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Analyzing the Current State of Coal Consumption and Combustion in Pakistan, including Trends, Patterns, and Major Sources of Coal Emissions

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Abstract: *Coal consumption, a major contributor to greenhouse gas emissions, is closely linked to the effects of climate change in Pakistan. This paper investigates the complicated relationship between coal consumption and the effects on the country's climate. As Pakistan seeks to meet its energy needs while also supporting economic growth, the environmental consequences of coal use must be carefully examined. This study assesses the extent of coal-related emissions, their influence on local and global climate patterns, and the subsequent environmental and socioeconomic implications using a comprehensive review of literature, data analysis, and climate modelling. The article examines Pakistan's coal usage, including home heating, industrial operations, and electricity generation, highlighting the need for greener energy sources and strategies to reduce coal reliance and promote sustainable growth.. Furthermore, the study looks into the short-term and long-term climate effects of coal consumption in Pakistan. It investigates temperature changes, precipitation patterns, glacial melting, sea-level rise, and extreme weather events, as well as the consequences for agriculture, water resources, and vulnerable communities. The paper also examines the country's vulnerability to climate change and the need for adaptation measures to effectively address its effects.*

Key Words: Coal, Climate Change, CO2, GHG, SO2

Introduction

Coal consumption and its impact on climate change have become major concerns around the world, including Pakistan. Coal is a fossil fuel that is formed due to the decomposition of vegetation. It is a carbon-rich fuel that is widely used in the production of fuels, electricity, and industrial processes. In Pakistan, coal is mined from many regions, including Sindh, Baluchistan, and Punjab, and is used to generate electricity in coal-fired power plants (Bari et al., 2019), but majorly Thar coal reserves are estimated to be one of the world's largest coal reserve, and the development of the Thar coal mine is an important move to meet the country's electricity needs (Ahsan et al., 2017).

Coal burning has both positive and negative effects on Pakistan's energy security, economic development, and social well-being. Coal is an important source of electricity generation in Pakistan. Coal-fired power generation helps provide stable, continuous electricity to businesses, industries, and homes. Historically, Pakistan is mainly dependent on oil and gas imports. Developing alternative resources allows us to diversify our energy mix and reduce our reliance on costly natural resources. Coal deposits, especially in the Thar region, now have opportunities to use local resources and improve energy security. Coal-fired power plants provide reliable electricity that can support economic growth and attract jobs across the economy (Ahmed et al., 2021).

Despite its importance in meeting energy needs and promoting economic growth, coal burning in Pakistan also causes serious problems and adverse effects (Rauf et al., 2020). The combustion of coal releases many harmful chemicals and gases into the atmosphere, including carbon dioxide (CO_2), sulfur dioxide (SO_2), methane (CH_4), and nitrogen dioxide (NO_2). These pollutants have serious effects on human

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health and the environment. Carbon dioxide (CO_2) is an important greenhouse gas that causes global warming by trapping heat in the Earth's atmosphere. Coal burning is an important source of carbon dioxide emissions that cause long-term changes in global climate and temperature. Sulfur Dioxide (SO_2) is a highly reactive gas released during the combustion of coal, especially when burning high sulfur metals. It is a major component of acid rain production when it reacts with moist air and affects soil, groundwater, and plants (Nasir et al., 2016). Sulfur dioxide emissions from power plants and factories in Pakistan cause air pollution, affecting public health and ecosystems. Nitrogen dioxide (NO_2) is a pollutant formed during the combustion of fossil fuels, including coal. It helps to form ground-level ozone and particulate matter, both of which can affect breathing (Shahid et al., 2015). Nitrogen dioxide emissions from coal-fired power plants and other sources cause air pollution and smog in Pakistan's major cities, such as Lahore and Karachi. The inhaling of methane through the airways and throats causes damage to various organs of the body, including eye, throat, and nose irritation; lung infection and impairment; and shortness of breath. Asthma, coughing, and chest pain. (Azad, 2015). Coal-fired thermal power plants require large amounts of water for cooling purposes. In water-scarce areas, this can degrade water resources and have an impact on local ecosystems and communities. Coal mining operations and the construction of coal-fired power plants frequently necessitate the clearing of large areas of land, including forests, to accommodate infrastructure requirements. This can result in deforestation and the loss of wildlife habitat. (Azad, 2015).

To ensure continued use of coal and address its negative impacts, as well as to reduce the environmental impact of coal-fired power plants, Pakistan must invest in advanced coal technologies and implement stringent emissions controls. Furthermore, accelerating the development and adoption of renewable energy sources such as solar and wind can aid Pakistan's transition to a more sustainable energy future, and balancing energy security, economic growth, and environmental sustainability is critical to Pakistan's energy future.

Significance

The significance of this research paper is to create awareness among people and policymakers in order to produce energy in a sustainable way and to conduct an in-depth study on region-wise coal-fired power plants.

Objectives

- To analyze the current state of coal consumption in Pakistan, including trends and major GHG emissions.
- To analyze the impact of excessive coal consumption on climate change in Pakistan and globally.
- To investigate global efforts to control GHG emissions and the significant impact of technologies used in Pakistan and globally.

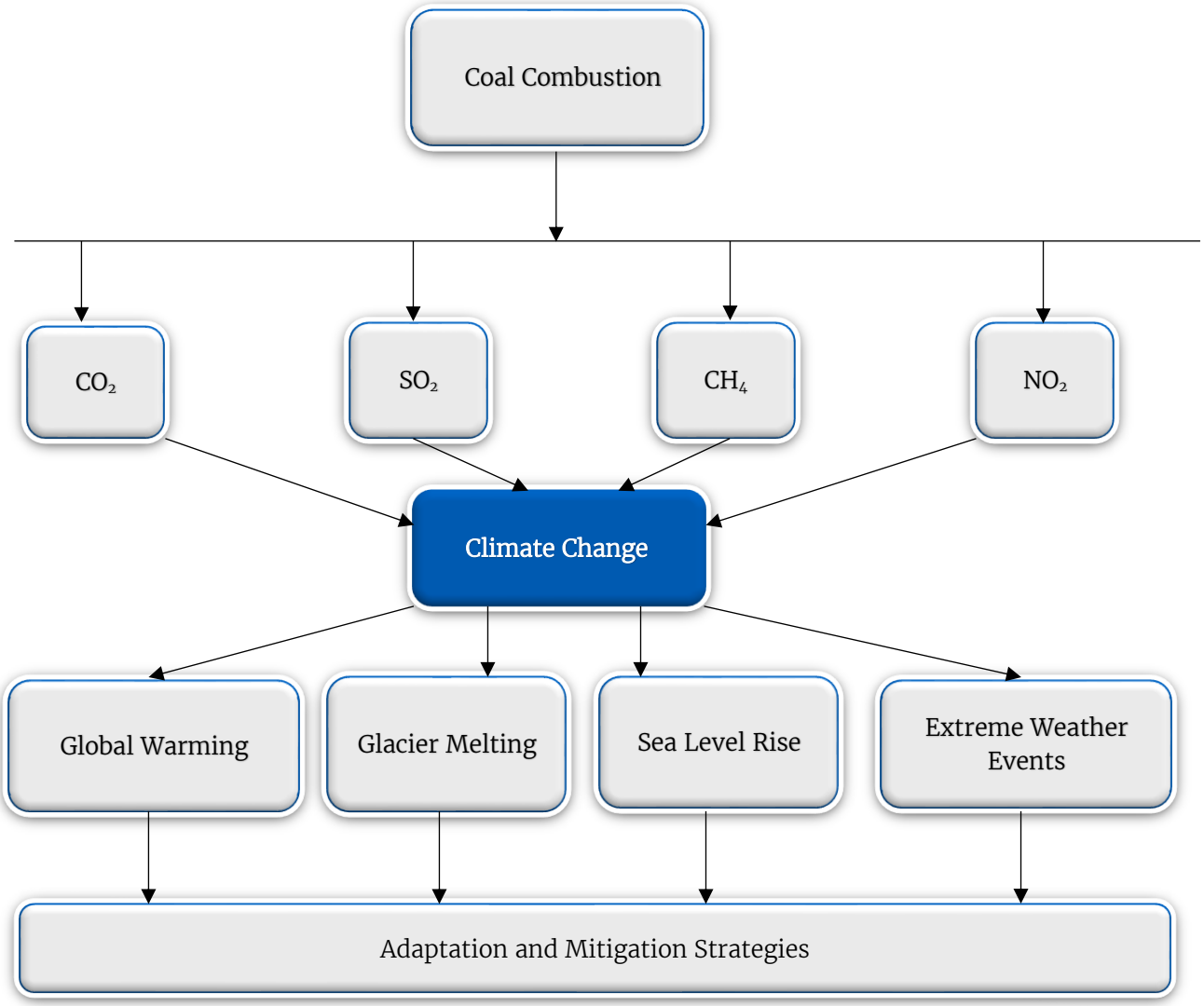
Research Questions

- What are the key pollutants released through coal combustion in Pakistan, and how do they impact Pakistan's air quality and climate patterns?
- How do changing climate patterns, influenced by coal combustion emissions, affect Pakistan's water resources, agriculture, and overall ecological systems?
- What policy frameworks and technological interventions are effective in reducing the climate impact of coal combustion in Pakistan, and what are the challenges and opportunities associated with their implementation?

Methodology

The methodology of this research paper is qualitative in nature, and data collection is from secondary sources, including government records, power generation companies, environmental agencies, Google Scholar, articles, and reports available on this topic.

Conceptual Framework



Literature Review

Most of the studies present on this topic have focused on the coal consumption pattern in Pakistan and its direct and indirect impacts on climate change, which further affects the ecosystem. Pakistan has 7th largest coal reserves in the world, with deposits being found in Sindh, Punjab and Baluchistan, KPK, as well as Azad Jammu and Kashmir, with a grand total of about 18,6007 million tons (Raza et al., 2022). Coal is the most important and economical energy source (Satti et al., 2014) and is effective in producing a high amount of heat; therefore, it can be used in electricity generation, and it generates about 37% of total global electricity (Ritchie, Roser, & Rosado, 2022).

Pakistan produces only 19% (PES, 2021) of total electricity from coal, but Pakistan has coal reserves which can produce about 100000 MW of electricity without any load shedding for the next 30 years (Ahmadani, 2017). According to the Pakistan Energy Yearbook 2012, coal contributed very little to the total energy production, about 6.6%. Imported oil 30% and natural gas 48% contributed to the total energy production; therefore, the shortfall of power in the energy sector, which was estimated to be about 1000 to 2000 MW in 2007, further increased to 6000 MW in 2022, which resulted in the closure of several industries such as textile industry (Naqvi, 2022). About 18.9 million tons of coal were imported throughout FY2021, whereas 12.21 million metric tons of coal were imported between July and February of FY2022. Domestic coal production was estimated to be 9.3 million tons during FY2021. (PES,2022). Several coal-fired power projects in different provinces have different energy outputs, such as Thar coal, which has a potential of 100,000 MW alone (Tribune 2020).

Despite its benefits, coal is considered the most harmful substance, which produces a lot of pollutants such as oxides of Sulphur, oxides of nitrogen, methane, heavy metals and (CO_2) which affects the health of humans and the environment and increases the emission of GHGs (Ali et al., 2021). 81% of the CO2 added to the Earth's atmosphere since 1870 has come from coal, which also contributes 40% of yearly global CO2 emissions. Based on current emissions rates, global warming will increase by four °C by the year 2100. (Burke & Fishel, 2020). Pakistan is ranked 5th (GCRI, 2023) among the most affected areas, although it can contribute less than 1% of GHGs (*Climate Change Does Not Need Visas to Cross Borders*, 2019). In Pakistan, coal is used in several industries such as cement, sugar, brick kilns, water and power authorities and for domestic purposes (Jabbar Khan et al., 2020)

Reports find that 80% of total global emissions are done by the G20 countries collectively, whereas three Asian cities, Lahore, New Delhi and Dhaka, are at higher risks due to the abundance of GHGs (Falak et al., 2022). In 2015, Pakistan only contributed 405 Mt GHGs, mainly CO_2 (Ali et al., 2021), but in an attempt to meet the needs of the growing population, 504.59 million tons of GHG emitted in 2018 (Tawiah et al., 2023).

Pakistan is spending only 1.5 % of its GDP on environmental protection by 2021 (government expenditure on environmental protection, 2023) which should be at least 5% according to the United Nations, and most of the CPEC projects of energy are coal-based and infrastructure development, therefore, larger number of environmental issues and climate change impacts are linked to CPEC (Zubedi et al., 2018), which is estimated to release up to 36.5 million tons of carbon dioxide only from transportation process (Qazilbash, 2017). By 2030, the energy sector will account for over 56% of Pakistan's total annual GHG emissions. (Janjua et al. 2018).

Even in the coal extraction industry, collapsed mines accounted for 36% of mine accidents, gas explosions for 19% of accidents and 17% of fatalities, and mine explosions for 16% of fatalities due to higher concentrations of methane (CH4) gas in coal mines, which may have lowered oxygen (O2) levels below the required level (18%). It could result in suffocation and fatalities for coal miners (Ayaz et al., 2022), and according to Neue (1993), a kilogram of methane may also heat up the atmosphere 72 times more than a kilogram of carbon.

There are several gaps in existing literature, such as the lack of comparative studies in terms of coal consumption patterns with respect to other energy resources and their contribution to climate change and GHGs. Technological innovation has also not been present in previous studies. They just focused on the impact of coal consumption without the precautionary measures and technologies to get the energy from coal in an eco-friendly way. Regional-specific studies are very few for the GHG emissions as most of the studies focus on the overall pattern of coal consumption GHGs across the country.

Findings and Discussion

Pakistan is known to have vast coal reserves, which are estimated to be among the world's largest. The total coal reserves of Pakistan are 186,007 million tonnes, out of which 185,456 million tonnes are primarily found in Sindh province (Raza et al., 2022). Then there's Punjab, with a total of 235 million tonnes, and Baluchistan, with 217 tonnes. Khyber Pakhtunkhwa has 90 million tons of coal reserves, while Azad Kashmir has only about 9 million tons.

Table 1

Coal reserves of Pakistan

Region	Azad Kashmir	Pakhtunkhwa	Punjab	Balochistan	Sindh	Total
Measured	1	1.5	55	54	7,664	7,775.5
Indicated	1	4.5	24	13	19,370	19,412.5
Inferred	7	84	11	134	44,290	44,524
Hypothetical	-	-	145	16	114,132	114,293
Grand Total	9	90	235	217	185,456	186,007

Source: *(Energy Exploration & Exploitation,2022)*

Pakistan's coal-fired power stations are mostly located in Baluchistan, Sindh, and Punjab. The Sindh-Engro Thar Coal Power Plant, HubCo Coal-fired Power Plant, Sahiwal Coal Power Plant, and Port Qasim Coal-fired Power Plant have all been supplying energy to the national grid since 2017. It is anticipated that there will be more coal-fired power facilities following the CPEC.

Table 2

Coal power plants in Pakistan

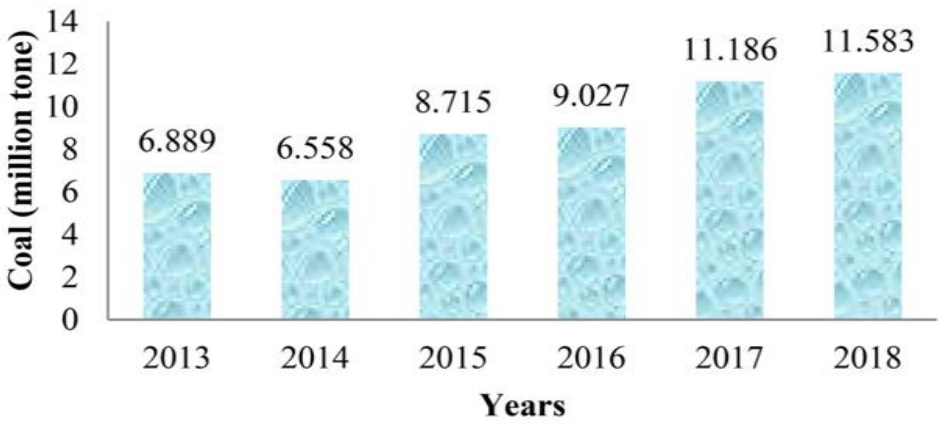
Station	Location	Capacity (MW)	Status
Lakhra Power Plant	Jamshoro, Sindh	150	Operational
Sitara Chemical Industries Ltd	Faisalabad, Punjab	40	Operational Since 2016.
Fauji Fertilizer Power Plant	Karachi, Sindh	118	Operational Since 2017.
Sahiwal Coal Power Project	Sahiwal, Punjab	1320	Operational Since 2017.
Maple Leaf Power Ltd	Mianwali, Punjab	40	Operational Since 2017.
Port Qasim Coal Power Project	Karachi, Sindh	1320	Operational Since 2017.
DG Cement Coal Power Project	DG Khan, Punjab	30	Operational Since 2017.
Hub Coal Power Project	Hub, Balochistan	1320	Operational Since 2018.
Enqro Powerqen Thar Pvt Ltd	Tharparkar, Sindh	660	Operational Since 2019.

Source: (Energy Exploration & Exploitation, 2022)

Coal consumption in Pakistan was relatively low compared to other energy sources from the early 2000s to the early 2010s. Natural gas, hydroelectric power, and oil dominated the country's energy mix. Pakistan began to experience energy shortages around the mid-2010s, prompting a renewed focus on increasing energy generation capacity. As a result, coal became more popular as a potential energy source to meet the growing demand for electricity. Coal consumption in Pakistan increased significantly in the late 2010s, particularly in the power generation sector. As seen in the figure, coal consumption increased by almost 5% between 2013-2018, and after China-Pakistan Economic Corridor (CPEC), Pakistan established a number of energy projects, including coal-fired power plants, with Chinese investment and technology, which further increased the coal consumption as shown in figure 1.

Figure 1

Pattern of Coal Consumption

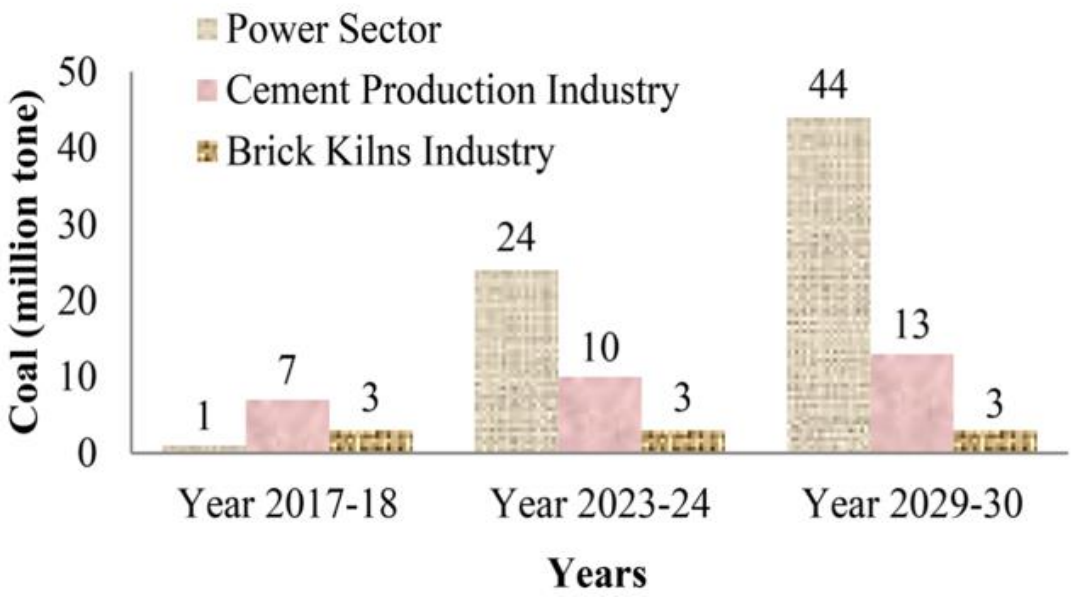


Source: (Energy Exploration & Exploitation, 2022)

Coal is contributing significantly to the country's energy mix and economic development. The power sector, cement production industry, and brick kilns industry are the major coal-consuming sectors, as shown in Figure 2.

Figure 2

Sector-wise, coal consumption in Pakistan



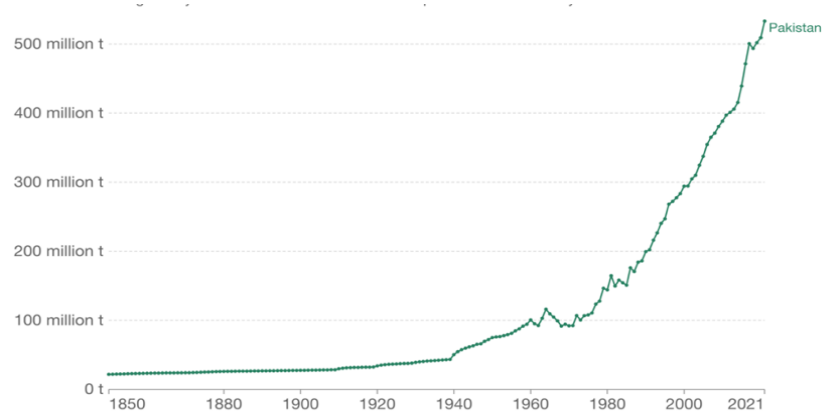
Source: (Energy Exploration & Exploitation, 2022)

In Pakistan, the majority of coal is used to generate electricity. The purpose of coal-fired power plants is to produce electricity for use in industry, commerce, and households. Power is essential to a nation's development, and Pakistan is a developing nation. But because of the country's increasing urbanization and rising living standards, Pakistan is today seen as having insufficient energy and depends entirely on fossil fuels to generate electricity. (Sáez-Martnez et al., 2016). Currently, total coal electricity generation has reached 5280 MW. The local coal production is estimated at 3.21 million tonnes, of which over 80% is currently used by brick manufacturers, with the remainder consumed by the cement industry. Reportedly, 85% of the cement sector moved from relatively expensive natural gas and furnace oil to less-priced coal (Raza et al., 2022). In addition, medium-density fiberboard—an ideal substitute for the wood needed to make furniture—is produced using coal as a fuel in the sugar industry, helping to preserve our quickly disappearing forests. In addition, coal is a crucial raw material for the production of refined coal tar, which is used to create pitch and creosote oil, among other compounds. In the steel and metal sectors, coal is utilized as a heat source to create steel and iron. It's also employed in the casting and smelting procedures.

In comparison to recent years, Pakistan's GHG emissions were relatively low in the early 1990s because the country's economy was less industrialized, with lower energy consumption. GHG emissions began to rise in the 2000s as Pakistan's economy expanded and industrialization increased. The usage of fossil fuels, including coal, oil, and natural gas, in the energy industry has made it one of the main sources of emissions. Agriculture and transportation were also significant. Pakistan's greenhouse gas emissions increased significantly during the 2010s. Despite efforts to improve energy efficiency and implement cleaner technologies, overall increases in energy demand and industrial output contributed to the increase in emissions. Pakistan's GHG emissions have continued to rise in the 2020s as the country strives to meet its targets and its energy and development requirements, as shown in Figure 3.

Figure 3

Pakistan's GHG emission

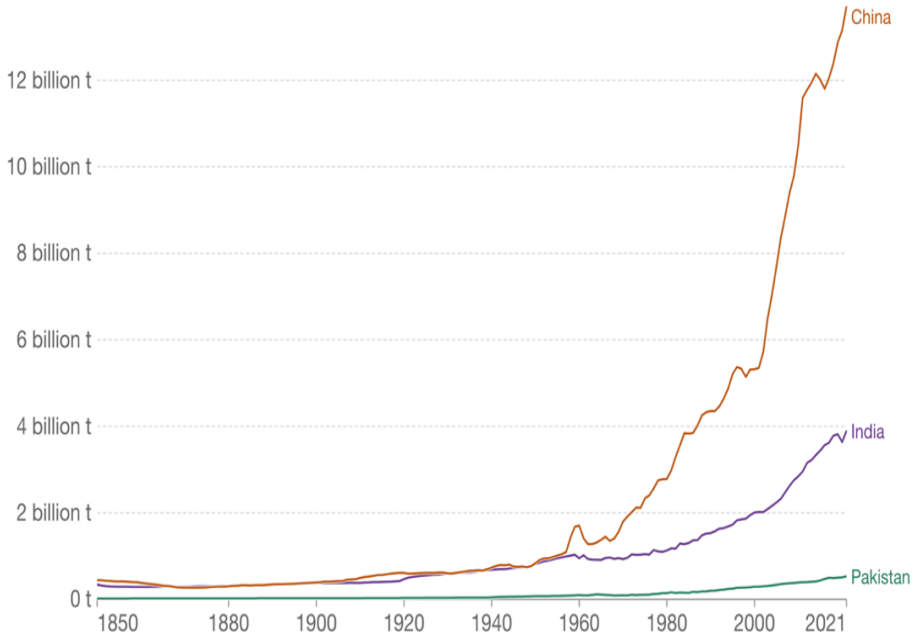


Source: (World Bank, 2023)

When contrasting Pakistan with its surrounding nations. With 27% of the world's greenhouse gas emissions coming from China, India comes in third place with 6.6% of the world's emissions. China is the world's biggest emitter of greenhouse gases. Pakistan is among the most vulnerable nations to the consequences of climate change, although making up just 0.9% of the world's greenhouse gas (GHG) emissions. The majority of China's and India's CO2 emissions come from energy use, industrial operations, and transportation. Pakistan's population and economy are less industrialized than those of China and India, which contributes to its lower GHG emissions. The use of fossil fuels, particularly coal, in the nation's industrial operations and energy production, is the main source of emissions. GHG emissions in China and India are significantly higher than in Pakistan due to larger populations and more advanced industrialization. While China and India are among the world's top emitters, Pakistan's emissions are lower in comparison. However, Pakistan faces several challenges as a result of greenhouse gas (GHG) emissions from larger emitters such as China and India. These issues are primarily concerned with the global impact of climate change, such as smog faced by the Punjab province of Pakistan, as well as the regional environmental and economic consequences, as shown in Figure 4.

Figure 4

Pakistan GHG emissions comparison with India and China



Source: (World Bank, 2023)

The increase in population is contributing to the release of GHGs due to urbanization, and the construction of buildings, roads, agricultural activities, and waste management processes causes deforestation, due to which the earth loses its capacity to capture CO_2 in the process of photosynthesis. Coal-fired power plants also release many gases during the process of electricity production, which is considered to be a major contributor to CO_2. Mining releases methane and other harmful minerals in the process of dewatering the mine, which is further released in the ponds, lakes and other water bodies, which can also be mixed with the groundwater, causing several diseases in humans and damage to marine life in freshwater bodies.

An increase in CO_2 concentration also traps the heat coming from the sun, which will not reflect back and warm up the environment and cause global warming. A huge number of problems are linked to global warming, such as the melting of glaciers, which raises the sea level and causes flooding and erosion. An increase in temperature leads to more frequent and intense heat waves, which can be harmful to natural ecosystems, agriculture, and human health. Ocean acidification and warming are occurring as a result of the oceans absorbing a large portion of the extra heat caused by global warming. Ocean acidification is also caused by carbon dioxide dissolving in saltwater and forming carbonic acid. Coral reefs and other marine creatures may suffer as a result of these changes. This makes extreme weather events like storms, droughts, torrential rains, and wildfires more common and intense. These occurrences have the potential to seriously harm communities, ecosystems, and infrastructure.

Changes in temperature and precipitation patterns have the potential to upset ecosystems, which can have an impact on the migration, distribution, and behaviour of various species. Certain species might find it difficult to change or relocate quickly enough, which might cause ecological imbalances and perhaps the extinction of some. Crop yields and agricultural productivity can be impacted by variations in temperature and precipitation patterns. Due to water constraints or shifting growth conditions, certain places may have lower crop yields, which could result in food shortages. Extinction is a possibility for species that are unable to move to more suitable habitats or adjust to changing environmental conditions. The functioning of ecosystems may be negatively impacted by the domino effect of this loss of biodiversity. The combined effects of global warming may cause social unrest and economic disruptions, such as population displacement brought on by rising sea levels, resource-related conflicts, and financial losses in industries like tourism and agriculture.

The frequency and length of heat wave episodes are predicted to rise. More than 1,200 people died in Karachi alone during the June 2015 heat wave, while another 200 people died in other parts of Sindh Province. The hottest temperature ever recorded in Karachi is 44.8°C, which came in second place after 1979. In Pakistan's plains, heat waves are typical during the premonsoon months of May through June. There is a correlation between the spread of many infectious diseases and food security and variations in temperature and rainfall. According to a preliminary UNDP research conducted during the 2021 floods, the number of people who do not consume the recommended amount of dietary energy grew by 3%, adding 5 million more people to the undernourished population. In a similar vein, there was a correlation found between the mental health of the impacted population and severe occurrences; that is, extreme events typically result in despair, distress, anger, etc. The danger of vector- and water-borne infections rises along with the temperature. Temperature variations and high precipitation are to blame for the rise in dengue and malaria cases, which may also lead to an increase in mosquito breeding grounds.

The level of GHGs, including CO_2, Methane, Nitrous oxide, CFC-12 and Sulphur Hexafluoride, which is extensively used in electric industries and electronic equipment, has increased rapidly from 1870-2023, as shown in Table 3, which shows that the CO_2 increases from 280ppm in 1870 to 423.68ppm in 2023 while methane which has 72 times greater warming potential than CO_2. Similarly, Nitrogen oxide, CFC-12, and sulfur hexafluoride are minor in the atmosphere but have higher warming potential, with sulphur hexafluoride having 16300 times higher relative to CO_2.

Table 3

GHGs with their level in different years with respect to warming potential (relative to CO_2)

S.No	GHGs	Level in 1870	Level in 2007	Level in 2023	Warming Potential (Relative to CO_2)
1	Carbon Dioxide	280ppm	399ppm	423.68ppm	1
2	Methane	700ppb	1745ppb	1922.2ppb	72
3	Nitrous Oxide	270ppb	314ppb	336ppb	310
4	CFC-12	0	533ppt	-	12000
5	Sulphur Hexafluoride	0	480ppt	-	16300

Source: (Pakistan Metrological Department, 2012; US Department of Commerce, 2023)

GHGs such as Sulphur dioxide (SO2), nitrogen oxides (NOx), particulate matter (PM), and volatile organic compounds (VOCs) are all released into the air when coal is burned, causing asthma, bronchitis, and other lung illnesses. They can also contribute to smog and haze. Fine particulate matter (PM2.5) emitted by coal burning can enter the circulation, increasing the risk of heart attacks, strokes, and other cardiovascular disorders. Even trace levels of mercury are also present in coal and can be discharged into the environment after burning. Mercury exposure can harm neurological development, particularly in fetuses and young children. Coal burning can generate a variety of byproducts, including polycyclic aromatic hydrocarbons (PAHs) and heavy metals, all of which are linked to an increased risk of cancer, particularly lung cancer. Moreover, Numerous occupational health issues are associated with coal mining for miners, including lung conditions like pneumoconiosis, commonly referred to as black lung disease, which is brought on by prolonged inhalation of coal dust. In addition to requiring labour-intensive work in hazardous environments, coal mining raises the possibility of mishaps, worker injuries, and miner deaths. It may cause water pollution by releasing heavy metals and chemicals from mine waste into bodies of water. Contaminated water sources may be harmful to both human health and ecosystems. Effects of coal mining on the environment, such as deforestation, habitat loss, and air and water pollution, can have an indirect influence on human health by changing ecosystems and contributing to larger environmental issues.

It is not possible to considerably reduce greenhouse gas (GHG) emissions from coal-fired power plants with current methods. Consequently, one of the biggest causes of global climate change is coal-fired power plants (IDB, 2009). Furthermore, of all the fossil fuels, coal has the largest carbon content and, consequently, the biggest amount of CO2 released per unit of energy produced by its combustion.

Pulverized coal technology, also known as pulverized coal combustion, is a popular way of producing energy from coal. It is extensively utilized to generate energy in coal-fired power plants. The main idea behind this technique is that coal is broken down into a fine powder and then burned in a furnace or boiler to produce steam, which powers a turbine attached to a generator to generate energy. This method, however, raises environmental problems due to the generation of pollutants. Modern pulverized coal power plants frequently combine technologies such as flue gas desulfurization (FGD) and microwave coal desulphurization (Amjed et al., 2017) to reduce SO_2 emissions and selective catalytic reduction (SCR) to minimize NOx emissions to solve these challenges.

Several other technologies that are used in China and the USA can also be combined with pulverized coal combustion, such as subcritical technology and supercritical and ultra-supercritical technology, to reduce emissions.

Carbon capture and storage (CCS) is one of the most promising possibilities going forward (Wilberforce et al., 2021). Carbon capture and sequestration technologies are at the centre of CO2 mitigation strategies. The extraction of CO2 from emission sources can occur either before or after combustion in order to achieve carbon capture. Pre-combustion CO2 capture usually entails gasification techniques, such as integrated gasification combined cycle (IGCC) technology, in which heat is applied under pressure in the presence of steam to transform biomass or coal into gaseous components. Since CO2 is present in synthesis gas at much higher concentrations than in post-combustion flue gas, IGCC systems currently seem to be the

more cost-effective option for new plants. These plants may be configured so that concentrated CO2 at high pressure can be captured from the synthesis gas that emerges from the gasification reactor before it is mixed with air in a combustion turbine.

Physical and chemical methods are used in post-combustion CO2 capture to extract CO2 from exhaust flue gas. These systems may be used in the retrofit of traditional coal-fired power stations as well as alternative combustion/thermal energy production methods. However, because of the low pressure and diluted CO2 concentrations, these systems are difficult to operate and currently expensive due to the large amount of gas that needs to be treated. Additionally, the efficiency of the CO2 adsorbing procedures is sometimes decreased by trace contaminants in the flue gas, and compressing collected CO2 from ambient pressure to pipeline pressure entails a significant parasitic load.

Utilizing pure oxygen diluted with recovered CO2 or water, oxygen combustion, also known as oxy-combustion, is one technological alternative for burning coal in an environment with enhanced oxygen. Through this process, the water in the exhaust stream condenses, allowing a reasonably concentrated stream of CO2 to be recovered. For current coal-fired power plants, oxy-combustion presents a number of possible advantages. Following the collection of CO2 emissions, the gas should be either geologically stored (such as in saline aquifers) or extracted using improved oil recovery. CO2-enhanced oil recovery, a commercially successful technique that has been widely employed in the US to boost oil production in depleted wells, is another possible kind of CO2 sequestration. Compressed CO2 is pumped into an oil reservoir close to the production well site in CO2-enhanced oil recovery, which forces the oil toward the well and increases yield. Pakistan may employ this technology, utilize all of its coal deposits, and use the coal in a variety of industries.

Numerous environmental agreements and pacts have been signed around the world to address various environmental challenges. International environmental treaties that promote international cooperation are an important tool for limiting environmental degradation that crosses national borders. The number of agreements has rapidly increased since 1970. As of 2015, 238 countries had signed the 1998 treaties.

Pakistan Environmental Protection Act (1997)

PEPA empowers the federal government to establish national environmental quality standards, including those related to air quality. PEPA sets the standard limits for various air pollutants, such as particulate matter (PM), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and carbon monoxide (C_0), among others. By setting these standards, PEPA provides a clear benchmark for air quality that industries, vehicles, and other sources of pollution must adhere to. Industries are mandated to install pollution control technologies and practices to limit the release of harmful pollutants into the air.

National Conservation Strategy (1992)

The NCS emphasizes the importance of conserving and restoring ecosystems to enhance their resilience against environmental challenges, including climate change impacts. Ecosystems like forests, wetlands, and coastal areas play a crucial role in mitigating climate change by absorbing carbon dioxide and providing natural buffers against extreme weather events. The NCS promotes sustainable land use planning and management. Responsible land use practices can help prevent deforestation, urban sprawl, and other activities that contribute to greenhouse gas emissions and reduce the capacity of ecosystems to mitigate climate change.

Clean Air Program (2004)

The Clean Air Program aims to reduce emissions from a variety of sources, such as industries, vehicles, and brick kilns. The program helps to reduce pollutants that cause poor air quality and health problems by implementing stricter emission standards, encouraging the adoption of cleaner technologies and the use of cleaner fuels like compressed natural gas (CNG), and improving vehicle inspection and maintenance systems. These efforts result in lower harmful pollutant emissions from the transportation sector.

Climate Change Policy (2021)

Pakistan's Climate Change Policy outlines the country's approach to dealing with climate change challenges and promoting sustainable development. While the policy's primary focus is on climate change mitigation and adaptation, its implementation could have a significant impact on both climate change and air pollution. The policy prioritizes the development and use of renewable energy sources like solar, wind, and hydropower. The policy encourages energy-saving practices and technologies in all sectors... The policy promotes initiatives that sequester carbon dioxide from the atmosphere, such as afforestation and reforestation.

National Clean Air Policy (NCAP) 2021

The main goal of the National Clean Air Policy is to improve air quality by addressing the sources of air pollution, reducing pollutant emissions, and protecting public health and the environment. Regulatory measures, technological advancements, and public awareness campaigns. Particulate matter ($PM_{2.5}$ and PM_{10}), Sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), and volatile organic compounds (VOCs) air quality standards are being developed. Regulations and measures to control emissions from various sources, such as industries, vehicles, construction, agriculture, and household activities, are being implemented. Setting targets for reducing key pollutant emissions and establishing a timetable for achieving these targets. Introduce and enforce stricter vehicle emission standards for both new and existing vehicles, as well as encourage the use of hybrid vehicles with cleaner fuels.

Pakistan, like many other countries, has signed international environmental treaties to address global environmental challenges and work with the international community to find solutions to a variety of environmental issues.

United Nations Framework Convention on Climate Change (UNFCCC)

The United Nations Framework Convention on Climate Change (UNFCCC) is an international treaty aimed at addressing the challenges of global climate change. Pakistan joined the UNFCCC in 1994, indicating its commitment to addressing climate change issues on a global scale. Pakistan attends the annual Conference of the Parties (COP) meetings, which are the UNFCCC's highest decision-making bodies. The goal of the Convention is to keep greenhouse gas concentrations in the atmosphere stable in order to avoid dangerous anthropogenic interference with the climate system...

Paris Agreement

In 2015, the Paris Agreement was signed. Its primary goal is to keep global warming well below 2 degrees Celsius above pre-industrial levels, with efforts aimed at keeping the temperature increase to 1.5 degrees Celsius. The agreement outlines countries' commitments to reduce greenhouse gas emissions, improve climate resilience, and support global climate change efforts. Pakistan signed and ratified the Paris Agreement on November 10, 2016.

Montreal Protocol on Substances that Deplete the Ozone Layer

The Montreal Protocol on Substances that Deplete the Ozone Layer is a 1987 international treaty that addresses ozone layer depletion caused by certain man-made chemicals known as ozone-depleting substances (ODS). The protocol's goal is to reduce the production and consumption of these harmful substances in order to protect the Earth's ozone layer, which protects us from harmful ultraviolet (UV) radiation. Pakistan is a signatory to the Montreal Protocol and has been actively involved in its implementation, but Pakistan ratified the Protocol in 1992, demonstrating its commitment to addressing ozone layer depletion and environmental protection. The country has been working to meet the protocol's obligations, which include reducing ODS consumption and production. As part of its responsibilities under the Protocol of Montreal, Pakistan has developed and implemented national strategies to reduce the use of ozone-depleting substances.

Stockholm Convention on Persistent Organic Pollutants (POPs)

The Stockholm Convention on Persistent Organic Pollutants (POPs) was established in 2001 to address the harmful effects of certain toxic chemicals that persist in the environment, bioaccumulate in living organisms, and can have serious health and environmental consequences. Pakistan is a signatory to the Stockholm Convention and has taken steps to implement its provisions for POP control and phase-out. The Stockholm Convention seeks to safeguard human health and the environment against the harmful effects of POPs. Pesticides (e.g., DDT), industrial chemicals (e.g., PCBs), and unintentional byproducts (e.g., dioxins and furans) are examples of these chemicals. Under the Stockholm Convention, Pakistan has developed a National Implementation Plan (NIP). The NIP describes the country's strategies, actions, and timetables for managing and reducing pollution. POPs are used. It includes steps to inventory, monitor, regulate, and eventually phase out POP production and use. Pakistan has implemented regulations and policies to regulate and manage the use of POPs. This includes measures to limit or eliminate the import, production, and use of these chemicals in various industries.

Limitations

There may be limitations to research papers on coal consumption and its impact on climate change in Pakistan. The majority of our research data comes from secondary sources. If we conducted primary research, we would have first-hand data, which would be more reliable. In Pakistan, access to accurate and comprehensive data on coal consumption, emissions, and climate impacts is limited, limiting the analysis's robustness. Data on GHG emissions from coal consumption and their impact on climate change may have been limited in the past, particularly for long-term analyses. The majority of coal reserve data is only available for that region of Pakistan; data for other regions is not available.

Recommendations

To address coal consumption and its impact on climate change in Pakistan, a multifaceted approach that balances energy needs with environmental sustainability is required.

- Tree planting is critical in combating the challenges posed by coal consumption and its environmental consequences. Through photosynthesis, trees absorb carbon dioxide (CO_2) from the atmosphere and store it in their biomass. This process contributes to the reduction of CO_2 emissions caused by coal combustion, which is a major contributor to greenhouse gas accumulation and climate change. More CO_2 can be sequestered by increasing the number of trees planted, contributing to a reduction in the net carbon footprint by absorbing pollutants and releasing oxygen. Trees act as natural air filters, improving air quality and making the environment healthier for humans and ecosystems. Campaigns such as The "Billion Tree Tsunami," a flagship reforestation initiative launched by the provincial government of Khyber Pakhtunkhwa (KP) in Pakistan, should be reintroduced. The province-wide campaign aims to plant a billion trees to combat deforestation, restore ecosystems, combat climate change, and promote biodiversity.
- Supercritical technology is used only in the Sahiwal coal power plant in Pakistan. It is a type of advanced steam cycle used in coal-fired power plants to improve electricity generation efficiency and reduce greenhouse gas emissions. Both the pressure and temperature of the steam are significantly higher in a supercritical steam cycle than in traditional subcritical cycles. Operating at higher pressures and temperatures improves heat transfer and energy conversion efficiency. Power plants that operate at supercritical temperatures can achieve higher net efficiency, which means they can produce more electricity with the same amount of coal, resulting in lower fuel consumption and emissions per unit of electricity produced. This technology should be used in all coal power plants in Pakistan, and policies should be put in place to encourage the use of this technology.
- Pakistan should transition to renewable energy sources such as solar, as the United States and France are planning to build solar panels on large parking lots and supermarket roofs. According to a World Economic Forum report, covering the roof with solar panels could generate enough power for 8 million homes while saving 51 million tons of CO_2 per year by switching from fossil fuels to renewable energy, such as solar power plants, which can significantly reduce greenhouse gas (GHG) emissions. During operation, solar power generation emits no direct greenhouse gas emissions. Solar

photovoltaic (PV) panels, unlike fossil fuel-based power plants, do not burn fuel or emit pollutants into the atmosphere while generating electricity, and they also meet the need for electricity in a more efficient manner.

- Increasing awareness and putting policies in place to address the negative effects of coal necessitates a multifaceted approach that includes education, communication, and regulatory measures.
- The government should launch national public education campaigns to educate the public about the environmental, health, and climate impacts of coal combustion. To reach a large audience with relevant information, use a variety of communication channels such as television, radio, social media, and community events. Highlight the advantages of switching to cleaner energy sources and the significance of sustainable development. Collaborate with environmental experts, scientists, and academics to provide credible, evidence-based information on coal's negative effects. The government should host seminars, workshops, and webinars to allow experts to present their research and findings to policymakers, stakeholders, and the general public.
- To reduce air pollution and GHG emissions, the government should enact and enforce stringent environmental standards and emission limits for coal-fired power plants. To encourage the transition away from coal, provide incentives for renewable energy sources, energy efficiency measures, and sustainable practices. Redirect subsidies that support coal consumption toward renewable energy development and other sustainable initiatives. Pakistan should continue its solar subsidy plan, which aims to provide subsidized panels to around 200,000 houses in both rural and urban areas. It should also allocate funds to support research and development of clean technologies and energy alternatives.
- Although Pakistan's greenhouse gas (GHG) emissions are lower than those of China and India, the impact of neighbouring countries' emissions on Pakistan's environment emphasizes the importance of taking proactive steps to address these challenges. Pakistan must continue to reduce emissions through energy efficiency, renewable energy adoption, afforestation, and sustainable land use practices. Pakistan should make diplomatic efforts and encourage China and India to take stronger measures to reduce emissions and address environmental issues. Pakistan should be an active participant in international climate agreements and negotiations in order to advocate for stronger commitments from major emitters such as China and India. Work with other countries to address transboundary environmental issues. Pakistan engages in bilateral and multilateral environmental dialogues with China and India, emphasizing shared responsibility to mitigate climate change and reduce transboundary pollution. Set up and maintain transboundary air quality monitoring systems to better understand the impact of neighbouring countries' emissions on Pakistan's air quality and public health. Collaborate with research institutions, think tanks, and universities to investigate the cross-border effects of emissions and climate change and provide data on the findings and recommendations for policy decisions based on evidence.

By combining these approaches, the Pakistani government can educate the public, encourage stakeholder participation, and drive policy changes that prioritize environmental sustainability, public health, and climate resilience over the negative effects of coal consumption.

Conclusion

Coal combustion has played a significant role in Pakistan's energy landscape, contributing to electricity generation, industrial processes, and economic development. However, the environmental and climate impacts of coal combustion cannot be overlooked. The combustion of coal releases substantial amounts of greenhouse gases (GHGs), particularly carbon dioxide (CO2), into the atmosphere, contributing to the global phenomenon of climate change. The increasing concentration of GHGs, including CO2, in the atmosphere has led to a rise in global temperatures, resulting in a range of adverse effects on Pakistan's climate and environment. Glacial melting in the mountainous regions threatens water supplies, while changing precipitation patterns lead to both droughts and floods, affecting agriculture and livelihoods. Rising sea levels pose risks to coastal areas, and extreme weather events can cause infrastructure damage and displacement of communities. Pakistan's vulnerability to climate change makes it imperative to address the impacts of coal combustion through alternative technologies and sustainable strategies. Transitioning to cleaner coal technologies, such as advanced coal-fired power plants with high efficiency

and carbon capture capabilities, can help reduce emissions and limit the environmental footprint. Additionally, promoting renewable energy sources, improving energy efficiency, and implementing reforestation initiatives are vital steps towards mitigating the impacts of coal-related emissions.

To safeguard Pakistan's environment and economy, a comprehensive approach is necessary. This approach should involve policy interventions, technological innovation, public awareness campaigns, and international cooperation. By embracing cleaner energy options, transitioning towards low-carbon alternatives, and aligning with global efforts to combat climate change, Pakistan can contribute to a more sustainable and resilient future, ensuring that its development is compatible with the well-being of both its people and the planet.

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