Working Paper # 030

CPEC WORKING PAPER SERIES

ANALYZING ENVIRNOMENTAL IMPACTS FOR COAL - FIRED POWER PLANTS UNDER CPEC

Numra Asif
Research Assistant,
Centre of Excellence for CPEC

Dr. Saleem Janjua
Head of Policy,
Centre of Excellence for CPEC

Adnan Khan
Research Associate,
Centre of Excellence for CPEC

Ministry of Planning, Development & Reform

Pakistan Institute of Development Economics

A PUBLICATION OF
CENTRE OF EXCELLENCE
CHINA-PAKISTAN ECONOMIC CORRIDOR

GET MORE
www.cpec-centre.pk

ANALYZING ENVIRNOMENTAL IMPACTS FOR COAL - FIRED POWER PLANTS UNDER CPEC

By

Numra Asif[1], Dr. Saleem Janjua[2], Adnan Khan[3]

ABSTRACT

Pakistan has been an energy deficit country from last two decades, facing acute power shortage of around 6000 MW. This acute shortfall has negatively impacted economic growth and has curtailed GDP growth of the economy by 4% percent (Shahbaz, 2015). In China - Pakistan Economic Corridor (CPEC), a special focus has been given to the energy sector such as 19 projects out of 39 Earlier Harvest Projects (EHP) worth around US $34 billion, which is equivalent to 70% of the CPEC funding basket, is marked for energy projects. The significant focus of the CPEC framework on energy projects portrays a strong commitment on the part of government to resolve energy crisis. Most of the energy projects in the CPEC portfolio are coal based. Out of the 19 energy projects, 10 projects are based on coal. The energy projects under CPEC are need of time; however they have raised concerns on the environmental front as well. Sahiwal Coal Fired Power Plant is the first plant that is now operational under CPEC portfolio. This study reviews the potential environmental impacts that may arise from Sahiwal coal fired power plant and suggests suitable mitigation measures. It then proceeds by exploring the actual measures that are being taken by the Sahiwal power plant to ensure environmental sustainability and assesses the overall environmental compliance of the plant. Findings show that the subject plant is contributing positive impacts like electricity generation, employment opportunities, improved accessibility of the region, and increase in standard of living. Similarly, the analysis of the subject plant shows various potential environmental impacts and suggests possible mitigation strategies. One of the pristine reasons for potential low environmental impacts is the use of new technology in Sahiwal Coal Fired Power plant, namely supercritical technology that reduces emissions through high efficiency as compared to the conventional subcritical technologies. With the help of latest technologies and other measures taken, the emissions of the subject plant are way below the National Environmental Quality Standards (NEQs) thus indicating that overall plant is environmentally compliant. The study concludes with relevant policy guidelines that may be adopted to ensure long – term sustainability of coal fired power plants and ensure minimal environmental degradation. Developing countries like Pakistan have a small carbon footprint. The usage of coal as an economical source of energy is important to strengthen the industrial sector and sustain a higher economic growth. Under CPEC, the immediate policy of government to fulfill the energy needs in short period of time through efficient coal fired power plants appears appropriate; however, in long term move to renewable energy should be priority of the government of Pakistan.

[1] Research Assistant, Centre of Excellence for China-Pakistan Economic Corridor, Islamabad
[2] Head of Policy, Centre of Excellence for China-Pakistan Economic Corridor, Islamabad
[3] Research Associate, Centre of Excellence for China-Pakistan Economic Corridor, Islamabad

Keywords: GHG Emissions, Sahiwal Coal Power Plant, CPEC, Energy, Sustainability Development.

1. INTRODUCTION

The globalized world of the 21st century requires energy as the fundamental factor for development. Without a stable supply of energy, hospitals would be dark, schools have to be close down and industries would be shut down. Energy is an important requirement for economic and social development; however, its cheap provision remains a pertinent issue and to date 1.3 billion people around the globe do not have access to electricity. Coal has remained the cheapest source of energy generation and electricity production and is widely used across the globe. It is mined in over 50 countries and this easy and cheap supply has assured that coal remains the most affordable fuel for power generation. To date it remains the major source of energy for developed and industrialized countries. (Coal Industry Advisory Board, 2010).

China has been the biggest consumer, user and importer of coal. Over half of its energy mix is based on coal. The World Bank estimates that a stable supply of energy has moved 600 million people out of poverty in the last three decades, with the major chunk from China. Overtime China has connected 99% of its population to the national grid thus ensuring greater economic growth. Coal generates 43 % of Germany total energy (Coal Atlas, 2015). India has used coal as a major source to move out of the energy poverty. Coal generates 50 % of energy in India and the coal consumption target by 2020 is 1 billion ton. The current consumption pattern makes India second largest coal consumer in the word. In USA 46 % of energy is generated through coal. Russia has also been a big consumer of coal. It has large domestic reserves, and is one of the major exporters of the fossil fuel.

The heavy dependence of the major developed countries on coal across the globe assign a significant role to coal as a source of energy. Despite new capacity from natural gas and renewables, coal currently supplies nearly 30% of global energy consumption and generates 40% of the world's electricity. The huge share of coal for power generation and its major share in the global energy mix have raised serious environmental concerns and challenges i.e. though the coal fired power plants/power stations provide 42% of electricity, at the same time they contribute 28% of global carbon dioxide emissions. The world does need coal for its energy generation; however, the environmental concerns have moved the policy focus towards the efficient use of coal. Countries around the world are striving to achieve maximum energy from coal and minimizing emissions at the same time.

To date, coal remains a dominant source of energy in the globe, however in a move to reduce emissions and pollutants, power plants have moved from sub-critical technology to super-critical technology. Unlike the developed world, Pakistan has been a low user of coal for power generation. Despite having coal reserves of 186 million tons, coal has contributed only 114 MW to the national grid (Economic Survey of Pakistan, 2017-18). From almost the last two decades, the energy crisis of Pakistan has become severe. According to Pakistan Electric Power Company (PEPCO), the current energy demand for Pakistan is 16,814MW, while total supply of electricity is 10,800 MW, thus the gap remains the energy deficit of Pakistan. The total installation capacity of power generation is of 21,375MW. The demand for electricity is increasing at a rate of 10% annually while the power generation capacity is increasing only by 7% (Rafique & Rehman, 2017).

Amidst this energy crisis, China-Pakistan Economic Corridor (CPEC) has served as a savior to the situation. CPEC is an ongoing mega development project aims to resolve the energy crisis of Pakistan and ensure economic stability. Overall, CPEC project of $46 billion expects to include nearly 17,000 MW of power generation projects at the expense of US$ 34 billion (Economic Survey of Pakistan, 2017-18). The remaining investment will be spent on transport, infrastructure development and mass transit projects (Bhattacharjee, 2015). Nineteen energy projects have been launched under the CPEC portfolio in the energy sector, however ten projects are based on coal. The tilt of CPEC energy basket towards a non-renewable source of energy i.e. coal has raised hue and cry. The society at large believes that coal projects under CPEC may lead to environmental degradation and are skeptical towards CPEC energy portfolio and the benefits that are claimed to be generated from these energy projects.

The above brief background highlights the global usage of coal and the need of coal as a source of energy for Pakistan. It also highlights the important role that may be played by CPEC portfolio to resolve the energy crisis; however, with coal as dominant source of energy in the CPEC portfolio, there are concerns on the environmental front. With this brief background, this research paper selects Sahiwal Coal fired power plant as a case study. The subject plant is the first one to be operational under the CPEC portfolio. Therefore, the key objectives of the research paper are to analyze the potential environmental impacts of Sahiwal coal fired power plant and suggest suitable mitigation measures; review the environmental measures that are being taken at the Sahiwal coal plant and assess the overall environmental compliance and thus to suggest suitable policy recommendations for environmental sustainability of coal fired power plants under CPEC in specific and Pakistan in general.

The research paper is divided into five sections. Section one is the introduction. Section two cites the literature review that analyzes the environmental impacts of coal fired power plants in the global scenario. Section three discusses the study area and the methodology. Sahiwal coal fired power plant is selected as the study area. Section four discusses the results and

discussion of the subject study. The conclusion of the paper presents brief policy recommendations that may be adopted to ensure environmental sustainability of CPEC portfolio in specific and Pakistan in general.

2. LITERATURE REVIEW

Coal fired power plants have been constructed and operated across the regions to fulfil the energy demand of the respective economy. These plants, however, have created environmental problems which have been mitigated with suitable mitigation measures. This section highlights some of the global cases in this regard.

Russia has world largest coal reserves. Almost 70% of coal is extracted through open mines. Coal industries employ around150, 000 people. Russia has almost 170 plants that run on coal and 80% of these plants are 20 years old. These plants have an efficiency of 23 percent. Through plants that employ new technology, efficiency rate can be increased to 46%. Coal power plants are subsidized by the government in Russia and this depicts strong dependence on coal fired power plants for energy generation. Despite the dependence on coal for energy generation, the environmental concerns remain a grave issue. Each year, 360 million cubic meters of air is blown into Russian underground mines, and over 200 million tons of water is pumped out. At open-cast mines, between 300 million and 350 million tons of rocks are shifted into waste dumps.

Coal acts as a source of pollution in all stages of its usage (drilling, blasting, processing, transportation etc.). Open-cast mining results in pollutants like solid particles, inorganic dust containing silicon dioxide, coal ash and black carbon (soot). Every year in Kemerovo, Russia, 1.5 million tons of pollutants are emitted into the atmosphere, and over half a million cubic meters of polluted wastewater are discharged. Coal mining affects not just the area immediately around the mines, but also the neighboring areas. Cities in mining areas, such as the Kuzbass and Vorkuta regions have high concentrations of suspended particles in the air causing health problems. Coal mining and improper handling also raise the levels of lead, cadmium, mercury and arsenic in soil and is thus found in locally grown crops. Coal is associated with respiratory alignments and health risks especially among women and children. The environmental consequences of coal fired power plants and the growing energy needs remain a major concern for the government. The immediate step being taken is the shift from sub critical to super critical technology and move gradually to renewable energy.

Throughout history, Germany has also remained dependent on coal which had to be imported and only recently it is moving towards renewables. Coal mines and industries occupy huge

land parcels which become dry and barren with the passage of time and can never be reclaimed. Thus coal mining activities impact environment negatively, degrade soil, deteriorate air quality and disturb ground water quality. Germany has been dependent on fossil fuels and has recently started moving towards renewables. Coal industries remains its major industry. The mines occupy acres of land that cannot be re used for cultivation, as the original ecosystem never fully recovers. Mining of coal is related to number of environmental consequences.

Currently, Germany is trying hard to phase out coal and move towards renewables. Germany's extraction of hard coal will end in 2018. Currently coal contributes 18% and renewables contribute 26 percent to the energy mix. To discourage coal emissions, besides renewables, the German government is taking steps like imposing "cli-mate levy" on old, emissions-intensive power plants. Shifting from coal to renewables is threatened by the existence of pressure groups that have vested interests in the coal business. However, the environmental consequences of coal fired power plants have made the public raised hue and cry and German government is being pressurized to move to renewables. Accordingly, Government of Germany has also drawn out subsidies from coal sector, and this is making the business unprofitable.

Mishra (2003) analyzes the environmental impact of coal for India. Coal is the only natural resource and fossil fuel available in abundance in India. It is used widely for producing electricity. India generates 90,000 MW energy through coal, remaining through hydel sources and minor amount is generated by nuclear power plants (NPPs). Problems associated with the use of coal include presence of high ash content which is damaging to the environment. Most of the coal has to be transported from large distances through trains which run on diesel thus contributing to pollution. To reduce environmental impacts, it is imperative to increase the installed generation capacity, diversify energy mix, and use power plants with new technology.

Chen & Xu (2008) assess energy and clean coal policies for China. Coal has been an abundant source of energy for China. However, the critical issue remains of environmental problems associated with its usage. In China, coal is responsible for 90% of the SO_2 emissions, 70% of the dust emissions, 67% of the NOx emissions, and 70% of the CO_2 emissions. Though China is moving massively to renewables, coal continues to dominate the energy supply. To combat the environmental challenges. China is using latest technologies to reduce emissions. This include high efficiency combustion and advanced power generation technologies, coal transformation technologies, IGCC (integrated gasification combined cycle) and carbon capture and storage (CCS). As a next step, most recent orders of coal-fired power plants are made on supercritical and ultra-supercritical systems and 150 coal plants are currently operating on this technology (Chen, 2010). China is also investing in research and development for deployments of latest technologies. Environmental monitoring for coal fired power plants needs to be further strengthened with fines imposed on non-compliers. The need

of the hour is to gain public and industrial support in the development and deployments of latest technologies, as only through latest technologies the need of energy and reduced emissions can be fulfilled at the same time.

To reduce the environmental impact and to meet the energy needs, the most pristine strategy adopted is converting sub-critical coal fired power plants into super-critical power plants in China. Supercritical and ultra-supercritical coal power generation technologies operate at higher temperatures and pressures than the conventional pulverized coal combustion (PCC) plants, thereby achieving high efficiencies

Reference to the Table 02-appendix that shows that countries around the world are opting for super critical technology over the subcritical technology mainly because it reduces emissions and has lower operating costs. (Abaasi, Mehmood, Kamal, n.d Policy Paper SDPI). A brief review of coal fired power plants across the globe demonstrate that coal is widely used for energy generation by the developed world. The heavy usage of coal has provided a stable supply of energy that has resulted in economic development and has moved millions out of poverty. On the flip side, coal plants have also contributed to environmental degradation and has raised serious issues for the governments to deal with. One of the pertinent solution adopted to reduce potential environmental impacts of coal fired power plants is the usage of latest technological advancements. Super critical coal fired power plants are preferred over the conventional power plants as they have greater efficiency and reduced emissions. The gradual phasing out of non-renewable energy sources, usage of latest technological advancements, removal of subsidy, and imposition of taxes are the general policy measures adopted by the governments to discourage usage of coal as source of energy. However, it is also to be remembered that these policy measures are adopted only when the country has achieved a certain level of economic stability. Thus implementation of these measures and phasing out of coal as a source of energy differ from country to country.

3. STUDY AREA & METHODOLOGY

The major focus of the CPEC is on energy sector of Pakistan. The Table 03-Appendix demonstrates prioritized and actively promoted energy projects under CPEC portfolio that are using coal as a source of power generation. Sahiwal coal fired power plant is one of the early harvest energy projects of CPEC portfolio. The project is launched by Hauneng Shan-dong and Shandong Ruyi Technology Group Co limited with the share of 50% each. The operational responsibility of the project is with Shandong Huaneng Company.The plant is located within the radius of 12 miles from the city of Sahiwal. The project started with an investment of 1.44 billion rupees in July 2015 and has been completed in 22 months. It is a 2*660 MW project, uses imported coal and utilizes supercritical technology for energy generation. The plant is first of its kind in Pakistan. Currently the plant is operational and is connected to national grid. While using the most advanced technology, it has the capacity to generate over nine billion KW of electricity annually, which is enough to meet the demand of over 10 million

households. Sahiwal coal power plant is expected to fill the one quarter deficit of the power energy crisis in Pakistan.

Sahiwal coal fired power plants operates at supercritical technology. This offers greater efficiency than older sub-critical designs and have lower emissions. In three defined stages the coal is transformed into electricity. The first conversion of energy takes place in the boiler. Coal is burnt in the boiler furnace to produce heat. Carbon in the coal and oxygen in the air combine to produce carbon dioxide and heat. The second stage is the thermodynamics process. The heat from combustion of the coal boils water in the boiler to produce steam. In modern power plant, boilers produce steam at a high pressure and temperature. The steam is then piped to a turbine. The high-pressure steam impinges and expands across a number of sets of blades in the turbine. The impulse and the thrust created rotate the turbine. The steam is then condensed and pumped back into the boiler to repeat the cycle. To condense the steam each unit is provided with giant natural draft cooling tower used to cool down the cooling water. Sahiwal power plant uses two natural draft hyperbolic type cooling towers to cool the circulating water used for condenser cooling. Since water resources are limited, power plants have no other options but to adopt the cooled cooling system with cooling towers. Hot water from the condenser pours down from the top and the air moves up from the bottom to top removing the heat in the form of water vapors disappearing in the sky. In the third stage, rotation of the turbine rotates the generator rotor to produce electricity based on Faraday's principle of electromagnetic induction.

The current study is exploratory in nature. The methodology includes field visit and focus group discussions with officials of the concerned departments for collection of first hand primary data. The content analysis of official reports and review of journal articles have also been carried out for collection of secondary data related to the research topic. Firstly a content analysis of existing official reports and studies was made to know about the potential environmental impacts and mitigation strategies for coal fired power plants. Secondly focus group discussions with concerned officers of related departments and organizations such as Punjab Environmental Protection Agency (Punjab EPA) and Sahiwal Coal Plant Authorities were conducted in order to know about environmental measures and compliance of Sahiwal Coal Plant. The results of all these reviews, discussions and meetings are presented in Section-4.

4. RESULTS & DISSCUSSION

4.1ANALYZING THE POTENTIAL ENVIRNOMENTAL IMPACTS & PROPOSED MITIGATION STRATEGIES

The first objective of the study was to assess the potential environmental impacts of the Sahiwal coal fired power plant. The potential impacts both positive and negative explored through literature as well as focused group discussions with the relevant stakeholders are listed

in the below table. In case of adverse impact on environment, culture, or society at large, suitable mitigation measures are also suggested.

The potential positive impacts of sahiwal coal plant are as follows:

Electricity Generation: Sahiwal power plant is expected to generate maximum of 1,320 MW of electricity. This will substantially reduce electricity deficit, and will thus improve electricity supply and raise overall standard of living.

Employment Opportunities: Electricity generation will help industry in producing more output and in being more efficient, which in turn will have a ripple effect of increasing local employment. During the construction phase of the project, the requirement of engineers, workers, laborers, technicians, para-professionals etc. will help to generate small businesses (for example, shop keeper's etc.) and increase income. Locals will also have the opportunity to diversify their incomes by being employed during the construction period of the project. As per estimate provided by SEPCOII the peak number of workers required will be about 4,000 during the construction phase and about 250 during the operation phase. Furthermore, these figures exclude the other staff required for the loading and unloading of coal from the port and at destination, as well as staff working during the planning and design phase. Employment opportunities in the sector of transportation and handling will also arise. Hence, there will be large number of employment opportunities mainly for the local people, during the construction phase of the project.

Increase in Businesses: With the influx of laborers for the proposed project, there will be more opportunities for small scale business such as small grocery shops, small cafes (khokas), and vehicle tuning, tyre- repair shops etc. Additionally, the generation of electricity will reduce load shedding and contribute towards more business in the country.

Increased Accessibility: To support the Sahiwal coal fired plant, a railway track will be extended from the main track into the proposed power plant, and roads will also be upgraded to accommodate the influx of workers/laborers and other equipment and machinery to be transported to the proposed power plant. Moreover, the proposed Project is based on imported coal for which the coal will be transported through the locomotive trains of Pakistan Railway Department from the Karachi port up to the Project Site near Qadirabad. Hence the infrastructure of the Railway Department which is currently in disarray will be upgraded. It is estimated that about six freight trains will be required daily on the tracks to fulfill the need of the power plant which will add to the revenue generation of the railway department.

Labor & social welfare: The coal fired power plant will be equipped with basic amenities such as schools for children, hospital/health clinics, local shops etc. This will facilitate the employees and business for investors and the local community. The plant may result in overall rise in standard of living of people of the area.

The potential impacts on environment & mitigation measures that can be adopted are as follows:

Land Acquisition for the Plant: The construction of Sahiwal coal plant involves acquisition of land which may be owned by different departments of government or general public. To date, most of the land acquired for Sahiwal Coal plant is owned by government, and only some has to be acquire from private individuals thus the impact of private land acquisition is not of significant nature. In case land acquisition is needed offering compensation as per the LAA, 1894 and in consultation with the affectees can be done.

Impact on water resources: The construction and operation of sahiwal coal plant will impact the water resources. The plant will require water from the nearby canals which may disrupt the flow of water to nearby agricultural land. Mitigation option that may be adopted is to develop new channels and paths to irrigate the agricultural land adjacent to the proposed plant boundary. Similarly the contamination of irrigation water in tributary canals and water courses can also occur. Sewage and wastewater may be generated. If the generated sewage is not properly treated or disposed of, this may contaminate the surface and might affect the groundwater resources apart from soil contamination. Contamination of canal water can have highly adverse impacts on agricultural productivity. Mitigation measure that may be adopted is to avoid sewage, untreated wastewater, chemicals and oil spillage from draining into the irrigation channels nearby during construction activities. Best management practices and good house-keeping should be done. In case of emergency spills, Standard Operating Procedures (SOPs) should be developed and strictly followed by contractor. The chemicals and other oils shall be disposed of at designated places or supplied to other industries as raw material to avoid contamination. Measures should also be taken to remove settle-able solids prior to discharging water from the site include the use of sediment sumps. Any visible oil and grease can be skimmed off the surface using absorbent pads. Wastewater treatment system needs to be selected carefully considering the characteristics of wastewater generated from the power plant. The raw water reservoir should also be managed properly to ensure non contamination.

Soil Erosion: Improper management of construction activities may result in soil erosion. Construction works will temporary change the grading of the natural ground surfaces and due to instability of top soil surface, soil erosion may occur. Mitigation measures that can be adopted is the deployment of good engineering practices that may help in controlling soil erosion at the construction site areas. Proper arrangements for drainage of water in the washing yards and quarry areas such as drainage channels should be done. Quarry management plan and Waste Management Framework (WMF) may also be developed.

Soil Contamination: It is imperative to handle carbon based compounds with utmost care, as almost all of them are poisonous. Proper care is required to avoid spillage during storing, handling and transportation as these may spill and contaminate the soil. The other waste

generated is mostly composed of rubbish, ashes and residues, demolition materials and hazardous wastes. These wastes will be generated due to the construction activities and materials used for construction. Indiscriminate disposal of solid waste will contaminate the soil. Another source of soil contamination is the discarded construction materials that include chemicals, wires, plastics, cut pieces of pipes, pieces of empty fuel and lubricants tins and cardboard packing and other discarded materials. Some of the mitigation measures that may be adopted to avoid soil contamination are:

- All chemicals should be provided proper storage and leakage should be avoided.
- It is imperative to educate workers regarding Material Safety Data Sheets (MSDS) of each chemical used at site. Labor should be properly educated and trained to handle chemicals.
- Proper disposal of solid waste should be ensured and in no way should it be openly thrown. All waste may be segregated in organic and inorganic and disposed accordingly.
- Regular clean-up of scrap material saw dust, rags, oil, paint, grease, flammable solvents and other residue of construction operation shall not only remove or reduce the fire hazard, but shall promote general safety at the same time.
- Mitigation measure to be adopted is the development of proper storage place for each type of material to be used during the construction should be built to avoid the development of water ponds. Left over material should be disposed of immediately at designated places

Impacts on Ambient Air and Noise: Since most of the machinery will use diesel as fuel, emissions will mainly consist of carbon monoxide (CO), particulate matter (PM), nitrogen oxides (NOx) and hydrocarbons (HC). Fugitive dust will be produced by earth moving activities, excavation, haulage, heavy machinery movement and construction of roads within the power plant. All types of emissions are damaging for the respiratory system and can lead to decreased lung function, respiratory disease and even death. During operation phase, emissions will also be generated. As coal is the main fuel of the power plant, its composition plays a major part in the emissions of the various gases such as SO2, PM10, Hg etc. The coal composition for the proposed power plant indicate that the design coal will have Sulphur content of 0.66%, ash content of 5.29% and calorific value of 5,027 kcal/kg. This shows that the coal is low Sulphur, and low ash coal. All construction activity will also generate noise and lead to noise pollution. Mitigation measures that may be adopted to ensure air quality and decrease noise level are as follows.

- Emissions points from concrete mixing plant or generators may be controlled by using cyclones. Diesel operated equipment and vehicles should be well maintained to minimize particulate emissions. Maintenance will include changing the lubricating oil, changing air and fuel filter, cleaning the fuel system, draining the water separators and proper tuning.
- Labor may wear Personal Protective Equipment (PPEs) in to save their health.

- Regular sprinkling of water may reduce dust emissions.
- Tuning of vehicles should be made mandatory to reduce the emissions of NOx, CO, HC and TSP to ensure that these emissions do not exceed NEQS limits of Motor Vehicle Exhaust Noise. All vehicles should carry a fitness certificate.
- All kinds of construction material like soil and sand may be kept covered with tarpaulin.
- All the provisions of NEQS, 2010 based on the zone classification should be strictly enforced.
- Plant area should be fenced and noise barriers should be added.

Impacts on Ecological Environment: Loss of vegetative cover in the form of removal of trees, shrubs and fruit plants may occur. It is estimated that about 1200 trees will be removed before the start of construction. The construction machines may generate pollutants and particulate matter such as TSP, NOx, SOx etc. which may adversely affect flora and fauna in the area. Due to noise and vibration during construction phase, reptiles, rodents and birds may also migrate from the area. Those species which do not shift may get killed by machines. Mitigation measures that are adopted is that ten (10) trees will be planted as a replacement of each of the tree affected and a total of 12,000 trees will be planted. Trees may be raised all along the roads and paths in the power plant area. The impact on reptiles, rodents and birds remain confined to a low level on account of proportionately small area for Project installation and may be avoided with vigilant movement of heavy machinery and equipment during construction.

Storage and Handling of Coal: For the proposed coal fired power plant, the hauling and storage of coal may have an impact. On an annual basis, about 6 million metric tons of coal will be used to fire the super critical boilers and will be coming into the plant via train tracks every day. Colossal stocks of coal would be maintained at plant site for uninterrupted operation. Improper handling and storage can result in coal particles contaminating the soil, and there is also a risk of fire breaking out. Improper handling and safety of coal may be hazardous for the plant as well as the residents living in the residential colony and/or nearby in the vicinity of the proposed Power Plant. Mitigation measures that may be adopted are Layout and design of coal stocks as per international standards should be done to ensure that hazard from the coal stocks is mitigated. Moreover, adequate modern firefighting facilities shall be made available at all coal stocks and plant. In addition, to prevent fires from starting, public education to plant employees and conducting regular inspections of firefighting facilities shall be ensured for their adherence to the local fire codes. A fire protection system should be in place which may include water supply systems, clean agent extinguishing, sprinkler systems, stand pipes and hose stations, and hand-held extinguishers.

Solid Waste (Coal Ash): One of the major solid wastes generated from the power plant's operation is the residual coal ash (Fly and Bottom Ash). This coal ash is a product of coal combustion. The handling and ultimate disposal of coal ash will be an important issue, and

which may have significantly high impacts if not properly dealt with. The potential dust from the coal piles may be controlled by a combination of water sprays, and wind screens.

Loss of Livelihood: The local communities may suffer loss of livelihood. Families may be displaced from their land for plant construction and operation impacting their social welfare. As per LAA, no provisions for the loss of livelihoods are provided. However if any such losses occur it should be compensated. Livelihood assistance should be provided to the affectees like loans, job assistances etc.

4.2 ASSESING EMVIRNOMENAL MEASURES & COMPLIANCE AT SAHIWAL COAL FIRED POWER PLANT

Against the previous section that highlights the potential environmental impacts that may arise during the pre-construction, construction and operation of the plant, it is now imperative to assess the environmental measures that are being taken by the relevant authorities at Sahiwal Coal Fired Power plant. The preceding section describes some of the environmental measures that have been taken at the plant. Moreover, do these measures taken make the plant environmentally compliant? This is assessed by comparing the emissions of different matters and gasses with the National Environmental Quality Standards (NEQS) of Pakistan.

In case of coal fired power plants, flue gases from the boiler are normally laden with harmful pollutants such as Oxides of Nitrogen (NOx), Mercury (Hg), Oxide of Sulfur (Sox) and Particulate Matter (PM). For Sahiwal Coal fired power plant, suitable environmental protection measures have been taken. Following are the environmental protection measures taken by the company to prevent pollution and ensure environmental friendly operation of the power plant. These environmental protection measures remove the pollutants before being discharged into the atmosphere and make the emissions environmentally safe.

Electrostatic Precipitators (ESPs): Electrostatic Precipitators (ESPs) are filtration devices that remove fine particles like dust and smoke, from flowing gas. BEH518/4-4 horizontal ESP for coal-fired boiler is used for Sahiwal Plant. Boiler is provided with two double-chamber four-field low temperature ESPs. The ESP uses high voltage DC field so that the dust in the flue gas can enter the field in corona status in the direction perpendicular to the electric line. The dust particles are charged electrically in collision charge and diffusion charge mechanisms and are absorbed to the collecting plate under the action of the electric field force and the electrostatic force. Then the dust on the collecting plate falls to the dust storage device under the action of rapping device and self-gravity and then is transported to the ash silo through ash conveying system so that the flue gasses purified through the ESP. From ESP the flue gases move to FGD. The efficiency of ESPs is maintained at 99%.

Flue Gas Desulfurization (FGD): Desulfurization technique used in Sahiwal power plant is wet spray limestone-gypsum technique in which slurry is forcedly oxidized in situ. The flue gas from boiler goes into a cryogenic heat exchanger to cool down below 95oC. After being treated in electrostatic precipitators (ESPs) and pressurized by induced draft fan, flue gas from boiler enters FGD system. The flue gas entering FGD system flows into absorber via ducts. In the absorber, flue gas flows from bottom to top and limestone slurry is sprayed from top to bottom, allowing for full contact and chemical reaction between limestone slurry and flue gas. Finally it is emitted to atmosphere through clean ducts of FGD system and stack. The efficiency of FGD is maintained at 95%.In this way, more than 90% of SO2 in flue gas is removed.

Parameter	**Plant Emissions**	**NEQs**
SO2:	95.72mg/Nm^3	1700mg/Nm^3
Dust	12.56 mg/Nm^3	500mg/Nm^3

Low NOx Burners: Sahiwal power plant uses Low NOx combustion Technology in boiler; Pulverized low NOx burners are utilized. Low NOx Burners used for Plant are Fuel-Air Mixing. Rate & Optimized Combustion technique is used for the control of NOx. Low NOx burners are used to control production of oxides of nitrogen at source. The concentration of NOx in emission is below the environmental standards. The NOx emissions form the Plant is given below:

Parameter	**Sahiwal Plant Emissions**	**NEQs**
NOX	137.53 mg/Nm^3	1200 mg/Nm^3

Chimney Height: The height of a chimney influences its ability to transfer flue gases to the external environment via stack effect. Additionally, the dispersion of pollutants at higher altitudes can reduce their impact on the immediate surroundings. The far surrounding is minimally impacted as concentration of gases is reduced by the time it reaches there. The height of the chimney for this project is 180m which has been designed after studying the wind patterns, climate and other related factors.in case of subject plant, the height of chimney is 180 metre.

Mercury Control Measures: The Company has adopted the technology to remove the mercury from the emission. This series of technology is comprised of Low NOx Burners to avoid the Oxidation of the Mercury, Electrostatic Precipitators (ESPs), FGD System, Chimney Height. During combustion, the mercury (Hg) in coal is volatilized and converted to elemental mercury (HgO) vapor in the high temperature regions of coal-fired boilers. As the flue gas is cooled, a series of complex reactions begin to convert HgO to ionic mercury (Hg2+) compounds and/or Hg compounds (Hgp) that are in a solid-phase at flue gas cleaning temperatures or Hg that is adsorbed onto the surface of other particles. In ESPs the Hg particulates are captured. In FGD the Hg2 particulates are captured, soluble Hg2+ compounds are also controlled II in FGD Systems.

Ambient Air Quality: The emissions of the plant are being monitored constantly by the company as per the EPD Punjab instructions. Continuous Emission Monitoring System (CEMS) & Ambient Air Quality Monitoring Systems are installed by the Company for the monitoring purposes.

Continuous Emission Monitoring System (CEMS): The Company has set up continuous Emission Monitoring System (CEMS) from Thermo Scientific Company for monitoring of the Particulate Matter (PM), SOx, NOx, CO, mercury, etc. emitting from the chimney of power plant. The purpose is to keep the emissions well below Punjab Environmental Quality Standards.

Parameter	**Emissions**	**NEQs limits**
SO2	95.72 mg/Nm^3	1700 mg/Nm^3
NOX	162.11 mg/Nm^3	1200 mg/Nm^3
Hg	.0076 mg/m^3	10 mg/Nm^3
Dust	12.56 mg/Nm^3	500 mg/Nm^3

Continuous Emission Monitoring System (CEMS)-Readings taken on Nov 08. 2017

Ambient Air Quality Monitoring Station**:** Project Company has also set up Ambient Air Quality Monitoring Station 1 km outside the power plant. Site has been selected by the EPA Punjab. The purpose is to closely monitor the ambient air quality. The results of ambient air quality monitoring are reported in the table below.

Pollutant & Averaging	****Sabinal Plant Area**	**US**	**JAPAN**	**WHO1**	***CHINA I**	***CHINA II**	***CHINA III**	**WORLD BANK**	**PAKISTAN 2013**
SO_2µg/m^3									
24 hour average statistics	**25	365	104	125	50	150	250	125	120
NO_2µg/m^3									
24 hour average statistics	35		75-113		80	80	120	200 Hourly	80
*China I: Residential Area, *China II: Residential Area, *China III: Residential Area									

The table clearly demonstrates that SOx and NOx emissions are better than the requirements set for China residential area and also better than World Bank prescribed limits.

Ash & Coal Handling: Ash is a byproduct of coal plants. Ash generated in power plant is about10-15% of total coal consumption. Improper handling of ash at a power plant can result in release of ash dust which is harmful for the environment. There are two types of ash in coal power plants;

- Bottom Ash

- Fly Ash

Project Ash handling system consists of Dry Ash Handling system, wet ash handling system and both are stored in the Ash Yard.

Bottom Ash Handling: Ash generated below furnace of the steam generator is the bottom ash. Bottom ash resulting from the combustion of coal in the boiler is collected is submerged, scraper conveyer already filled with water. Bottom ash is then dewatered and moved to the slag silo, then to ash yard through trucks. Every boiler is equipped with one slag silo, with an effective volume of not less than 80m3.

Fly Ash Handling: Ash captured in the ESP, which got carried out with the flue gasses is collected in ESP storage buckets. Fly ash extracted from ESP hoppers is passed on through pipes to ash storage silos. Ash stored at silos is shifted to Ash yard through hopper trucks. Water sprinkling is carried out in every two hours in the Ash storage yard through watering carts;

Ash Yard: According to the Environmental Impact Assessment approval, seepage control measures are also taken. Ash yard is designed according to Chinese standards, dam slope and ash fields laying of polyethylene geo-membrane (two cloth one membrane) of the design to (artificial barrier layer) has the equivalent permeability coefficient of1.0x10-7cm/s and 1.5M thick clay layer to control seepage.

Coal Handling: Sub-bituminous coal is being used for the project. From Karachi coal is transported through trains - each train mainly consists of 40 wagons having weight of 2400 tons. Firstly, the train enters the plant and passes from the dynamic weight scale. After that, train enters the trench at a time 20 wagons placed on trench. After placing the wagons, they are opened one by one, the coal falls in unloading ditch, down the ditch there are set of conveyors, each conveyor has 2 impeller coal feeders with the help of these feeders, plant management feed coal from ditch on the conveyors. After that the conveyors system starts 7 sets of conveyor are being used, with the help of these conveyors coal is stored in coal yards or can directly send to the coal silos for burning. Mist Sprinklers are used for the coal unloading ditch. The coal conveyer belt is covered so that no coal dust is released during transportation to the coal stack yard.

Coal Yard: For storing and reusing the coal, coal stacker and re-claimer are used. To avoid coal particles from going into the air, water is auto sprinkled on the coal by spraying guns, there are 48 spraying guns installed in coal yard. Spray guns are installed to timely sprinkle the water on the top of coal pile to ensure the surface moisture about 6% to effectively reduce the coal dust. Coal water tank is installed that will collect the wastewater after the separation of coal to reuse, which can effectively reduce the influence on the groundwater around the power plant. According to the EIA requirements, the Company is setting wind dust-controlling

nets around coal yard, having height 2 m higher than the coal pile, which can effectively control he coal dust.

Tree Plantation: To ensure environmental sustainability, tree plantation has been included in the layout of plant. It has been planned to plant 30000 trees of the various classes within and outside the plant area. In order to improve the ecological environment, continuous efforts are applying to select the trees of both Chinese and Pakistani origin that can be planted depending upon their ornamental and ecological growth based on Pakistan's climate, with an effective volume of not less than $80m^4$.

5. CONCLUUSION AND POLICY RECOMMENDATIONS

Coal has been a global source of energy. The developed countries have used it as a source of energy for long and have developed sound economies based on a stable supply of energy. Though the world is moving towards renewables, coal still contribute 40% of the global energy mix. Pakistan has been an energy deficit country from the last two decades. Major emphasis under the CPEC portfolio is on removal of this bottleneck. These energy projects are imperative to move Pakistan out of energy deficit, however most of the energy projects are based on coal and this has raised serious concerns on the environmental front. With this background, this paper selects Sahiwal Coal fired power plant as a case study. The subject plant is the first one to be operational under the CPEC portfolio. Therefore, this paper reviewed the potential environmental impacts of the subject plant and suggested mitigation measures that may be adopted to ensure environmental sustainability. Moreover, the paper also analyzed the environmental measures that are being taken at the subject plant and the environmental compliance is also assessed.

The potential environmental impacts for the subject coal fired plant were analyzed during pre-construction, construction, and operation phase. During pre-construction stages land acquisition appears to be an issue. However, it can be settled with negotiation and offering land compensation at government rates. During construction phase major issue may arise of soil erosion, degradation of water quality, and deterioration of air quality and creation of noise. These impacts may be curtailed with mitigation measures mentioned above. Besides these environmental impacts, the plant is associated with creation of positive impacts like increase in employment opportunities, electricity generation, revived economic growth, improved accessibility, labor benefits etc.

The second objective of the study was to analyze the environmental measures that are being taken at the plant and assess the overall environmental compliance of the plant. Regarding environmental measures that are being taken, results show that for reduction in emissions at the subject plant, various technologies are employed. These include super critical technology which is used to improve plant efficiency, reduce Carbon Dioxide (CO2) emissions, Nitrogen Oxide (NOx), and Sulfur Dioxide (Sox); and can be fully integrated with appropriate carbon

[4] Section 4.2 is based on the report of Punjab Power Development Board (PPDB), Energy Department, 2017.

capture technology. Moreover, technologies like ESP, FGD systems and other technologies in order to ensure compliance with NEQS are also implemented. With the help of latest technology, and other environmental measures being taken, the emissions of the subject plant are way below the NEQs. This shows that environmental compliance of the subject plant is ensured.

Besides the mitigation strategies suggested in the preceding section, some of the recommendations that may be followed/implemented to ensure sustainability of coal fired plants in specific and environment under CPEC portfolio are as follows:

- Pakistan faces serious energy challenges. To combat this, the government of Pakistan is implementing a comprehensive plan under CPEC to meet the future energy requirements through establishing the coal-based power generation facilities, which may further add to the environmental degradation of the country. However, GHG emissions from these coal-based power plants can significantly be reduced by the implementation of suitable environmental mitigation measures, like carbon capture, storage and the application of advanced combustion and related technologies. Employing state-of-the-art and highly efficient and low-carbon advanced technologies - deployed in the developed world and China - may also be helpful in this regard. China has established power plants that are based on ultra-supercritical technology in their country. Pakistan may also commission such technologies for power generation through future agreements under CPEC. Sahiwal coal fired power plants appears one example that has installed latest technology. The usage of coal as a source of power generation is the need of time; however, the usage of latest technologies such as ultra-supercritical technology can further significantly reduce emissions from the power plants being commissioned under CPEC.
- Under the Pakistan Environmental Protection Act, 1997/ provincial environmental protection acts, it is mandatory to conduct EIAs of development projects. The same legislative requirement may be followed for all CPEC projects with diligence (and in true letter and spirit) both at federal and the provincial levels. Moreover, Strategic Environmental Assessment (SEA) for CPEC related energy projects may also be employed. SEA is an analytical and participatory approach that is used to integrate environmental considerations into policies and plans and to evaluate the inter-linkages between economic and social considerations. As a tool, SEA is more effective than environmental impact assessment (EIA) while considering larger programmes. Hence, SEA for all energy projects under CPEC may be planned and carried out as an analytical, participatory and integrated approach to mainstream environmental considerations in CPEC portfolio. This will help evaluate the inter-linkages of environment, economic and social considerations.
- CPEC portfolio includes a number of projects related to renewable energy. The need of the hour is that these projects are completed with the latest technology. China is a leading producer of renewable energy technology and may help Pakistan in this regard.

- As compared to developed countries, Pakistan always had a low carbon footprint. It still has committed 20 % reduction in the projected GHG inventory for 2030, which is possible by utilizing domestic resources, as well as on receipt of some international financial assistances. For this purpose, comprehensive 'climate change mitigation' and 'climate change adaptation' plans related to energy projects under CPEC need to be developed and implemented at federal & provincial levels to achieve the above target.

REFERENCES

1. Arshad H. Abbasi, F. M. (n.d.). Coal-fired Power Generation in Pakistan: A Policy Paper. Pakistan: SDPI. Retrieved April 10, 2018, from http://sdpi.org/
2. Bhattacharjee, D. (2015). China Pakistan Economic Corridor (CPEC). Indian Council of World Affairs. Retrieved May 10, 2018, from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2608927
3. Board, C. I. A. (2010). Power generation from coal: measuring and reporting efficiency performance and CO2 emissions. CIAB International Energy Agency, Paris, Report: OECD/IEA2010, 1-114.
4. Chen, W., & Xu, R. (2010). Clean coal technology development in China. Energy policy, 38(5), 2123-2130.
5. De Gouw, J. A., Parrish, D. D., Frost, G. J., & Trainer, M. (2014). Reduced emissions of CO2, NOx, and SO2 from US power plants owing to switch from coal to natural gas with combined cycle technology. Earth's Future, 2(2), 75-82.
6. Coal Atlas, (2015), Heinrich-Böll-Stiftung, Schumannstr. 8, 10117 Berlin, Germany, Retrieved May 1, 2018, from www.boell.de.
7. Economic Survey of Pakistan 2017-2018. Islamabad: Government of Pakistan Retrieved May 10, 2018, from http://www.finance.gov.pk/
8. Leu, Z., Guan, D., Wei, W., Davis, S. J., Ciais, P., Bai, J. ... & Andres, R. J. (2015). Reduced carbon emission estimates from fossil fuel combustion and cement production in China. Nature, 524(7565), 335-338.
9. Mishra, U. C. (2004). Environmental impact of coal industry and thermal power plants in India. Journal of environmental radioactivity, 72(1-2), 35-40.
10. Ministry of Climate Change. (2016). Pakistan's Intended Nationally Determined Contribution (PAK-INDC) Report. Retrieved February 05, 2018, from http://www4.unfccc.int/ndcregistry/PublishedDocuments/Pakistan%20First/Pak-INDC.pdf
11. Rafique, M. M., & Rehman, S. (2017). National energy scenario of Pakistan–Current status, future alternatives, and institutional infrastructure: An overview. Renewable and Sustainable Energy Reviews, 69, 156-167.
12. Shahbaz, M. (2015). Measuring economic cost of electricity shortage: current challenges and future prospects in Pakistan.

13. Van Dijk, P., Zhang, J., Jun, W., Kuenzer, C., & Wolf, K. H. (2011). Assessment of the contribution of in-situ combustion of coal to greenhouse gas emission; based on a comparison of Chinese mining information to previous remote sensing estimates. International Journal of Coal Geology, 86(1), 108-119.
14. Zhu, L., Peng, P., Wang, X., & Fan, Y. (2018). Exploring optimal mitigation and adaptation investment strategies in China. *Climate Policy*, *18*(6), 781-793.

APPENDIX:

Table 1: Types of Technologies in Coal Fired Power Plants

	Efficiency Rate	CO2 Intensity	Coal Consumption	Steam Temperature
Advanced Ultra-Super Critical	45-50%	670-740gCO_2/kWh	290-320g	700˚C+
Ultra-Supercritical	Up to 45%	740-800 gCO_2/kWh	320-340g	600˚C+
Supercritical	Up to 42%	800-880 gCO_2/kWh	340-380g	Approx. 550˚C-600˚C
Subcritical	Up to 38%	≥880 gCO_2/kWh	≥380g	< 550˚C+

Source: Adapted from IEA, Technology Roadmaps, High-efficiency low-emissions coal-fired power generation, 2012

Table 2: Supercritical Plants around the Globe

Plant Name	Country	Total Capacity	Technology	Efficiency	USD Cost/KW	USD Cost/KW
RWE Power	Germany	1000	Ultra Super Critical	43.2	1175	1.175
Genesee 3	Canada	450	Super Critical	41	1100	1.1
Isogo New Unit	Japan	600	Ultra Super Critical	42	1800	1.8
Younghung	Korea	800	Super critical	43	993	0.993
Wangqu 1 and 2	China	600	Super Critical	41	580	0.58
Adani	India	1320	Super Critical	41.75		1.06

Source: IEA, 2014 "Fossil Fuel Power Generation, pg, 37-38"

TABLE 3: Coal Fired Power Plants Under CPEC Portfolio

S.NO	PROJECT NAME	FUEL	LOCATION	CAPACITY (MW)	Cost in USD million	Technology Used
1.	Port Qasim Coal Power Project	Imported Coal	Port Qasim, Sindh	1,320	1, 980	Super-critical
2.	Sahiwal Coal Power Project	Imported Coal	Sahiwal, Punjab	1,320	1600	Super-critical

3.	Gwadar Coal Project	Imported coal	Gwadar, Balochistan	300	600	-
4.	SSRL Coal Power Project	Coal local	Thar Block-I, Sindh	1,320	3300	Sub-Critical
5.	Oracle Thar Coal Power Project & Mining	Thar Coal	Thar Block-VI, Sindh	1,320	1300	-
6.	Rahimyar Khan Fuel Based Power Project	Coal	Punjab	1,320	1600	Super-critical
7.	CPHGC Coal-Fired Power Plant	Coal	Hub,Balochistan	1,320	1940	Super-Critical
8.	Engro Thar Block II 2×330MW Coal fired Power Plant	Local Coal	Sindh, Pakistan	660	2000	Sub Critical
9.	TEL 1×330MW Mine Mouth Lignite Fired Power Project at Thar Block-II	Local Coal	Sindh, Pakistan	660		Sub-Critical
10	Thal Nova 1×330MW Mine Mouth Lignite Fired Power Project at Thar Block-II	Local Coal	Sindh, Pakistan	330		Sub critical

Source: http://cpec.gov.pk/