Saturn Publications

Frontiers in Engineering Science and Technology 1(2022) 2229-2234

www.saturnpublications/fest

Is Thermal Power Plant a Better Alternative to Coal Fired Power Plant? A Comparative Analysis

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Received 10 June 2022; Accepted 16 September 2022

Abstract

Thermal power plants are used worldwide to generate electricity by using heat energy. The thermal power plants in Pakistan are outdated and inefficient and use expensive fuel to generate electricity which has a huge environmental impact. Thermal power plants not only lead to air pollution but also have serious impacts on land and soil. The existing thermal power plant's efficiency can be improved by using imported coal which will reduce emissions and reach the increasing demand for electricity in the country. The government of Pakistan is currently interested in installing a coal-fired power plant. A coal-fired plant is a power plant in which electricity is generated by burning coal as steam is produced. The need to install a coal-fired power plant in Pakistan arises due to the lack of technology to process the coal that the country receives from the coal reserves in Thar. The amount of coal in Thar is huge, but its quality is considered low, and it needs significant investment in infrastructure for extraction and processing. The coal-fired power plant provides affordable and reliable constant power that can meet the country's demand for energy consumption. But it also has a negative impact on our environment. However, both plants have a considerable impact on the environment. Thermal power plants usually emit large amounts of mercury and fly ash which, one way or another, destroys our environment. These power plants discharge large volumes of wastewater, containing vast quantities of pollutants, into the waters, and these discharge pollutants cause severe health and environmental problems. As coal is burned in the coal-fired plant, a number of pollutants are released. Air pollution from coal-fired power plants can cause asthma, cancer, neurological problems, and global warming. A major man-made contributor to climate and global warming is the release of greenhouse gases into the atmosphere from power plants. However, measures have been put in place to reduce the environmental impact, such as regular ecological monitoring should be done to ensure compliance with the relevant regulations and standards. Overall, the government of Pakistan and the public need to work together and present effective ideas to develop and implement the required solutions that will increase economic growth and should take steps to minimize the environmental impacts caused by the power plants. And efforts should be made to improve the efficiency of both plants cost-effectively.

Keywords: Thermodynamics; Thermal Power Plants; Coal-Fired Plants.

1. Introduction

Thermal power plants can be described as power stations in which heat energy is converted into electrical energy. The thermal power plant uses various fuel sources like natural gas, coal, oil, and nuclear power to generate electricity. In a Thermal power plant, heat is produced by burning different fuel sources (natural gas, coal), which generate electricity. Steam is produced by the heat (produced by the burning of fuels), which then drives a turbine to generate electricity. The produced steam is then condensed and recycled back into the system. Thermal power plants were initially established as a backup to hydropower. Transmission losses have become an important issue over long distances. Thus, thermal power was intended to facilitate the areas difficult to be served by hydropower. The rational thermal power base has been developed and is controlled by three major players, i.e., WAPDA, Independent Power Producers (IPPs), and Karachi Electric (KE).

The first coal-fired plant in the 19th century used reciprocating engines to generate direct currents. These plants generate electricity by burning coal in a boiler to produce steam, which then flows into a turbine to spin a generator. Coal-fired power stations are a major contributor to climate change, emitting 10 Gt of carbon dioxide and about one-fifth of the world's greenhouse gas. There are four main types of coal-fired power stations: subcritical, supercritical, ultra-supercritical, and cogeneration, which vary in efficiency.

The usage of different fuels leads to the difference between both the power plants. A thermal power plant uses a variety of fuels, such as natural gas, coal, and even biomass, to produce steam to generate electricity. Whereas

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coal-fired power plants rely solely on coal as a fuel to generate electricity.

The overall efficiency of the power sector of Pakistan is 0.907. The efficiency of the thermal power plant is defined as the ratio of heat equivalent of output electrical energy to the heat of coal combustion. The overall efficiency of a modern thermal power plant is about 29%. In contrast, coal-fired plants are less efficient than other thermal power plants as they have lower heat-to-electricity conversion rates. This plant also produces more greenhouse gas emissions and air pollutants. Coal-fired power plants hold the upper hand in producing electricity on demand, making them more reliable. They are considered more reliable and affordable than other thermal power plants, at least in countries like Pakistan with large coal reserves. Both plants have a negative impact on the environment and cause severe health problems. The government should make efforts to reduce these impacts.

In conclusion, both power plants are used worldwide to generate electricity. The thermal power plant is more efficient and environmentally friendly than coal-fired power plants as coal-fired plants produce more air pollutants. But coal-fired plants are more affordable and reliable.

2. Literature Review

Shutting Down of Thermal Power Stations

In recent years, several thermal power stations in Pakistan have been shut down, leaving the country with a severe electricity crisis. Pakistan is currently facing a severe foreign exchange crisis, which is leading to a shortage of foreign currency that is needed to import fuel and equipment for the operation and maintenance of its thermal power stations. This shortage of foreign exchange has also resulted in making it difficult to invest in the construction of new power plants with modern technology, which will be much more efficient and will also result in generating more electricity.

Block	Description	Reference Fuel Cost Component (Rs./kWh)	Revised Fuel Cost Component (Rs./kWh) w.e.f 15-10-2019
		Furnace Oil	Furnace Oil
I	Jamshoro Unit 1	19.5519	21.4749
II	Jamshoro Unit 2	21.9576	24.1173
II	Jamshoro Unit 3	21.3659	23.4674
II	Jamshoro Unit 4	20.916	22.9732

Fig. 1. Fuel cost revision for the FY 2019 of Jamshoro Power Plant.

Technical Reasons with Justifications for Shut Down:

i. Unavailability/High Prices of Fuel:

The main reason for the shutdown of thermal power stations in Pakistan is the result of the unavailability of furnace oil, which is the fuel required to generate electricity. With minimal refining capacity, Pakistan relies heavily on imported fuel to meet the demand. As the country is facing extreme foreign exchange crises, it becomes expensive to import fuel, leading to a fuel shortage.

Moreover, the domestic production of furnace oil has also declined over the years, leading to an increasing reliance on imported fuel. The lack of fuel has reduced electricity generation from thermal power plants, contributing to frequent power outages and load shedding.

According to the Pakistan Bureau of Statistics, the country's oil production declined from 24.8 million barrels in 2012-13 to 19.5 million in 2019-20. This decline in domestic production has resulted in an increasing reliance on imported fuel. In the fiscal year 2020-21, Pakistan imported 11.4 million metric tons of petroleum products worth $4.4 billion, up from 10.4 million metric tons worth $3.8 billion in the previous year.

Period	Description	Reference FCC Rs./kWh	Revised FCC Rs./kWh
August 2022	Block I Unit 1	19.5519	43.8050
	Block II Unit 2	21.9576	49.1948
	Block II Unit 3	21.3659	47.8691
	Block II Unit 4	20.9160	46.8612

Fig. 2. Fuel cost revision for the FY 2022 of Jamshoro Power Plant.

ii. Outdated Technology:

Another major justification for the shutdown of thermal power stations in Pakistan is the use of outdated technology. Many of the thermal power plants in Pakistan were constructed several decades ago and are still using technology that is no longer efficient or cost-effective. The outdated technology leads to higher electricity production costs and contributes to environmental pollution.

The use of outdated technology in thermal power plants also makes it difficult to maintain and repair the power plants, leading to frequent breakdowns and shutdowns. As a result, the electricity produced by these plants is often unreliable, leading to frequent power outages and load shedding. According to the Pakistan Energy Yearbook 2019-20, the thermal power generation in Pakistan was around 24,325 GWh, with a total installed capacity of 22,931 MW. Out of this, the share of oil-fired thermal power generation was about 16,317 GWh, with a total installed capacity of 8,257 MW. Many of these oil-fired thermal power plants in Pakistan use outdated technology, some of which are over 30 years old. For instance, the Jamshoro Thermal Power Station in Sindh province was commissioned in 1989 and still uses technology from that era.

Furthermore, the National Electric Power Regulatory Authority (NEPRA) has identified several issues with the operation and maintenance of thermal power plants in Pakistan due to outdated technology. In its annual report for the fiscal year 2019-20, NEPRA reported that the efficiency of thermal power plants run on fuel in

Pakistan was only around 36%, compared to the global average of 46%.

iii. Environmental Concerns:

Thermal power plants in Pakistan are a significant source of environmental pollution. They emit large amounts of greenhouse gases, such as carbon dioxide (CO2), which contribute to climate change. Additionally, they release other harmful pollutants such as sulfur dioxide (SO2), nitrogen oxides (NOx), and particulate matter (PM), which can cause respiratory problems, heart disease, and other health issues.

The environmental impact of thermal power plants is particularly acute in urban areas where they are located. The air pollution from these plants contributes to poor air quality and smog, which can have severe health consequences for people living in these areas. Furthermore, the discharge of untreated wastewater and cooling water from these power plants can also have significant environmental impacts, particularly on aquatic ecosystems.

The National Electric Power Regulatory Authority (NEPRA) of Pakistan regularly monitors the emissions from thermal power plants in the country. According to NEPRA's annual report for the fiscal year 2019-20, the Jamshoro Thermal Power Station emitted around 1.2 million tons of CO2 during that period. This is a significant amount of greenhouse gas emissions and highlights the environmental impact of thermal power plants in Pakistan.

		Furnace Oil	Natural Gas
(i).	SO_x (mg/Nm^3)	1550 to 1650	-
(ii).	NO_x (mg/Nm^3)	300 to 400	90 to 130
(iii).	CO_2 %	10.8 % to 14.0%	2.5 % to 2.7%

Fig. 3. Emission Values

NEPRA also reported that the air quality in the vicinity of thermal power plants was poor, with high concentrations of PM2.5 and PM10 (Particulate Matters). Additionally, the discharge of untreated wastewater and cooling water from these plants was also a concern, as it can impact the quality of water in nearby rivers and streams and is even more hazardous if the networks are near a residential area.

Environmental Impact of Steam and Coal Power Plants

Through its construction and operation, a power plant always affects our environment. As a power plant and its components take some space on the ground and in the air, it uses water resources and emits pollutants in many cases, which negatively impact our climate. Power plants emit air pollutants and water vapors, which affect the growth of certain crops. The plants are killed as some of the emitted pollutants are toxins or promote diseases.

Environmental Impact of Steam Power Plants

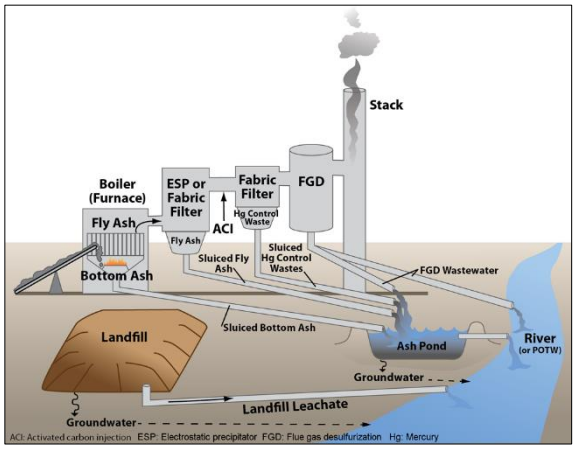

Fig. 4. Emission Values

According to the research, the impact of steam power plants on the environment is considered negative as we compare it to other energy sources. Steam power plants use three steam systems to generate electricity (nuclear power, coal power, and concentrated solar power), and each steam power system has a different impact on the environment. The steam system that has the mildest impact on the environment is the concentrated solar power system; it only affects our climate during its construction. Whereas nuclear power system has a negative impact on the environment due to the emission of carbon dioxide and other pollutants into the air.

There is a chance of catastrophic disaster while dealing with nuclear energy. Wastewater which contains large quantities of pollutants is discharged into the waters by steam power plants. The discharged pollutants sometimes include both toxic and bio accumulative pollutants, which include arsenic, lead, mercury, chromium, and selenium. Severe health and environmental problems are caused in the form of cancer and non-cancer risks in humans and lowered IQ among children. It not only affects humans but also causes deformities and reproductive harm in fish and wildlife. Many discharge pollutants remain in the environment for about three years, affecting our climate.

Environmental Impacts of Coal Power Plants

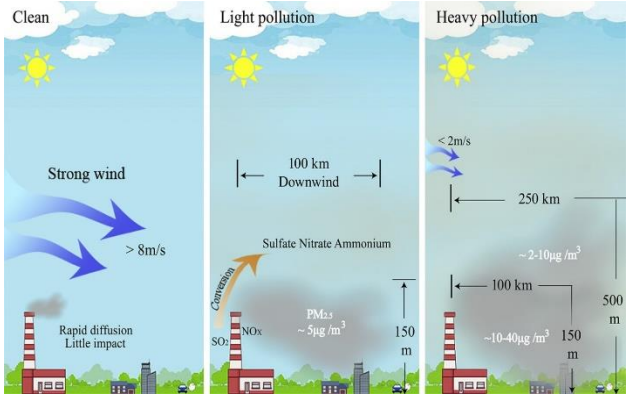

Fig. 5. Emission Values

When fossil fuels lie underground for thousands of years and heat and pressure are acted upon them, coal is formed, a carbon black rock that releases energy when burned. In Pakistan, coal is used by the power sector, and about 44.5% of the share has increased. About 61% of electricity comes from coal in Pakistan. In coal-fired power plants, steam is produced by burning fossil fuels to generate electricity and is considered to have the worst impact on the environment. Caron dioxide and other pollutants are released into the atmosphere as the burning of fossil fuels produces steam to generate electricity.

About 100 million tons of coal ash is produced by coal-fired power plants every year, and more than half of that waste ends up in rivers, lakes, ponds, and other sites, which with passing time, contaminate waterways and drinking water supplies. Pollutants from coal-fired plants lead to air pollution, which is linked to asthma, heart and lung ailments, cancer, acid rain, and other severe health impacts. Coal mostly consists of carbon, which produces carbon dioxide, a heat-trapping gas when burned in the air with oxygen. The most serious impact of the burning of coal on our environment leads to global warming.

Environmental Monitoring Report on Steam & Coal Power Plants

Air Quality:

The thermal and coal power stations emit pollutants such as particulate matter, sulfur dioxide (SO2), nitrogen oxides (NOx), and carbon monoxide (CO) into the atmosphere. The station uses flue gas desulfurization (FGD) technology to reduce SO2 emissions and low NOx burners to minimize NOx emissions. However, the emissions of particulate matter and CO can still have a significant impact on air quality. The concentration of particulate matter (PM10 and PM2.5) in the air surrounding the power station is higher than the national and international air quality standards.

Water Quality:

The Thermal & Coal Power Stations use water from the river for cooling and other processes. After treatment, the water is discharged back into the river to remove any pollutants. The water discharged from the power stations has to meet the national and international standards for pH, dissolved oxygen (DO), and the presence of heavy metals.

Soil Quality:

The emissions from the power station could impact soil quality, especially if the ash generated during coal combustion is not properly managed. The power station has measures in place to manage and dispose of the ash generated during combustion. The ash is transported to a nearby disposal site and is covered with soil to prevent it from being carried away by the wind. The ash disposal site does not have any impact on the surrounding soil quality.

Efficiency Of Thermal Power Plant Vs. Coal Power Plant

Thermal power plant	Coal Power Plant
• The overall efficiency of a thermal power plant is typically high, around 35% to 49%. • The efficiency of a thermal power plant depends on various factors, including the type of fuel used, the age of the plant, and the technology used. • Thermal power plants can use a variety of fuels, including coal, natural gas, and oil. • The efficiency of a thermal power plant can be improved by using more advanced technologies, such as combined-cycle power plants. • Thermal power plants require a steady supply of fuel to maintain their efficiency.	• The overall efficiency of a coal-fired power plant is typically lower than that of a thermal power plant, usually around 33%. • The efficiency of a coal-fired power plant is affected by various factors, including the quality of coal used, the age of the plant, and the technology used. • Coal-fired power plants require a steady supply of coal to maintain their efficiency. • The efficiency of a coal-fired power plant can be improved by using advanced technologies such as ultra-supercritical technology. • Coal-fired power plants emit a large number of greenhouse gases and pollutants, which can negatively impact the environment and human health.

Table 1. Emission Values

Why Is Thermal Power Plant Better Than Coal-Fired Power Plant?

There are various reasons why thermal power plants are considered better than coal power plants. Some of the reasons are as follows:

- A thermal power plant can use various fuels such as natural gas, oil, biomass, and even municipal waste, whereas a coal-fired power plant is restricted to only one fuel source: coal.
- Depending on the type of fuel, a thermal power plant's emission of pollutants and greenhouse gases are low when compared with coal power plants, which can emit lower levels of pollutants and greenhouse gases compared to a coal-fired power plant.
- The most crucial reason a thermal power plant is better is due to efficiency. Thermal power plants have higher efficiencies than coal-fired power plants, which means less fuel usage for the same amount of generation.
- Coal-fired power plants use large amounts of water to generate steam for their turbines, whereas thermal power plants can use condensers that require significantly less water.

Energy Outlook in Pakistan in 2025 And Beyond

Pakistan is currently facing major financial crises due to a combination of factors, including a high trade deficit, low foreign exchange reserves, and rising public debt. In its energy sector, the country faces high circular debt and a shortage of electricity supply. Circular debt, which refers to the accumulation of unpaid bills and inter-corporate borrowing, has been a longstanding issue in the energy sector, with the government struggling to clear the debts owed to power producers and distributors. This has led to a shortage of electricity supply, which has significantly impacted the economy and the daily lives of citizens.

Energy Supply and Demand Situation in Pakistan:

Pakistan's energy sector has been facing significant challenges in recent years, including a widening gap between demand and supply, outdated infrastructure, and increasing reliance on imported fuel. These challenges have led to frequent power outages and load shedding, negatively impacting the country's economic growth and development. Demand for energy in Pakistan has steadily increased due to population growth, urbanization, and industrialization.

According to the World Bank, Pakistan's energy demand is projected to triple by 2050. The country's electricity demand alone is expected to increase by an average of 6.5% per year until 2030. However, Pakistan's energy supply has been unable to keep pace with this rising demand, resulting in a significant energy deficit.

Pakistan's primary sources of energy are oil, gas, and coal, with renewables accounting for a very small share of the energy mix. However, the country has been exploring renewable energy sources such as solar, wind, and hydropower to diversify its energy mix and reduce dependence on imported fuel. The country's energy infrastructure needs modernization and investment as the transmission and distribution system is outdated and prone to frequent breakdowns.

Trends in Energy Consumption and Production in Pakistan:

Pakistan is facing a severe energy crisis due to a lack of investment in the energy sector, inefficient energy use, and an over-reliance on fossil fuels. Pakistan's primary energy source is oil, followed by natural gas, coal, and hydroelectricity. However, the country has been facing challenges in meeting its energy needs, resulting in frequent power outages and load shedding. To address these challenges, the government of Pakistan has been taking steps to diversify the country's energy mix and increase its renewable energy capacity. In recent years, Pakistan has made significant progress in renewable energy production, with solar and wind power becoming increasingly important sources of energy.

In 2020, renewable energy sources contributed approximately 5% to Pakistan's energy mix, with hydroelectricity being the largest contributor at 30%. However, the government aims to increase the share of renewable energy to 30% by 2030. Pakistan has also been investing in the development of its coal reserves, particularly in the Thar region. The country has one of the largest coal reserves in the world, but the quality of the coal is relatively low, requiring significant investment in infrastructure for extraction and processing.

Future of Coal-fired Power plants and Thermal Power Plants:

Coal-fired Power Plants

Despite having huge amounts of coal reserves in Thar, Pakistan may need to import coal. One of the main reasons is that the coal found in Thar may not be suitable for power generation technologies, so importing coal of better coal is necessary. Another reason is importing coal will be cheaper and more efficient than developing the domestic coal industry.

Coal-fired power plants will likely continue to play a significant role in Pakistan's energy mix, along with the growing interest in renewable energy. In order to reduce the environmental impact of coal-fired power plants, the government is likely to focus on improving the efficiency and environmental performance of plants.

Thermal power plants:

Thermal power plants are a major component of Pakistan's energy mix, and their outlook in the coming years will depend on several factors, including government policies, investment, and technological advancements. Some general trends or projects that may follow through with the future in Pakistan in terms of its thermal power generation are as follows:

1. According to the Pakistan Energy Outlook 2021 by the International Energy Agency (IEA), Pakistan's electricity generation is expected to increase by around 50% by 2030.
2. The government has announced plans to shift towards cleaner energy sources, including renewable energy and liquefied natural gas (LNG), which may impact the demand for thermal power plants in the coming years.
3. The efficiency of the current thermal power plants in Pakistan is relatively low compared to international standards, while investments and upgrading these plants could improve their outlook in the future.
4. Technological advancements in Carbon Capture, Utilization, and Storage (CCUS) could help reduce the environmental impact of thermal power plants on the environment, making it a more favorable component in the energy mix in the future.

Sustainable Solutions

The challenges facing thermal and coal power stations in Pakistan have many sides and require a joint effort to address. The unavailability of fuel, particularly furnace oil, and the use of outdated technology are significant obstacles that need to be overcome to ensure reliable and sustainable energy production. To overcome these challenges, Pakistan needs to explore alternative energy sources and invest in upgrading the technology used in thermal power plants. This will require a significant investment in energy infrastructure, including adopting modern technologies, using more efficient fuels, and better operation and maintenance practices.

It is essential for Pakistan to address these challenges and develop a sustainable energy system that meets the

country's growing energy demands. This can happen in the following ways:

Water Conservation

Power plants consume a significant amount of water for cooling and other processes. Implementing water conservation measures such as recycling and reusing water can reduce water consumption and help reduce the environmental impact of power plant operations. Pipeline leakages of water should be taken care of, so no water gets wasted.

Carbon Capture and Storage (CCS)

It is a process that involves capturing carbon dioxide (CO2) emissions from power plants and storing them underground instead of releasing them into the atmosphere. The process involves three main steps: capture (capturing CO2 emissions from the plant), transport (transported to a storage site), and storage (stored in a storage site such as depleted oil and gas reservoirs).

3. Conclusion

In conclusion, Pakistan's inefficient and outdated thermal power plants pose a significant environmental risk, and their efficiency can be improved by using imported coal. While coal-fired power plants offer affordable and reliable energy, they also have a considerable environmental impact. It is crucial for the government and the public to work together to find effective solutions that balance economic growth with environmental protection. Regular environmental monitoring and cost-effective measures should be carried out regularly to improve the efficiency of both types of power plants and should also be prioritized to minimize the environmental impacts.

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