integrating solar power in steam turbines may seem easier since they use water as a working fluid and therefore heating the water using solar panels is considered feasible. However, most gas turbines use air as a working fluid, which eliminates the need of natural gas and non-renewable fuels. Rovense et al. (2017) discuss the possibility of utilizing solar powered gas turbines with air as a working fluid and only using fossil fuels when the solar power source is lacking. In addition, to accommodate for efficiency losses, fuel integration is imperative. To this day, the only functioning gas turbine solar hybrid system in the market is produced by Aora-Solar and it produces a unit 100 kilowatt (kW) for off grid and cogeneration applications. The article shows that the energy production is 1.29 MWh and the average electric efficiency is 29% (Rovense et al., 2017). This energy extraction system has been compared to the Aora Solar Tulip of which the estimated power production was 788,400 kilowatt hour (kWh) with the use of fuel. Therefore, we have estimated that the closed loop micro gas turbine allows producing about 38% of energy more than the commercial system Aora Solar Tulip, avoiding fuel usage as well. The efficiency of the gas micro turbine then totals to 67%, providing a difference of 5.4% compared to that obtained by the solar powered steam turbine prototype. Consequently, the study proves the achievability of gas turbines operating on solar power and how they are still able to obtain higher efficiencies than steam turbines.

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Conclusion

Throughout the paper, efforts were made to show that gas turbines are more efficient than steam turbines. Support arguments included how the power to weight ratio is higher in gas turbines compared to steam turbines, how the cost of installation is less for gas turbines

Commented [cp40]: Avoid technical writing terms in your paper than for steam turbines and how steam turbines have proved to work poorly at higher temperatures. Some counter arguments were worth mentioning, and these include how steam turbines have a longer life span than gas turbines, how gas turbines are more prone to deterioration than steam turbines and how steam turbines can be made more eco-friendly. The latter counter argument was refuted by providing evidence that gas turbines can also be made more environmentally friendly, with an ever higher efficiency than that for a "green" steam turbine. With respect to the arguments presented, a conclusion on how gas turbines are more efficient than steam turbines was reached.

An even more efficient power plant includes both gas turbines as well as steam turbines, and are known as combined power cycles. This combination increases the efficiency of the power cycle exponentially. A combined cycle power plant with ambient air cooled steam condenser obtained a thermal efficiency of 48.3% and an average power output of 64.5 Megawatts (Rovense et al., 2017). A difference in efficiency of 15.2% exists between a combined cycle and a gas power cycle, while a difference of 19.7% lies between a combined cycle and a steam power cycle. Therefore, these cycles are taking over the industry as a result of their extremely high efficiency, compared to that of individual simple gas or simple steam power cycles.

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No-one has done this before – and that alone gets you points! ☺

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This is a very good working draft – and you've clearly worked extremely hard – I like it!

(but – much to be done for the final draft!) ☺

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