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EIA Guidance for Coal Fired Power Plants in Pakistan

National Impact Assessment Programme

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Editor:
Sadia Rauf

Technical Support:
Netherlands Commission for Environmental Assessment (NCEA)

Facilitation:
Ahmad Saeed
Arfa Zaheer Azmat

Design:
Hasan Ruvi Zaman

Cover Photographs:
IUCN Pakistan

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IUCN Pakistan
National Impact Assessment Programme
House No. 2, Street 83
Embassy Road, G-6/4, Islamabad
Tel: +92 (51) 2271027-34
Fax: +92 (51) 2271017
www.niap.pk

Why and how to use this guidance?

In the next decade, Pakistan will invest in the planning, preparation, construction and implementation of several coal-fired power plants as a reaction to the current energy shortage crisis. These power plants will be developed in the framework of important energy initiatives that cover three provinces:

- The Gadani Energy Park in Balochistan;
- The Punjab Power Production Initiative in Punjab;
- The Thar Coal Project in Sindh.

Environmental and social impacts caused by the coal-fired power plant will vary from site to site and especially from region to region depending on the original geographical, environmental and demographical setup. However, it is possible to state that, in general, coal power production in Pakistan will pose important challenges in the following topics:

- Air quality: coal-fired power plants emit significant amounts of air pollutants such as particle matter, SO_2 and NO_x. The effect that these emissions will have on the surrounding air quality needs to be addressed in detail.

- Water: the demand for large quantities of water for cooling purposes needs to be managed taking into account previous water uses and its multiple users.

- Solid waste management: one of the outputs of coal-fired power plants is a large quantity of solid wastes. These solid wastes require an appropriate disposal facility close to the power plant.

- Climate change: expected effects of climate change such as droughts and heat waves may inflict additional stresses on the regular operation of a power plant.

It is important to mention that impacts from coal-fired power plants will occur in an already stressed environment. This fact highlights the importance of having clear and defined technical procedures to conduct an environmental impact assessment of coal-fired power plants.

The present guidance will provide support to provincial EPAs, financial institutions and civil society in addressing environmental and social concerns associated with such thermal plants. The Environmental Impact Assessment Guidance for Coal-Fired Power Plants in Pakistan is organized into 8 main chapters. This document was developed not only to be read comprehensively and linearly from A to Z but also to allow partial reading from special interest users:

- Do you need information on the EIA process in Pakistan, its legal framework and updated information about the Pakistani regulations for environmental assessment? -> read chapter 2.

- Do you want to obtain knowledge about coal and on the technical characteristics of coal-fired power plants, different types of combustion technologies available as well existing environmental control systems? -> read chapter 3.

- Are you somehow involved in the process of site selection for a coal-fired power plant? Do you want to identify the criteria that should be applied for a better decision? -> go directly to chapter 4.

- Are you somehow involved in the earlier stage of preparation or evaluation of an EIA of a coal-fired power plant and you need support for the scoping phase? -> read chapter 5.

- Do you need detailed information concerning a specific environmental topic? Do you want to have additional knowledge on potential impacts of coal-fired power plants, the data needed to develop a correct impact assessment and which assessment methods are already developed? -> read chapter 6.

- If you want information focused in a single environmental component you can read only a subchapter:

- Geology and soils -> read subchapter 6.2.1.
- Water resources -> read subchapter 6.2.2.
- Air quality -> read subchapter 6.2.3.
- Climate change -> read subchapter 6.2.4.
- Noise and vibrations -> read subchapter 6.2.5.
- Aesthetic resources -> read subchapter 6.2.6.
- Social-economical-cultural environment -> read subchapter 6.2.7.

- Do you need a compilation of measures that are currently applied to mitigate environmental impacts of coal-fired power plants? -> read chapter 7.
- Are you somehow involved in a tender for the preparation of an EIA of a coal-fired power plant? -> go to subchapter 8.1
- Do you need a detailed template to organize or evaluate an EIA of a coal-fired power plant and its Environmental Management Plan? -> go to subchapters 8.2 and 8.3.
- Do you want to expand your knowledge about coal-fired power plant and its environmental and social impacts? -> explore the reference list (chapter 9).

Following is the overall structure of the guidance:

1. Introduction
- Energy crisis in Pakistan
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1- Introduction

The Government of Pakistan (GoP) and IUCN, the International Union for Conservation of Nature, are jointly implementing the National Impact Assessment Programme (NIAP) that aims to contribute to sustainable development in Pakistan through strengthening the Environmental Impact Assessment (EIA) process and introducing Strategic Environmental Assessment (SEA) in national development planning. The Project has four implementing partners: Pakistan Environmental Protection Agency (Pak EPA) and Environment Wing (EW) of the Climate Change Division (CCD), Environment Section of the Planning Commission of Pakistan (PC), and IUCN Pakistan. The Netherlands Commission for Environmental Assessment (NCEA) has an advisory role in the Project and provides technical support. The Project is funded by the Embassy of the Kingdom of the Netherlands. The total duration of the Project is four-and-a-half years and ends in May, 2014.

The programme has the following expected outcomes:

- EIA procedures improved through the development of tools and guidance material and implementation of pilot projects.

- SEA introduced and piloted in planning processes and practice.

- Understanding and capacity for EIA and SEA enhanced.

- Effective programme management systems and mechanisms developed and introduced.

For further information, please visit **www.niap.pk**

As part of its strategy to carry out capacity building, develop tools and procedures, NIAP recognizes the unavailability of quality sectoral guidelines as one of the major constraints faced by the EPAs in adequately reviewing EIAs of large projects. Little attention has been paid towards the development of guidelines in emerging sectors that have national and international significance. The development of EIA Sectoral Guidelines for Coal-Fired Thermal Power Plants responds to the need and the increasing national priority given to this sector in the future.

The guidelines aim to strengthen Environmental Impact Assessment of proposed coal-fired power plant projects undergoing review by government officials, investors, proponents, non-governmental organizations, and the general public throughout the life of the projects. The Guidelines are intended to help users:

- Streamline the assessment process;

- Identify, avoid, prevent and/or mitigate potential adverse impacts; and

- Increase potential beneficial impacts.

1.1 The energy crisis in Pakistan

The growing Pakistani economy has been brought to a virtual stand-still due to the Country's acute power shortage in the recent years. Many industries (including the very significant textile industry) have been forced to shut down entirely or slow down their industrial production; and households in cities and villages alike are facing load-shedding of 12 hours per day in summer months. The power shortage that was estimated to be between 1,000 and 2,000 megawatt (MW) in 2007 is estimated to be in excess of 6,000 MW in 2013 (HBP, 2013); and electricity shortfalls reached a peak of 8,500 megawatts (MW) in June 2012 - more than 40% of national demand (NBR, 2013).

There are multiple reasons for the current energy problems in the country. In addition to actual supply shortfall, there are issues of financial mismanagement and governance weaknesses. There is no comprehensive and integrated energy strategy and an insufficient level of funding is available for investment in energy projects (NBR, 2013). In 2012, the figure for circular debt (induced by financial mismanagement) exceeded PKR 872 Billion (IPRI, 2013).

For the purpose of these guidelines, choosing a sub-optimum energy mix can be considered as the biggest reason for the current energy crisis. In fact there have been structural aspects of the energy sector in Pakistan that can be identified as the cause of the present day energy crisis. The start of Pakistan's energy crisis can be traced back to the 1990s. The introduction of the 1994 Independent Power Policy in Pakistan marked the privatization of the energy sector. The 1994 IPPs were very investor-friendly. However, the power supplied by IPPs was very expensive not only because they were all oil-based but, more importantly, because the agreements signed with them were not negotiated prudently, allowing them very high tariff and lavishing unnecessary guarantees. The same mistake was repeated while signing agreements for rental power in recent years. While approving projects for IPPs, no thought was given to keeping a cap on the capacity in line with demand projections, resulting in installation of excess capacity putting an extra burden on the consumer in the form of unutilized capacity charge (IPRI, 2013).

During 2011-12 Pakistan's total energy availability was 66.015 million tonnes of oil equivalent (mtoe), of which 45.251 mtoe (i.e. 68.54%) was indigenous production while 20.764 mtoe (31.46%) was imported. The domestic energy sources comprised natural gas, hydel power, about one third of our crude oil supply, and small quantities of coal and nuclear energy. Imported energy mainly comprised petroleum and petroleum products. The share of various energy sources in energy supply was as follows: Natural gas 49.5%, Oil 30.8%, Hydel energy 12.5%, Coal 6.5%, Others (Nuclear, LPG, etc.) 0.7% (IPRI, 2013).

The energy crisis is anticipated to worsen in the coming years due to increase in demand and a host of other factors on the supply side, the most critical of these being the depletion of natural gas reserves, which was the primary fuel for thermal power plants. The depleting natural gas reserves plus the failure to develop new hydroelectric energy resources has resulted in an increasing dependence of the country on imported fuel (HBP, 2013). And with fluctuating oil prices in the international market, the price tag on imported oil will increase significantly.

Pakistan is a country with enormous hydropower projects. But except for the development of Tarbela and Mangla as the two large hydropower projects in 1970s, Pakistan has not focused on developing these projects. One of the reasons for this has been the strong political opposition causing lengthy gestation periods of constructing large dams.

According to the Pakistan Energy Yearbook 2012, Coal is a minor source of energy production with a contribution of 6.6% (HDIP, 2012). Imported oil and natural gas featured at 30% and 48% respectively. In the context of contracting natural gas supplies and the major fluctuation of the imported oil prices, Pakistan is extremely vulnerable to these prices.

With the current government focusing on increasing the mix of coal in energy prices, the energy mix, it is predicted to help alleviate the energy problems in the country by adding relatively domestic and cheap energy with a medium gestation period.

1.2 Aim and purpose of the guidance

To support the implementation of the EIA regime in the country, several guidelines have been developed in the past. Some of the notable guidelines are EIA Guidelines 1986, EIA Energy Sector Guidelines 1992, EIA Guidelines for Oil & Gas Exploration in Environmentally Sensitive Areas 1997, Sub-sectoral Guidelines of twenty two sectors were developed by Khyber Pakhtunkhwa EPA, and Sub-sectoral Guidelines of three sectors developed by Balochistan EPA.[1] Landmark projects like the oil and gas development in Kirthar National Park have managed to bring EIA to the forefront but have also highlighted that there is still ample scope to strengthen its practice in Pakistan.

Recent years in Pakistan have seen a rise in prominence of coal as an input for thermal power generation plants; and future trends point towards an even higher bigger contribution of coal. In 2012, coal contributed 6.7% to the total energy supply mix and accounted for 10.4% of the total energy consumption (GoP, 2012). Over the last decade (2001-2011) an average of 2.5% of total coal consumption was utilized for power generation purposes. However, this share has gone up to 25.6% in 2011-12 alone.

A worsening power crisis, problem of circular debt and the discovery of approximately 175 Billion tonnes coal reserves in Thar (GoP, 2012) has offered an impetus to the federal and provincial governments to develop coal as a source of energy and power generation. Reports on the power sector in Pakistan all point towards the under-utilization of its coal reserves. By conservative estimates, these reserves can generate up to 100,000 MW of power (OSEC, 2011). According to the 2011-2016 strategic business plan of the Central Power Generation Company, the projected aggregate energy supply contribution of coal will go up to 13,331 MW by 2015 (CPGCL, N.D.).

In January 2014, the Government of Sindh (GoS) inaugurated the Thar Coal Block II Mining and Power Project which will involve the extraction of 3.8 Million tonnes and power generation of 660 MW; and in phase II, the extraction will go up to 13.5 million tonnes and power generation between 2400 MW and 3600 MW. (SECMC, 2014)

[1]More information on http://www.environment.gov.pk/info.htm.

The Government of Punjab (GoPb) has recently launched the Punjab Power Production Initiative 2014 to cater to the province that consumes approximately 68% of the country's total national grid electricity. The goal of this initiative is to add affordable and cheap coal based power in the national grid in order to rebalance the energy mix in line with the goal identified in the National Power Policy, 2013 (GoPb, 2014). Under this program, 6 locations have been identified in central and south Punjab where power projects of 660 MW each will be selected.

The last major sectoral guidelines for thermal plants were developed almost two decades ago in 1997 (GoP, 1997). The lack of sectoral guidelines has far-reaching implications, e.g. the US$900 Million thermal power plant that was sanctioned in February 2013 was initially not approved by the ADB due to the adverse and unaccounted environmental impacts associated with the use of Thar Coal.[2] Although international best practice on EIAs for thermal power plants do exist, e.g. the USAID EIA Technical Review Guidelines (USEPA, 2011) developed for Central America, there is no set of guidelines available for Pakistan. Once developed, these guidelines will provide the much needed support to provincial EPAs, financial institutions and civil society in addressing environmental and social concerns associated with such thermal plants.

These guidelines will be aimed at the following stakeholders:

Environmental Protection Agencies (Federal/Provincial/AJK/GB)	With the development of major coal projects in Sindh and Punjab, one of the main audiences will be provincial EPAs. As the regulator, they will have to review and approve/modify the EIAs submitted by the proponents. EPAs can use these guidelines to maintain an acceptable level of EIA quality and ensure standardization. The federal EPA can effectively use these guidelines for addressing transboundary issues arising from a large-scale coal power development initiative.
Multilateral donor organisations	A rise in the national government's interest to increase the country's energy mix in favor of coal will lead to more assistance in this sector. These local guidelines are synchronized with guidelines issued by major multilateral institutions.
Private Sector Proponents	Private sector proponents interested in investing in this sector can form an understanding of what is expected of them vis-a-vis EIA and other forms of environmental governance. It will be particularly helpful for them in understanding the resource commitment required to carry out a high-quality EIA and develop a post-EIA monitoring plan.
Environmental Consultants	Private sector proponents often engage environmental consultants to develop EIA reports. In the absence of an accreditation mechanism in the country, these guidelines will serve as a tool to enable standardization in reports that are submitted.
Civil Society	Civil society members (public) as well as NGOs can use these guidelines to ensure that there is public engagement in all coal-fired thermal power plants that are constructed. Due to its technical language, it is advised to engage the services of a professional in interpreting these guidelines.

1.3 Scope of the guidance

The purpose of this document is to provide detailed information about the potential environmental and social impacts arising from the construction and operation of coal-fired power plants in Pakistan. The type, dimension and project boundaries of the present guidance are clearly defined:

- Coal-fired power plants using any type of combustion technology;
- Coal-fired power plants with a production capacity above 50 MWth;
- Gate-to-gate system boundaries.

[2] http://tribune.com.pk/story/507021/coal-fired-power-plant-govts-about-turn-paves-way-for-900m-adb-loan/

This last statement means that upstream activities such as coal mining, coal import and transport by bulk carriers, coal handling in ports, as well as coal transport through land by railway, by road, by barge in an inland canal or by a slurry pipeline are out of the scope of this guidance. The same happens to activities downstream of the power plant such as electricity transmission to the national distribution grid. All these activities may demand significant infrastructure construction works and may require specific environmental impact assessment studies. Coal transportation, for instance, may be a significant source of dust emission and noise; special care has to be dedicated to the detection, prevention and control of spontaneous combustion of coal during transport.

IFC industry sector Environmental. Health and Safety guidelines[3] can be used as a starting point when developing an assessment that goes beyond gate-to-gate boundaries. The following sector guidelines could be of interest:

• Mining;
• Shipping;
• Ports, harbors and terminals;
• Railways;
• Electric power transmission and distribution.

Occupational health and safety prevention are also relevant for the successful completion of a project. Nevertheless these specific topics are out of scope of the present document. Specialized guidance and examples of reasonable precautions to implement in managing principal risks to occupational health and safety can be found in the IFC guidelines (IFC, 2007, 2008) that were used in the development of this document. These guidelines cover the following topics:

• General facility design and operation;
• Communications and training;
• Physical hazards;
• Chemical hazards;
• Biological hazards;
• Radiological hazards;
• Personal protective equipment;
• Special hazard environments;
• Monitoring.

1.4. Framework for the development of the guidance

These guidelines are a product specifically designed to support Environmental Impact Assessment of coal-fired power plant projects planned for Pakistan, drawing upon existing materials from several international organizations. These guidelines do not intend to be fully innovative, creative or unique.

Its preparation started with the identification of pre-existing resource material, standards, practices, laws and guidelines at international level related to assessing the environmental impacts from coal-fired power plants. Several reports dedicated to environmental impact assessment of project in general were identified as well as some publications devoted to the energy sector and to thermal power plants. No previous work concentrated only on coal-fired power plants was found.

From this research emerged a set of guidelines published by the International Finance Corporation (IFC) that were almost integrally adopted and included in the guidelines for Pakistan:

• IFC: Environmental, Health, and Safety General Guidelines, IFC – International Finance Corporation, World Bank Group, 2007.

• IFC: Environmental, Health, and Safety Guidelines for Thermal Power Plants, IFC – International Finance Corporation, World Bank Group, 2008.

These two documents include a detailed and almost comprehensive description of environmental concerns that must be tackled on any EIA of coal-fired power plants. IFG guidelines focus on air pollutant emissions, greenhouse gases (GHG) emissions, water consumption, effluents, solid waste, hazardous materials and noise.

Another important document that was used, was originally developed by the United States Environmental Protection Agency (USEPA) in cooperation with the US Agency for International Development (USAID) and the Central American Commission on Environment and Development (CCAD):

• USEPA: EIA Technical Review Guidelines: Energy Generation and Transmission, Volume I, CAFTA-DR, USEPA, USAID, EPA/315R11001, 2011.

[3]More information can be found in:
http://www.ifc.org/wps/wcm/connect/Topics_Ext_Content/IFC_External_Corporate_Site/IFC+Sustainability/Sustainability+Framework/Environmental,+Health,+and+Safety+Guidelines/

This last guideline expands its focus on biological and socio-economic-cultural resources and includes a description of the several activities of a project, type of impacts and how they affect the environment. However, it is relevant to mention that the guidelines prepared by IFC (2007, 2008) are fully integrated in the work published by USEPA. This is so because IFC guidelines, as part of the Sustainability Framework that articulates IFC's strategic commitment to sustainable development and as an integral part of the World Bank approach to risk management, were adopted by the financial institutions signatory of the Equator Principles. As a result of this process, almost any project requiring financial support will need to show compliance to the IFC guidelines.

Originally adopted in 2006, the IFC Sustainability Framework was updated in 2012. The updates reflect the evolution in good practice for sustainability and risk mitigation. They incorporate modifications on challenging issues that are increasingly important, including climate change mitigation and adaptation, and ecosystem services. Addition of climate change and ecosystem services in the Pakistani guidelines was based on recent work published by the European Union

- EU: Guidance on Integrating Climate Change and Biodiversity into Environmental Impact Assessment, European Commission, 2013.

The set of above mentioned reports are fully used and integrated in the Pakistan guidelines. As such, most often they are not cited along the text. Table 1-1 describes how these baseline documents were used in the preparation of the guidelines.

The overall approach to the development of this document was supplemented by the gathering of information on current practice, existing standards, guidance and norms related to environment, environmental impact assessment and energy production in Pakistan.

Preparation of the present guidance included the consultation of interested stakeholders in two different stages:

- Individual meetings by the end of January 2014 at the launch of the project to define the aim and objectives of the guidance;

- A consultation workshop involving a large number of participants after the publication of the first draft version of the guidance.

The full list of participants consulted is included in Annex B. Authors want to express their thanks to all experts who participated in the consultation meetings and their important contributions to the guidance outcomes.

Table 1-1 Baseline documents used in the preparation of present guidelines:
☑- primary source ☑ - secondary source

<table>
<tr><th>Resources</th><th>IFC 2007,2008</th><th>USEPA 2011</th><th>EU 2013</th></tr>
<tr><td>Geology and soil</td><td>☑</td><td>☑</td><td>-</td></tr>
<tr><td>Acoustic</td><td>☑</td><td>☑</td><td>-</td></tr>
<tr><td>Water</td><td>☑</td><td>☑</td><td>-</td></tr>
<tr><td>Aesthetic</td><td>-</td><td>☑</td><td>-</td></tr>
<tr><td>Air</td><td>☑</td><td>-</td><td>-</td></tr>
<tr><td>Climate change</td><td>-</td><td>-</td><td>☑</td></tr>
<tr><td>Terrestrial biological</td><td>-</td><td>☑</td><td rowspan="3">☑</td></tr>
<tr><td>Aquatic biological</td><td>-</td><td>☑</td></tr>
<tr><td>Socio-economic-cultural</td><td>-</td><td>☑</td></tr>
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Part 2 - The EIA Process in Pakistan

2.1 Environmental progress in Pakistan

The concept of sustainable development that has emerged in the past decades, aims to develop a new framework for economic and social development, while maintaining the environmental and ecological integrity for the present as well as future generations. The history of environmental studies for the development projects dates back to the National Environmental Policy Act of the United States of America (NEPA) in 1969. Following the US initiative, several countries implemented EIA systems, for example Australia (1974), Thailand (1975), France (1976), Philippines (1978), Israel (1981) and Pakistan (1983).

This indicates that in developing countries, the Asian countries started taking environmental measures very early, with many countries having an EIA system in place by the 1980s. The formalized arrangements for implementation of EIA system in Pakistan evolved over a period of fifteen years. It started with the promulgation of Pakistan Environmental Protection Ordinance (PEPO) of 1983 (repealed in 1997). EIA became mandatory for all new projects since July 1, 1994. Documentation of sectoral guidelines as EIA Package has been effective since 1997. Enactment of Pakistan Environmental Protection Act, 1997 in 2000 followed by government notification IEE/EIA Regulations, 2000. Finally, the National Environmental Policy in 2005, which describes integration of environment into development planning through implementation of EIA at the project level and promotion of strategic environmental assessment (SEA) as a tool for integrating environment into the decision-making process.

This section provides an overview of the policy framework and national legislation related to environment in the country with details on Initial Environmental Assessment (IEE) and Environmental Impact Assessment (EIA) regulation. The environmental law of the country provides standards and guidelines as a basis for the selection of appropriate pollution prevention/mitigation/control/disposal measures.

2.2 Constitutional provision

2.2.1 Prior 18th amendment

Before 18th Amendment in the constitution of Pakistan, the legislative powers were with federal parliament and legislative assemblies of four provinces of Pakistan. The fourth schedule of the constitution provided two lists of subjects. One is Federal Legislative List, which includes sub-subjects on which the federal government has legislative powers. The second is the Concurrent Legislative List that includes subject on which both, federal and provincial government have legislative powers. If a particular legislation passed by the provincial assembly comes into conflict with a law enacted by the national assembly, then according to the constitution, the federal legislation will prevail over provincial legislation to extend the inconsistency.

Environmental pollution and ecology were in the Concurrent Legislative List of the constitution, thus allowing both federal and provincial government to enact laws on this subject. However, only the federal government has enacted laws on environment and the provincial environmental institutions derived their power from federal law. Article 9 of the constitution defines the right of life as fundamental rights in these words: “No person shall be deprived of life or liberty save in accordance with law.”

2.2.2 Post 18th amendment

After the 18th Amendment in 2010, the concurrent list has been abolished and a limited number of subjects on the list have been included in the federal legislative list, whereas, the provincial governments have been given powers to legislate on the subjects transferred to provinces. The provision of the 18th Amendment, which has a direct impact on the subject of 'Environment' is section 101(3), whereby the Concurrent Legislative List and the entries thereto from 1 to 47 (both inclusive) have been omitted from the Fourth Schedule. The power to legislate and decide on the subject of “environmental pollution and ecology” now lies with the provincial government. Following subjects remain under federal jurisdiction.

2.3 National policy and administrative framework (Prior 18th amendment)

The Pakistan National Conservation Strategy (NCS), which was approved by the federal cabinet in March

1992, is the principal policy document on environmental issues in the country. The NCS outlines the country's primary approach towards encouraging sustainable development, conserving natural resources, and improving efficiency in the use and management of resources. The NCS has 68 specific programs in 14 core areas in which policy intervention is considered crucial for the preservation of Pakistan's natural and physical environment. The core areas that are relevant in the context of the proposed project are pollution prevention and abatement, restoration of rangelands, increasing energy efficiency, conserving biodiversity, supporting forestry and plantations, and the preservation of cultural heritage.

2.3.1 Organizational setup

The Pakistan Environmental Protection Council (PEPC) and the Pakistan Environmental Protection Agency (Pak-EPA) and provincial EPAs, are primarily responsible for administering the provisions of the Pakistan Environmental Protection Act, promulgated by the Government of Pakistan in 1997. The PEPC was responsible to oversee the functioning of the Pak-EPA. Its members included representatives of the government, industry, non-governmental organizations, and the private sector.

The federal and provincial environmental protection agencies were required to ensure compliance with the NEQS and establish monitoring and evaluation systems. They were also responsible for identifying the need for, as well as initiating legislation whenever necessary. The provincial EPAs had complete powers related to review and approve environmental assessment reports of projects undertaken in their respective jurisdictions.

2.3.2 Pakistan environmental protection act, 1997

The definition of environment can be drawn from the legal definition of environment. In Section 2(x) of Pakistan Environmental Protection Act, 1997 (1997 Act) 'environment' means - air, water and land; all layers of the atmosphere; all organic and inorganic matter and living organisms; the ecosystem and ecological relationships; buildings, structures, roads, facilities and works; all social and economic conditions affecting community life; and the inter-relationships between any of the above mentioned factors. The act empowered the Pak-EPA with the following:

- Delegate powers, including those of environmental assessment to the provincial EPAs.
- Identify categories of projects to which the IEE/EIA provision will apply.
- Develop guidelines for conducting initial environmental examinations (IEE) and EIAs and procedures for the submission, review and approval of the same.
- Develop environmental emission standards for parameters such as air, water and noise.
- Enforce the provisions of the Act through environmental protection orders and environmental tribunals headed by magistrates with wide-ranging powers, including the right to fine violators of the Act.

Under the provisions of the 1997 Act prior to 18th Amendment, the Pak-EPA has empowered four provincial EPAs to manage the environmental concerns of their respective provinces. The provincial EPAs can frame environmental regulations tailored to the requirements of their province, provided these regulations meet or exceed the minimum standards set by the Pak-EPA. They are also required to review and approve EIAs of all development projects undertaken in their respective provinces, including those projects implemented by federal agencies. PEPA 1997 now applies to Islamabad Capital Territory and has been adopted by the provinces with amendments until they pass their own laws.

> "No proponent of a project shall commence construction or operation unless he has filed with the Government Agency designated by Federal Environmental Protection Agency or Provincial Environmental Protection Agencies, as the case may be, or, where the project is likely to cause an adverse environmental effects an environmental impact assessment, and has obtained from the Government Agency approval in respect thereof."

2.3.3 Environmental impact assessment

Section 12 of the PEPA 1997 states the requirement of Initial Environmental Examination and Environmental Impact Assessment as:

Under Section 12 (and subsequent amendment) of the act, an IEE/EIA regulation[4] was notified on June 13, 2000. The regulation defines the categories of projects requiring an IEE in Schedule I whereas projects requiring

[4] The "regulations" are defined as regulations made under Act

an EIA in Schedule II. The proponents of the projects have to file an IEE and EIA with the concerned environmental protection agency (the Pak-EPA or provincial EPAs) and get an NOC prior to start of the project. If the project not listed in Schedules I and II have adverse environmental impacts, then the proponents shall file an IEE or EIA with the concerned environmental protection agency.

Coal-Fired Thermal Power Plants in Pakistan require an EIA/IEE. The relevant agency has to confirm that the document submitted is complete for the purpose of review within ten working days of filing. During this time, should the concerned agency require the proponent to submit any additional information, it will return the IEE or EIA to the proponent for revision, clearly listing those aspects that need further discussion. Subsequently, the relevant agency shall make every effort to complete an IEE review within 45 days and an EIA review within 90 days of filing. An EIA had to be submitted to one of the relevant federal or provincial EPA based on the location of the project. If the project was located in more than one province then Pak-EPA could grant approval with the consent of provinces. At the time of application, the project proponent is also required to pay a specified fee to the EPAs concerned.

The EIA process followed in Pakistan is provided in Figure 2-1.

2.3.4 Guidelines for environmental assessments:

Pak-EPA published a set of environmental guidelines for conducting IEE/EIA and the environmental management of different types of development projects:[5]

- Policy and Procedure for filing, review and approval of Environmental Assessments.
- Guidelines for the Preparation and Review of Environmental Reports, Pakistan Environmental Protection Agency, 1997.
- Guidelines for Public Consultation.
- Guidelines for Sensitive and Critical Areas.

A number of EIA guidelines were produced for the projects notified in the regulation to assist developers, consultants and regulators implement the law. These guidelines elaborate upon the environmental and social impacts of specific developmental projects and their mitigation procedures.

2.3.5 National environmental quality standards:

Coal-fired thermal power plants need to comply with the National Environmental Quality Standards (NEQS), 2000. NEQS[6] specify the following standards:

- The National Environmental Quality Standards (NEQS) for municipal and liquid industrial effluent
- NEQS for Industrial Gaseous Emission
- NEQS for Vehicle Exhaust and Noise
- NEQS for Ambient Air Quality
- NEQS for Drinking Water Quality
- NEQS for Noise

These standards also apply to the gaseous emissions and liquid effluents produced by generators, process waste etc. The standards for vehicles will apply during the construction, as well as operation phase of the project.

[5] http://www.environment.gov.pk/info.htm
[6] http://www.environment.gov.pk/info.htm

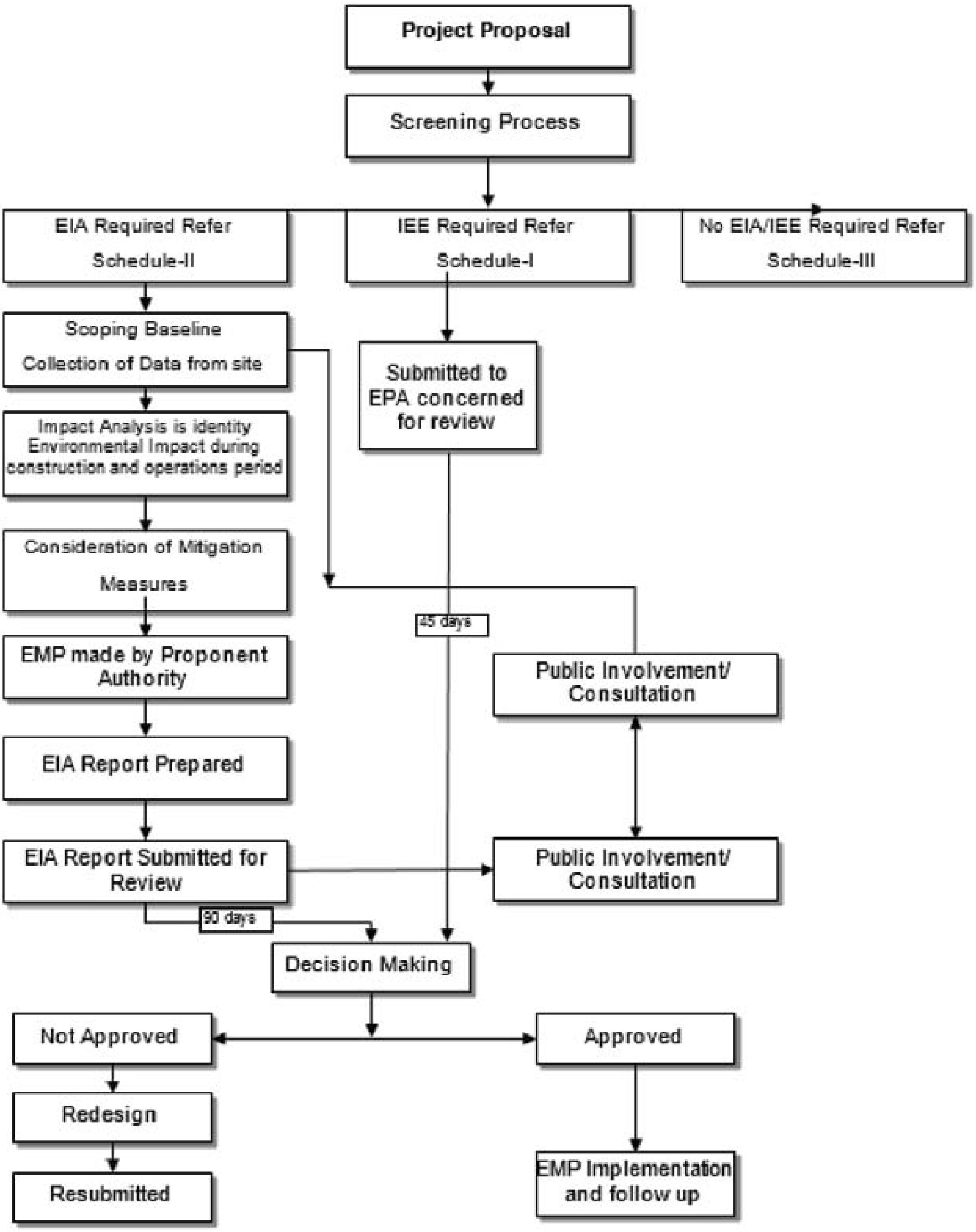


Figure 2-1 IEE/EIA Process in Pakistan**. (Note: Schedule I:** List of projects requiring an IEE; **Schedule II:** List of projects requiring an EIA; **Schedule III:** IEE/EIA Review Fees; **Schedule IV:** Application Form; **Schedule V:** Decision on IEE; **Schedule VI:** Decision on EIA).

2.4 Regulations and guidance for environmental assessment (Post 18th amendment)

2.4.1 Environmental protection legislation

Immediately after the 18th Amendment, provinces adopted PEPA 1997 with amendments. IUCN Pakistan assisted in the formulation of the Provincial Environmental Protection Act under a committee in Planning Commission of Pakistan. The committee developed the Provincial Environmental Protection Act draft according to the province requirements. The provinces are still in the process of formulation of proper acts. To date, the following Acts have been passed from the provincial assemblies:

- Sindh Environmental Protection Act 2014
- Balochistan Environmental Protection Act 2013

Islamabad and remaining provinces and the capital territory adopted PEPA 1997 with ammendments.

With prerequisite requirement of EIA, Sindh province has also included SEA in their laws. The projects geographically located within the boundaries of each province have to follow the laws adopted by the provincial environmental protection agency. Whereas those located in capital territory have to follow the law by Pakistan Environmental Protection Agency. Following projects require approval, public consultation and hearing in all the relevant environmental protection agencies:

- Projects located in more than one province or capital territory
- Projects having impact on other provinces

The relevant section for EIAs and IEEs in each of the provincial legislation is shown in the table below:

Table 2-1 Relevant sections covering EIA and IEE in provincial legislation.

Environmental Protection Acts	Date	Relevant Section	Approval IEE/ EIA	Review Fee for EIA(PKR)	Approval Fee
Punjab Environmental Protection Act (Amendment 2012)	April 18, 2012	Section 12	3/4 months	15,000* 30,000*	None
Sindh Environmental Protection Act 2014	March 4, 2014	Section 17	2 months	15,000* 30,000*	None
Balochistan Environmental Protection Act 2012	January 15, 2013	Section 15	3/4 months	100,000	None
KPK Environmental Protection Act 2012	Not approved yet	Section 12	3/4 months	15,000* 30,000*	None
GB Environmental Protection Act	Not approved yet	Section 12	3/4 months	15,000* 30,000*	None
Pakistan Environmental Protection Act (For Islamabad and Federally Administered Tribal Areas)	Not approved yet	Section 12	3/4 months	15,000* 30,000*	None
AJK Environmental Protection Act 2000	October 11, 2000	Section 11	3/4 months	15,000* 30,000*	None

*Project cost of PKR 5,000,001 to 10,000,000 = 15000, Greater than Rs. 10,000,000 = 30,000

2.4.2 Organizational setup

A number of issues arose after the 18th Amendment concerning environmental legislative setup of the country and the environmental protection law was directly impacted. The organizational setup changed and the role of Pak EPA is now limited to Islamabad capital territory. The provincial environmental protection councils and the Pakistan Environmental Protection Agency and provincial EPAs, are primarily responsible for administering the provisions of the provincial environmental protection acts. Following is the existing organizational setup for the implementation of environmental laws in the country:

- Sindh Environmental Protection Agency
- Khyber Pakhtunkwa Environmental Protection Agency
- Punjab Environmental Protection Agency
- Pakistan Environmental Protection Agency (capital territory)
- Balochistan Environmental Protection Agency
- Gilgit Baltistan Environmental Protection Agency
- AJK Environmental Protection Agency

The federal agency now lacks the power to approve the EIA of the projects falling in more than one province. The proponents have to take approval from each province prior to construction. The agency cannot influence and regulate the provinces in the subject of environment. The role of Pakistan environmental protection council has been revised to provincial environmental protection council with members from provincial government.

2.4.3 Law related regulations and guidelines

The rules and regulations under the PEPA 1997 have been adopted by the provinces and intend to update the related regulation and guidance according to their environmental requirements and sensitivities. Existing IEE/EIA Regulation, NEQS, rules and Guidelines for Environmental Assessments notified by Pak-EPA are currently being used for compliance and include the set of EIA guidelines prepared by the federal and provincial environmental protection agencies. The rules and regulations under the provincial laws are being formulated to replace the existing standards. These aim to improve the country's environment and ensure compliance to EIA integration in development projects. Proponents must meet the requirements of the relevant environmental protection agency prior to filing an IEE and EIA. The proponents should identify forthcoming advancement in environmental laws and compliance requirement of each province at an early stage by meeting the regulators.

2.4.4 Environmental impact assessment

As per the prerequisite requirement of EIA, three provinces have also included requirement of SEA in their laws. Thresholds for EIA and IEE, mentioned in regulation 2000, are currently being followed by all provinces for coal-fired thermal power plants. The EIA process is same however review fee, number of days for review and approval has been revised by the provinces. The EIA rules are also revised to incorporate the gaps in the existing regulation.

The IEE or EIA is valid for three years after the date of the confirmation of compliance and approval by the EPA concerned. If construction is not started within three years, or if the EPA considers that changes in location, design, construction and operation of the project will change the assessment of impacts, they may require the proponent to submit a fresh IEE or EIA.

2.4.5 Interdepartmental coordination

The proponents of projects are responsible for ensuring the project complies with laws and regulations controlling environmental concerns. For this purpose, liaison with following departments shall be ensured:

- Federal and Provincial EPA: The proponents are responsible for providing the complete environmental documentation required by the Environmental Protection Agencies and remain committed to the approved project design. No deviation is permitted during project implementation without the prior and explicit permission of the EPAs concerned.

- Provincial Revenue Department: Under the national law, matters relating to land use and ownership are provincial subjects, and the revenue department of the province concerned is empowered to carry out the acquisition of private land or built-up property for public purposes, including on behalf of another provincial or federal agency. For this purpose, the lead department must lodge an application with the provincial government concerned to depute a land acquisition collector (LAC) and other revenue staff who will be responsible for handling matters related to acquisition and the disbursement of compensation. The proponents need to liaise with the provincial departments of agriculture, horticulture, and forestry in order to evaluate affected vegetation resources, such as trees and crops, etc. for compensation purposes.

- Provincial Government: The projects must meet the provincial government criteria for safe disposal of wastewater, solid waste, and toxic materials. The proponents have to coordinate and monitor environment-related issues.

2.4.6 Environment related statutes

This section outlines statutes apart from the Pakistan Environmental Protection Act, 1997, which are relevant to the IEE and EIA of the proposed projects.

- Antiquities Act, 1975 - The Antiquities Act relates to the protection, preservation and conservation of archaeological/historical sites and monuments. It prohibits construction (or any other damaging) activity within 200 m of such sites unless prior permission is obtained from the Federal Department of Archaeology and Museums. The Antiquities Act also binds the project proponents to notify the department should anything of archaeological value be excavated during project construction.

- Provincial Local Government Ordinances, 2001 - These ordinances, issued following the devolution process, establish regulations for land use, the conservation of natural vegetation, air, water, and land pollution, the disposal of solid waste and wastewater effluents, as well as matters related to public health and safety.

- Factories Act, 1934 -The clauses relevant to the project are those that concern the health, safety and welfare of workers, disposal of solid waste and effluent, and damage to private and public property. The Factories Act also provides regulations for handling and disposing of toxic and hazardous materials. Given that construction activity is classified as ‘industry’, these regulations will be applicable to the project contractors.

- Pakistan Penal Code, 1860 - The Pakistan Penal Code deals with offences where public or private property and/or human lives are affected due to the intentional or accidental misconduct of an individual or body of people. In the context of environment, the Penal Code empowers the local authorities to control noise, noxious emissions and disposal of effluents. The NEQS enforced by the EPAs supersede the application of this legislation on industries and municipalities. The Penal Code, however, can provide a basis for the client to coordinate its activities with the local authorities to ensure that its construction activities do not become a cause of public nuisance or inconvenience.

- Explosives Act, 1884 - Under the Explosives Act, the project contractors are bound by regulations on handling, transportation and using explosives during quarrying, blasting, and other purposes.

- National Resettlement Policy and Ordinance - The provisions of the Draft Resettlement Policy are consistent with the requirements of the World Bank’s OP 4.12 on involuntary resettlement. After becoming law, these provisions will apply when addressing the resettlement issues that arise in the project.

2.5 Other requirements

There are a number of laws and regulations that relate to coal-fired thermal power plants in the country. The project proponents must ensure compliance to these laws in coordination with stakeholders of the projects mentioned in following section.

2.5.1 Policies & strategies

The main policies and strategies that are relevant to CFPP development include:

- National Environmental Policy 2005 – Aims to conserve, restore and manage the environmental resources of the country. Projects of such nature have to take environmental consideration on a priority for conserving the environment.

- National Drinking Water Policy 2009 – The policy aims to improve access to clean drinking water through various initiatives. Coal-fired thermal power plants use water for cooling, and environmental standards are needed to ensure that the water being released is safe for human consumption. National drinking water policy provides guidance to utilization and use of drinking water through appropriate means.

- National Resettlement Policy 2002 (Draft) – CFPPs may likely relocate large number of people from the site, upstream and downstream. This policy provides details on resettlement issues.

2.5.2 International conventions and transboundary agreements

The international conventions, to which Pakistan is a signatory and may be relevant for CFPPs are listed in Table 2-2. Pakistan is not yet a signatory of the 1991 Espoo Convention on Environmental Impact Assessment in a Transboundary Context. This is a modern dynamic international treaty, designed to adapt to changing and more complex circumstances (Koivurova and Pölönen 2010). It was negotiated under the auspices of the United Nations Economic Commission for Europe (UNECE) and signed in Espoo, Finland, in 1991. The Convention entered into force in 1997, while the SEA Protocol to the Convention was signed in 2003. Kazakistan, Kyrgystan, Tajikistan and Russia are Parties to the Espoo Convention, and Uzbekistan is preparing to ratify (Maarsden 2011).

The Espoo Convention regulates situations where a significant adverse transboundary impact is likely to be caused to a state's environment by a proposed activity in another contracting state (the origin state). The Convention requires the parties to cooperate with each other before the activity is undertaken. In order for this procedure to function effectively, the Espoo Convention requires the states to establish national EIA procedures that allow for the integration of foreign impacts and foreign stakeholders. The origin state is first required to notify the potentially affected state of the likely significant adverse transboundary impact and to provide basic information regarding the proposed activity. The affected state must next confirm that it wants to participate in the procedure. The origin state is then obligated to study the transboundary impacts together with the affected state and allow the public of that state to participate in the process on the same terms as its own public would be entitled to. After the EIA, the affected state has an opportunity through consultations with the origin state to comment on the proposed activity. The final decision taken on the proposed activity in the origin state must take due account of the comments from the potentially affected state and its public. A note prepared by the Espoo Convention Secretariat lists (inter alia) the following examples of "complex activities":

- Pipelines, roads or other linear infrastructure projects that are part of an energy or transport network crossing several Parties;
- Large energy projects that could affect sub-regional policies.

Category	Convention/convention	Came into force
Chemicals and hazardous wastes conventions	1. Stockholm Convention on Persistent Organic Pollutants	April 2008
	2. Rotterdam Convention on the Prior Informed Consent procedures for Certain Hazardous Chemicals and Pesticides in International Trade.	July 2005
	3. Basel Convention on the control of Trans-boundary Movement of Hazardous Wastes and their Disposal.	July 1994
Atmosphere conventions/protocols	4. United Nations Framework Convention on Climate Change (UNFCCC)	June 1994
	5. Kyoto Protocol to UNFCCC	Jan 2005
	6. Vienna Convention for the Protection of the Ozone Layer.	Dec1992
	7. Montreal Protocol on Substances that Deplete the Ozone Layer.	Dec 1992
Land / environmental cooperation conventions	8. United Nations Convention to Combat Desertification (UNCCD) in those Countries Experiencing Serious Drought and / or Desertification, Particularly in Africa.	Feb 1997
Cultural and natural heritage	9. Convention Concerning the Protection of World Cultural and Natural Heritage (World Heritage Convention)	July 1976
Biodiversity related conventions/protocols	10. Convention on Biological Diversity (CBD).	July 1994
	11. Cartagena Protocol on Bio-safety to the Convention on Biological Diversity.	March 2009
	12. Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention)	Nov 1976
	13. Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).	April 1976
	14. Convention on the Conservation of Migratory Species of Wild Animals (CMS)	Dec 1987
Regional seas conventions	15. Convention on the Law of Seas (CLS).	Feb 1997

Table 2-2 Relevant international conventions to which Pakistan is a signatory.

Part 3 - What are the main characteristics of a coal-fired power plant?

Not taking into account environmental externalities, coal is the least expensive, most abundant fossil fuel source for electric generation (IDB, 2009). It is one of the world's fastest growing energy sources and is likely to increase its share in the energy matrix in many countries.

Coal-fired power plants produce a series of pollutants and other environmental impacts derived from the combustion of the coal. Technological developments over the last few decades have led to cleaner coal technologies that are able to increase the efficiency of a coal plant (i.e. increase the amount of energy gained from each tonne of coal) and to significantly decrease its air emissions (specifically sulphur dioxide, particulate matter, and nitrogen oxides) and therefore its environmental impact.

3.1 Coal

3.1.1 Types of coal

Coal is the most common example of solid fuel. Coal is the altered remains of prehistoric vegetation that originally accumulated in swamps and peat bogs. The build-up of silt and other sediments, together with movements in the earth´s crust (known as tectonic movements) buried these swamps and peat bogs, often to great depths.With burial, the plant material was subjected to high temperatures and pressures, causing physical and chemical changes in the vegetation, transforming it into peat and then into coal.

Coal formation began during the Carboniferous Period – known as the first coal age – which spanned 360 million to 290 million years ago.

The quality of each coal deposit is determined by temperature and pressure and by the length of time in formation, which is referred to as its "organic maturity". Initially the peat is converted into lignite or "brown coal", these are coal types with low organic maturity. In comparison to other coals, lignite is quite soft and its color can change from dark black to various shades of brown.

Over millions of years, the continuing effects of temperature and pressure produced further change in the lignite, progressively increasing its organic maturity and transforming it into the range known as sub-bituminous coals. Further chemical and physical changes occured until the coal became harder and blacker – subsequently transforming into the bituminous or hard coal. Under the right conditions the progressive increase in the organic maturity can continue, finally forming anthracite. The referred conditions under which the coal as formed defines the different ranks of coal found in nature (known as coalification) (WCI, 2005).

Classification by rank is based on the volatile matter, moisture content, and fixed carbon content of the coal. The natural transition of coal with time is as follows, with each step in the progress enriching the carbon content (Davis, 2000):

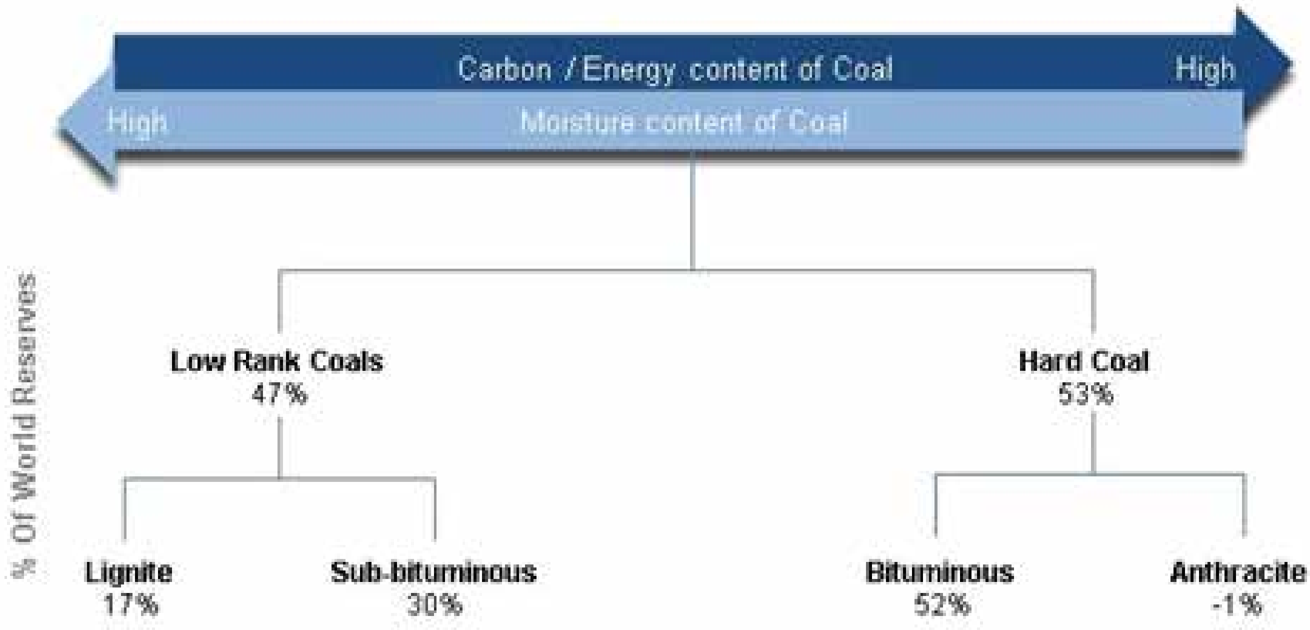
Peat → lignite → sub-bituminous → bituminous → anthracite

Low rank coal, such as lignite and sub-bituminous coals are typically softer, friable materials with a dull, earthy appearance. They are characterized by high moisture levels and low carbon content, and there for a low energy content. Higher rank coals are generally harder and stronger and often have a black, vitreous lustre. They contain more carbon, have lower moisture content, and produce more energy. Anthracite is at the top of the rank scale and has a correspondingly higher carbon and energy content and a lower level of moisture (WB, 1998).

3.1.2 Coal in the world

Coal is a very effective solid fuel as it burns easily and produces a great deal of heat and is the reason that it plays a vital role in electricity generation worldwide. Coal-fired Power Plants are currently fuelling almost 41% (IEA, 2011) of global electricity. In many countries such as South Africa, United States, Australia, Poland, China, India, this figure is much higher. Figure 3-2 is a graphic representation of the coal leading consumption countries.

Figure 3-1 Different types of coal.



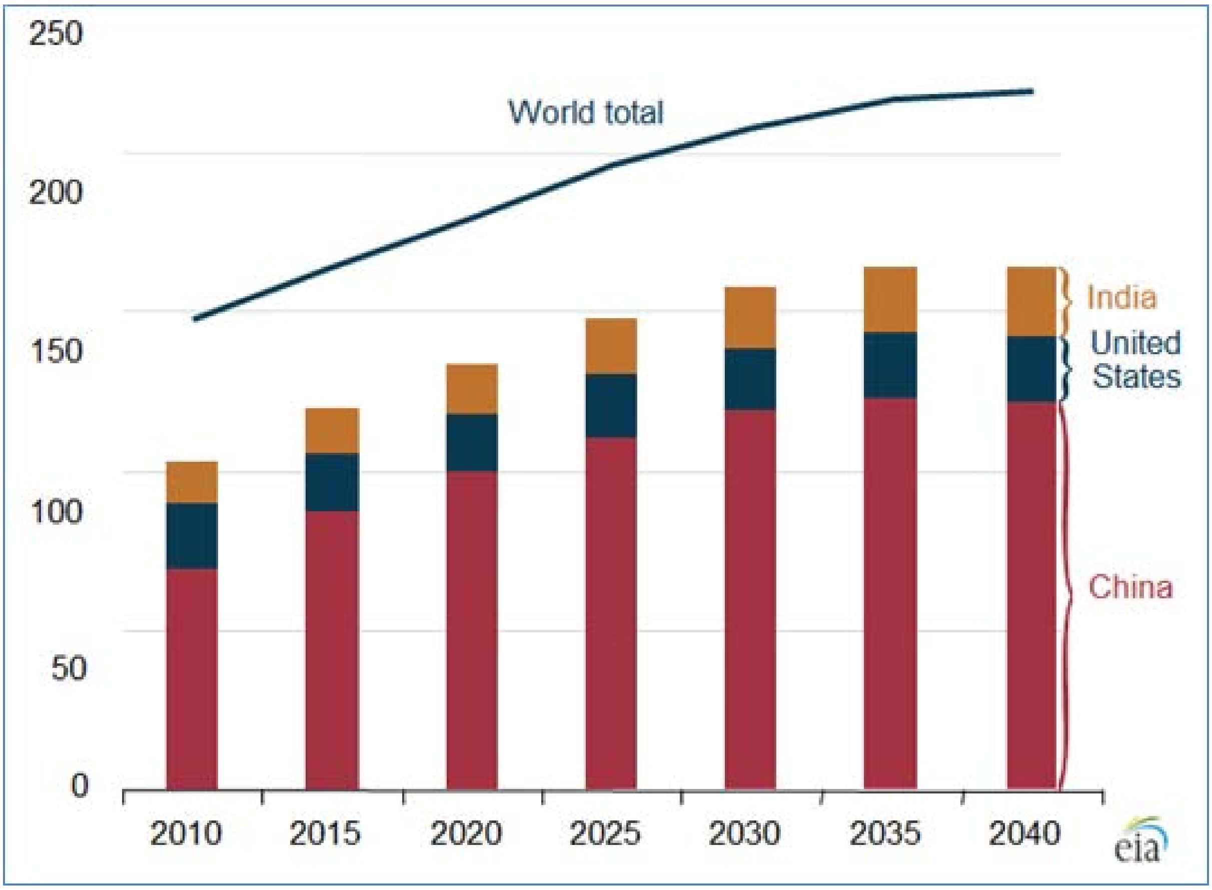


Figure 3-2 World coal consumption by leading consuming countries, 2010-2040.
(http://www.eia.gov/forecasts/ieo/coal.cfm)

3.1.3 Coal in Pakistan

3.1.3.1 Mineral resources

Pakistan has the 6th largest reserves of coal in the world with deposits being found in all four provinces of Pakistan; as well as Azad Jammu and Kashmir (see Table 3-1). The total reserve in Pakistan currently stands at 186,282.41million tonnes (Mt). Out of this, 3479.45 Mt have been measured, 12023.20 Mt have been indicated and 56947.26 Mt inferred, whereas hypothetical reserves are about 113832.30 Mmt (Malkani, 2012). For ease of analysis, the coal deposits in Pakistan can be divided into three major categories:

1. Major reserves: The large reserves of Pakistan are found in the Southern province of Sindh. The estimated reserves are 184.6 billion tonnes with major fields present in Lakhra, Sonda, Jherruck and Indus East (PPIB, 2004). The 9000 sq km field in Thar alone accounts for approximately 175,500mt (HDIP, 2013). Sindh coal is classified as Lignite coal with calorific value ranging from 5,219 to 13,555 Btu/lb. Lakhra coal is of Lignite A type and contains a high sulphur content whereas Thar coal is of Lignite A-B and contains a low sulphur but a very high moisture content. Due to the large level of reserves in Thar, it has become the priority of the country to start mining it. The Geological Survey of Pakistan (GSP) reports that it has drilled 14 holes in Thar for the Underground Coal Gasification Project (GSP, 2012).

2. Medium reserves: The medium reserves in Pakistan are found in the Province of Balochistan with total reserves measured at 217 mt in 2012 (HDIP, 2013). The major coalfields are Sor-Range/Degari, Khost/Sharigh/Harnai/Ziarat, Mach and Duki (PPIB, 2004). The recent discovery of coal at Kingri – Shikar – Tor Shah fields is the most suitable for extraction in the area of Balochistan, which has otherwise one of the deepest coal mines in the region and low level of infrastructure (HDIP, 2013). The estimate for the mineable coal in Balochistan is 32mt and can be characterized under sub-bituminous to bituminous with a heating value from 9637 to 15499 Btu/lb. It has high sulphur but low ash content and is suitable for power generation (PPIB, 2004).

3. Minor reserves: The minor reserves are found in the provinces of Punjab and Khyber Pakhtunkhwa (KPK); and Azad Jammu and Kashmir (AJK). Total reserves at these locations are 235 mt, 90 mt and 9 mt respectively (HDIP, 2013). In Punjab, the main areas where fields are found are in salt range in the Potwar Plataeu and Makarwal and the current mineable levels are measured at 33mt with a heating value of 9,472 to 15,801 Btu/lb and a low ash and high sulphur content. (PPIB, 2004). In KPK, the main deposits are in Hangu and Cherat whereas in AJK, the deposits are at Kotli. The coal is classified as sub-bituminous and the heating value ranges from 7,336 to 12,338 Btu/lb (PPIB, 2004).

Figure 3-3 maps the location of all major coal reserves in Pakistan.

Province	Measured	Indicated	Inferred	Hypothetical	Total Reserves	%
Sindh	3339	11635	56346	114137	185457	99.7
Balochistan	54	13	134	16	217	0.12
Punjab	55	24	11	145	235	0.13
Khyber Pakhtunkhwa	1.5	4.5	84	-	90	0.05
Azad Kashmir	1	1	7	-	9	0.00
Total	**3450**	**11677**	**56582**	**114298**	**186007**	**100.00**

Table 3-1 Breakdown of all coal reserves found in the Pakistan (Source: HDIP, 2013) (data in million tonnes).

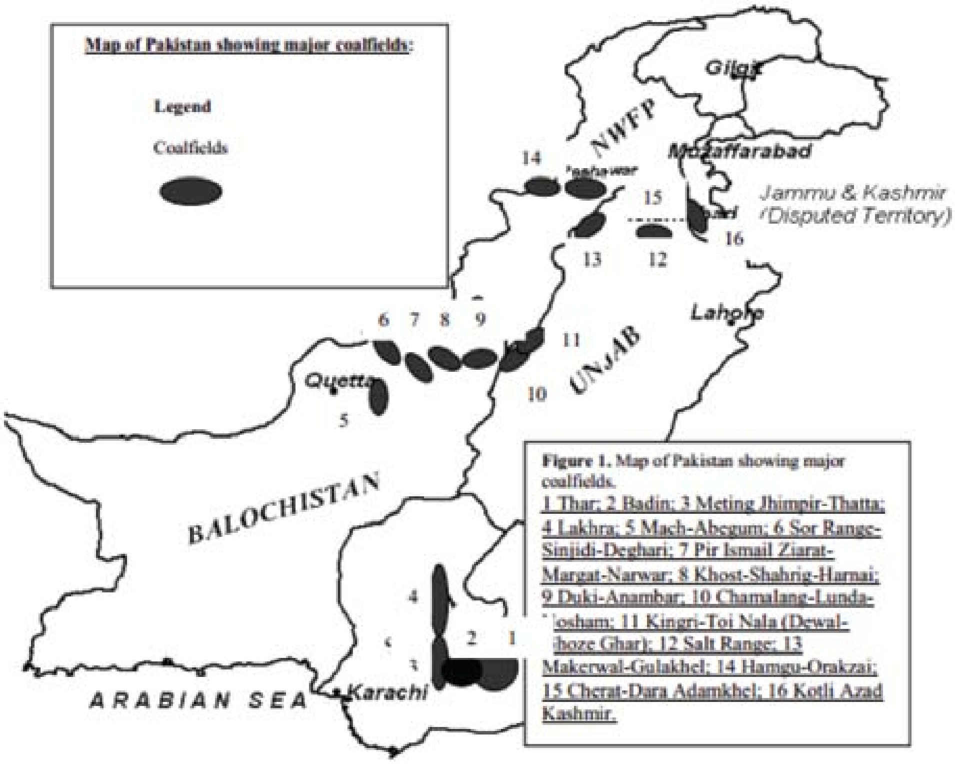


Figure 3-3 Major coal reserves in Pakistan (Malkani, 2012).

3.1.3.2 Coal-based power initiatives in Pakistan

In the last couple of years, policy makers have realized the benefits of shifting the power production to Coal to overcome the country's power woes. Coal-fired thermal power initiatives in Pakistan are clustered into three specific projects:

Gadani power project:

In late 2013, the current government of Pakistan announced the launch of the Gadani Energy Park (or Pakistan Power Park) which will establish approximately 10 coal power plants of 660 MW each - taking the total projected capacity to 6,600 MW. It has also been decided that out of these ten units, 660 MW each, two units (2 x 660 MW Gross) will be developed in the public sector by GENCO-IV under GENCO Holding Company Limited (GHCL) (whose financing will be arranged by GoP), whereas the rest will be developed as eight different IPPs. (The Daily Times, 20 Feb 2014).

Gadani is located in the Lasbela District of Balochistan and will aim to develop a power corridor with an estimated investment of PKR 50 Billion (The Nation, 2013). The implementation of this plan will require development of infrastructure such as a 7 km deep jetty, breakwater and allied infrastructure, coal handling and conveying system, coal storage yards, ash disposal yards, intake and outfall channels, desalination plant and an access and internal road network for the Park (GENCO, 2013). Other amenities include a water supply system, including treatment storage facilities for the power plants, residential colonies and sewerage system for the Power Park along with treatment facilities and disposal arrangement, storm water and effluent disposal system, fire-fighting arrangement and fire station, electrical power supply and distribution system, communication system, administrative block and a security boundary wall.

The estimated project cost is US$ 520 million (The Nation, 2013). To carry out the implementation of this project, GoP has constituted the Pakistan Power Park Management Company Ltd (PPPMCL), that will be responsible for land acquisition and infrastructure/common facilities development, to be provided to prospective Independent Power Projects (IPPs) (The Nation, 2013). The construction of these plants is one stage in a plan to convert many of the country's existing oil-based thermal plants and upgrade its ports for coal import. This project will result in reduced load-shedding and will provide the power needed to help address the country's power shortage. This move will also add reliability to the power system in the country and provide energy security by diversifying the fuel mix.

Punjab power initiative:

Punjab Government's Coal Based Power Production Initiative aims at adding 6000 MW affordable power to the national grid in which the private sector is invited to set up 6 state-of-the-art supercritical coal-fired power plants. Coal-fired power plants, based on imported coal, are preferably installed in the coastal areas. Punjab, however, is away from the coast and the plants can only be installed inland.

Following parameters have been kept in view while identifying sites (GoPb, 2014):

i) Availability of un-encumbered piece of plain land;

ii) Closeness to the load center;

iii) Availability of power evacuation infrastructure;

iv) Proximity to railway track;

v) Nearness to an adequate supply of water source;

vi) Nearness to existing infrastructure such as service roads, educational and medical facilities etc.;

vii) Suitability of waste water disposal;

viii) Suitability of ash disposal; and

ix) Favorable ambient environmental conditions.

Government of Punjab (GoPb) has conducted an exercise to identify sites which conform to the above mentioned parameters. National Transmission and Dispatch Company (NTDC) has conducted a survey which pinpointed appropriate sites near Qadirabad (Sahiwal), Bhikki (Sheikhupura) and Haveli Bahadur Shah (Jhang), for establishment of thermal based power plants. In addition, Balloki (Kasur), Trinda Saway (Rahim Yar Khan) and Mouza Saddan Wali (Muzaffargarh) are also potential sites for establishing large sized coal-based power plants.

Pakistan Railways has made a commitment for transportation of coal from the coast to the project site. The project developing company must ensure sustainable supply of coal through Coal Supply Agreement(s) "CSA" with the coal supplier and with Pakistan Railways or other transportation companies of its choice. (GoPb, 2014).

Thar coal power:

As mentioned in the sections above, Thar has the largest coal reserves in the country with a resource potential of 175 billion tonnes of coal.

The area is covered by stable sand dunes and there are no rock exposures (Thar Coal Energy Board, 2014). The measured reserves are over 2,357 million tonnes and the Government of Sindh (GoS) reports that it has an electricity potential of 100,000 MW (GoS Presentation, ND). In 2009, the Sindh Engro Coal Mining Company (SECMC) was created as a public-private partnership. The project aims at developing a coalmine in Thar with the production capacity of 6.5 million tonnes per year and construct a 660 MW power plant in the first Phase (by 2017) while in the second phase another 660 MW power plant would be in place by 2019. Total cost of the project, including mining and power generation, is USD 1.6 billion and it will be completed in 3.5 years. The project will be executed by the Sindh Engro Coal Mining Company (SECMC) - a joint venture between the Government of Sindh and Engro Powergen (Dawn, 01 February 2014).

Thar coalfield block-III spreads over 100 square kilometers with estimated two billion tonnes of coal (see Table 3-2). Initially, the project will generate 660MW but with the completion of other phases, the capacity will increase to 5,000MW. The Block-II Thar coalfield project, according to a feasibility study, is commercially viable with no significant environmental threats and social implications. In phase I, the project envisages mining of 3.8 million tonnes of coal per year and power generation of 660MW. Subsequently, the mine will be expanded to an annual capacity of 6.5 million tonnes to support a 1,300MW power plant. In phase II, the mining project will be expanded to 19.5 million tonnes with a power generation capacity of 3600MW (Dawn, 01 February 2014).[7]

Thar has been divided into 12 blocks, out of which four blocks have been awarded to different investors. The Government of Sindh and M/s ENGRO are investing in Block-II that will produce 3,960 MW power, which is only 1% of the total capacity of Thar coal mines (Pakistan Today, 2014).

[7]http://www.dawn.com/news/1084148/sharif-zardari-jointly-launch-thar-coal-project

Table 3-2 Block-wise Deposits of Thar coal fields.

Blocks	Area (sq km)	Drill Holes	Seam Thickness (m)	Depth (m)	Deposits (Billion Tonnes)			
					Measured	**Indicated**	**Inferred**	**Total**
Block – I	122.0	43	8-36	137-189	0.620	1.918	1.028	3.566
Block – II	55.0	43	7.5-31	117-166	0.640	0.944	-	1.584
Block – III	99.5	41	7.2-25	114-203	0.413	1.337	0.258	2.008
Block – IV	82	42	10.7-33.45	117-166	0.684	1.711	0.076	2.471
Block – V	63.5	35	16.74-30.9	117-166	0.637	0.757	-	1.394
Block – VI	66.1	35	9-20.7	115	0.762	0.893	-	1.655
Total	**488.1**	**239**			**3.756**	**7.560**	**1.362**	**12.772**

Fig 3-4: Concession Blocks within Thar Coal Field

3.2 A thermal power plant

3.2.1 Typical layout of a coal-fired power plant

Steam coal, also known as thermal coal, is used in power stations to generate electricity. The coal is first milled to a fine powder, which increases the surface area and allows it to burn more quickly. In these pulverized coal combustion (PCC) systems, the powdered coal is blown into the combustion chamber of a boiler where it is burnt at high temperature. The hot gases and heat energy produced converts water (in tubes lining the boiler) into steam.

The high pressure steam is passed into a turbine containing thousands of propeller-like blades. The steam pushes the blades, causing the turbine shaft to rotate at high speed. A generator is mounted at one end of the turbine shaft and consists of carefully wound wire coils. Electricity is generated when these are rapidly rotated in a strong magnetic field. After passing through the turbine, the steam is condensed and returned to the boiler to be heated once again (see Figure 3-4) (WCI, 2005).

The electricity generated is transformed into higher voltages (up to 400.000 volts) used for economic, efficient transmission via power line grids. When it nears the point of consumption, the electricity is transformed down to the safer 220 voltage systems used in the domestic market.

There are two major concerns over the use of coal: firstly, it is a fossil, so supplies are finite; and secondly, the levels of pollutants emitted. Emissions that result from the combustion of coal process consists mainly of particulates, sulphur oxides, nitrous oxides, heavy metals and CO_2 – chemicals that cause serious health and environment damage as well as high emissions of greenhouse gases (IL&FS, 2010).

There are a range of flue gas treatment technologies for reducing such flue emissions of these pollutants, which are now typically a part of specific coal-utilization technology packages. The add-on pollution-reducing technologies are broadly installed in three stages namely: pre-combustion, in-combustion and post-combustion.

Coal cleaning, also known as coal beneficiation or coal preparation, increases the heating value and the quality of the coal by lowering levels of sulphur and mineral matter. Reducing of ash by fuel cleaning decreases the generation of PM emissions and sulphur content. Coal beneficiation can remove 50% of pyritic sulphur and 20-30% of total sulphur. This approach may, in some cases, be cost-effective in controlling emissions of sulphur oxides, but it may generate large quantities of solid waste and acid wastewaters that must be properly treated and disposed of (WB, 1998).

source: http://en.wikipedia.org/wiki/Thermal_power_station

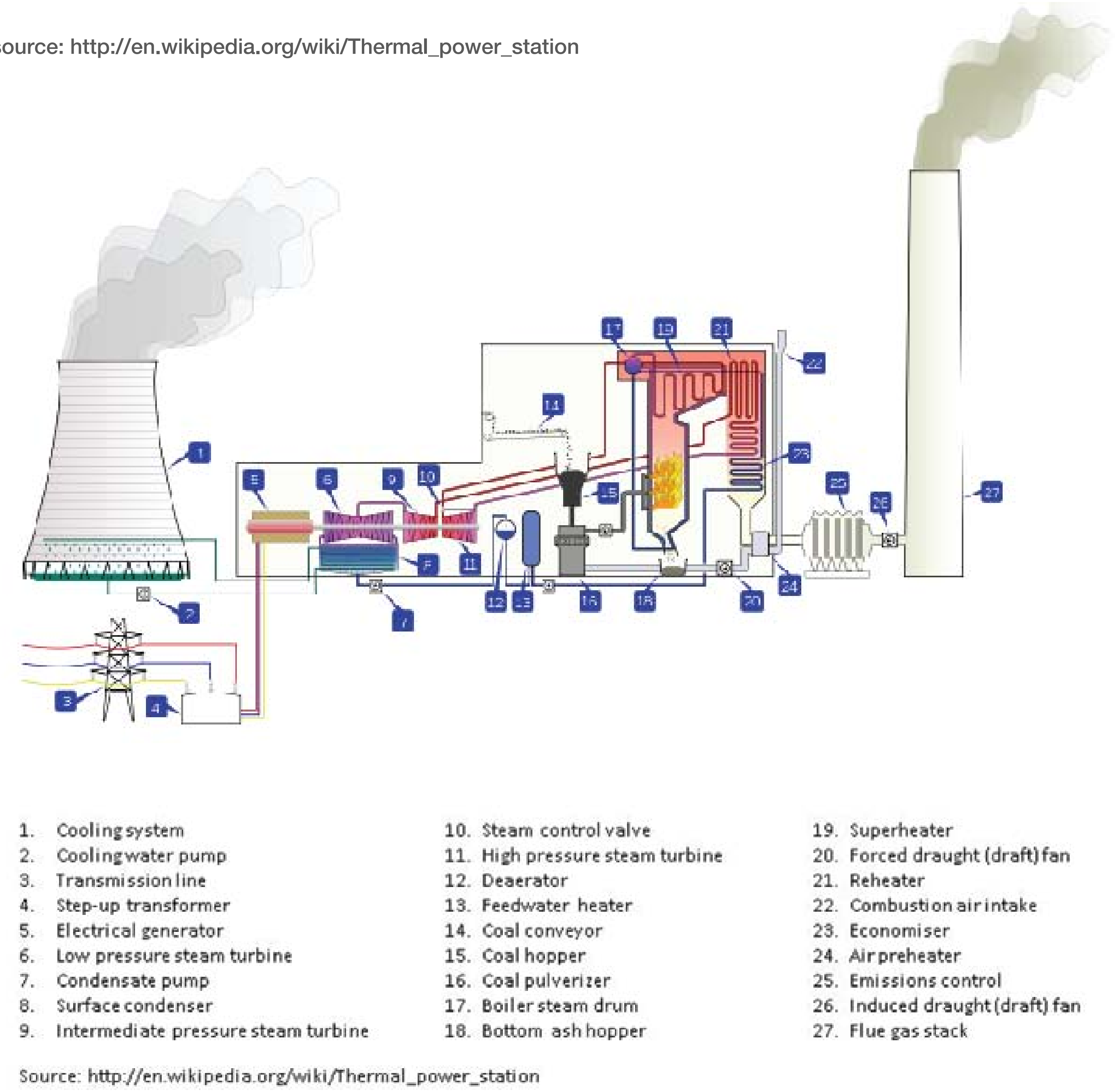


Figure 3-4. Typical diagram of a coal-fired thermal power station

Figure 3-5 gives a global overview of a coal-fired power plant with a presentation of the general organization of its sub-units. Black boxes are the core components of the power plant and include fuel preparation, combustion and power generation. Air pollutants treatment components are depicted in blue, water control related sub-units are represented in green and waste treatment facilities in brown boxes. Interaction between sub-units and flow of materials are also represented. This Figure does not pretend to be a comprehensive operational layout of a coal-fired power plant.

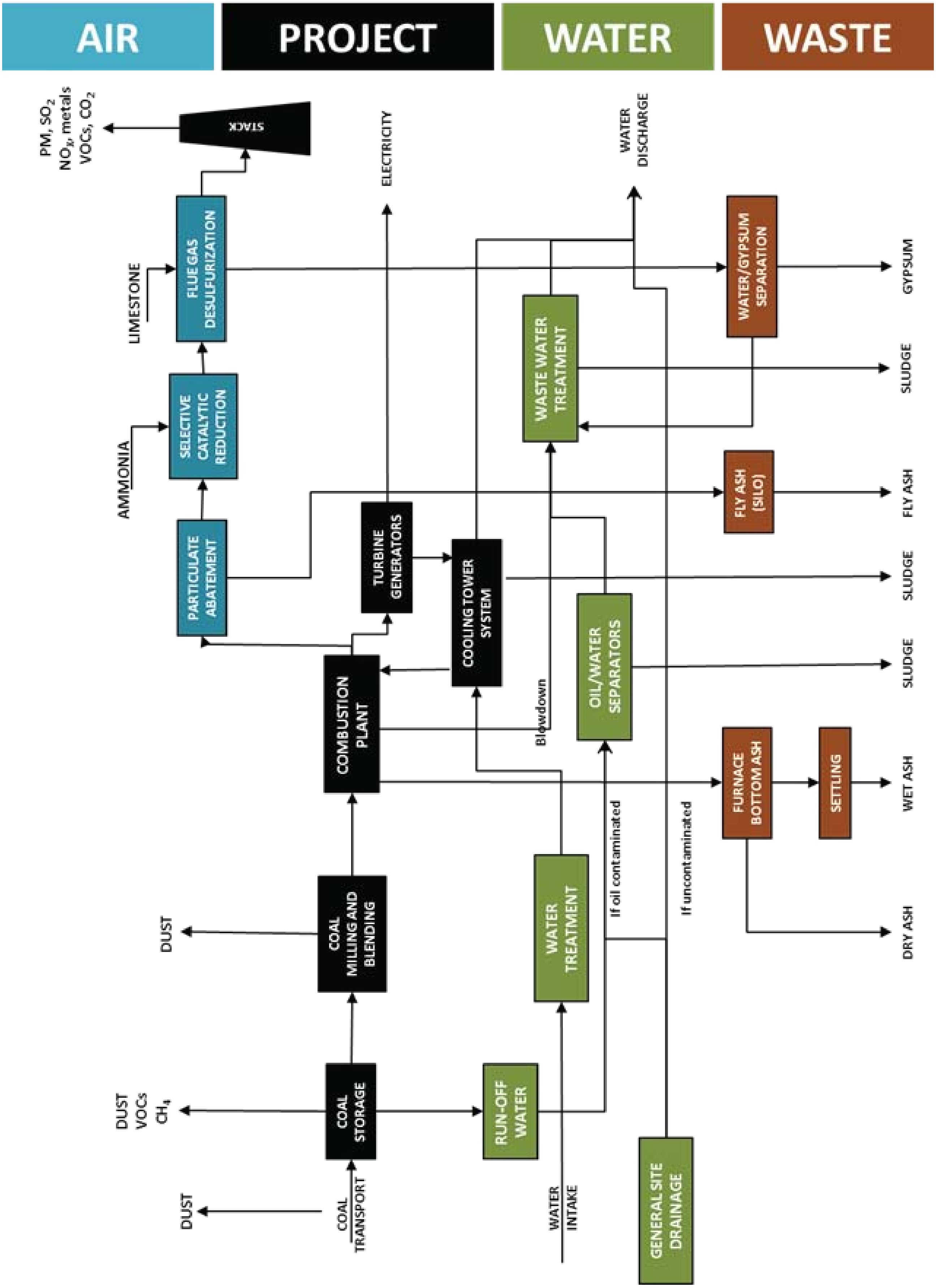


Figure 3-5 Operational layout of a coal-fired power plant.

3.2.2 Coal combustion technologies/alternatives

There are several coal combustion techniques:

- Pulverized Coal
- Subcritical Technology
- Supercritical Technology
- Ultra-supercritical Technology
- Fluidized Bed Combustion
- Integrated Gasification Combined Cycle (IGCC)

3.2.2.1 Pulverized coal combustion

Suspension firing is the primary combustion mechanism in pulverized-coal-fired and cyclone-fired units. Grate firing is the primary mechanism in underfeed and overfeed stoker-fired units. Both mechanisms are employed in spreader stokers. In a fluidized bed combustor (FBC), the coal is introduced to a bed of either sorbent or inert material (usually sand), which is fluidized by an upward flow of air (Davis, 2000).

The Pulverized-coal is generally entrained in primary air before being fed through the burners to the chamber, where it is fired in suspension. Pulverized-coal furnaces are classified as either dry or wet bottom, depending on the ash removal technique. Dry-bottom furnaces fire coals with high ash fusion temperatures, and dry ash removal techniques are used. In wet-bottom furnaces, coal with low ash fusion temperature is used, and molten ash is drained from the bottom of the furnace. Pulverized coal furnaces are further classified by the firing position of the burners, that is, single (front and rear) wall, horizontally opposed, vertical, tangential (comer fired), turbo, or arch fired.

In pulverized coal boilers, coal is ground to the consistency of flour and air blown into a furnace for rapid combustion. Pulverized coal technology is the most prevalent type for coal-based generation and is used in steam boilers around the world operating with subcritical, supercritical and ultra super critical steam conditions. (OECD/IEA 2013)

The coal is fed tangentially, with primary air, to a horizontal cylindrical combustion chamber. In this chamber, small coal particles are burned in suspension, while the larger particles are forced against the outer wall.

Regarding the grade firing the combustion occurs partly in suspension and partly on the grate. Because of significant carbon on particulates, fly ash reinjected from mechanical collectors is commonly employed to improve boiler efficiency. Ash residue in the fuel bed is deposited in a receiving pit at the end of the grate. In overfeed stokers, coal is fed onto a traveling or vibrating grate, and it burns on the fuel bed as it progresses through the furnace. Ash particles fall into an ash pit at the rear of the stoker. The term overfeed applies because the coal is fed onto the moving grate under an adjustable gate. Conversely, in underfeed stokers, coal is fed into the firing zone from underneath via mechanical rams or screw conveyers.

The coal moves in a channel, known as a retort, from which it is forced upward, spilling over the top of each side to form and feed the fuel bed. Combustion is completed by the time the bed reaches the side dump grates, from which the ash is discharged to swallow pits. Underfeed stokers include single-retort units and multiple-retort units, the later having several retorts side by side (Davis, 2000).

New pulverized coal combustion systems - utilizing supercritical and ultra-supercritical technology - operate at increasingly higher temperatures and pressures and therefore achieve higher efficiencies than conventional pulverized coal combustion units and significant CO2 reductions.

Subcritical technology is most commonly used in coal-fired plants, for conventional pulverized coal combustion. Powdered coal is injected into the boiler and burned to raise steam for subsequent expansion in a steam-turbine generator. Subcritical steam cycles have a main steam pressure that is below the critical point of water. The steam conditions used in current subcritical units are up to ≈ 179bar/541ºC (2600 psia/1100ºF). Although subcritical steam cycles are not considered “advanced” technology for Rankine cycles plants, many “advanced” technology coal plants (e.g., IGCC and oxy-combustion) may incorporate subcritical steam cycles (OECD/IEA 2013).

Supercritical technology involves the increasing steam temperature and pressure; the efficiency of the steam turbine (and hence, of electricity generation) can be increased. As the steam pressure and temperature increases to a critical point, the characteristics of steam are altered such that water and steam are no longer distinguishable. This is known as supercritical steam and is a more efficient technology (IL&FS, 2010).

Supercritical steam cycle technologies became fully commercial in coal plants in the early 1960s (OECD/IEA 2013), and have been used for decades and are becoming the system of choice for new commercial coal-fired plants in many countries. Research and development is under way for ultra-supercritical units operating at even higher efficiencies, potentially up to around 50% (see Figure 3-6). The introduction of ultra-supercritical technology has been driven, over recent years, in countries such as Denmark, Germany and Japan, in order to achieve improved plant efficiencies and reduce fuel costs. Research is focusing on the development of new steels for boiler tubes and on high alloy steels that minimize corrosion (WCI, 2013).

Current supercritical steam cycles typically have main steam pressures of about 240 bar (3500psi) or higher and main steam and reheat temperatures of around 565ºC (1050ºF). Supercritical plants are more economical at larger boiler and turbine sizes; typically units are superior to 500MW (OECD/IEA 2013).

Ultra-supercritical technology is similar to supercritical generation, but operates at even higher temperatures and pressures. Steam conditions are defined as the main steam temperature of around 600ºC (1110ºF) and main steam pressure greater than 300 bar (4365 psig). While not common, these plants represent the highest efficiency in pulverized coal plants available today (up to 40%) (OECD/IEA 2013).

3.2.2.2 Fluidized Bed Combustion

Another type of combustion-based coal power plant is Fluidized Bed Combustion (which can operate at atmospheric or pressurized furnace conditions). Coal is burned in a more coarse form in a bed of hot sorbent particles suspended in motion (fluidized) by combustion air (OECD/IEA 2013).

Fluidized Bed Combustion (FBC) systems improve the environmental impact of coal-based electricity, reducing SO_x and NO_x emissions by 90%. The coal is burned in a reactor comprised of a bed through which gas is fed to keep the fuel in a turbulent state. This improves combustion, heat transfer and recovery of waste products. The higher heat exchanger efficiencies and better mixing of Fluidized Bed Combustion systems allows them to operate at lower temperatures than conventional pulverized coal combustion. By elevating pressures within a bed, a high-pressure gas stream can be used to drive a gas turbine, generating electricity (WCI, 2013).

FBC fits into two groups, non-pressurized systems (FCB) and pressurized systems (PFBC), and two sub-groups, circulating or bubbling fluidized bed.

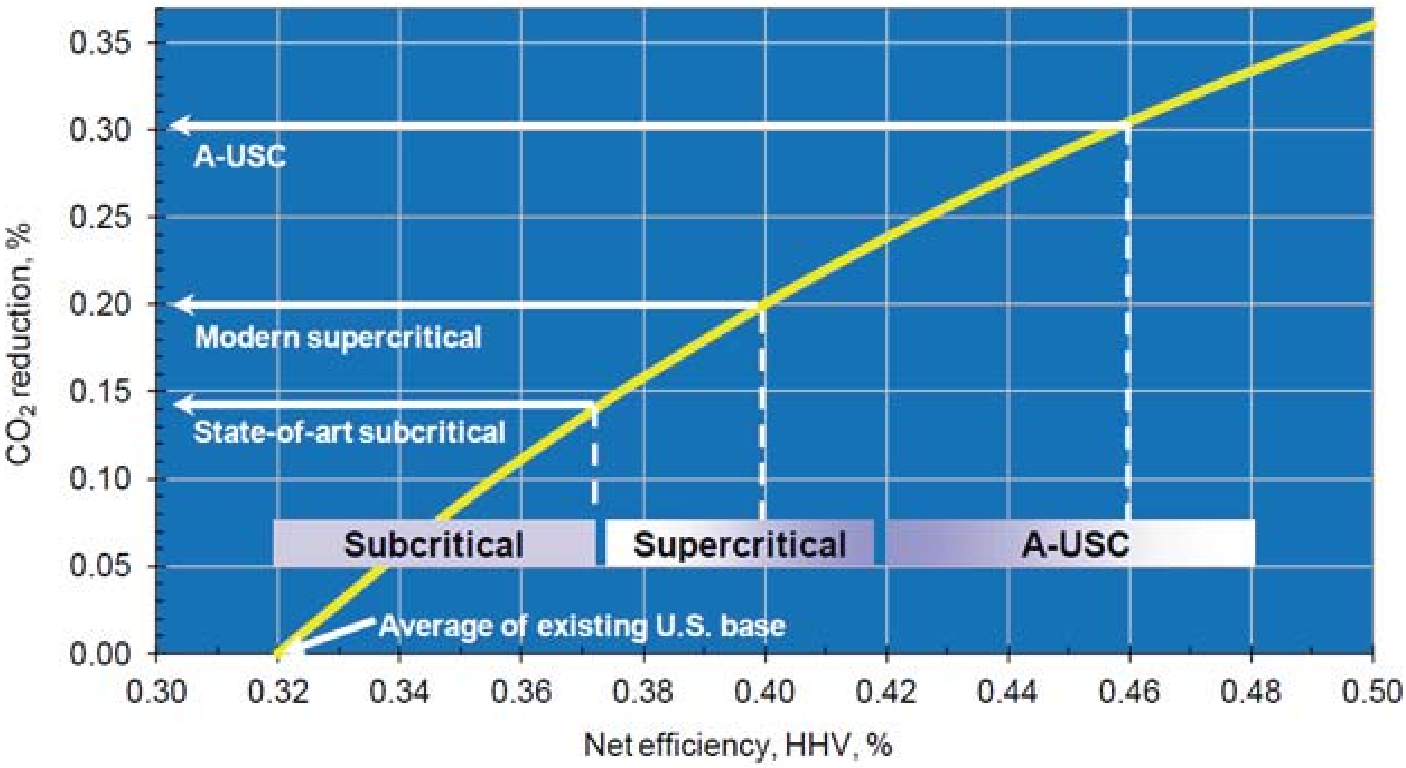


Figure 3-6 High-efficiency coal power plants substantially reduce CO_2 emissions (OECD/IEA, 2013

1. Non-pressurized FBC systems operate at atmospheric pressure and are the most widely applied type of FBC (also known as Atmospheric FBC). They have efficiencies similar to PCC – 30 to 40%;

2. Pressurized FBC systems operate at elevated pressures and produce a high-pressure gas stream that can drive a gas turbine, creating a more efficient combined cycle system – over 40%;

3. Bubbling uses low fluidizing velocity, so the particles are mainly held in a bed. This is generally used with small plants offering a non-pressurized efficiency of around 30%.

4. Circulating uses a higher fluidizing velocity, so the particles are constantly held in the flue gases, and is used for much larger plants offering an efficiency of over 40%.

The flexibility of FBC systems allows them to utilize abandoned coal waste that previously would not be used due to its poor quality (WCI, 2013).

3.2.2.3 Integrated Coal Gasification Combined Cycle (IGCC)

Integrated Gasification Combined Cycles power plants use a gasifier to convert coal into a gas, which can subsequently be burned using a gas turbine. IGCC technology allows the use of solid fuels in a power plant that leverages the environmental benefits and thermal performance of a gas-fuelled combined cycle. In an IGCC gasifier, a solid feed is partially oxidized with air or high-purity oxygen. The resulting hot, raw “syngas” consists of CO, CO_2, hydrogen, water, methane (and sometimes heavier hydrocarbons), hydrogen sulfide (H_2S), carbonyl sulfide (COS), other sulphur compounds, and nitrogen and argon. After it is cooled and cleaned of particulate matter (PM) and undesired species, the syngas is fired in a gas turbine. The hot exhaust from the gas turbine passes to a heat recovery steam generator where it produces steam that drives a steam turbine.

State-of-the-art IGCC configurations for bituminous coal normally achieve overall net thermal efficiencies in the range of 38-41%, comparable to critical pulverized combustion units. By removing the emission-forming constituents from the pressurized syngas prior to combustion in the power block, IGCC plants can meet extremely stringent air emissions standards (OECD/IEA 2013).

3.2.2.4 Future technologies

New energy technologies are being developed, such as integrated gasification combined-cycle power plants, pressurized pulverized-coal-firing technology, humid air turbines, oxy-combustion and fuel cells. Some of these technologies are capable of efficiencies well in advance of current technology and show greatly reduced emissions, but are not yet in a mature state of development.

Oxy-combustion

Conducting oxy-combustion under gas pressure (typically at ≈10–15 bar [160–230 psig]) has been proposed to improve net efficiency and potentially reduce plant costs.

The major efficiency benefit from pressurized oxy-combustion is the reduction of latent heat losses in the flue gas (higher boiler efficiency) by recovering the heat of flue gas moisture condensation at a temperature usable to the power cycle. Operating the combustion and heat transfer under pressure will offer opportunities to reduce the size/cost of the steam generator through a variety of mechanisms. The elimination of air ingress (diluting the flue gas) will reduce CO2 purification unit performance requirements.

Pressurized oxy-combustion process development has been conducted at the 5 MWth level. There are a number of developers proposing pressurized oxy-combustion operations at pilot scale but none of these have been deployed yet.

A parallel challenge to pressurized oxy-combustion is the development of the associated gas pressurized boiler design. Capital costs for pressurized oxy-combustion power plants with uncertainty comparable to atmospheric pressure oxy-combustion power plants await more detailed component designs, particularly the gas pressurized (OECD/IEA 2013).

Advanced ultra-supercritical (A-USC)

Advanced ultra-supercritical (A-USC) technology, uses the same basic principles as USC. Development of A-USC aims to achieve efficiencies in excess of 50%, which will require materials capable of withstanding steam conditions of 700°C to 760°C and pressures of 30 MPa to 35 MPa. The materials under development are non-ferrous alloys based on nickel (termed super-alloys), which cost much more than the steel materials used in SC and USC plants. Developing super-alloys and reducing their cost are the main challenges to commercialization of A-USC technology pressurized (OECD/IEA 2012).

Technology	Benefits	Timing to technical maturity
Advanced Cycles		
Advanced fuel cells	▪ High efficiency with CCS; DCFC at 60% and IGFC at 56,3% ▪ Very low water cost	> 15 years
Chemical Looping combustion	▪ Higher efficiency with CCS ≈ 41%	10-13 years
Closed Brayton Power Cycle	▪ Higher efficiency by 2-3 % ▪ Incrementally lower cost	8-10 years
Pressurized oxy-combustion	▪ Incrementally higher efficiency and lower cost	8-10 years
IGCC		
Advanced gas turbines	▪ Higher efficiency ▪ Lower capital cost	10-12 years
Air separation membranes	▪ Higher efficiency ▪ Smaller footprint	5-8 years
HTM (Hydrogen transport membranes)	▪ Lower compression power ▪ Eliminates low temperature cooling of syngas	5-8 years
Improving WGS (water gas shift)	▪ Improves efficiency ▪ Incrementally lower cost	< 8 years
Liquid CO_2 coal slurry	▪ Improved efficiency with CCS ▪ Potentially lower capital cost	< 8 years
Warm-gas clean-up	▪ Higher efficiency by 3 percentage points	5-8 years
Pulverized Coal		
A-USC steam conditions (700ºC [1290ºF])	▪ Raises net efficiency to 44%	8 years
A-USB steam conditions (760ºC [1400ºF])	▪ Raises net efficiency to 48%	13 years
Mercury control	▪ Reduces mercury capture costs by 50%	5 years
Multi-pollutant control	▪ NZE (near-zero emissions) NO_X and PM Levels	5-8 years
Oxy-combustion		
Near-commercial	▪ No steam extraction or chemical process and less cost for CO_2 capture ▪ Lower water consumption	4-6 years
Advanced	▪ Incrementally higher efficiency ▪ Negligible emissions	6-8 years

Table 3-3. Overview of coal future technology review

3.2.3 Air emissions control technologies

The major pollutants of concern from coal combustion are particulate, sulphur dioxides (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds and greenhouse gases, such as carbon dioxide (CO_2). Metals are constituents of coal and are emitted as part of fly ash during combustion. Trace metals emissions include antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, magnesium, manganese, mercury, nickel, and selenium.

Currently, mercury emissions from coal-fired utility and industrial boilers are of specific concern. Mercury emissions from combustion of coal depend on the concentration in coal. Due to its volatility, almost all mercury in the coal is entrained in the flue gases (Davis, 2000).

3.2.3.1 Particle matter

Particulate matter is emitted from the combustion process, and proven technologies for particulate removal in power plants are fabric filters and electrostatic precipitators (ESPs). The choice between a fabric filter and an ESP depends on the fuel properties, type of flue gas desulphurization (FGD) system if used for SO2 control and ambient air quality objectives (IFC, 2008). Wet scrubber is also referred as a particulate control device.

The electrostatic precipitator is used extensively in large combustion plants and is capable of operating over a wide range of temperature, pressure and dust burden conditions. It is not particularly sensitive to particle size, and collects dust in both wet and dry conditions. Corrosion and abrasion resistance are built into the design (EC, 2006).

An ESP consists of a hopper-bottomed box containing rows of plates forming passages through which the flue-gas flows (see Figure 3-7). Centrally located in each passage are emitting electrodes energized with high voltage direct current, which is provided by a transformer/rectifier (T/R) set. The electrical field is applied across the electrodes by a small direct current at high voltage (100 kV). The voltage applied is high enough to ionize the gas molecules close to the electrodes, resulting in a visible corona. The flow of gas ions from the emitting electrodes across the gas passages to the grounded collecting plates constitutes what is called corona current.

When passing through the flue-gas, the charged ions collide with, and attach themselves to fly ash particles suspended in the gas. The electric field forces the charged particles out of the gas stream toward the grounded plates, where they collect in a layer. The plates are periodically cleaned by a rapping system to release the layer into the ash hoppers as an agglomerated mass. In practice, an ESP is divided into a number of discrete zones (up to five zones are commonly used). In most cases, the ESP is located after the air heater or economizer and referred to as a cold-side installation. In special cases, it is located before the air heater to take advantage of the higher temperature. In this case, it is called a hot-side installation (EC, 2006).

Because of their modular design, ESPs can be applied to a wide range of system sizes and should have no adverse effect on combustion system performance. The operating parameters that influence ESP performance include fly ash mass loading, particle size distribution, fly ash electrical resistivity, and precipitator voltage and current. Other factors that determine ESP collection efficiency are collection plate area, gas flow velocity, and cleaning cycle (USEPA, 2011).

Cyclone separators can be installed singly, in series, or grouped as in a multicyclone or multiclone collector. These devices are referred to as mechanical collectors and are often used as a pre-collector upstream of an ESP, fabric filter, or wet scrubber so that these devices can be specified for lower particle loadings to reduce capital and/or operating costs. Although these devices do reduce PM emissions from coal combustion, they are relatively ineffective for collection of particles less than 10 micron (PM10) (USEPA, 2011).

Fabric filtration is a method widely used worldwide to remove particles (especially fly ash) from the flue-gas of industrial and smaller combustion plants. However, the current trend is towards greater use of this technology for larger scale plants as well (EC, 2006).

A fabric filter unit consists of one or more isolated compartments containing rows of fabric filter bags or tubes. Particle-laden gas passes up (usually) along the surface of the bags then radially through the fabric. Particles are retained on the upstream face of the bags while the now cleaned gas stream is vented to the atmosphere. The filter is operated cyclically, alternating between relatively long periods of filtering and short periods of cleaning. During cleaning, dust that has accumulated on the bags is removed from the fabric surface and deposited in a hopper for subsequent disposal. The major operating feature of fabric filters that distinguishes them from other gas filters is the opportunity to check the filtering surface periodically when cleaning. In addition to collecting fly ash, there have been a number of applications where bag houses have been used together with the dry scrubbing-injection of slurried or powdered sulphur dioxide absorbent (such as lime or sodium bicarbonate) to simultaneously control both sulphur dioxide and fly ash emissions (EC, 2006).

Wet scrubbers for control of particulate emissions have been in use for several decades. The low capital cost of wet scrubbers compared to that for ESPs and bag houses makes them potentially attractive for industrial scale use, though this may be offset by a relatively high pressure drop and operating costs. The flue-gas is cooled during wet scrubbing and requires reheating prior to emission to the atmosphere; this incurs higher energy costs. Partly due to such operating costs, the use of wet scrubbers for the control of particulate emissions has declined during the last decade. However, wet scrubbers have been used in some high temperature and pressure combustion applications such as integrated gasification combined cycle (IGCC) and pressurized fluidized bed combustion (PFBC). Here, the pressure drop experienced is less significant in relation to operating pressure, and in IGCC the problem of reheating is overcome as the gas is subsequently heated by combustion (EC, 2006).

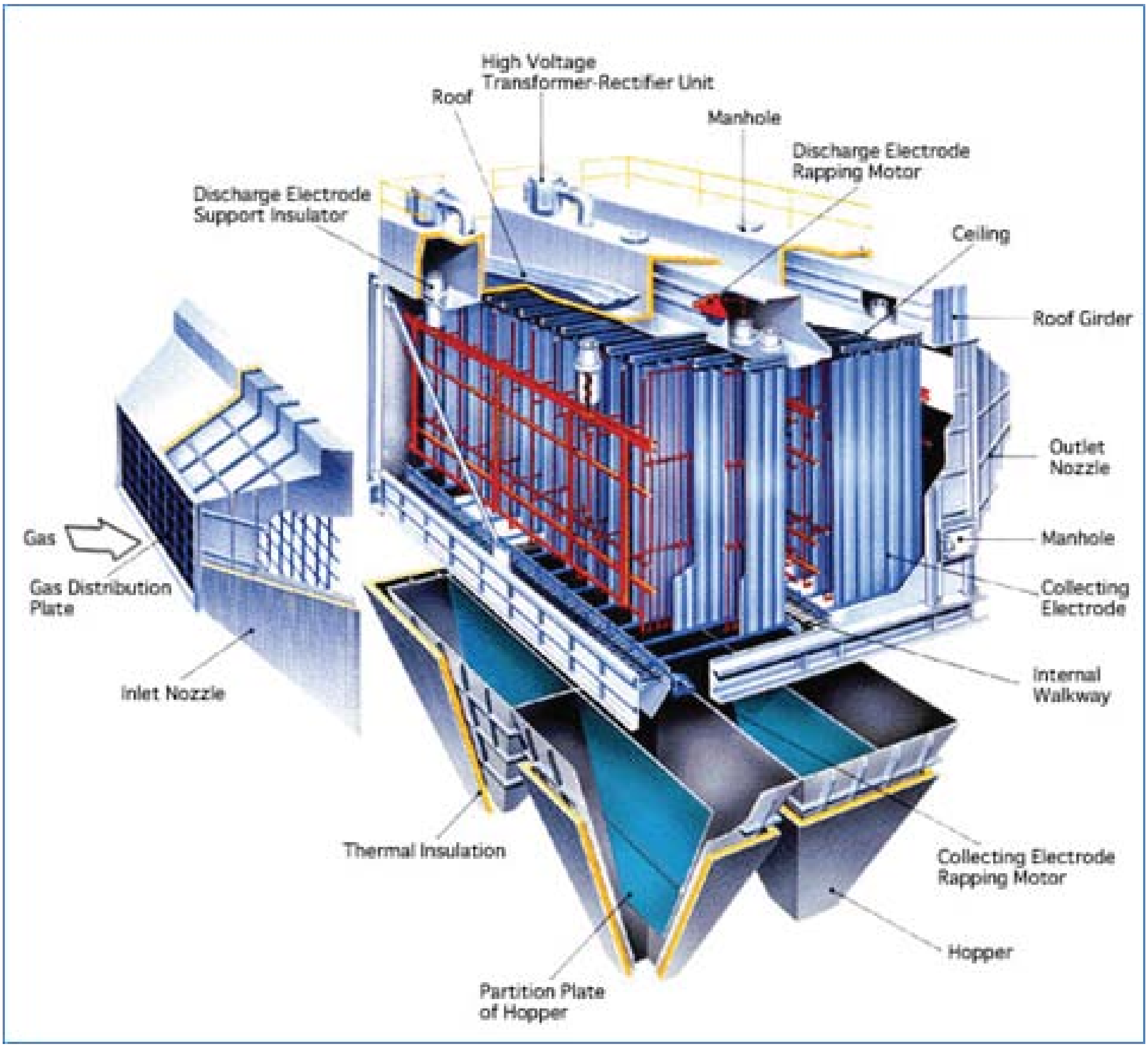


Figure 3-7 Typical schematic arrangement of an ESP

The performance and principal characteristics of ESP, Fabric Filter and Wet Scrubbers are described in Table 3-4.

Type	Performance / Characteristics
ESP	▪ Removal efficiency of > 96,5% (<1μm), > 99,95% (>10μm); ▪ 0,1-1,8% of electricity generated is used; ▪ It might not work on particulates with very high electrical resistivity. In these cases, flue gas conditioning (FGC) may improve ESP performance; ▪ Can handle very large gas volume with low pressure drops.
Fabric Filter	▪ Removal efficiency of > 99,6% (<1μm), > 99,95% (>10μm). Removes smaller particles than ESPs; ▪ 0,2-3% of electricity generated is used; ▪ Filter life decreases as coal S content increases; ▪ Operation costs go up considerably as the fabric filter becomes dense to remove more particles; ▪ If ash is particularly reactive, it can weaken the fabric and eventually it disintegrates.
Wet Scrubber	▪ Removal efficiency of > 98,5% (<1μm), > 99,9% (>10μm); ▪ Up to 3% of electricity generated is used; ▪ As a secondary effect, can remove and absorb gaseous heavy metals; ▪ Wastewater needs to be treated.

Table 3-4. Performance/Characteristics of Dust Removal Systems (IFC,2008)

3.2.3.2 SO_2

Sulphur oxides are emitted from the combustion of most fossil fuels through oxidation of the sulphur contained in the fuel. Measures to remove sulphur oxides, mainly SO_2, from flue-gases during or after combustion have been used since the early 1970s, first in the US and Japan and then, in the early 1980s, in Europe. Presently, there are many ways of reducing SO_2 emissions generated by coal combustion.

Fuel treatment to reduce SO_2 is possible with coal and involves using physical, chemical, or biological processes to wash the coal before it is burned as it was referred on the coal introduction of this chapter (EC, 2006).

Other control technologies for SO_2 include post-combustion technologies. Post-combustion flue gas desulphurization (FGD) techniques can remove SO_2 formed during combustion by using an alkaline reagent to absorb in the flue gas and produce a sodium or a calcium sulphate compound. These solid sulphate compounds are then removed in downstream equipment. FGD technologies are categorized as wet, semi-dry, or dry depending on the state of the reagent as it leaves the absorber vessel. These processes are either regenerable (such that the reagent material can be treated and reused) or non-regenerable (in which case all waste streams are de-watered and discarded).

Wet regenerable FGD processes are attractive because they have the potential for better than 95% sulphur removal efficiency, have minimal waste water discharges, and produce a saleable sulphur product. Some of the current non-regenerable calcium-based processes can, however, produce a saleable gypsum product (USEPA, 2011). The lime and limestone wet scrubbing process uses a slurry of calcium oxide or limestone to absorb SO_2 in a wet scrubber. Control efficiencies in excess of 91% for lime and 94% for limestone over extended periods are possible. Sodium scrubbing processes generally employ a wet scrubbing solution of sodium hydroxide or sodium carbonate to absorb SO_2 from the flue gas. Sodium scrubbers are generally limited to smaller sources because of high reagent costs and can have SO_2 removal efficiencies of up to 96,2%. The double or dual alkali system uses a clear sodium alkali solution for SO_2 removal followed by a regeneration step using lime or limestone to recover the sodium alkali and produce a calcium sulphite and sulphate sludge. SO_2 removal efficiencies of 90 to 96% are possible (USEPA, 2011).

Today, wet limestone scrubbers are the most widely used of all the FGD systems, with a share of 80% of all the installed FGD capacity.

Figure 3-8 shows a typical flow diagram of a type of wet lime/limestone FGD system. Limestone is commonly used as a reagent because it is present in large amounts in many countries and is usually around three or four times cheaper than other reagents. Lime was commonly used as a reagent in earlier plants because of its better reactivity with SO_2. However, lime has been replaced by limestone to reduce the risk of lime calcination which is energy intensive, costly, and time consuming to repair. Nevertheless in some cases, lime has to be used instead of limestone due to the whiteness requirements of the FGD gypsum users. In any case, FGD using limestone could achieve almost the same SO_2 removal as lime. The reactivity of limestone has an important influence on the efficiency of a FGD system; however, at the present time there is no standard or normalized method to test reactivity. Other reagents, such as magnesium-enhanced lime, are also used (EC, 2006).

The effectiveness of these devices depends not only on control device design but also on operating variables (see Table 3-5). Particulate reduction of more than 99% is possible with wet scrubbers, but fly ash is often collected by upstream ESPs or bag houses to avoid erosion of the desulphurization equipment and possible interference with FGD process reactions. Also, the volume of scrubber sludge is reduced with separate fly ash removal and prevents contamination of the reagents and by-products.

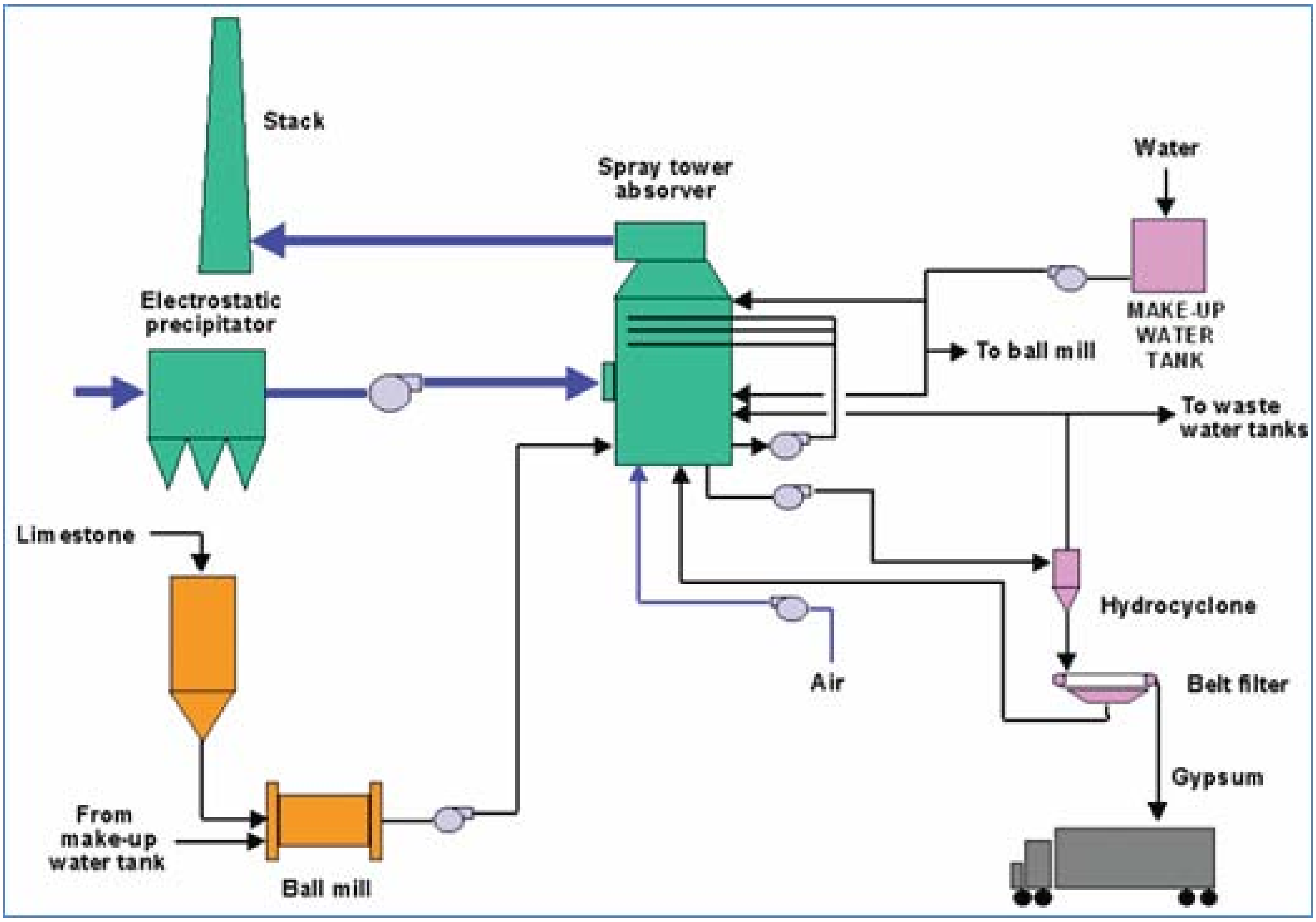


Figure 3-8 Schematic flow diagram of a lime/limestone wet scrubber FGD process (EC, 2006)

Type of FGD	Characteristics
Wet FGD	▪ Flue gas is saturated with water; ▪ Limestone ($CaCO_3$) as reagent; ▪ Removal efficiency up to 98%; ▪ Use 1-1,5% of electricity generated; ▪ Most widely used; ▪ Distance to limestone source and the limestone reactivity to be considered; ▪ High water consumption; ▪ Need to treat wastewater; ▪ Gypsum as a saleable by-product or waste; ▪ Plant capital cost increase 11-14%.
Semi-Dry FGD	▪ Also called "Dry Scrubbing" – under controlled humidification; ▪ Lime (CaCO) as reagent; ▪ Removal efficiency up to 94%; ▪ Can remove SO_3 as well at higher removal rate than Wet FGD; ▪ Use 0,5-1,0% of electricity generated, less than Wet FGD; ▪ Lime is more expensive than limestone; ▪ No wastewater; ▪ Waste – mixture of fly ash, unreacted additive and $CaSO_3$; ▪ Plant capital cost increase 9-12%.
Seawater FGD	▪ Removal efficiency up to 90%; ▪ Not practical for High S coal (>1% S); ▪ Impacts on marine environment need to be carefully examined (e.g., reduction of pH, inputs of remaining heavy metals, fly ash, temperature, sulfate, dissolved oxygen, and chemical oxygen demand); ▪ Use 0,8-1,6% of electricity generated; ▪ Simple process, no wastewater or solid waste; ▪ Plant capital cost increase 7-10%.

3.2.3.3. NO_x

Formation of nitrogen oxides can be controlled by modifying operational and design parameters of the combustion process (primary measures). Additional treatment of NO_x from the flue gas (secondary measures) may be required in some cases depending on the air quality objectives (IFC, 2008).

Nitrogen oxides (NO_x) formed during the combustion of coal are mainly NO, NO_2 and N_2O. There are, in theory, three different formation mechanisms for NO_x: thermal NO formation; prompt NO; and the formation of NO from nitrogen as a component of the fuel (EC, 2006).

Coals of lower rank, when being burnt, produce lower N_2O emissions than coals of higher rank (Bonn et al., 1995). These authors suggested that this is due to the different bonding of nitrogen in the structure of coals of different rank. Lignite releases a large proportion of volatile nitrogen compounds such as NH. With increasing rank the proportion of nitrogen released as HCN increases; because HCN, according to present knowledge, is the main precursor of N_2O, it is also conclusive that N_2O emission increases with increasing coal rank.

Use of low NO_x burners with other combustion modifications, such as low excess air firing, for boiler plants may be required. Installation of additional NO_x controls for boilers may be necessary to meet emissions limits; a selective catalytic reduction (SCR) system can be used for pulverized coal-fired or a selective non catalytic reduction (SNCR) system for a fluidized-bed boiler (IFC, 2008).

Low NO_x burners have reached a mature stage of development, but further improvements involve an ongoing process and a considerable amount of research work is still devoted to the enhancement of the same.

Low NO_x burners modify the means of introducing air and fuel to delay the mixing, reduce the availability of oxygen, and reduce the peak flame temperature. These burners retard the conversion of fuel-bound nitrogen to NO_x and the formation of thermal NO_x, while maintaining high combustion efficiency. The pressure drop in air ducts increases, causing more operational expenses. Coal pulverization, for instance, must usually be improved, and that may lead to higher operating and maintenance costs. There could also be some corrosion problems, especially if the process is not properly controlled (EC, 2006).

The selective catalytic reduction (SCR) process is a widely applied process for the reduction of nitrogen oxides in exhaust gases from large combustion installations, in Europe and other countries throughout the world, such as Japan and the US (see Table 3-6). The SCR process is a catalytic process based on the selective reduction of nitrogen oxides with ammonia or urea in the presence of a catalyst. The reducing agent is injected into the flue-gas upstream of the catalyst. NO_x conversion takes place on the catalyst surface at a temperature usually between 170 and 510°C, by one of the following main reactions. Base metal oxide SCR catalysts operating in the above-mentioned temperature range are available on the market and used in numerous applications (EC, 2006).

The selective catalytic reduction reactor can be located at various positions in the process including before an air heater and particulate control device, or downstream of the air heater, particulate control device, and flue gas desulphurization systems. The performance of SCR is influenced by flue gas temperature, coal sulphur content, NH_3 to NO_x ratio, inlet NO_x concentration, space velocity, and catalyst condition. Although there is currently very limited application of SCR in the U.S. on coal-fired boilers, NO_x reductions of 75 to 86 percent have been realized on a few pilot systems (USEPA, 2011).

Selective non catalytic reduction (SNCR) is also a post-combustion technique that involves injecting ammonia (NH_3) or urea into specific temperature zones in the upper furnace or convective pass. The NH_3 or urea reacts with NO_x in the flue gas to produce nitrogen, CO_2 and water. The effectiveness of SNCR depends on the temperature where reagents are injected; mixing of the reagent in the flue gas; residence time of the reagent within the required temperature window; ratio of reagent to NO_x; and the sulphur content of the coal that may create sulphur compounds that deposit in downstream equipment (USEPA, 2011).

Type	Characteristics
SCR	▪ NO_X emissions reduction rate of 80-95%; ▪ Use 0,5% of electricity generated; ▪ Use ammonia or urea as reagent; ▪ Ammonia slip increases with increasing NH_3 / NO_X ratio may cause a problem (e.g., too high ammonia in the fly ash). Larger catalyst volume / improving the mixing of NH_3 and NO_X in the flue gas may be needed to avoid this problem; ▪ Catalysts may contain heavy metals. Proper handling and disposal/recycle of spent catalysts is needed; ▪ Life of catalysts has been 6-10 years; ▪ Plant capital cost increase 4-9%.
SNCR	▪ NO_X emissions reduction rate of 30-50%; ▪ Use 0.1-0.3% of electricity generated; ▪ Use of ammonia or urea as reagent; ▪ Operate without using catalysts; ▪ Plant capital cost increase 1-2%.

Table 3-6. Performance/Characteristics of Secondary NO_X Reduction Systems (IFC, 2008)

3.2.3.4 Other pollutants

Depending on the coal type and quality, other air pollutants may be present in environmentally significant quantities requiring proper consideration in the evaluation of potential impacts to ambient air quality and in the design and implementation of management actions and environmental controls. Examples of additional pollutants include mercury and other heavy metals.

Recommendations to prevent, minimize, and control emissions of other air pollutants, such as mercury in particular, from thermal power plants include the use of conventional secondary controls such as fabric filters or ESPs operated in combination with FGD techniques, such as limestone FGD, Dry Lime FGD, or sorbent injection. Removal of metals such as mercury can be achieved in a high dust SCR system along with powered activated carbon, bromine-enhanced Powdered Activated Carbon (PAC) or other sorbents.

Since mercury emissions from thermal power plants pose potentially significant local and transboundary impacts to ecosystems and public health and safety through bioaccumulation, particular consideration should be given to their minimization in the environmental assessment and accordingly in plant design (IFC, 2008).

Fuel cleaning (mainly the cleaning of coal) is one option for removing mercury from the fuel prior to combustion. There are many types of cleaning processes, all based on the principle that coal is less dense than the pyritic sulphur, rock, clay, or other ash-producing impurities that are mixed or embedded in it. Mechanical devices using pulsating water or air currents can physically stratify and remove impurities. Centrifugal force is sometimes combined with water and air currents to aid in a further separation of coal from impurities. Another method is dense media washing, which uses heavy liquid solutions usually consisting of magnetite (finely ground particles of iron oxide) to separate coal from impurities. Smaller sized coal is sometimes cleaned using froth flotation. This technique differs from the others because it focuses less on gravity and more on chemical separation (EC, 2006).

Most metals have sufficiently low vapor pressures at typical air pollution control device operating temperatures that condensation onto particulate matter is possible.

Mercury, on the other hand, has a high vapor pressure at typical control device operating temperatures, and collection by particulate matter control devices is highly variable. The most important factors affecting mercury control on utility boilers include the flue-gas volume, flue-gas temperature and chloride content, the mercury concentration and the chemical form of the mercury being emitted. The chemical species of mercury emitted from utility boilers vary significantly from one plant to another. Removal effectiveness depends on the species of mercury present.

Factors that enhance mercury control are low temperatures in the control device system (less than 150 ºC), the presence of an effective mercury sorbent and the application of a method to collect the sorbent. In general, high levels of carbon in the fly ash enhance mercury sorption onto particulate matter, which is subsequently removed by the particulate matter control device. Additionally, the presence of hydrogen chloride (HCl) in the flue-gas stream can result in the formation of mercury chloride, which is readily adsorbed onto carbon-containing particulate matter. Conversely, sulphur dioxide (SO_2) in flue gas can act as a reducing agent to convert oxidized mercury to elemental mercury, which is more difficult to collect.

Control technologies designed for controlling pollutants other than mercury (e.g. acid gases and particulate matter) vary in their mercury-removal capability, but generally can achieve reductions no greater than 50% (except for high removal efficiencies for mercury chloride by wet scrubbers).

Carbon filter beds have been used successfully in Germany for mercury control on utility boilers and municipal waste incinerators. Injection of activated carbon into the flue gas has been applied for LCP co-combusting sewage sludge where mercury reductions of at least 85 percent have been achieved. The addition of activated carbon to utility flue gas for mercury control increases the amount of particulate matter requiring disposal (EC, 2006).

3.2.3.5 Comparison of coal combustion technologies

Table 3-7 presents a summary of coal combustion technologies according to its air pollutant environmental performance.

Base processes	Subcritical pulverized coal combustion (PCC)	Supercritical PCC	Atmospheric Fluidized Bed Combustion (AFBC)	Pressurized Fluidized Bed Combustion (PFBC)	Integrated Gasification Combined Cycle (IGCC)
Flue gas desulphurization (FGD)	FGD required to meet most standards. Wet FGD can achieve >95% recovery, dry can achieve up to 70-80%.	FGD required to meet most standards. Wet FGD can achieve >95% recovery, dry can achieve up to 70-80%.	Not required	Not required	Not required
NO_X control: Low NO_X burners (LNB)	LNB can reduce approx. 50% NO_X formation.	LNB can reduce approx. 50% NO_X formation.	May not be required due to low combustion temperature.	May not be required due to low combustion temperature and LNB on turbine	Standard equipment. Can achieve single digit ppm (better than 90%) NO_X in flue gas with LNB.
NO_X control: Selective Catalytic Reduction (SCR)	80% removal without ammonia slip problems.	80% removal without ammonia slip problems.	May not be required due to low combustion temperature.	May not be required due to low combustion temperature and LNB on turbine	May not be required where LNBs are available to reduce NO_X by at least 90%.
	Note: typically bot LNB and SCR rewuired for PCC plants to meet most standards				
ESP or baghouse	Requires baghouse or ESP.	Requires baghouse or ESP.	Requires baghouse or ESP.	Requires baghouse or ESP.	Not required
Mercury	With baghouse and FGD 60-70% removal. ESPs not as effective.	Requires baghouse or ESP,	With baghouse up to 70% removal	With baghouse up to 70% removal	Not required

Table 3-7 Coal combustion technology comparison: air pollution control add-ons (PIR, 2001)

3.2.4 CO_2 reduction

Greenhouse Gas (GHG) emissions originating from coal-fired power plants cannot be significantly abated with existing technologies. As a result, coal plants are one of the most significant contributors to global climate change (IDB, 2009). Additionally, the carbon content of coal, and therefore the quantity of CO_2 released per unit of energy produced by its combustion, is the highest of all fossil fuels. Consequently, an important factor in the future use of coal will be the level to which CO_2 emissions can be reduced. Much has been done to achieve this, such as improvements in efficiency levels. One of the most promising options for the future is carbon capture and storage (CCS) (WCI, 2005) even if is unlikely to be available on commercial basis before 2020.

Mitigation measures for CO_2 are focused on carbon capture and sequestration technologies. Carbon capture may involve either pre-combustion or post-combustion separation of CO_2 from emission sources (see Figure 3-9). Pre-combustion CO_2 capture typically involves gasification processes, such as integrated gasification combined cycle (IGCC) technology, where coal or biomass is converted into gaseous components by applying heat under pressure in the presence of steam. IGCC plants may be designed so that concentrated CO_2 at a 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. Because CO_2 is present at much higher concentrations in synthesis gas than in post-combustion flue gas, IGCC systems currently appear to be the economic choice for new plants.

Post-combustion CO_2 capture involves physical and chemical processes to separate CO_2 from the exhaust flue gas. These systems might be applicable to retrofits of conventional coal energy plants, and also might be applicable to other thermal/combustion energy production technologies.

However, such systems are challenging and, currently, costly because the low pressure and dilute CO_2 concentrations dictate a high actual volume of gas to be treated. Further, trace impurities in the flue gas tend to reduce the effectiveness of the CO_2 adsorbing processes, and compressing captured CO_2 from atmospheric pressure to pipeline pressure represents a large parasitic load. One technological option, oxygen combustion (oxy-combustion), combusts coal in an enriched oxygen environment using pure oxygen diluted with recycled CO_2 or water. This process enables a relatively concentrated stream of CO_2 to be captured by condensing the water in the exhaust stream. Oxy-combustion offers several potential benefits for existing coal-fired plants.

After CO_2 emissions have been collected/captured, the CO_2 should be sequestered (immobilized or removed), either geologically (e.g., saline aquifers) or via enhanced oil recovery. In the U.S., significant research is ongoing to demonstrate the feasibility of geologic sequestration in saline aquifers and to overcome implementation barriers, such as concerns about safety, effectiveness, liability, and public acceptance.

Another potential type of CO_2 sequestration is CO_2- enhanced oil recovery, a commercially proven technology that has been used extensively in the United States to increase oil production at diminished wells. In CO_2- enhanced oil recovery, compressed CO_2 is injected into an oil reservoir near the production well site, forcing the oil toward the production well and increasing yield. Several planned IGCC plants in the U.S. expect to derive a substantial economic benefit through the sale of their CO_2 for CO_2- enhanced oil recovery (USEPA, 2011).

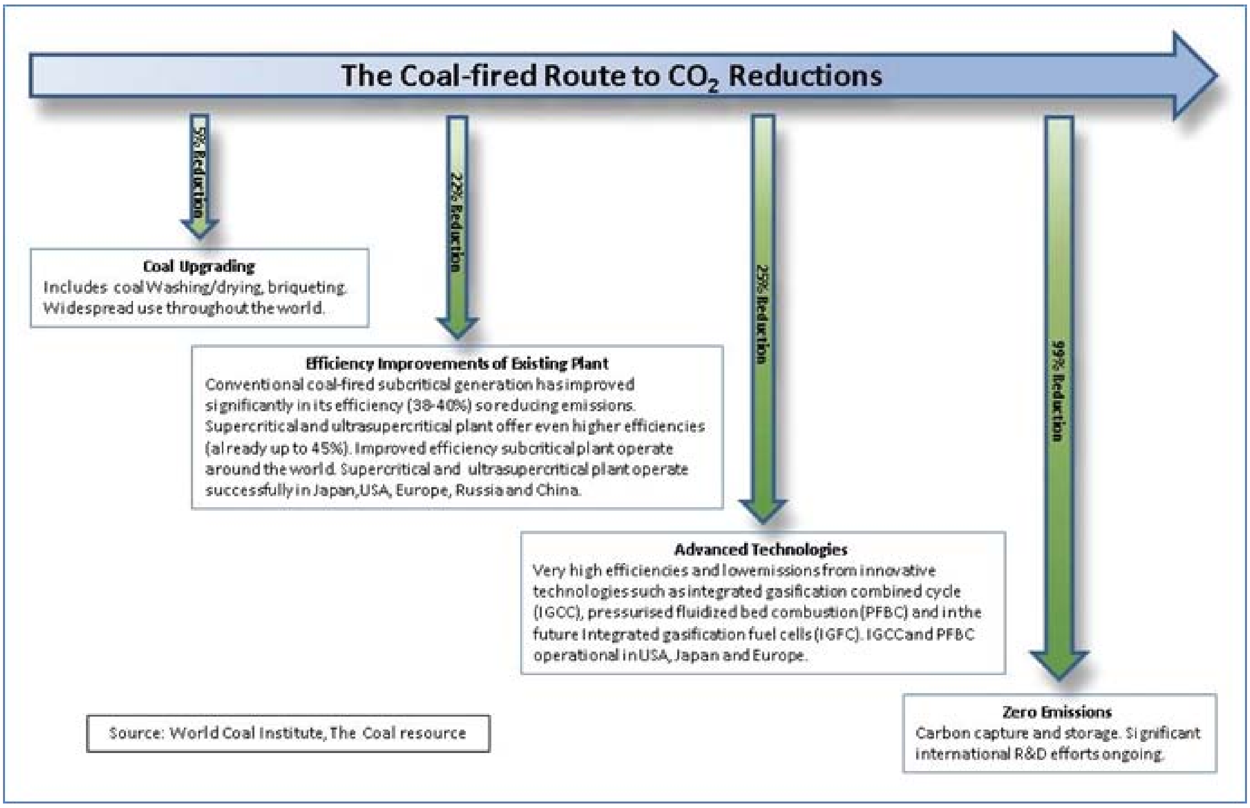


Figure 3-9 The Coal-fired Route to CO_2 reduction.

3.2.5 Cooling systems

The water used in the condenser's coils comes from a cooling system. The water in the cooling system is separate from the "working" water in the steam system, although it usually comes from the same source. A constant flow of cooling water is required to reduce the temperature of the steam and water in the condenser. The heat carried away from the condenser is waste heat, and usually accounts for about 50 percent of the total heat energy that is emitted from the steam generator (the other 50 percent being converted into mechanical energy inside the turbines). Steam turbine electric plants use either once-through cooling water systems or recirculating cooling water systems (USEPA, 2011).

Once-through cooling systems are used only where sufficient cooling water and receiving surface water are available. Recirculating cooling systems include closed circuit wet cooling system; and closed circuit dry cooling system (e.g., air cooled condensers) (IFC, 2008).

3.2.5.1 Once-through system

In once-through cooling water systems, the cooling water is withdrawn from a body of water, flows through the condenser, and is discharged back to the body of water (Figure 3-10). These systems require a significant amount of water for cooling. For example, a 200 MW coal-fired plant can require up to 480 000 m^3 per day of cooling water. If that water is supplied via a once-through system, then that full amount of water is needed each day. If, on the other hand, the cooling water is reused after being cooled by a pond or a tower, the amount of water needed each day can drop to 15 000 m^3.

However, once-through systems consume less water. That is because the cooling water is generally not raised to evaporative temperatures in the cooling system, so that almost 100 percent of the withdrawn for cooling is discharged back into the source. At a typical coal-fired 200 MW plant with a once-through cooling system may only consume 1 000 m^3 per day of cooling water, or less than 0.2 percent of the water withdrawn. The same size facility using a cooling pond or cooling tower may only use 15 000 m^3 per day of cooling water, but will consume nearly all of it (14 000 m^3) due to evaporation (USEPA, 2011).

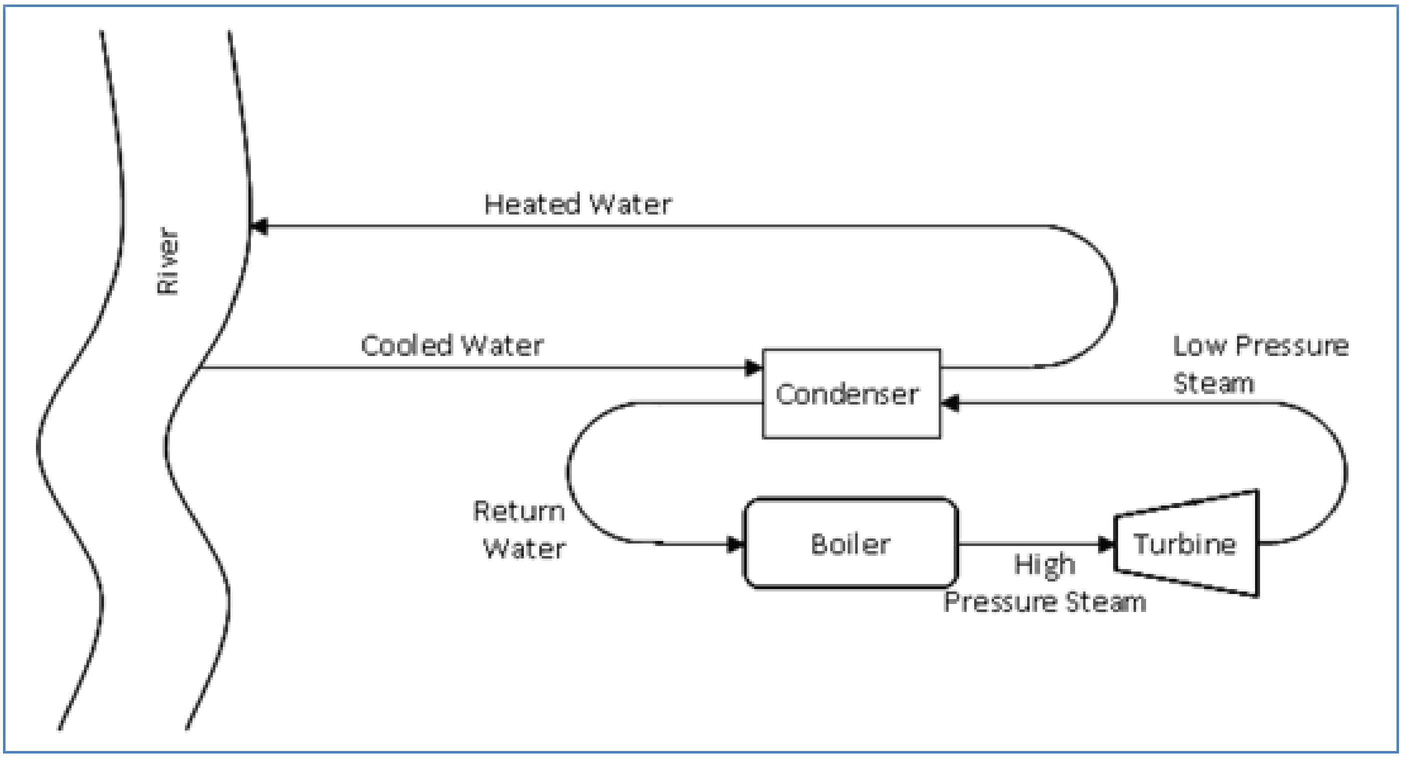


Figure 3-10 Once-through cooling system diagram (USEPA, 2011).

Although once-through systems consume very little water, they require large amounts, and the water they discharge back into the environment is at elevated temperatures, which can have a significant impact on aquatic ecosystems if the quantity of discharged water exceeds the receiving water's capacity to dilute the temperature to an acceptable level. Some once-through designs use cooling ponds at the end of the cooling system to allow the water to cool to an acceptable level before being discharged back to the source (Figure 3.11).

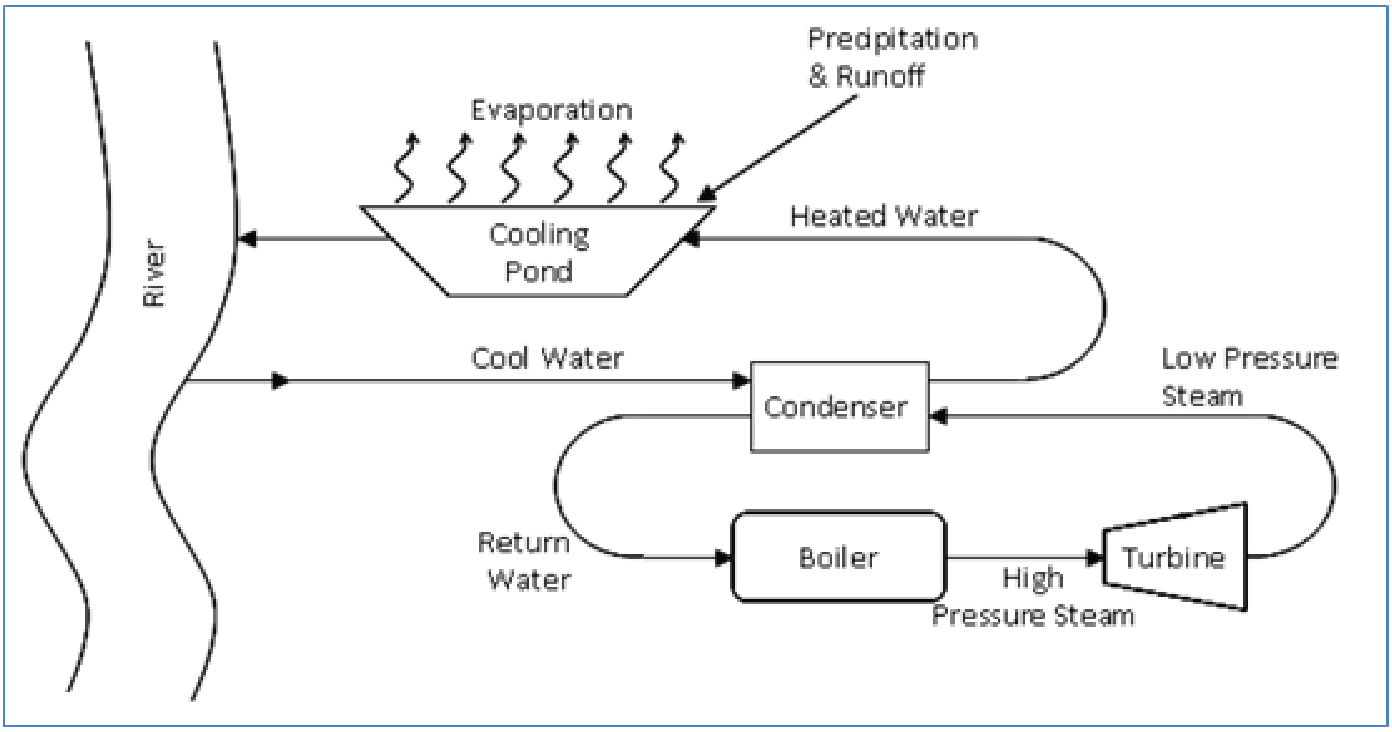
Another practice which has had some use in the United States is to build constructed wetlands to receive cooling water and provide additional cooling before returning water to the source. Constructed wetlands are not as deep as a cooling pond, so more land is needed to treat the same volume of water. These systems loose more water to evaporation (one of the primary cooling mechanisms in the ponds and wetlands) than a simple once-through system, however, rainwater run-off and direct precipitation will compensate for part of the evaporation losses (USEPA, 2011).

3.2.5.2 Wet system

In a recirculating cooling system the water that passes through the condenser is sent to a cooling pond or cooling tower to lower its temperature so that it can be reused in the cooling system. At some plants, both ponds and towers are incorporated into the cooling system. Recirculating cooling systems can be divided into two groups: wet cooling, which relies upon evaporation for cooling, and dry systems, that use air to cool the turbine steam or cooling water.

Wet cooling systems may use either cooling towers or cooling ponds to reduce the temperature of the cooling water before it is recirculated through the condenser. Ponds are generally less expensive as they do not require extensive construction and maintenance and generally require lower pumping costs. Ponds can also create secondary recreational uses such as fishing, swimming, boating, camping and picnicking and can also be used as fish hatcheries. Ponds, however, require much more space than towers.

Figure 3-11. Once-through cooling system with cooling pond diagram (USEPA, 2011).



In a recirculating cooling pond system, cooling water is drawn from and discharged to the cooling pond (Figure 3-12). Water in the pond will evaporate, as one of the key cooling mechanisms. The evaporation will be somewhat compensated by rainwater run-off and direct precipitation, but make up water will have to be withdrawn from the source to compensate for the remainder of evaporation. If the site hydrology is favorable, the evaporation losses from the cooling pond could be balanced by rainwater harvesting, making the cooling pond a “closed system,” needing no water from the source. In this way, pond recirculating systems often consume less water than tower systems (USEPA, 2011).

The size of the pond will depend upon the size of the power plant, in that it must be large enough to provide adequate cooling water during periods of peak production. Depending on the design, it may also be quite deep, because deep water tends to stay cooler longer.

In a cooling tower, the heated water from the condenser enters at the top and falls down through a fill material with a high surface area that interrupts the flow of the water (Figure 3-13). Depending on the design of the fill material, the water will either splash or trickle through the tower. In either case, as water flows downward, air flows upward through the tower, causing some of the water to evaporate.

As water evaporates, the heat required to evaporate the water is transferred from the water to the air, thus cooling the water. The water that does not evaporate is collected at the bottom of the tower and pumped back to the condenser. In the process, however, water is lost via evaporation, so that additional fresh water must be periodically added to the cooling system (USEPA, 2011).

As cooling water evaporates in the cooling tower, dissolved minerals present in the water remain behind in the fill material and on the inside of the tower walls. Over time, these minerals will increase in concentration and can inhibit the effectiveness of the tower. To prevent a build of minerals, a volume of water must be discharged periodically to purge the minerals from the system, which is referred to as “cooling tower blowdown”.

Cooling towers can be hyperboloid or rectangular structures. Hyperboloid structures can be larger than rectangular structures, up to 200 m tall and 100 m in diameter. Rectangular structures can be over 40 m tall and 80 m long. Cooling towers use two mechanisms to draw air up through the water: natural draft and mechanical draft. Some plants combine natural and mechanical components in a fan assisted natural draft. Natural draft towers rely on the difference in air density between the warm air in the tower and the cooler ambient air outside the tower to draw the air up through the tower. Hyperboloid cooling towers (as shown in Figure 3-13) have become the design standard for natural draft cooling towers because of their structural strength and minimum usage of material and because their shape aids in accelerating the upward convective air flow.

Mechanical draft towers utilize fans to move air up through the tower. They may be hyperboloid or rectangular structures. The fans may be used to create an induced draft with fans at the discharge to pull air through the tower, or a forced draft with a blower type fan at the intake pushing air up through the tower. Forced draft design has some technical drawbacks as well as usually requiring bigger fans, so they are less common than induced draft towers.

Figure 3-12 Recirculating cooling system with cooling pond diagram (USEPA, 2011).

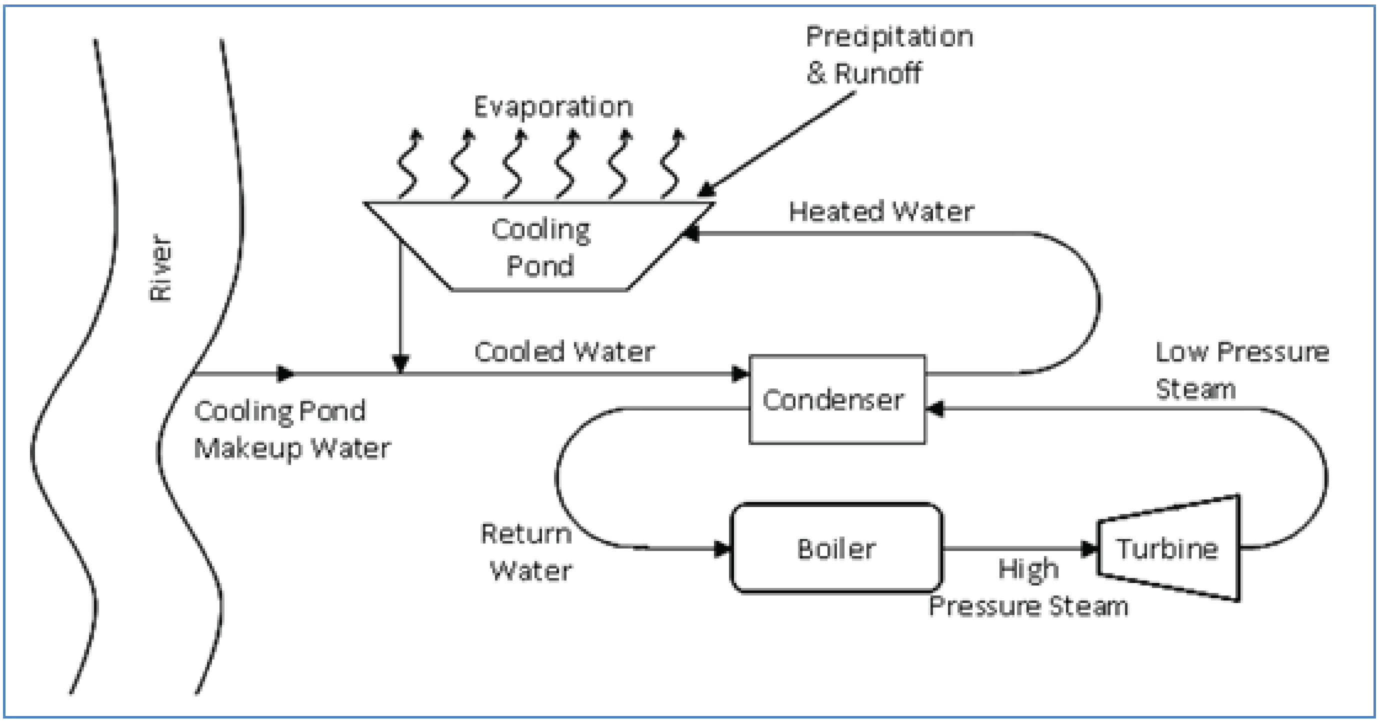
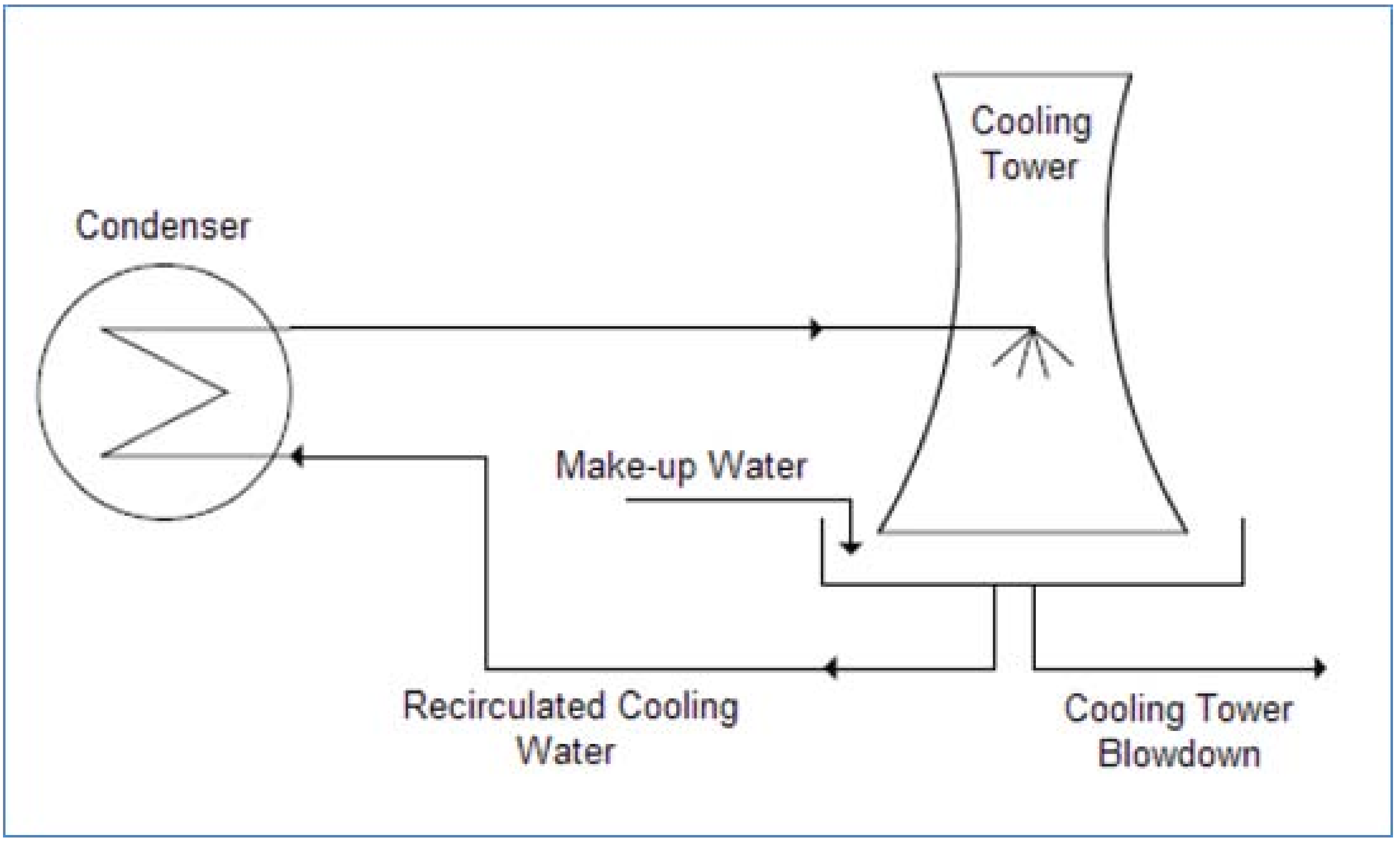


Figure 3-13 Cooling tower diagram (USEPA, 2011).



3.2.5.3 Dry system

Dry cooling towers are essentially large radiators with hot water flowing down through the tower through multiple layers of relatively small diameter, finned pipes. Air is passed up through these pipes by large fans at the top or bottom of the tower (depending on the design), thus cooling the water before it is used again.

Dry cooling towers are usually rectangular or A-frame in shape. Dry cooling towers can either use direct or indirect cooling. In direct cooling systems, the turbine exhaust steam flows directly to the tower, where it is cooled and reused in the boiler (Figure 3-14). In an indirect cooling system the hot cooling water flowing out of the condenser is pumped up to the top of the tower, where it flows down through the tower, cooling on its way, and then is used again in the condenser (Figure 3-15) (USEPA, 2011).

Dry cooling is the most expensive form of cooling, but it may be necessary in areas where there is a water shortage or other limitation on water availability. Because dry cooling systems transfer heat to the atmosphere without water evaporation, they use very little water (USEPA, 2011).

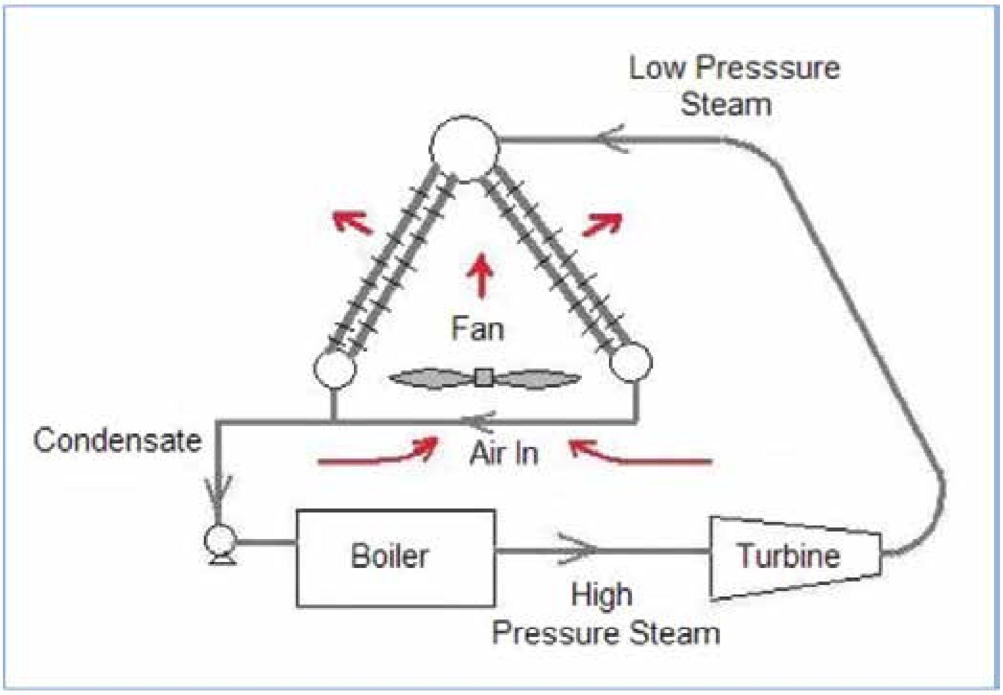


Figure 3-14 Dry cooling tower diagram for direct cooling (USEPA, 2011).

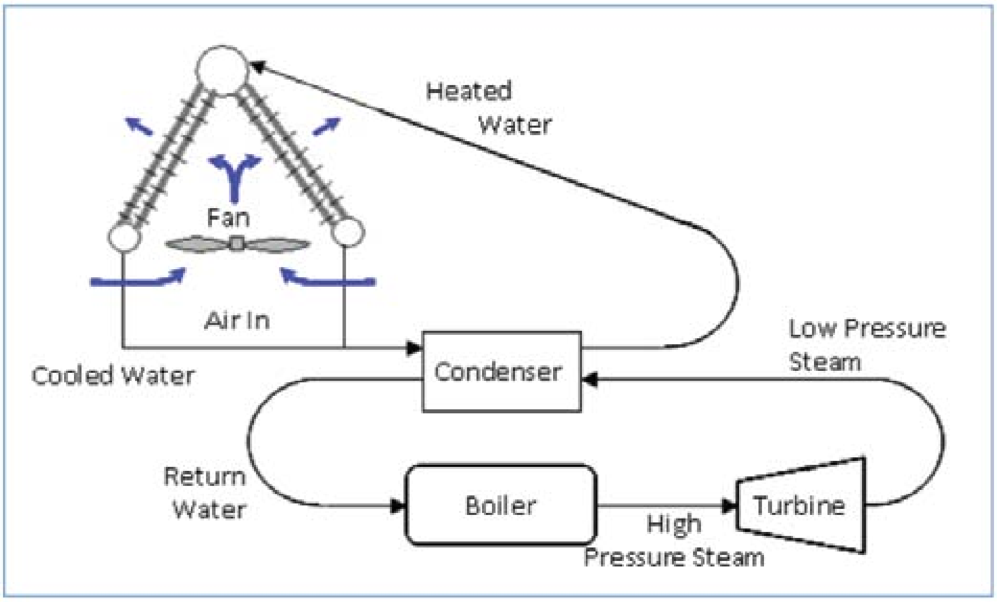


Figure 3-15 Dry cooling tower diagram for indirect cooling (USEPA, 2011).

Part 4 - Which criteria should be applied for selecting a site for a coal-fired power plant?

While siting a coal-fired power plant, care should be taken to minimize the adverse impact of the facility on immediate neighborhood as well as distant places. Some of the natural life sustaining systems and some specific landuses are sensitive to industrial impacts because of the nature and extent of fragility.

The application of good and sound siting criteria is often the best and first strategy to minimize the environmental and social impacts that can be caused by a coal-fired power plant. Siting criteria can be used not only to screen in and out potential project sites but also to compare valid alternative locations.

Power plant types and designs have a wide range of land requirements. Coal plants tend to need larger areas to support rail lines, coal piles, and landfills. Generally, sites with ample space may be preferred. Typically the construction of a coal-fired power plant represents the following land requirements (IL&FS, 2010):

- Land requirement for large capacity power plant is about 0.2 km^2 per 100 MW for the main power house only excluding land for water reservoir (required if any).

- The land for housing is taken as 0.4 km^2 per project.

- Land requirement for ash disposal is about 0.2 km^2 per 100 MW considering 50% of ash utilization.

A site might be able to support more generating capacity than proposed. It's usually more economical and environmentally acceptable to add generating capacity at an existing site than to build at a new site. Information is needed on the potential or plans for a site to support more capacity than initially proposed, including the number and size of potential, future generating units or other facilities. Often, an expandable site may be more desirable.

Siting criteria are intended as a "common language" for power plant characteristics. They should not be used as a "cookbook" for finding or eliminating sites (PSCW, 1999). The following criteria should be used when determining where to locate a new coal-fired power plant:

- **Sensitive areas:**

- With a view to protect sensitive sites, the power plant site may maintain the following distances as far as possible from (ILFS, 2010):

- Coastal areas: preferably 500 m away from high tide line.

- Flood plain of the riverine system: preferably 500 m away from flood plain or modified flood plain affected by dam in the upstream or by flood control systems.

- Transport/Communication system: preferably 500 m away from highway and railway line.

- Locations of thermal power stations are avoided within 25 km of the outer periphery of the following:

- Metropolitan cities;

- National park and wildlife sanctuaries;

- Ecologically sensitive areas such as a tropical forest, biosphere reserve, important lake and coastal areas rich in coral formation;

- The sites should be chosen in such a way that chimneys of the power plants do not fall within the approach funnel of the runway of the nearest airport due to air space restrictions;

- Location of the sites is avoided in the vicinity (say 10 km) of places of archaeological, historical, cultural/religious/tourist importance and defense installations.

- **Land use:**

- Identify any legally protected area that could be affected by the project.

- Identify any sensitive land use or buildings that might be affected by the project.

- Land acquired shall be sufficiently large to provide space for a buffer zone with appropriate green cover including greenbelt, around the battery limit of the industry.

- Site layout must conform to the landscape of the area, without affecting the scenic features of that place.

- Associated township of the industry may be created at a space having physiographic barrier between the industry and the township.

- The construction of a plant at a particular site may create limitations on future development in the local area through its effect on land use, air pollution increments, water resources, of water discharge capacity. Generally, sites that impose fewer limitations on future development may be more desirable.

- **Geology and soils:**

- Identify and avoid unstable slopes and factors that can cause slope instability (groundwater conditions, precipitation, seismic activity, slope angles, and geologic structure) and landslide hazards. Sites with relatively flat topography are preferred over rolling hills or steep grades.

- Avoid locating facilities, in alluvial fans and other areas prone to erosion or flash floods.

- Soil types with good weight-bearing capacity are preferred over soils with poor engineering characteristics. Favorable sites also have adequate groundwater depths to support plant construction and avoid shallow water table problems.

- **Air quality:**

- Avoid areas where air quality baseline concentrations values are already critical vis-à-vis to NEQS.

- Obtain available meteorological information concerning prevailing wind direction and inversion layer formation (fogs) representative of the site.

- Analyze existing land use until 15-20 km downwind of the proposed site:

- Avoid sites that could impact high densely populated areas and/or with intense agricultural land;

- Identify potential cumulative effects:

- Identify air pollutants (PM, SO_2, NO_X) emission sources (existing and planned) on a radius of 10 km from the proposed site;

- Identify VOCs emission sources and consider potential effect on ozone background levels.

- **Water:**

- Surface water is used for plant cooling and groundwater is used for plant processes. Generally, the presence of adequate and usable water resources at or near a site is preferred over sites with remote, inadequate, or low-quality water resources.

- Identify the cooling system that will be adopted for power plant:

- Once-through cooling technologies withdraw 10–100 times more water per unit of electric generation than cooling tower technologies, yet cooling tower technologies can consume twice as much water as once-through cooling technologies.

- Estimate water withdrawal and consumption requirements of the system:

- Macknick et al. (2012) present the following median water use factors for supercritical coal-fired power plants:

- Cooling towers:
  - withdraw: 634 gal MW^{-1} h^{-1}
  - consumption: 493 gal MW^{-1} h^{-1}

- Once-through:
  - withdraw: 22590 gal MW^{-1} h^{-1}
  - consumption: 103 gal MW^{-1} h^{-1}

- Pond:
  - withdraw: 15046 gal MW^{-1} h^{-1}
  - consumption: 43 gal MW^{-1} h^{-1}

- Compare requirements with the flow regime of the natural water body and water availability.

- Sites with no competing water uses are generally preferred to sites with many uses. Identify water uses and users upstream and downstream of site:

- Avoid areas with pre-existing water scarcity problems.
- Consider potential effects of climate change scenarios on water availability of the region.

• If cooling system includes a thermal discharge, assess if sensitive ecosystems might be affected.

• **Noise:**

• Information of interest includes noise caused by plant construction and operations, distance of noise sources from sensitive locations such as parks and residences. More desirable sites maximize the distance between the noise source and the public, have landscape features that would absorb noise between the plant and the public, and have no receptors within any areas where noise guidelines or ordinances are exceeded.

• Siting new facilities with consideration of distances from the noise sources to the receptors to the extent possible. Locate facilities more than 1.0 km from sensitive noise receptors (e.g., quiet recreation, religious buildings, medical care facilities, schools, child care facilities, parks, residences, wildlife areas).

• If the local land use is not controlled through zoning or is not effectively enforced, examine whether residential receptors could come outside the acquired plant boundary.

• **Solid waste management:**

• A coal-fired power plant may need a site to meet on-site landfill, off-site landfill, or other waste disposal requirements. Information is needed on the area, location, groundwater conditions, and soil types of potential on-site, or nearby off-site landfill or waste management areas.

• Estimate amount of wastes (bottom ash, fly ash, waste water treatment sludge, others) produced by the power plant.

- Estimate area needed for waste disposal.

• Generally, a preferred site may have suitable on-site conditions (or correctable inadequacies) to meet solid waste standards.

• Identify pre-existing appropriate waste disposal facilities:

- If none, then identify new waste disposal facility.

- Consider geological characteristics of the site.

- Develop hydrogeological study.

• Least-preferred sites may be those where suitable landfill conditions exist only off-site with a long haul distance.

• **Transportation of coal:**

• Information is needed on access and distance to: existing fuel transport systems, competing fuel transporters, and alternate fuel delivery systems. On-site space may be needed for coal storage. Generally, sites with access to competing fuel transporters and alternate fuels are preferable to sites without this access.

• Coal transportation is preferred by dedicated merry-go-round (MGR) rail system. The availability of corridor for the MGR need to be addressed while selecting the sites.

• **Transmission of electricity:**

• Any new transmission line required to connect the power plant into the electrical transmission system can be a significant cost of plant siting and a major cause of community concern. Generally, shorter new power lines are preferred to longer new lines, and lower-voltage lines are preferred to higher-voltage lines.

• Identify connection point to the national distribution grid.

• Transmission line routes that minimize the number of residences, schools, etc., exposed to electric and magnetic fields within the area of influence may be more desirable.

• **Social issues:**

• Labor availability: A power plant requires labor for construction and operation. Local communities can benefit from these employment opportunities. Generally, sites that can make use of local labor are more desirable. These sites would have a larger skilled work force within a short distance from the plant site.

5. Rapid environmental and social impact assessment scoping checklist

Scoping is an early stage in the EIA process and is designed to ensure that the environmental studies undertaken provide all the relevant information required for the assessment (EC, 2001). Scoping is the process of determining the content and extent of the matters which should be covered in the environmental information to be submitted to the competent authority for projects which are subject to EIA. The findings of the scoping define the amplitude of the environmental information to be submitted to the component authority and the terms of reference for the environmental studies to be undertaken to compile that information.

Scoping can be considered as a discrete stage in the EIA process which ends with the issue of the terms of reference for the EIA. However the activity of scoping should continue throughout the assessment, so that the scope of work can be amended in the light of new issues and new information. The scope of an EIA must be flexible enough to allow incorporation of new issues which might emerge during the course of the environmental studies, or as a result of design changes or through consultations.

EIA scoping brings a number of benefits (EC, 2001) such as:

- It helps ensure that the environmental information used for decision making provides a comprehensive picture of the important effects of the project, including issues of particular concern to affected groups and individuals.
- It helps focus resources on the important issues for decision-making and avoids wasted effort on issues of little relevance.
- It helps effective planning, management and resourcing of the environmental issues.
- It should identify alternatives to the proposed project and mitigating measures which ought to be considered by the developer.
- It reduces the risk of disagreement about impact assessment methods after submission of the environmental information.

Scoping is therefore primarily focused on identifying the impacts to be assessed and which of these are most important. When scoping is undertaken there are three key questions to be answered:

- What effects could the project have on the environment?
- Which of these effects are likely to be significant and therefore need particular attention in the environmental studies?
- Which alternatives and mitigating measures ought to be considered in developing the proposals for the project?

A checklist is provided over Tables 5-1 to 5-4 to help with scoping. The scoping checklist is divided in four parts:

- The first part (Table 5-1) provides a detailed list of general characteristics of a coal-fired power plant.
- The second part (Table 5-2) provides a checklist on alternatives and mitigation measures which can be considered in scoping.
- The third part (Table 5-3) compiles a set of information relevant to describe the location and its sensitivity.
- Finally, the fourth part (Table 5-4) includes a list of technical characteristics of a coal-fired power plant that are relevant to asses effects on specific environments (e.g. air quality, water quality), as well as the list of data necessary to characterize these same environments.

For each of the questions/topics included in the scoping checklist, it is necessary to define if it is likely to be relevant for the implementation of the project (yes, no or "?" uncertain at this stage). If the answer is yes or "?" it is necessary to identify which characteristics of the project environment could be affected as well as to identify if the effect is likely to be significant.

PART 1: **Coal-Fired Power Plant Characteristics**	**Units**	**Y/N/?** **Comment**
General description		
Type of combustion technology		
Installed capacity	MW	
Mode of operation	Peak load Base load	
Hours of operation/day	hrs	
Annual electricity production expected	MWh	
Construction time	years	
Operational lifespan	years	
Access road	km	
Fuel		

Type of coal or mix
▪ Amount required per day and month
▪ Heating value
▪ Water content
▪ Sulphur content
▪ Other characteristics
▪ Origin of fuel
▪ Transport to site
  ▪ Roads, railways or waterways
  ▪ Conveyor belts
  ▪ Pipelines
▪ Storage requirements
▪ Required processing or cleaning
	
	Tonnes/day
	BTU/lb
	%
	%
	%
	Region
	
	km
	km
	km
	ha	

Combustion and steam components		
Combustion chambers		
Boilers		
Steam controls		
Power generation components		
Turbines ▪ Type ▪ Number ▪ Capacity	 type # MW	
Generators		
Electric Power Transmission		
Substations		
Transformers and/or alternators		
Onsite connecter		
Transmission lines		
Manpower and local purchases		
Employees (per phase) ▪ Number ▪ Type		
Local businesses ▪ Goods ▪ Services		
Decomissioning		
Closure and decommissioning plan		
Plan for closing facility		
Decommissioning of machinery and structures		
Restoring land surface		

Table 5-1 Scoping: coal-fired power plant characteristics

PART 2: Types of alternatives and mitigating measures to be considered	Y/N/? Comment
Locations	
Processes or technologies	
Site plans and layouts	
Timetable for construction, operation and decommissioning including any phase of the project	
Start and finish dates	
Size of the site or facility	
Level of production	
Pollution controls	
Waste disposal arrangements including recycling, recovering, reuse and final disposal	
Access arrangements and routes for traffic to and from site	
Ancillary facilities	
Decommissioning arrangements, site restoration and procedures	

Table 5-2 Scoping: types of alternatives and mitigating measures to be considered

PART 3: **Information about the location and its sensitivity**	**Y/N/?** **Comment**
Are there features of the **local environment** on or around the power plant location which could be affected by the Project?	

▪ Areas which are protected under international or national or local legislation for their ecological, landscape, cultural or other value, which could be affected by the project?
▪ Other areas which are important or sensitive for reasons of their ecology e.g.
    o Wetlands,
    o Watercourses or other waterbodies,
    o The coastal zone,
    o Mountains,
    o Forests or woodlands
▪ Areas used by protected, important or sensitive species of fauna or flora e.g. for breeding, nesting, foraging, resting, overwintering, migration, which could be affected by the project?
▪ Inland, coastal, marine or underground waters?
▪ Areas or features of high landscape or scenic value?
▪ Routes or facilities used by the public for access to recreation or other facilities?
▪ Transport routes which are susceptible to congestion or which cause environmental problems?
▪ Areas or features of historic or cultural importance?
▪ Areas affected by emission of light or electromagnetic radiation including electrical interference?	

Is the power plant in a location where it is likely to be highly **visible** to many people?	
▪ Entire industrial site ▪ Stacks ▪ Cooling towers ▪ Cooling tower's plumes	
Are there **existing land uses** on or around the power plant location which could be affected by the Project?	
▪ Densely populated or built-up areas ▪ Homes, gardens, other private property ▪ Industry ▪ Commerce ▪ Recreation ▪ Public open space ▪ Community facilities ▪ Agriculture ▪ Forestry ▪ Tourism ▪ Mining or quarrying	
Are there any plans for **future land uses** on or around the location which could be affected by the power plant?	
▪ At provincial level ▪ At local level	
Are there any areas on or around the location which are occupied by **sensitive land uses** which could be affected by the power plant?	
▪ Hospitals ▪ Schools ▪ Places of worship ▪ Community facilities	

Table 5-3 Scoping: Information about the location and its sensitivity

PART 4: **Environmental Impact Questions** **General Issues**	**Y/N/?** **Comment**
Are there any areas on or around the location of the power plant which are already subject to **pollution or environmental damage** e.g. where NEQS are exceeded, which could be affected by the power plant?	
▪ Air quality ▪ Water quality ▪ Noise ▪ Soils	
Is the power plant location susceptible to **external natural phenomena** which could cause the project to present environmental problems?	
▪ Earthquakes ▪ Subsidence ▪ Landslides ▪ Erosion ▪ Flooding ▪ Extreme or adverse climatic conditions e.g. temperature inversions fogs, severe winds	
Is the power plant likely to affect the **physical condition** of any environmental media?	
▪ Soils – e.g. quantities, depths, humidity, stability or erodibility of soils? ▪ Geological and ground conditions? ▪ The atmospheric environment including microclimate and local and larger scale climatic conditions? ▪ Water – e.g. quantities, flows or levels of rivers, lakes, groundwater? ▪ Estuaries, coastal waters or the sea?	
Air quality	
Are releases from the power plant likely to have **effects on the air quality**?	
▪ Local air quality? ▪ Global air quality including climate change and ozone depletion? ▪ Productivity of natural or agricultural systems	
Does the design of stacks minimize downwash or near field plume impact	
▪ Stack height ▪ Number of stacks ▪ Layout ▪ Flue gas velocity and temperature	
Is there a **emission treatment system for exhaust gases**?	
Description of air pollution control devices ▪ Particle matter ▪ NO_X ▪ SO_2 ▪ Mercury ▪ Others	
Is representative **meteorological data** available?	
▪ Long temporal series obtained in local mast ▪ Long temporal series at regional scale ▪ Short period campaign ▪ Mesoscale meteorological modelling output	
Is there any air pollutants **emission inventory** for the region?	
▪ Industry ▪ Traffic ▪ Anthropogenic area sources ▪ Biogenic	
Is there pre-existing **air quality data** for the site?	
▪ Long-term continuous data ▪ Short term campaign	
Water	
Are releases from the power plant likely to have **effects on water quality**?	
▪ Rivers, lakes, groundwater?	

PART 4: Environmental Impact Questions		**Y/N/? Comment**
▪ Estuaries, coastal waters or the sea? ▪ Nutrient status and eutrophication of waters? ▪ Acidification of soils or waters?		
Is there sufficient **water related data?**		
▪ Hydrological data ▪ Tides ▪ Water quality data ▪ Water consumption (up and downstream) ▪ Water users (up and downstream)		
Does the adopted **cooling system** have impacts on water availability?		
Type of cooling systems		
Heat and extent of associated thermal discharge		
Heat discharge control technology		
Water intake or diversion	m^3/s	If applicable
Water tunnels, canals, penstocks and pipelines	m	If applicable
Dam, reservoir or ponds ▪ Proposed filling rate ▪ Options to control filling ▪		If applicable
Cooling towers		If applicable
▪ Number ▪ Layout ▪ Height	# m	
Cooling water treatment and discharge		If applicable
Waste		
What **type of waste** is produced in the power plant?		
Amount, type and constituents ▪ Wastes from fuel combustion ▪ Wastes from flue gas treatment ▪ Wastes from water treatment ▪ Others		
Is there an adequate solid **waste disposal facility**?		
▪ Land requirements		
▪ Hydrogeological conditions		
Noise		
Are emissions from the power plant likely to have **effects on noise levels**?		
Noise receptors ▪ Distance from the power plant ▪ Sensible receptors Noise background levels		
Noise control device		
Resources		
Is the power plant likely to affect the **availability or scarcity of any resources** either locally or globally?		
▪ Fossil fuels? ▪ Water? ▪ Minerals and aggregates? ▪ Timber? ▪ Other non-renewable resources? ▪ Infrastructure capacity in the locality - water, sewerage, power generation and transmission, telecommunications, waste disposal roads, rail?		
Are there any areas on or around the location which **contain important, high quality or scarce resources** which could be affected by the power plant?		
▪ Groundwater resources ▪ Surface waters ▪ Forestry ▪ Agriculture ▪ Fisheries ▪ Tourism ▪ Minerals		

PART 4: **Environmental Impact Questions** **Social Issues**	**Y/N/?** **Comment**
Is the power plant likely to affect **human or community health or welfare**?	
▪ The quality or toxicity of air, water, foodstuffs and other products consumed by humans? ▪ Morbidity or mortality of individuals, communities or populations by exposure to pollution? ▪ Occurrence or distribution of disease vectors including insects? ▪ Vulnerability of individuals, communities or populations to disease? ▪ Individuals' sense of personal security? ▪ Community cohesion and identity? ▪ Cultural identity and associations? ▪ Minority rights? ▪ Housing conditions? ▪ Employment and quality of employment? ▪ Economic conditions? ▪ Social institutions?	

Part 6 - What are the potential environmental and social impacts of coal-fired power plants?

6.1 Key impacts

Table 6-1 presents potential impacts to the physical, biological and social environments associated with coal-fired power plants. Impacts are organized along the life of the project in the following phases:

- Site preparation and construction activities;
- Construction camp and onsite housing activities;
- Operation;
- Decommissioning

Table 6-1 organizes impacts by activity, affected environment and environmental concern.

Activity	Affected environment	Environmental concern
Site preparation and construction activities		
Land clearing, earthmoving, terrain shaping	Geology	Landslide hazards
	Soil	Erosion Soil compaction Spills and leaks of hazardous materials Disposal of cleared debris
	Water quality	Modification of drainage patterns Increased run-off due to soil compaction and changes in vegetation cover Modification of stream and rivers due to crossings Run-off carrying sediments and associate contaminants Spills and leaks of hazardous materials
	Air quality	Equipment emissions and fugitive dust Increased traffic
	Noise and vibration	Heavy equipment Disruption and blast Increased traffic
	Aesthetic resources	Disruption of views Degradation of landscapes Use of night-time lighting
	Terrestrial flora and associated ecosystems	Deforestation, wetland destruction and other vegetation Wildfire
	Terrestrial fauna	Loss of habitat Habitat fragmentation Disruption and dislocation of local and/or migratory wildlife, including disturbance of migratory corridors and breeding, spawning, nesting and calving areas Poisoning via contamination of waste and spills and leaks of hazardous materials Wildfire
	Aquatic species and associated ecosystems	Wetland destruction Run-off carrying sediments and associated contaminants Poisoning via contamination of waste and spills and leaks of hazardous materials

	Threatened and endangered species	Reductions in species and habitats
	Cultural resources	Destruction of cultural heritage
	Resettlement and relocation	Displacement and relocation of current settlements
	Socio-economic conditions Gender	Disruption of people's livelihoods (use of natural resources)
Construction and landscaping of onsite facilities, structures and buildings	Soil	Erosion Soil compaction Spills and leaks of hazardous materials Disposal of construction wastes
	Water quantity	Water needs for construction, such as cement mixing and dust control
	Water quality	Increased run-off due to soil compaction and changes in vegetable cover Run-off carrying sediments and associated contaminants Spills and leaks of hazardous materials
	Air quality	Equipment emissions and fugitive dust
	Noise and vibration	Heavy equipment Use onsite of tools
	Aesthetics	Disruption and degradation of views Use of night-time lighting
	Terrestrial flora and associated ecosystems	Spread of invasive species Wildfires
	Terrestrial fauna	Disruption and dislocation of local and/or migratory wildlife, including disturbance of migratory corridors and breeding, spawning, nesting and calving areas
	Aquatic species and associated ecosystems	Run-off carrying sediments and associated contaminants
Construction and/or upgrade of access roads. Construction of power line connections	Same as Construction and landscaping of onsite facilities, structures and buildings	
	Water quality	Modification of streams and rivers due to crossings
	Air quality	VOC emissions from asphalt batch plants
	Terrestrial flora and fauna and associated ecosystems	Increased road access in remote areas may lead to increased use of natural resources and to invasion of previously inaccessible areas
	Aquatic species and associated ecosystems	
	Threatened and endangered species	
	Protected areas	
Manpower	Socio-economic conditions Gender	Individual income increase by direct and indirect employment Increased purchases and other economic activities from local business
	Health	Hazardous jobs Occupational diseases due to exposure to dust

Construction camp and onsite housing activities		
Camp management	Terrestrial and aquatic fauna and associated ecosystems	Animals attracted to garbage and food waste Disruption and dislocation of local and/or migratory wildlife, including disturbance of migratory corridors and breeding, spawning, nesting and calving areas Degradation of ecosystems from fuel wood gathering Increased collecting, hunting and fishing (food for workers)
Solid and human waste disposal	Soil	Soil contamination
	Water quality	Water quality degradation from discharges and leaching
	Terrestrial fauna	Attraction of pests and vectors
	Aquatic species and associated ecosystems	Run-off carrying associated contaminants
Water supply	Water quantity	Depletion of nearby water sources
Fuel and chemical storage and handling	Soil	Spills and leaks of hazardous materials
	Water quality	Spills and leaks
	Terrestrial fauna	Poisoning via spills and leaks
	Aquatic species and associated ecosystems	Contamination from spills and leaks
Energy production	Air quality	Emissions from generators
Transportation	Water quality	Spills and leaks
	Air quality	Emissions from vehicles and fugitive dust
Existence of structures	Water quality	Accidental releases of insulating fluids
	Air quality	Accidental releases of insulating gases
	Noise and vibration	Transformers and switches
	Aesthetics	Disruption or degradation of views Light pollution
	Terrestrial fauna	Electrocution
Manpower	Socio-economic conditions Gender	Individual income increase by direct and indirect employment Increased purchases and other economic activities from local business
	Health	Hazardous jobs Occupational diseases due to exposure to dust
Operation		
Dams for cooling ponds	Geology	Dam failure
	Water quantity	Raising water tables
	Water quality	Ground water recharge by cooling ponds
	Terrestrial flora and associated ecosystems	Destruction of ecosystems by inundation
	Aquatic species and associated ecosystems	Individuals killed, damaged or entrapped by intake structures, cooling systems or turbines

Cooling systems	Soil	Disposal of material dredged from ponds or removed from cooling towers
	Water quality	Disposal of material dredged from ponds or removed from cooling towers Discharges of cooling tower
	Aquatic species and associated ecosystems	Habitat alteration from discharges of cooling tower
	Water quantity	Water needs for cooling
	Health	Water-related vector diseases
On-site equipment	Noise	Turbines and generators Boilers, pumps, cooling towers, fans, other equipment Emission control equipment
	Terrestrial fauna	Disruption and dislocation of local and/or migratory wildlife, including disturbance of migratory corridors and breeding, spawning, nesting and calving areas
Maintenance	Soil Water quality	Disposal of material dredged from cooling ponds, reservoirs or other structures
	Water quantity	Boiler water needs Water needs for ash handling and FGD systems
	Aquatic species and associated ecosystems	Habitat alteration from water contamination from disposal of dredged or removed material
Fuel washing and preparation	Soil Water quality	Soil contamination from residue disposal
	Air quality	Dust from pulverizers, choppers, etc.
	Aquatic species and associated ecosystems	Habitat alteration from water contamination from residue disposal
Fuel combustion	Soil	Soil contamination from ash and sludge disposal (from the combustion chamber and air control devices) Deposition of air contaminants on downwind soils
	Water quality	Ash and sludge disposal (from the combustion chamber and air control devices)
	Air quality	Stack and exhaust pipe emissions
	Noise	Emission control equipment
	Landscape	Visibility
	Terrestrial flora and associated ecosystems	Destruction or degradation of ecosystems downwind from stack emissions
	Aquatic species and associated ecosystems	Habitat alteration from water contamination from ash and sludge disposal
Solid and human waste disposal	Soil	Soil contamination
	Water quality	Water quality degradation from discharges and leaching
	Terrestrial fauna	Attraction of pests and vectors
	Aquatic species and associated ecosystems	Run-off carrying associated contaminants

Water supply	Water quantity	Depletion of nearby water sources
Fuel and chemical storage and handling	Soil	Spills and leaks of hazardous materials
	Water quality	Spills and leaks
	Terrestrial fauna	Poisoning via spill and leaks
	Aquatic species and associated ecosystems	Contamination from spill and leaks
Existence of structures	Water quality	Accidental releases of insulating fluids
	Air quality	Accidental releases of insulating gases
	Noise and vibration	Transformers and switches
	Aesthetics	Disruption or degradation of views Light pollution
Manpower	Socio-economic conditions Gender	Individual income increase by direct and indirect employment Increased purchases and other economic activities from local business
	Health	Hazardous jobs Occupational diseases due to exposure to dust
Economy	Socio-economic conditions	Increased tax base Electric power reliability
Decommissioning		
Removal and transport of machinery and equipment	Noise and vibration	Use of heavy equipment, transport of equipment and machinery from site Use of onsite tools
Decommissioning and disposal of damaged or obsolete equipment	Soil	Disposal of wastes, including potentially hazardous waste
Removal or decommissioning of structures and buildings	Soil	Erosion Soil compaction Spills and leaks Disposal of construction waste
	Water quantity	Water needs for construction, such as dust control
	Water quality	Increased run-off die to soil compaction and changes in vegetative cover Run-off carrying sediments and associated contaminants Spills and leaks
	Air quality	Equipment emissions and fugitive dust
	Noise and vibration	Use of heavy equipment and on site machinery and possible blasts Use of onsite tools
	Aesthetics	Effect on view (positive or negative)
	Terrestrial flora and associated ecosystems	Wildfire
	Terrestrial fauna	Disruption and dislocation of local and/or migratory wildlife, including disturbance of migratory corridors and breeding, spawning, nesting and calving areas Wildfire

Restoration of terrain and vegetation	Soil	Erosion (positive and negative)
	Aesthetics	Effects on view (positive and negative)
Manpower	Socio-economic conditions Gender	Individual income increase by direct and indirect employment Increased purchases and other economic activities from local business
	Health	Hazardous jobs Occupational diseases due to exposure to dust

Table 6-1 Potential impacts associated to coal-fired power plants to physical, biological and social environments.

6.2 Impact assessment of coal-fired power plants

In the following sub-chapters, potential impacts of coal-fired power plants are described. Impacts are described for the following components:

- Geology and soils;
- Water resources (quantity and quality) including surface water and groundwater;
- Air;
- Climate change;
- Noise and vibrations;
- Aesthetic resources;
- Biological resources;
- Socio-economic-cultural resources.

For each component, the description is organized in:

- Brief description of Pakistan setting;
- Impact description;
- Baseline survey;
- Impact assessment tools.

6.2.1 Geology and soils

Soils are the interface between the geosphere, biosphere and hydrosphere and they cannot be easily compartmentalized. Conservative estimates presented in a report published by the World Bank (WB, 2006) suggest that reduced agricultural productivity due to soil degradation cost Pakistan at least 1.2% of GDP, or about Rs.70 billion per year, and these costs fall disproportionately upon the poor. Over 60% of Pakistan's population is rural and depends on natural resources such as agricultural soils, water, rangelands and forests that are strained and degrading.

Soils play an important part in biodiversity conservation therefore, it is vitally important that the soils information is included as an integral part of the environmental assessment process, not only because changes to soils can have subsequent effects on other parts of ecosystems, such as vegetation composition and watercourses, but also because of the intrinsic value of the soil resource in its own right (SNH, 2011).

6.2.1.1 Potential impacts

Almost any energy project will include construction activities that can impact geology and soils including:

- Land clearing for site preparation and access routes.
- Earth moving and terrain shaping including excavation and filling, involving earth moving equipment and often blasting.
- Disposal of spoils (vegetation, soil, stones) removed during these activities and construction debris.
- Use and possible storage of lubricants, fuels and other chemical products.
- Decommissioning.

Table 6-2 presents a summary of potential impacts that can occur on geology and soils due to coal-fired power plant projects. Land clearing, earth moving and terrain shaping will remove vegetative cover and change the topography of the affected area, which can cause increased soil compaction, erosion and associated sedimentation. Changing the topography of the site can create the potential for landslides or slope failure, depending on the soil types and magnitude of the change. It will also change the drainage patterns and, in combination with removal of vegetative cover, can lead to erosion, the magnitude and extent of which will in part be determined by the resulting gradients, soil types, rainfall and local hydrology. Exposing bare soil during these activities can also increase wind erosion. These impacts can be short-term, if proper soil erosion and slope stability controls are used or installed, although they may often exist through the completion of construction of onsite facilities, structures and buildings, access roads and transmission line connections, as these activities also disturb soil.

If construction of lengthy access roads is required by the project, this issue also will be of great concern. Right-of-ways may cover a significant land mass, but seldom require land clearing, earth moving and terrain shaping.

Disposal of solid waste and spills of lubricants, fuels and chemicals (e.g., wood preservatives, herbicides) during land clearing, terrain shaping, construction (both onsite and off-site) and decommissioning and restoration creates the potential for soil contamination. The types of solid waste generated during these activities include:

- Trees and other vegetation removed during site preparation.

- Casting forms.

Phase	Activity	Impact sources
Site preparation and construction	Land clearing, earth moving, terrain shaping	Landslide hazards (geology) Erosion Soil compaction Spills and leaks of hazardous materials Disposal of cleared debris
	Construction and landscaping of onsite facilities, structures and buildings	Erosion Soil compaction Spills and leaks of hazardous materials Disposal of construction waste
Construction camp and onsite housing	Solid and human waste disposal	Soil contamination
	Fuel and chemical storage and handling	Spills and leaks of hazardous materials
Operation	Dam for cooling pond	Dam failure (geology)
	Cooling systems	Disposal of cooling water sludge, material dredged from ponds or removed from cooling towers
	Maintenance	Disposal of material dredged from cooling ponds, reservoirs or other structures
	Fuel washing and preparation	Soil contamination from residue disposal
	Fuel combustion	Soil contamination from ash and sludge disposal (from the combustion chamber and air control devices) Deposition of air contaminants on downwind soils
	Solid and human waste disposal	Soil contamination
	Fuel and chemical storage and disposal	Spills and leaks of hazardous materials
Decommissioning	Decommissioning and disposal of damaged or obsolete equipment	Disposal of wastes, including potentially hazardous waste
	Removal or decommissioning of structures and buildings	Erosion Soil compaction Spills and leaks Disposal of construction waste
	Restoration of terrain and vegetation	Erosion (positive and negative)

Table 6-2 Potential impacts to geology and soils associated to coal-fired power plants

- Defective or compromised building materials.
- Waste concrete.
- Waste from on-site maintenance and repair of machinery and equipment.
- Waste from demolition of existing structures.
- Packaging, pallets and crates.
- Other wastes associated with onsite activities of workers in relation to the number of workers.

Solid waste disposal and chemical and fuel leaks and spills at construction camps can also contaminate soil. Camps and facilities will generate human wastes and solid wastes generated by the workers. Construction camps often include storage and dispensing facilities for fuels, lubricants and chemicals used during construction. Most power plants also have onsite facilities for storage of lubricants and other chemicals and hazardous materials used at the plant on a regular basis.

During operation, and particularly during maintenance of machinery and equipment, the following solid and hazardous wastes may be generated:

- Used oil
- Contaminated absorbent materials
- Burned out light bulbs
- Used batteries
- Toxic and hazardous substances and associated wastes
- Hazardous and toxic substance containers
- Tires
- Used parts, scraps and debris

Most power plants also have equipment onsite that contain hazardous substances, including insulating oils associated with transformers and switches. If these substances leak, they can contaminate soil. Insulating oils are used to cool transformers and switches and provide electrical insulation between live components.

Coal-fired power plants will generate residues from onsite fuel washing or preparation as well as ash and sludge from combustion and collected by pollution control devices, which may contain mercury, selenium, arsenic and other metals.

Coal-fired thermal power plants generate a great amount of solid wastes due to the relatively high percentage of ash in the fuel. Coal combustion wastes include fly ash, bottom ash, boiler slag, and bed ash (the combination of fly ash and bottom ash generated in a fluidized-bed combustion boiler). Coal-fired plants will also generate flue gas desulphurization (FGD) sludge. The amount of ash produced in a coal-fired power plant depends on the type of combustion and gaseous effluent control system used. The non-combustible components of coal remain behind as bottom ash. The physical properties of bottom ash are similar to those of natural sand with particle sizes ranging from fine gravel to fine sand with low percentages of silt and clay-sized particles (Gaffney et al., 2009). Bottom ash includes slag and particles that are coarser and heavier than fly ash.

When pulverized coal is combusted in either a dry-bottom boiler or a cyclone furnace, about 80% of all the ash leaves the furnace as fly ash, entrained in the flue gas. In a wet-bottom furnace, 50% of the ash formed leaves the furnace as fly ash (McKerall et al., 1982). Fly ash removed from exhaust gases makes up 60 to 85% of the coal ash residue in pulverized coal boilers and 20% in stoker boilers. Electrostatic precipitators are used for particulate control to remove the fly ash from the flue gasses. Although these systems have efficiency rates of nearly 99.9%, considerable amounts of fly ash are still emitted to the atmosphere due to the large amounts of coal required for electric power generation. A 1000 MW power station with a normal consumption of 12,000 tonnes per day (t d−1) of sub-bituminous coal, has a mean combustion fly ash production of about 2,400 (t d−1). Even with a particulate removal efficiency of 99.9%, almost 900 tonnes per year (t yr−1) are emitted to the atmosphere as primary PM (Querol et al., 1998).

The composition of fly ash is determined by the composition of the coal burned. The normal composition of fly ash from the combustion of various ranks of coal is given in Table 6-3 (Meyers et al., 1976 and McKerall et al., 1982). The principal components of bituminous coal fly ash are silica, alumina, iron oxide, and calcium, with varying amounts of carbon. Lignite and sub-bituminous coal fly ashes contain higher concentrations of calcium and magnesium oxides and reduced percentages of silica and iron oxide, as well as lower carbon content, compared with bituminous coal fly ash. Lignite and sub-bituminous coal fly ashes may have a higher concentration of sulphate compounds than bituminous coal fly ashes. Since very little anthracite coal is used in utility boilers there is little data on anthracite coal fly ash.

Due to the presence of sorbent material, fluidized-bed combustion boiler wastes have a higher content of calcium and sulphate and a lower content of silica and alumina than conventional coal combustion wastes.

In addition to the major constituents listed in Table 6-3, fly ash also contains a number of potentially toxic trace materials. Metals are constituents of concern in coal combustion wastes. For example, ash residues and the dust removed from exhaust gases may contain significant levels of heavy metals and some organic compounds, in addition to inert materials.

Ash residues are not typically classified as a hazardous waste due to their inert nature. However, where ash residues are expected to contain potentially significant levels of heavy metals, radioactivity, or other potentially hazardous materials, they should be tested at the start of plant operations to verify their classification as hazardous or non-hazardous according to local regulations or internationally recognized standards.

Coal-fired power plants requiring cooling systems can generate solid wastes removed from the system. These wastes may be partially dehydrated or dried before disposal and include:

- Cooling water sludge;
- Materials dredged in cooling ponds and associated structures;
- Materials removed from cooling towers.

6.2.1.2 Baseline survey

Documentation of geology, soils and topography at the power plant site and along the transmission route should be presented in the EIA. A site specific soil survey and test boring may be required if such data is not reliable, adequate or readily available. Seismic zone determination (see Figure 6-1), frequency and intensity of earthquakes and tremors, maximum credible earthquake, and maximum probable earthquake data should be included in this subsection. If the power plant site or right-of-way is located within a radius of 30 km from an active volcanic emission center, information should also be presented on the general volcanic features of the area near the site, historical eruptions, and period of recurrence, type of eruptions, and areas most likely to be affected by eruptions.

During baseline data collection it is important to collect information on the erosion potential of the soils, the chemical composition of each soil type, and the availability and suitability of soils for use during restoration and revegetation. If a soil survey is necessary, it should include: soil type, grain size distribution, engineering properties including stability, depth of various horizons, permeability, erosion and sedimentation potential, current uses, fertility, and vegetative growth potential, etc.

Component	Bituminous	Sub-bituminous	Lignite
SiO_2	20–60	40–60	15–45
Al_2O_3	5–35	20–30	10–25
Fe_2O_3	10–40	4–10	4–15
CaO	1–12	5–30	15–40
MgO	0–5	1–6	3–10
SO_3	0–4	0–2	0–10
Na_2O	0–4	0–2	0–6
K_2O	0–3	0–4	0–4

Table 6-3 Chemical composition of fly ash from coal combustion expressed as a percentage by weight (Meyers et al., 1976 and McKerall et al., 1982)

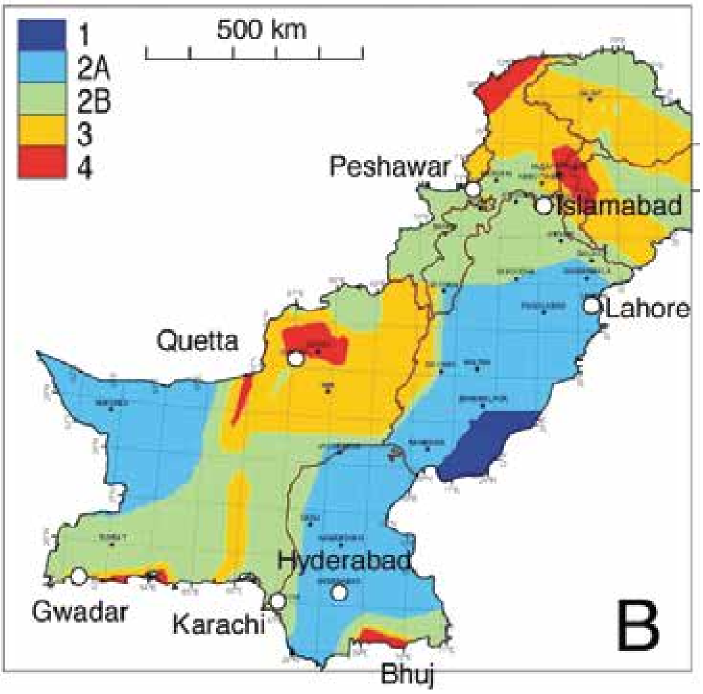


Figure 6-1 Pakistan seismic zoning map. For the purpose of seismic design of buildings, Pakistan has been divided into five zones. These zones are based on the peak ground acceleration ranges (zone 1: 0.05 to 0.08g; zone 2A: 0.08 to 0.16g; zone 2B: 0.16 to 0.24g; zone 3: 0.24 to 0.32g; zone 4 > 0.32g, where "g" is the acceleration due to gravity) (BCP, 2007).

6.2.1.3 Methods for impact assessment

Impact assessment on soils and geology is usually based on professional judgment as well as on existing literature, field studies, surveys, trend analysis or measured resource responses in other geographic areas. Tools such as Geographical Information Systems (GIS) overlaying activities on maps of soils and geology and graphics generated from comprehensive databases are useful toward visualization and determination of the magnitude of potential impacts.

It is also important to have a thorough understanding of the geologic hazards that are or could be at the site. These include:

- Landslide hazards: Types of movements and depths, such as shallow or deep-seated, translational or rotational landslides, slumps, debris flows, earth flows, mass wasting, etc. It is important that the project does not increase potential hazards on and off-site. Analytical and numerical approaches can be used to analyze this potential problem.

- Seismic hazards: Potential for strong ground shaking, surface rupture, fault creep, and/or liquefaction. Deterministic seismic hazard analysis methods can be used to estimate most expected seismic hazards.

- Volcanic hazards: Potential for molten rock, rock fragments being propelled great distances, dust, gases, ash fall, fumaroles, landslides and mudflows. Potential for volcanic activity in the area should be assessed by a literature search.

- Other geologic hazards (e.g., subsidence, rock fall): In some localities, hazard areas have been identified in the process of developing local critical or sensitive area ordinances. In these instances, hazard areas should be mapped by identifying where the defining characteristics apply to the project area.

6.2.2 Water resources

Water is central to many critical environmental issues on Pakistan (WB, 2006). On the one hand, the vast Indus Basin system sustains the life and livelihoods of the majority of the population; on the other hand, shortage of water and the uncertainties of rainfall dictate the patterns of activity in most non-irrigated areas. Pakistan faces serious deterioration of surface and ground water quality because of unabated industrial, municipal and agricultural pollution (MFPAK, 2013). The most recent economic survey developed by the Pakistani Ministry of Finance states that "in the absence of a regular surveillance or monitoring program and weak regulatory enforcement, several drains, irrigation canals and rivers have become severely polluted. The indiscriminate discharge of untreated industrial wastewater, municipal sewage as well as unchecked agricultural run-offs is increasingly polluting irrigation systems, rivers as well as other aquatic and marine ecosystems. Subsequently this is leading to severe contamination of ground water. Pollution of surface water in major rivers and seawater is also posing a threat to aquatic life."

This statement is consistent with a report published by the Asian Development Bank (ADB, 2008) that refers that Pakistan has reached the withdrawal limits of its surface and groundwater sources. The per capita availability of water has decreased from 5,300 m3 per person per year in 1951 to less than 1,100 m3 per person per year in 2007 owing to population growth. According to ADB, Pakistan is heading inexorably into the category of water-stressed countries, defined as having less than 1,000 m3 per person per year.

Water resources management is a critical topic because Pakistan is largely arid and entirely dependent on the Indus River for its surface water (WB, 2006). The World Bank estimated that the mean annual cost from inadequate water supply, sanitation and hygiene represents circa Rs. 112 billion (approximately 2% of GDP). The areas of concern identified by Government and donor agencies in Pakistan have highlighted a number of water related issues, including declining water availability, pollution of water bodies, groundwater depletion and inadequate service delivery (ADB, 2008).

Pakistan's major groundwater resource is in the irrigated areas of the Indus Basin, while the second source lies in the areas outside the Indus Basin. Canal irrigation was introduced in the Indus Basin about a century ago. Before the irrigation system the groundwater table was 30 m below the ground surface in most of the Basin. With the introduction of the irrigation system, groundwater is now in a range of 2 to 10 m below ground surface (Amin, 2004). The groundwater outside Indus Basin is in Balochistan province, where the recharge source is mainly by precipitation.

Groundwater development initially started in the public sector in 1960s. Groundwater development during the last 5 decades fulfilled the water requirements for the increasing population of the country and private farmers have invested about Rs. 24 billion in groundwater development. Current rates of exploitation are unsustainable in many regions. Qureshi et al. (2010) state that falling water tables and increasing salt contents in the pumped groundwater attest that more expensive and poor quality groundwater will have to be used for irrigation in future, which will have serious consequences for Pakistan's capacity to feed its growing population.

According to these authors, in the most populous province of Punjab, about 90% of the population depends on groundwater for their daily domestic needs. In Balochistan, about 4% of the population depends on groundwater but it is estimated to reach 50% in the next 10 years. Due to increasing urbanization, improved living standards and industrialization, the share of groundwater for non-agricultural uses is expected to increase further which will have a direct impact on the availability of groundwater for agriculture.

Pakistani local context confirms that EA should have an equal focus on both, water availability and water quality at surface and underground level.

6.2.2.1 Potential impacts

Potential impacts of a coal-fired power plant project on water availability and water quality are presented, respectively in Table 6-4 and 6-7.

Nearly all power plant projects involve land clearing for site preparation and access routes and earth moving and terrain shaping, which may change the drainage patterns and increase run-off and associate soil erosion and sedimentation.

Run-off can carry sediments and other contaminants either attached to the sediment or in solution, including soil nutrients and lubricants, fuels and chemicals that may be spilled at the sites. Any source of soil contamination identified in the previous subsection, can be carried in run-off. If agricultural chemicals are used on farms or forests associated with biomass production or if herbicides are used during land clearing or to manage vegetation in right-of-ways, they can also become components of run-off. Depending on the local conditions and the distance to surface water, these contaminants can impact water quality in the surface waters that receive drainage from the affected areas.

Construction or upgrading of access roads to the facility site or to the right-of-way, in the case of transmission projects, may also require construction across wetlands or streams, which can disrupt watercourses and wetland flow regimes, directly impact water quality and cause bank erosion.

Power production facilities generate various types of process solid wastes that have the potential to contaminate soil. These same solid wastes can also contaminate surface water and groundwater quality. If run-off is allowed to flow off areas where these wastes are stored or disposed, they have the potential of contaminating surface water. If rainfall is retained on the

Phase	Activity	Pressure
Site preparation and construction activities	Construction and landscaping of onsite facilities, structures and buildings.	Water needs for construction, such as cement mixing and dust control.
	Construction and/or upgrade of access roads. Construction of power line connections.	Water needs for construction, such as cement mixing and dust control.
Construction camp and onsite housing activities	Water supply	Depletion of nearby water sources.
Operation	Dams for cooling ponds	Raising water tables.
	Cooling systems	Water needs for cooling.
	Maintenance	Boiler water need. Water needs for ash handling and FGD systems.
	Water supply	Depletion of nearby water sources.
Decommissioning	Removal or decommissioning of structures and buildings.	Water needs for construction, such as dust control.

Table 6-4 Potential impacts of a coal-fired power plant on water availability.

storage or disposal areas, and the sites are not lined, then the solid wastes have the potential to contaminate groundwater via leachate.

All power plants will need domestic water and will produce domestic solid wastes and domestic wastewater due to the onsite presence of workers. The amount of water required for domestic purposes and the amount of waste generated will generally be minimal, but the EIA should assess the impacts of these activities to ensure that they will not impact water availability or contaminate surface or groundwater.

Thermal power plants use steam turbines with boilers and require a cooling system to condense steam used to generate electricity. Typical cooling systems (more information in subchapter 3.2.5) used in thermal power plants include:

- Once-through cooling system where sufficient cooling water and receiving surface water are available;

- Closed circuit wet cooling system;

- Closed circuit dry cooling system (e.g., air cooled condensers).

There are two aspects of water usage that need to be considered when analyzing a cooling system: withdrawal and consumption.

According to the USGS, 'withdrawal' is defined as the amount of water removed from the ground or diverted from a water source for use, while 'consumption' refers to the amount of water that is evaporated, transpired, incorporated into products or crops, or otherwise removed from the immediate water environment (Kenny et al, 2009). Both, water withdrawal and consumption values, are important indicators for water managers determining power plant impacts and vulnerabilities associated with water resources.

For the vast majority of power generation technologies, most of the water used in the life cycle of the plant occurs during the operational phase, excluding water usage in the fuel cycle or other aspects of the life cycle. Operational water use in this study includes cleaning, cooling, and other process-related needs that occur during electricity generation, such as flue gas desulphurization (FGD) in coal facilities.

The cooling system employed is often a greater determinant of water usage than the particular technology generating electricity, both in terms of water consumption and water withdrawal. Once-through cooling technologies withdraw 10–100 times more water per unit of electric generation than cooling tower technologies, yet cooling tower technologies can consume twice as much water as once-through cooling technologies (Macknick et al., 2012).

Water consumption factors for coal-fired power plants vary substantially within and across technology categories (see Table 6-5). The highest water consumption factors for all technologies result from the use of evaporative cooling towers. Pulverized coal with carbon capture utilizing a cooling tower represent the upper bound of water consumption, at approximately 1000 gal MW−1 h−1 of electricity production. The lowest operational water consumption factors result from technologies that utilize dry cooling. Water withdrawal factors show a similar variability within and across technology categories (Table 6-6). The highest water withdrawal values result from once-through cooling systems, whereas the smallest withdrawal values are for IGCC with cooling towers.

Wet cooling systems are the most common systems used in thermal power plants. Once-through cooling systems require large quantities of water to cool and condense the steam for return to the boiler. This cooling water is discharged back to receiving surface water or into cooling ponds. It will have elevated temperature and can carry biocides or other additives, if they are used, but otherwise will have little difference in composition than the source of the water. If the water is cooled (via a cooling pond for instance) and reused, the natural chemical components in the source water as well as any additives can become concentrated due to evaporation.

The withdrawal of such large quantities of water has the potential to compete with other important uses such as agricultural irrigation or drinking water sources. The heated water is normally discharged back to the source water (i.e., river, lake, estuary, or the ocean) or the nearest surface water body. In general, thermal discharge should be designed to ensure that discharge water temperature does not result in exceeding relevant ambient water quality temperature standards outside a scientifically established mixing zone. The mixing zone is typically defined as the zone where initial dilution of a discharge takes place within which relevant water quality temperature standards are allowed to exceed and takes into account cumulative impact of seasonal variations, ambient water quality, receiving water use, potential receptors and assimilative capacity among other considerations. Establishment of such a mixing zone is project specific and may be established by local regulatory agencies and confirmed or updated through the project's environmental assessment process. Pakistani NEQS (S.R.O. 549 (I)/2000) defines that the effluent should not result in a temperature increase of more than 3ºC at the edge of the zone where initial mixing and dilution take place in the receiving body. In cases where this zone is not defined, it is limited to 100 m from the point of discharge (see details in Annex A Table A-1).

Cooling	Technology	Median	Min	Max	*n*
Tower	Generic	1005	500	1200	4
	Subcritical	587	463	714	8
	Supercritical	634	582	670	9
	IGCC	393	358	605	12
	Subcritical with CCS	1329	1224	1449	3
	Supercritical with CCS	1147	1098	1157	4
	IGCC with CCS	642	479	742	7
Once-through	Generic	36 350	20 000	50 000	4
	Subcritical	27 088	27 046	27 113	3
	Supercritical	22 590	22 551	22 611	3
Pond	Generic	12 225	300	24 000	2
	Subcritical	17 914	17 859	17 927	3
	Supercritical	15 046	14 996	15 057	3

Table 6-6 Water withdrawal factors for coal power plants (gal MW−1 h−1) (Macknick et al., 2012).

Activity	Activity description	Environmental concern
Site preparation and construction activities	Land clearing, earthmoving, terrain shaping	Modification of drainage patterns. Increased run-off due to soil compaction and changes in vegetation cover. Modification of stream and rivers due to crossing. Run-off carrying sediments and associate contaminants. Spills and leaks of hazardous materials.
	Construction and landscaping of onsite facilities, structures and buildings	Increased run-off due to soil compaction and changes in vegetable cover. Run-off carrying sediments and associated contaminant. Spills and leaks of hazardous materials.
	Construction and/or upgrade of access roads. Construction of power line connections	Increased run-off due to soil compaction and changes in vegetable cover. Run-off carrying sediments and associated contaminants. Spills and leaks of hazardous materials.
		Modification of streams and rivers due to crossings.
Construction camp and onsite housing activities	Solid and human waste disposal	Water quality degradation from discharges and leaching.
	Fuel and chemical storage and handling	Spills and leaks.
	Transportation	Spills and leaks.
	Existence of structures	Accidental releases of insulating fluids.
Operation	Dams for cooling ponds	Ground water recharge by cooling ponds.
	Cooling systems	Disposal of material dredged from ponds or removed from cooling towers. Discharges of cooling tower.
	Maintenance	Disposal of material dredged from cooling ponds, reservoirs or other structures.
	Fuel washing and preparation	Soil contamination from residue disposal.
	Fuel combustion	Ash and sludge disposal (from the combustion chamber and air control devices).
	Solid and human waste disposal	Water quality degradation from discharges and leaching.
	Fuel and chemical storage and handling	Spills and leaks.
	Existence of structures	Accidental releases of insulating fluids.
Decommissioning	Removal or decommissioning of structures and buildings	Increased run-off die to soil compaction and changes in vegetative cover. Run-off carrying sediments and associated contaminants. Spill and leaks.

Table 6-7 Potential impacts of a coal-fired power plant in water quality.

Thermal discharges should be designed to prevent negative impacts to the receiving water taking into account the following criteria:

- The elevated temperature areas because of thermal discharge from the project should not impair the integrity of the water body as a whole or endanger sensitive areas (such as recreational areas, breeding grounds, or areas with sensitive biota);

- There should be no lethality or significant impact to breeding and feeding habits of organisms passing through the elevated temperature areas;

- There should be no significant risk to human health or the environment due to the elevated temperature or residual levels of water treatment chemicals.

Cooling water discharges are not the only wastewater streams in thermal power plants. Other wastewater streams include:

- Cooling tower blow-down;
- Ash handling wastewater;
- Wet FGD system discharges;
- Coal storage run-off;
- Cleaning wastewater;
- Low-volume wastewater, such as.
  - Air heater and precipitator wash water;
  - Boiler blow-down;
  - Boiler chemical cleaning waste;
  - Floor and yard drains and sumps;
  - Laboratory wastes;
  - Back-flush from ion exchange boiler water purification units;
  - Domestic wastewater.

Contaminants from these wastewater streams can degrade water quality via discharge to surface water or recharge to groundwater. The characteristics of the wastewaters generated depend on the ways in which the water has been used. Contamination arises from the use of demineralizers; lubricating and auxiliary fuel oils; trace contaminants in the fuel (introduced through the ash-handling wastewater and wet FGD system discharges); and chlorine, biocides, and other chemicals used to manage the quality of water in cooling systems.

Cooling tower blow-down tends to be very high in total dissolved solids but is generally classified as non-contact cooling water and, as such, is typically subject to limits for pH, residual chlorine, and toxic chemicals that may be present in cooling tower additives (including corrosion inhibiting chemicals containing chromium and zinc whose use should be eliminated).

Each wastewater stream should be identified and fully characterized in regards to volume and composition, to determine if it will pose a threat to water quality.

6.2.2.2 Baseline survey

Surface water

The Environmental Setting section should include an evaluation of surface water resources in the direct vicinity of the project. This should include the analysis of the watershed characteristics including water quality, flow characteristics, drainage patterns and run-off characteristics, soils, vegetation, and impervious cover.

This information should be included on topographic maps which should include all surface water resources and floodplains in the area of influence overlaid with the proposed project facilities including all monitoring stations and discharge points.

All nearby rivers, streams, wetlands, lakes and other water bodies should be identified as well as current uses of the water. All existing historic surface water flow data in the area of influence should be collected, compiled and analyzed to present information on:

- Average daily, monthly and annual flows in cubic meters per second (m^3/s);

- Maximum monthly flows in m^3/s;

- Minimum monthly flow in m^3/s;

- 2-, 10-, 25-, 50- and 100-year run-off events and associated floodplains for streams and rivers;

- Seasonal fluctuations in area and volume of wetlands, lakes and reservoirs.

For thermal plants with large water demand for cooling, the Environmental Setting section should also present inventories of consumptive and non-consumptive use (including types of uses by volume of use) and a calculation of the current surface water balance.

An important aspect of an EIA is the development and presentation of baseline surface water quality monitoring data, which should be collected prior to disturbance. All existing historic water quality data for the area of influence should be collected and compiled to help define the baseline.

For coal-fired power plant projects that will have significant wastewater discharges, including thermal discharges, the data should be augmented by the results of a surface water quality monitoring program conducted at specific sites in the project area. Monitoring of baseline conditions should take place for at least a year so seasonal fluctuations in flow and water quality can be determined.

Groundwater

Coal-fired power plants may have impacts on groundwater quality or quantity or both, and therefore require more information on groundwater conditions. The storage of fuel at thermal/combustion plants can potentially impact groundwater quality. Consumptive use of water by thermal power plants and discharge of cooling waters into cooling ponds can have impacts on both the quantity and quality of groundwater.

The Environmental Setting section should include descriptions of aquifers (bedrock and alluvial) including their geology, aquifer characteristics (hydraulic characteristics), and the flow regime/direction for each aquifer. The influences of geologic structures (faults, contacts, bedrock fracturing, etc) and surface water bodies on the aquifers should also be mapped or determined.

All wells and springs in the area should be mapped and information provided on their flows, water levels and uses. These maps should be overlaid with the topography and should cover the area of influence.

For wells, depth and construction information should be presented. The EIA should also indicate which ones have been monitored and which ones will be monitored during and after operations. This information can then be used, along with the locations of potential recharge and contaminant sources, to determine potential impacts.

For those projects that can impact groundwater quality or quality, the information on vadose[8] zone and aquifer characteristics should include sufficient data on the parameters to allow aquifer and vadose zone modeling.

The necessary parameters will depend on the type of modeling that will be required, which should be selected based on the nature of the potential impacts. A project with cooling ponds or a project with storage of solid or liquid fuel should use a groundwater flow model and a hydrochemistry model to determine the potential impacts. Any model used requires good data to make realistic predictions.

As with surface water, an important aspect of the EIA is the development and presentation of baseline groundwater monitoring data, collected prior to disturbance. All existing data on quantity and quality of water from springs and wells in the vicinity of the project should be collected and reported in the EIA to help define the baseline. Water quality in all springs and nearby wells should be reported at least quarterly for at least one year (and preferably two years) to determine baseline quality and chemistry. In addition, maps showing variations on a seasonal basis of water quality and groundwater levels should be included.

For projects that can potentially have impacts on groundwater quality, if data for existing wells and springs is not available, a “Sampling and Analysis Plan” should be prepared and a sampling program implemented. The sampling should include water levels and flow rates as well as other parameters such as pH, temperature, and specific conductance. The selection of chemical parameters to be monitored is dependent on the nature of the activity and its potential to contaminate the aquifer.

6.2.2.3 Methods for impact assessment

It is important to evaluate the impacts of an energy generation and/or transmission project in relation to the entire watershed.[9] Watershed management involves both, the quantity of water (surface and ground water) available and the quality of these waters. Understanding the impact of the project on the quantity and quality of water must take into account the cumulative impacts of other activities in the same watershed.

A watershed-based impact assessment approach involves the following 10 steps:

1. Identify and map the boundaries of the watershed in which the project is located and place the project boundaries on the map.

2. Identify the drainage pattern and run-off characteristics in the watershed.

3. Identify the downstream rivers, streams, wetlands, lakes and other water bodies.

[8]The vadose zone, also termed the unsaturated zone, is the part of Earth between the land surface and the top of the phreatic zone i.e. the position at which the groundwater (the water in the soil's pores) is at atmospheric pressure.
[9]http://water.epa.gov/type/watersheds/approach.cfm

4. Determine the existing quality of the water in these resources.

5. Determine the current and projected consumptive and non-consumptive uses of the water in these resources:

- Drinking water
- Irrigation
- Aquaculture
- Industry
- Recreation
- Support of aquatic life
- Navigation

6. Determine the nature and extent of pollutants discharged throughout the watershed.

7. Determine the anticipated additional pollutants discharge from the proposed activity.

8. Estimate the impact of the project on the consumptive and non-consumptive use of water.

9. Identify other anticipated additional developments planned or projected for the watershed.

10. Identify stakeholders involved in watershed and encourage their participation in project design.

Steps 1-6 apply directly to establishing the Environmental Setting. Steps 7-9 are concerned with assessing the impacts of the project. Step 10 ensures that stakeholders are involved in the design and analysis of the project.

Surface water

If a coal-fired power plant project alters surface water flow in the catchment and/or affects surface water quality in the catchment and there is conflict over water use, then it is necessary to determine the magnitude and nature of the impact. This includes, but is not limited to:

- An estimate of volume of water used (cooling) and volume of water consumed (boilers, cooling towers, cleaning, etc.)

- Long and short-term effects of water diversions and impoundments on the river or streams including its flood plain characteristics and its structural stability as well as effects on the water table.

An accurate understanding of the water balance in the watershed is necessary to successfully manage storm run-off, stream flows, and point and non-point source pollutant discharges from a power plant site. Natural system waters are fed to the site through rainfall, seeps and springs, groundwater and surface water. Water is lost from the system through surface water run-off, infiltration, and evaporation. Each of these factors is quite variable and difficult to predict. Process and cooling water use is reasonably constant and predictable. Water is lost from the system water through evaporation; facilities such as cooling towers and sedimentation or cooling ponds may result in significant evaporative losses.

Impacts on surface water quality will depend on the quality of the water discharged from project activities and the assimilative capacity of the receiving water. The assimilative capacity of the receiving water body depends on numerous factors including, but not limited to:

- the total volume of water;
- flow rate;
- flushing rate of the water body;
- the loading of pollutants from other effluent sources.

To estimate impacts of discharges of polluted water on the receiving water body it is necessary to estimate discharge volumes and quality characteristics and characterize existing quantity, quality and performance of the receiving body. Measurements of wastewater quality and baseline water quality should be taken to assure that receiving waters are able to assimilate the waste stream and that incremental effluents will not cause violation of applicable water quality standards (S.R.O. 549 (I)/2000, see Annex A Table A-1).

If a once-through cooling system is used for large projects, impacts of thermal discharges should be evaluated in the EA with a mathematical or physical hydrodynamic plume model, which can be a relatively effective method for evaluating a thermal discharge to find the maximum discharge temperatures and flow rates that would meet the environmental objectives of the receiving water.

The assessment of the heating of a river subsequent to a warm water discharge is relatively complex (EC, 2001). Indeed, the cooling mechanism of the river downstream mainly results from the exchange of energy between the river and the atmosphere. The energy flow between the stretch of water and the atmosphere fluctuates considerably depending on the meteorological conditions and the time of day.

Thermal efficiency of heat exchangers suffers greatly if the cooling water intake is contaminated by the heated discharge in the near-field or far-field. It is therefore essential in outfall design to predict plume behavior. Particular attention should be paid to surface density current and buoyant upstream spreading flow behavior.

In a river, diffusers distributed all along the width of a waterway serve to carry out the mixture over a distance of several dozen to several hundred meters. If the discharge is performed along the bank, complete mixing by natural flow is carried out over a few kilometers instead.

In all cases, recirculation in the river must be avoided, or the recirculation rates for discharges into the sea and especially in the estuary reduced to a minimum, to ensure efficiency and safe operation of power plants. The position and design of water intake and outlet structures are determined to eliminate the risk of recirculation.

Preliminary studies make it possible to design water intake and outlet structures and devices best adapted to avoid recirculation and favor the initial mixing of heated water discharges. They rely on physical models (hydraulic models) and numerical models. Where possible the numerical modeling etc. should be based on site-specific hydrographic survey data.

The use of these tools as part of the impact study of projected facilities serves to give assurance that regulatory thermal limitations will be respected, whether they concern maximum heating in the mixing area or the temperature level after the mixing.

The interest of numerical models has been mentioned for forecasting thermal changes in the near field as in the far field. The purpose of modeling is to study any physico-chemical impacts and adapt to the facilities so as to reduce these impacts to the greatest extent possible. It is particularly important to study:

- water withdrawals and discharges,
- the visual aspect of the site,
- the evolution of plumes,
- the thermal and chemical impacts on the receiving environment.

In the near field, fairly sophisticated tools serve to describe the dilution conditions of thermal discharges. They are used at the local discharge level. These models serve to dimension the outfall structures to the best possible extent so as to ensure the optimum dispersion of the warm water plume in the receiving environment as quickly as possible and thus limit its impact to a minimum (meteorological and hydrobiological data).

In the far field, the parameters that have to be taken into account are much more complex. They concern not only the characteristics specific to the receiving environment, but also discharges originating from other companies. Much more complex models have been developed to this effect. They take into account biological parameters of water quality and the presence of chemical pollutants. They integrate various pollution sources and provide an assessment of response of waterways or lakes to thermal and chemical disturbances or the excessive contribution of nutriments (eutrophication phenomenon).

The Cornell Mixing Zone Expert System (CORMIX)[10] is the most renowned model and was applied in many coal-fired power plant studies (Doneker and Jirka, 2007). CORMIX is a PC-based software package for the analysis, prediction and design of chemical and thermal discharges into diverse water bodies. The model focuses on prediction of the geometry and dilution characteristics of the initial mixing zone so that compliance with regulatory constraints can be evaluated. CORMIX also predicts plume behavior at larger distances.

CORMIX was intended as a first-order screening and design tool. CORMIX uses a simplified representation of the physical conditions at the discharge location to approximate the fundamental behavior of the plume. The most recent version (8.0) was released in 2012. The model is available for download at http://www.mixzon.com/downloads/

Groundwater

If groundwater is extracted for use in the power plant then a thorough understanding of the site hydrogeology is required to adequately characterize and evaluate potential impacts. Aquifer pump tests and drawdown tests of wells need to be conducted under steady-state or transient conditions to determine aquifer characteristics. If possible, it is important that these tests be performed at the pumping rates that would be used by a power plant for durations adequate to determine regional impacts from drawdown and

[10]*www.cormix.info.*

potential changes in flow direction. These tests require prior installation of an appropriate network of observation wells. Transmissivities, storage coefficients and vertical and horizontal hydraulic conductivities can be calculated from properly designed pump tests. These measurements are necessary to determine the volume and rate of groundwater discharge expected during operation of a thermal power plant to evaluate environmental impacts. Tests should be performed for all aquifers that could be affected by the project to ensure adequate characterization of the relationships between hydrostratigraphic units (USEPA, 2003).

Characterization studies should define the relationships between groundwater and surface water, including identifying springs and seeps. Significant sources or sinks to the surface water system also need to be identified. Hydrogeological characterizations should include geologic descriptions of the site and the region.

Descriptions of rock types, intensity and depth of weathering, and the abundance and orientation of faults, fractures, and joints provide a basis for impact analysis and monitoring.

6.2.3 Air Quality

Air pollution is a major environmental health problem that can result from both human and natural actions. Human sources of air pollutants include emissions from industry, agriculture, forestry, transportation, power generation, and space heating, whereas natural sources derive mainly from forest fires, pollen, volcanic emissions, and dust.

Air pollution in Asian cities has grown with the progressing industrialization and urbanization. According to the World Health Organization (WHO, 1992), South Asia has become one of the most polluted areas in the world due to its rapid industrialization and increasing population. The region is one of the most densely populated in the world, with present population densities of 100-500 persons/km^2 (Ghauri, 2007; UNEP and C4, 2002). The global 2005 update of air quality guidelines (WHO, 2005), refers that PM10 levels indeed present serious problems in developing countries, with concentrations reported from countries such as India and Pakistan to be 4–5 times international air quality limit values. A recent report looked to the data from about 1100 monitoring stations in 91 countries (WHO, 2011) and concluded that Pakistan has some of the cities with the worst air quality worldwide with PM10 levels above 200 μg/m^3.

Over the last decade, the Asian countries have undergone a substantial growth in development and urbanization coupled with motorization and increase in energy use. Intense industrial activity, large population, and unprecedented rise in motor vehicle usage are posing severe environmental impact in the region. As a consequence, and according to Colbeck et al. (2010) air pollution has emerged as a significant threat to the environment, quality of life, and health of the population in Asia, especially in South Asia where emission control technologies and strategies are not always being adopted.

Pakistan is the most urbanized country in South Asia, with an estimated 35 percent of its population living in cities (World Bank, 2006). Rapid urbanization has been accompanied by many problems such as waste management, congestion and the destruction of fragile ecosystems but probably urban air pollution remains the most significant environmental problem facing the cities.

In a recent study (Colbeck et al., 2010) Karachi, one of the mega-cities of Pakistan, appeared as the most air polluted city in the world with respect to Total Suspended Particles (TSP) and held fourth position based on a multi-pollutant index ranking, which reflects the severity of air pollution in Pakistan. The World Bank (2006) estimated that, fine particulates are implicated in 500,000 premature deaths and 415 million new cases of chronic bronchitis worldwide. In Pakistan, urban air particulate pollution is estimated to cause around 22,000 premature deaths among adults and 700 deaths among young children. The total health costs are between Rs. 62-65 billion, or approximately 1 percent of GDP (WB, 2006). Air quality is deteriorating with enormous speed and has been recognized as a serious problem by the Government of Pakistan and various other organizations (ADB, 2008).

The available information on air quality in Pakistan is little and sporadic but it clearly reflects the severity of the problem. Those studies which have been carried out reveal that the current levels of PM, SO_2, NO_2, CO, and Pb are many times higher than WHO air quality guidelines. The principal anthropogenic sources of air pollution are vehicular emissions and industrial pollution.

In 2001, concentrations of suspended particulate matter in Lahore, Rawalpindi, and Islamabad were four to seven times higher than levels recommended by the World Health Organization (Colbeck et al., 2010).

During 2003–2004, SUPARCO, the Pakistan Space and

Upper Atmosphere Research Commission conducted a yearlong baseline air quality study in country's major urban areas (Karachi, Lahore, Quetta, Rawalpindi, Islamabad and Peshawar). The objective of this study was to establish baseline levels and behaviour of airborne pollutants in urban centres with temporal and spatial parameters (Ghauri , 2007). One of the important objectives of the study was to establish the baseline air quality data in Pakistan with temporal and spatial parameters, to identify pollution sources and to determine their relative contribution towards prevailing ambient air quality of urban areas. Measurements of SO_2, CO, CO_2, O_3, NO_X, Hydrocarbons, Particulates (TSP & PM10) were carried out.

This study reveals that the highest concentrations of CO were observed at Quetta while other pollutants like SO_2, NO_X and O_3 were higher at Lahore compared to other urban centres like Karachi, Peshawar, etc. The maximum particulate (TSP) and PM10 levels were observed at Lahore (996 µg/m^3 and 368 µg/m^3 respectively), Quetta (778 µg/m^3, 298 µg/m^{3}3) and in Karachi (410 µg/m^3, 302 µg/m3). These pollutants showed highest levels in summer and spring while lowest were observed in winter and monsoon (Ghauri , 2007). The levels of TSP and other parameters were higher in summer (May–June) than in winter and monsoons, which can easily be interpreted in terms of time dependent changes related with the meteorological conditions. The high concentrations of CO, NO_X and also hydrocarbons are related to excessive generation of the gases due to high volume of traffic congestions at intersections. At that time, SO_2 and O_3 levels at all sites were within USEPA limits (Ghauri, 2007). However, due to a marked rise in CNG vehicles, it is very likely that the O_3 concentration could increase substantially downwind of urban centres due to increases in vehicular NO_2 emissions (Colbeck et al., 2010).

As part of the 5-year plan for 2005–2010, the Government of Pakistan published the Pakistan Clean Air Program (PCAP) for improving ambient air quality. The PCAP highlighted vehicular emissions, industrial emissions, burning of solid waste and natural dust as major sources of urban air pollutants in Pakistan and proposed a number of short and long-term measures that require action at all levels of government. In March 2007, under grant aid from the Government of Japan, continuous monitoring was initiated in Karachi, Lahore, Quetta, Peshawar, and Islamabad (Colbeck et al., 2010).

Recent data, shared by EPA-Punjab, obtained from field campaigns in different Cities of Punjab, from 2008 to 2013, confirm the existence of high concentrations for some pollutants (see Figure 6-2). With this information it is clear that exposure to fine particulate matter remains one of the most serious environmental health issues. In these measurement campaigns PM2.5 concentrations exceeded the NEQS limit values in 98% of the measurements. The same occurred in 64% of the measurements for NO_X, 19% for SO_2 and 15% for ozone.

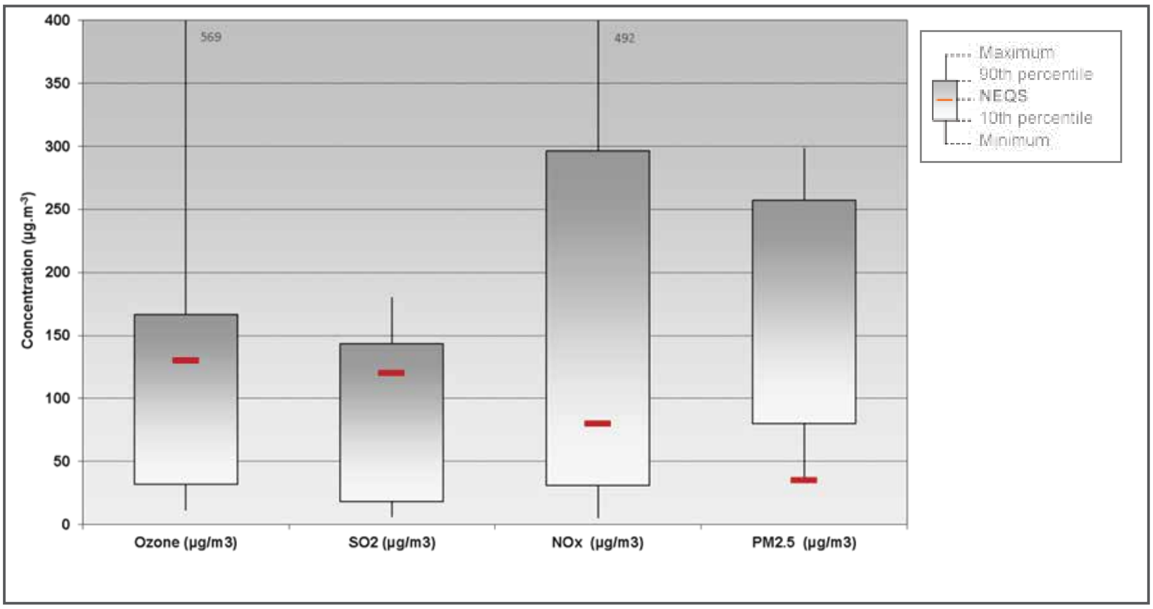


Figure 6-2 Ozone, SO_2, NO_x and PM2.5 concentration from air quality measurements in different Cities of Punjab (2008-2013, n=53) (maximum, 90th percentile, 10th percentile, minimum and NEQS).

The increase in urbanization, transport and energy use in South Asia over recent decades has been accompanied by increased NO_X and VOC emissions. These precursor emissions are mainly responsible for the gradual rise of ground level background ozone concentrations. Ozone (O_3) is a very reactive gas, produced through photochemical reactions involving natural and anthropogenic precursors, that is harmful to humans as well as vegetation, affecting crop growth and yield in this region. Usually O_3 concentrations are lower in urban environments due to the reaction with NO – which is abundant in these high emission areas (Ahmad et al., 2013; Engardt, 2008).

The quantification of global impacts of ozone pollution on food security currently relies on the use of concentration-based ozone metrics such as AOT40[11] and 8h mean ozone concentration. In Asia there are no air quality standards to protect agriculture from ground level ozone (Mills and Harmens, 2011). Moreover, ozone standards established in some Asian countries to protect human health will not protect agriculture as they are above critical levels for crop yield response and are only implemented in urban areas.

Regional scale modeling studies provide useful insights into the spatial and temporal variability in ozone concentrations both under current and projected future conditions. However, there is still significant uncertainty associated with modelled ozone concentrations primarily due to lack of appropriate emission inventories and extremely limited opportunity for model evaluation (Engardt, 2008, Mills and Harmens, 2011). However, available modeling studies suggest that critical levels of ozone for effects on crop yield are exceeded over much of the Indian sub-continent, with the greatest ozone exposure occurring in the densely populated Indo-Gangetic plain (Ahmad et al., 2013). In contrast to USA and Europe, little information is available about the responses of air pollution on major agricultural crops in developing countries.

Two approaches have been taken to evaluating the impacts of O_3 on crops in South Asia: first, a top-down approach links regional or global models of O_3 formation to exposure-response relationships to assess the effects on the yield of staple crops under different scenarios. The second approach is to rely on local experimental data, which are limited in many regions. Studies in India and Pakistan reported by the Royal Society (2008) have reported yield losses due to ambient O3 concentrations (for example 10% for rice, 13–47% for wheat, 24% for spinach and 45% for carrot) that are larger than those suggested by the 'top-down' approach. In Pakistan, a number of studies on wheat, rice and soybean have been carried out that reported 30-70% reduction in yield compared with control plants but extensive information on urban, suburban and rural arable productive areas, phytotoxic pollutant concentration is still not sufficient in Pakistan (Ahmed, 2009, Ahmad et al., 2012)

Measurements performed by Ahmad et al. (2012) show that O_3 concentration levels fluctuate throughout the year in different months. The low concentration values of O_3 were recorded by these authors in December and January (winters) and July and August (monsoon), while the high concentration values were recorded in May and June (summers). Comparison of ozone concentration levels with the World Health Organization (WHO) standards shows that values of O_3 obtained are still under the WHO standards. But due to increase in O_3 precursors, the O_3 levels are continuously increasing.

So Pakistan, being an agriculture country, needs to take appropriate steps before it reaches the alarming levels and becomes a serious hazard for human health, the agriculture sector and environment (Ahmad et al., 2012). Miles and Harmens (2011) conclude that for South Asia (and other developing areas), a network of ozone monitors is urgently required to facilitate improved ozone mapping and prediction of impacts.

6.2.3.1 Potential impacts

Air contamination at coal-fired power plant projects arise primarily from stack emissions during operation and from dust and equipment emissions during construction and decommissioning (see Table 6-8).

Dust is generated during land clearing, earth moving, terrain shaping, construction and decommissioning activities. Despite the best attempts to control dust, there will be areas and times when elevated dust concentrations will occur during these activities. A large portion of dust is made up of large particles, with diameters greater than 10 µm. This coarse dust usually settles gravitationally within a few hundred meters of the source. The smaller particle size fractions (PM 10), however, can be carried by wind in dust clouds for great distances and may be deposited on or near populated areas. Dust from land clearing and construction, however, is a short-term impact.

At coal-fired power plants, fugitive dust will also be released during transportation, unloading, storage and processing of the fuel. During site preparation and

[11]AOT40 is a numerical index that describes the ozone exposure of ecosystems in terms of the hourly accumulated exposure over a threshold of 40 ppb.

construction, the project will generate particulate and gaseous air pollutant emissions from vehicle and construction equipment exhaust. Particulate emissions (including PM10 emissions), carbon monoxide, unburned hydrocarbons (volatile organic compounds), nitrogen oxides and sulphur dioxide result from fuel combustion in vehicles, heavy equipment, and generators associated with land clearing and construction. If asphalt batch plants will be used during these activities, then there will also be emissions of volatile organic compounds (VOCs).

Many power generation and transmission projects include substations with electrical transformers and switches. Some transformers, switches, associated cables and tubular transmission lines contain insulating gases such as fluorocarbons, silicon hexafluoride (HF_6) and sulphur hexafluoride (SF_6). These are all greenhouse gases. SF_6 is a greenhouse gas with a significantly higher global warming potential than carbon dioxide (CO_2).

The primary emissions from the combustion of coal are sulphur dioxide (SO_2), nitrogen oxides (NO_X), particulate matter (PM), carbon monoxide (CO), heavy metals (i.e., mercury, arsenic, cadmium, vanadium, nickel, etc), halide compounds (including hydrogen fluoride), unburned hydrocarbons and other VOCs, and greenhouse gases, such as CO_2.

The amount and nature of air emissions depends on factors such as type of coal, the type and design of the combustion unit, operating practices, emission control measures, and the overall system efficiency.

Activity	Activity description	Environmental concern
Site preparation and construction activities	Land clearing, earthmoving, terrain shaping	Equipment emissions and fugitive dust; Increased traffic.
	Construction and landscaping of onsite facilities, structures and buildings	Equipment emissions and fugitive dust.
	Construction and/or upgrade of access roads. Construction of power line connections	Equipment emissions and fugitive dust.
		VOC emissions from asphalt batch plants.
Construction camp and onsite housing activities	Energy production	Emissions from generators.
	Transportation	Emissions from vehicles and fugitive dust.
	Existence of structures	Accidental releases of insulating gases.
Operation	Fuel washing and preparation	Dust from pulverizers, choppers, etc.
	Fuel combustion	Stack and exhaust pipe emissions.
	Existence of structures	Accidental releases of insulating gases.
Decommissioning	Removal or decommissioning of structures and buildings	Equipment emissions and fugitive dust.

Table 6-8 Potential impact on air quality caused by coal-fired power plants.

6.2.3.2 Baseline survey

Climate and Meteorology

Understanding climate and meteorology in the project area is important for the design of a long-term air monitoring program as well as to develop a water balance for the site, and designing water/erosion control structures. During the baseline data collection period, climatic data from local weather stations should be gathered and analyzed. The data should include at least historic rainfall data (total precipitation, rainfall intensity, and duration), wind direction and speed, solar radiation, evaporation rates, barometric pressure, and temperature variations. If no data is available near the site, a weather station should be established and baseline data should be collected for at least one year to reflect the seasonal changes at the site. All sampling site and weather station locations should be depicted on a map in the EIA.

Output from meso-meteorological models can be used as an alternative to local data when models are adequately validated for the region of study.

Ambient Air Quality

Baseline air quality data is critical for it will be used to assess air quality impacts from stack emissions. For power plants the air pollutants of primary concern will be the compounds regulated[12] in the National Environmental Quality Standards for Ambient Air (S.R.O. 1062(I)/2010 (see Annex A Table A-2):

- particulate matter (PM, PM10 and PM2.5),
- sulphur dioxide (SO_2),
- oxides of nitrogen (NO and NO_2),
- ozone (O_3), and
- carbon monoxide (CO).

Air monitoring should be conducted, both upwind and downwind of the facility. Monitoring should include the use of high volume samplers and/or other methods to collect samples of airborne particulates and gases that may be emitted from the facility. Sampling may be either continuous or by grab or composite samples. Selection of monitoring locations requires an understanding of site-specific meteorological conditions that can affect pollutant fate and transport.

Remember that according to S.R.O. 549(I)/2010 – Annex II (see Annex A Tables A-3 and A-4), if background air quality is considered as very polluted (in a SO_2 basis) then coal-fired power plant projects should not be recommended in that location.

This subsection of the Environmental Setting should also include an inventory of all current air pollutant emission sources including greenhouse gases (primarily as CO_2, nitrous oxide (N_2O) and methane (CH_4)) in the area of influence. In order to assess impact on future ozone levels, the inventory should include information on Volatile Organic Compounds (VOCs) emissions. The inventory should include locations of emissions and current emission levels.

Emission data and inventories

According to FAIMODE, 2011a and 2011b, the results of air quality model simulations are strongly determined by the emissions of pollutants in the area of interest. Whilst chemical reactions may alter the molecular form of the primary emissions, it is the emission of pollutants that determine the eventual level of pollution. The importance of emission data is not restricted to their use as input data for air quality simulations. Emission data also constitutes as a useful air quality management tool, as it helps to define environmental priorities by identifying the activities and sectors responsible for the main air quality problems. As a result, relevant authorities can set explicit objectives for individual emission sources and assess the potential environmental impacts of suggested strategies and plans.

There can be many sources of atmospheric emissions for a pollutant of interest and many examples of each type, including factories, domestic heating systems, cars and other vehicles etc. In order to create a complete and accurate emission dataset, all important emission sources have to be identified for the area of interest. The collection, organization and maintenance of all the required data is preferably addressed through the creation of an emission inventory.

Emission inventories do not usually contain direct measurements, as it would be unfeasible to measure emissions from all the individual units of the different types of emission sources. Therefore, emission inventories include emission estimates based on measurements performed at selected representative samples of the main sources. An emission estimate, when direct measurements are not available, is usually the product of at least two variables, such as an activity operation rate and an average emission factor for the activity (Box 1).

A basic general methodology for the estimation of

[12] Lead (Pb) is part of NEQS but not included in this list because it is not significantly emitted in coal-fired power plants.

emissions is described in the Atmospheric Emission inventory Guidebook (EMEP/EEA; 2009). The Quantity (Q) of each air pollutant emitted depends on the Activity Level (AL) and the Emission Factor (EF), a factor which defines the linear relationship between Q and AL according to the general formula:

$$Q_{s,i,j,k} = 10^{-6} \times EF_{s,i,j,k} \times AL_{s,i,j}$$

Where s refers to the pollution source examined, i refers to the technology (e.g. coal-fired power plant), j refers to the activity (combustion of coal) and k refers to the pollutant examined. $Q_{s,i,j,k}$ is the quantity of pollutant k, from source s, technology i and activity j (in t yr^{-1}). $EF_{s,i,j,k}$ is the emission factor for the same pollutant, source, technology and activity. Finally, $AL_{s,i,j}$ is the activity level of the emission source, the technology and the activity (in t yr^{-1} or in GJ yr^{-1}, etc.).

Apart from emission estimates, emission inventories should also contain relevant supporting data (metadata), such as the location of the emission sources, emission measurements where available, production or activity rates, methodology of measurements or calculations, emission factors, uncertainties etc.

From a modeling perspective, emissions are typically classified into three types of sources according to their spatial characteristics:

- **Stationary or Point Sources:** emissions originating from large point sources at fixed locations (such as coal-fired power plants)

- **Mobile/Line Sources:** emissions from traffic of all types should ideally be included in this category, in particular vehicle emissions from road transport, railways and inland navigation (e.g., for coal transport).

- **Area Sources/Volume Sources:** emissions from both stationary and mobile sources that are transient and widespread.

One of the major challenges when implementing air quality modeling is acquiring an emissions inventory of suitable quality. In developing such emissions inventories both bottom-up methods and top-down methods may be applied.

High quality emission information is only possible through the use of comprehensive source and activity data. In the regularly used bottom-up approach, pollutant emission rates are calculated on the basis of this data and on the corresponding emission factors. The emission factors are typically defined as the amount of the concerned pollutant emitted per unit mass of fuel burned (mass-based emission factors with typical units in $kg.ton^{-1}$ or $kg.m^{-3}$) or per a defined task performed. The unit of task-based emission factors depends on the definition of tasks. Typical emission factors can be obtained from published databases, such as US Environmental Protection Agency databases or the European CORINAIR database. The top-down methods are based on aggregated consumption data (e.g. national census). If direct measurements from the relevant sources are limited or unavailable, estimate emissions based on global fuel burn can be applied.

6.2.3.3 Methods for impact assessment

Compare emissions with national emission limit values shown in Table A-3 and A-4 and assure that project emissions are below legislated emission limits. It is also recommendable to compare project emission with the emission guidelines for solid fuels specified by IFC (2008) and listed in Table 6-9.

In evaluating the potential impacts of a coal-fired power plant project on ambient air quality, prediction should be made to determine the extent to which ambient air quality standards may be compromised.

The predictions should assess the likelihood of air pollution from the plant, identify the areas of maximum impact and assess the extent of the impacts at these sites. Although analytical approaches can be used, international experience indicates that numeric modeling is the most appropriate method to evaluate the impacts of a power plant project on air resources. These models can be used to calculate pollutants in air and compare the results to air quality standards (USEPA, 2011).

At facility level, impacts should be estimated through qualitative or quantitative assessments by the use of baseline air quality assessments and atmospheric dispersion models to assess potential ground level concentrations. Local atmospheric, climatic, and air quality data should be applied when modeling dispersion, protection against atmospheric downwash, wakes, or eddy effects of the source, nearby structures (in an area within a radius of up to 20 times the stack height), and terrain features.

Pollutant	>50 MWth to <600 MWth	≥600 MWth
Particulate Matter (PM)		
Non-degraded airshed	50	50
Degraded airshed	30	30
Sulphur dioxide (SO_2)		
Non-degraded airshed	900 - 1500[13]	400
Degraded airshed	200 - 850[14]	200
Nitrogen dioxide (NO_2)		
Non-degraded airshed	510[15] Or < 1100 if volatile matter < 10%	200
Degrade airshed		
Dry gas, excess O_2 content	6%	6%

Table 6-9 Emission guidelines (in mg/Nm^3) for boilers operating with solid fuels (IFC, 2008).

Atmospheric dispersion models

Air quality models are the primary tools for relating emissions to air quality impacts. An atmospheric dispersion model is a mathematical simulation of the physics and chemistry governing the transport, dispersion and transformation of pollutants in the atmosphere.

Most air pollution models are computer programs that calculate the pollutant concentration downwind of a source using information such as: emissions, characteristics of the sources, topography, land use, meteorology data and background concentrations.

Models require acceptable input data for emissions, surface topography, meteorological parameters, receptor configurations, baseline air quality, and initial and boundary conditions for each modeling scenario. Since the quality and reliability of model outputs can never be any better than the inputs, quality control of the input data is an important concern.

The baseline air quality and predicted emission of the project must be characterized before structuring the air quality impact analysis. The baseline air quality may be characterized as representative background air quality, or it may be represented as a particular air quality scenario associated with worst-case air quality experienced at some point in the past. It is also important that any modeled emission scenario is appropriate for evaluating the project's future compliance with the given regulatory requirement.

Project emission rates used for air quality impact modeling should clearly depict and reflect worst-case conditions for any operating scenario requiring evaluation (USEPA, 2011).

Dispersion models can generally be categorized by their type (e.g. Gaussian, Lagrangian, Eulerian) or by their application (e.g. street canyon, urban models). In general a dispersion model will consist of a meteorological part, a pollutant dispersion part and a chemical part. Sometimes these parts are inseparable, e.g. a particular Gaussian dispersion model will have been developed using a particular meteorological pre-processor, or they may be interchangeable, e.g. Lagrangian particle models may use almost any wind field. Different models use different combinations of the meteorological, dispersion and chemical parts and, as such, it is not always straightforward to categorize an individual model (FAIRMODE, 2011a).

The dispersion model applied should be internationally recognized, or comparable. Examples of acceptable emission estimation and dispersion modeling approaches for point and fugitive sources are included in Table 6-10. These approaches include screening models for single source evaluations (such as SCREEN3 or AIRSCREEN), as well as more complex and refined models (AERMOD or ADMS). Model selection is dependent on the complexity and geomorphology of the project site (e.g., mountainous terrain, urban or rural area). A comprehensive listing of air quality models can be found at the European Environmental Agency's Model Documentation System (EEA, 2011a), at the USEPA (2011) and FAIRMODE (2011a).

The choice of dispersion model depends on a number of factors. In this framework, the decision of the level of modeling needed for the coal-fired power plant air quality assessment is an important issue. The following actions may be useful in determining the appropriate

[13]Targeting the lower guidelines values and recognizing issues related to quality of available fuel, cost effectiveness of controls on smaller units, and the potential for higher energy conversion efficiencies (FGD may consume between 0.5% and 1.6% of electricity generated by the plant).
[14]b. Targeting the lower guidelines values and recognizing variability in approaches to the management of SO2 emissions (fuel quality vs. use of secondary controls) and the potential for higher energy conversion efficiencies (FGD may consume between 0.5% and 1.6% of electricity generated by the plant). Larger plants are expected to have additional emission control measures. Selection of the emission level in the range is to be determined by EA considering the project's sustainability, development impact, and cost-benefit of the pollution control performance.
[15]Stoker boilers may require different emissions values which should be evaluated on a case-by-case basis through the EA process.

Model	Link	Description
ADMS-3 Atmospheric Dispersion Modeling System	http://www.epa.gov/ttn/scram/dispersion_alt.htm#adms3	An advanced dispersion model for calculating concentrations of pollutants emitted both continuously from point, line, volume and area sources, and discretely from point sources. The model includes algorithms which take account of the following: effects of main site building; complex terrain; wet deposition, gravitational settling and dry deposition; short term fluctuations in concentration; chemical reactions; radioactive decay and gamma-dose; plume rise as a function of distance; jets and directional releases; averaging time ranging from very short to annual; condensed plume visibility; meteorological preprocessor.
AERMOD	http://www.epa.gov/scram001/dispersion_prefrec.htm#rec	A steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain.
AERSCREEN	http://www.epa.gov/ttn/scram/dispersion_screening.htm#aerscreen	A screening model based on AERMOD. The model will produce estimates of "worst-case" 1-hour concentrations for a single source, without the need for hourly meteorological data, and also includes conversion factors to estimate "worst-case" 3-hour, 8-hour, 24-hour, and annual concentrations.
BLP	http://www.epa.gov/scram001/dispersion_prefrec.htm#rec	A Gaussian plume dispersion model designed to handle unique modeling problems associated with aluminum reduction plants, and other industrial sources where plume rise and downwash effects from stationary line sources are important.
CAL3QHC/ CAL3QHCR	http://www.epa.gov/scram001/dispersion_prefrec.htm#rec	A CALINE3 based CO model with queuing and hot spot calculations and with a traffic model to calculate delays and queues that occur at signalized intersections; CAL3QHCR is a more refined version based on CAL3QHCthat requires local meteorological data.
CALINE3	http://www.epa.gov/scram001/dispersion_prefrec.htm#rec	A steady-state Gaussian dispersion model designed to determine air pollution concentrations at receptor locations downwind of highways located in relatively uncomplicated terrain.
CALPUFF	http://www.epa.gov/scram001/dispersion_prefrec.htm#rec	A non-steady-state puff dispersion model that simulates the effects of time- and space-varying meteorological conditions on pollution transport, transformation, and removal. CALPUFF can be applied for long-range transport and for complex terrain.
CTDMPLUS Complex Terrain Dispersion Model Plus Algorithms for Unstable Situations	**http://www.epa.gov/scram001/dispersion_prefrec.htm#rec**	**A refined point source Gaussian air quality model for use in all stability conditions for complex terrain. The model contains, in its entirety, the technology of CTDM for stable and neutral conditions.**
ISC3 Industrial Source Complex Model	http://www.epa.gov/ttncatc1/cica/9904e.html	A steady!state Gaussian plume model which can be used to assess pollutant concentrations from a wide variety of sources associated with an industrial complex. ISC3 operates in both long!term and short-term modes.
PCRAMMET	http://www.epa.gov/ttncatc1/cica/9904e.html	A preprocessor for meteorological data that is used with the Industrial Source Complex 3 (ISC3) regulatory model and other U.S. EPA models.
SCREEN3	http://www.epa.gov/ttncatc1/cica/9904e.html	SCREEN3 is a single source Gaussian plume model that provides maximum ground!level concentrations for point, area, flare, and volume sources.
TAPM	http://ww-w.cmar.csiro.au/re-search/tapm/	Local scale to urban scale integrated meteorological and air quality model containing a hybrid LPM that uses Lagrangian particle motion in the vertical and Gaussian puffs in the horizontal.

Table 6-10 Air quality models.

level of analysis:

- The nature of the pollutant (e.g., gaseous, particulate, reactive, inert);
- The meteorological and topographic complexities of the area of concern;
- The predicted emissions from the coal-fired power plant and its alternatives;
- The distance (in km) of the project to the areas of concern (population, natural parks);
- The current air quality condition of the area;
- The spatial scale and temporal resolution required for the analysis;
- The level of detail and accuracy desired for the study and the amount of uncertainty that the analyst/risk manager is willing to accept;
- The technical expertise of user.

There are a wide range of models available, and it is important that the user selects the model that fits the demands of the task. Generally, the international entities endorse three levels of assessment:

1. Screening assessment is utilized to determine a specific event or the likelihood of a specific event. Screening assessments are a simple and quick way to estimate a "worst-case" concentration.

2. Refined assessment, because of its higher level of sophistication, this type of model estimates more closely actual air quality impacts. Refined models run on complete meteorological data set and allow geographical mapping of the plume caused by a power plant. These models do not incorporate chemical schemes and treat pollutants as passive chemicals.

3. Advanced assessment treats specific dispersion processes in greater detail. It potentially gives more accurate results but requires more input data especially at the emission level. The user must be careful to ascertain whether the selected dispersion model is being applied to a situation for which the model was designed.

Advanced models include chemical schemes that allow simulation of secondary pollutants such as ozone and PM2.5.

The first tier, screening assessment, of evaluation for single-or multiple-source impact employs a screening method using a Screening Model. The screening model results serve as benchmark for each type of source and for comparison against other sources. The model will calculate worst-case concentrations and may provide the user with information on the meteorological conditions that gave rise to these concentrations. In this tier the modeling only accounts with the primary impacts. Results obtained through the application of screening models give an adequate response within EIA for power plants only in the case of relatively small units (< 200 MW).

To select the pollutants to be modelled, it is necessary to take into account the main pollutants emitted by a coal-fired power plant. It should be included in the air quality modeling, at least: CO, SO_2, NO_X, mercury and particulates.

The second tier or refined assessment is required to address the impacts of single or multiple sources using Refined Models and it is normally applied when the screening assessment predicts air quality concentrations above 25% of National Environmental Quality Standards, the area is environmentally sensitive (e.g., a national park) and/or the emissions are greater than some emissions thresholds.

When modeling NO_X emissions impacts on ambient NO_2 concentrations, a tiered approach is normally used to estimate NO_2 concentrations for a source.

Under the first tier, 100 percent conversion of NO_X to NO_2 is assumed (screening assessment). In the next tier it is recommended that the Ozone Limiting Method (OLM) as specified in the EPA Modeling Guidelines be used; it assumes ten percent of plume NO_X and 100 percent conversion of remaining NO_X as a function of ozone availability. A more refined approach is to conduct hour-by-hour simulations using hourly values of ozone, NO_2, and NO_X emissions. Use of Plume Volume Molar Ratio Method (PVMRM) and Ozone Limiting Method (OLM) options for modeling the conversion of NO_X emissions to NO_2 are considered by EPA non-regulatory default options for modeling (CAPCOA, 2011).

In some cases the particular circumstances of topography, climate, source configuration, emissions characteristics, sensitivity of receptors, local concerns, or other unusual features will require the selection of more sophisticated models better suited to the situation.

High concentrations of ozone and PM2.5 and regional haze often have a common origin. Ozone formation and formation of secondary particulates result from several common reactions and reactants. Secondary particulates are a major part of PM2.5. There are often similar sources that contribute precursors to both ozone and PM2.5. Coal-fired power plants are major sources of NO_X emissions, which in combination with VOC, sunlight, and warm temperatures, lead to the production of ozone, the primary component of photochemical pollution.

Due to the potentially important contribution from secondary formation of PM2.5, certain aspects of standard modeling practices used for PM10 and other criteria pollutants may not be appropriate for PM2.5. Given these issues, and especially the important contribution from secondary formation of PM2.5, which is not explicitly accounted for by some refined models (i.e., AERMOD) used to simulate dispersion of direct PM2.5 emissions, the modeling of secondarily formed PM2.5 should be viewed as advanced assessment (USEPA, 2013).

A set of reports has been recently published about this topic (Colorado DPH&EAPCD, 2010; NRPCARD, 2011; AQD Arizona, 2013 and USEPA, 2013). Based on these reports a modeling decision tree is presented in Figure 6-3 structured on the following criteria:

- If emissions of NO_X (as NO_2) > 40 tonne/year:

- In rural area: apply advanced photochemical model to estimate changes on O_3 background levels and its impact on agriculture production;

- If densely populated area: apply advanced photochemical to estimate future 8 hour peaks of ozone concentration to asses impact on human health;

- Additionally if emissions of SO_2 > 40 tonne/year and of PM2.5 > 10 tonne/year and current PM2.5 concentrations in ambient air already exceed NEQS:

- Apply advanced model to simulate the formation of PM2.5.

For an advanced assessment it's often used with an alternative or modified model (Advanced Models). This is the case where photochemical modeling is very important. These photochemical reactions are strongly influenced by volatile (or reactive) hydrocarbons and some models require these emissions to be known to great accuracy. Other models can perform adequately by using a single estimate of reactive hydrocarbon emissions. Advanced models can deal with SO_x, NO_X and organic chemistry, aqueous-phase chemistry and secondary aerosol production.

Models input

As described above, meteorology, topography, and emissions data are processed and used as primary input data for air quality models. Depending on the level of refinement of the model, the required input data for an air quality model will include (but not necessarily be limited to) these parameters.

Meteorological Data

All air quality models require some form of meteorological data to drive them. However, the types of inputs can vary significantly from model to model (FAIRMODE, 2011b).

Typical meteorological data used in air quality modeling are:

1. **Observed meteorological data:** Various forms of data are available that may be used directly for air quality models or processed further in conjunction with models. These include a range of surface synoptic measurements, turbulence measurements, radiation measurements and vertical profile measurements.

2. **Statistical meteorological data:** Some models use observed statistical meteorological data (e.g. wind roses). This data is usually based on observations.

3. **Diagnosed meteorological data:** Meteorological wind fields (2D or 3D) may be determined using simplified models based either on linearized techniques or on interpolation of available wind observations applying a mass conservation constraint. The latter are widely used in air pollution models and are referred to as diagnostic (or mass-consistent) wind models.

4. **Prognosed meteorological data:** These are outputs from numerical models that solve the relevant physical equations using some form of Eulerian grid, e.g. Numerical weather prediction models or mesoscale meteorological models.

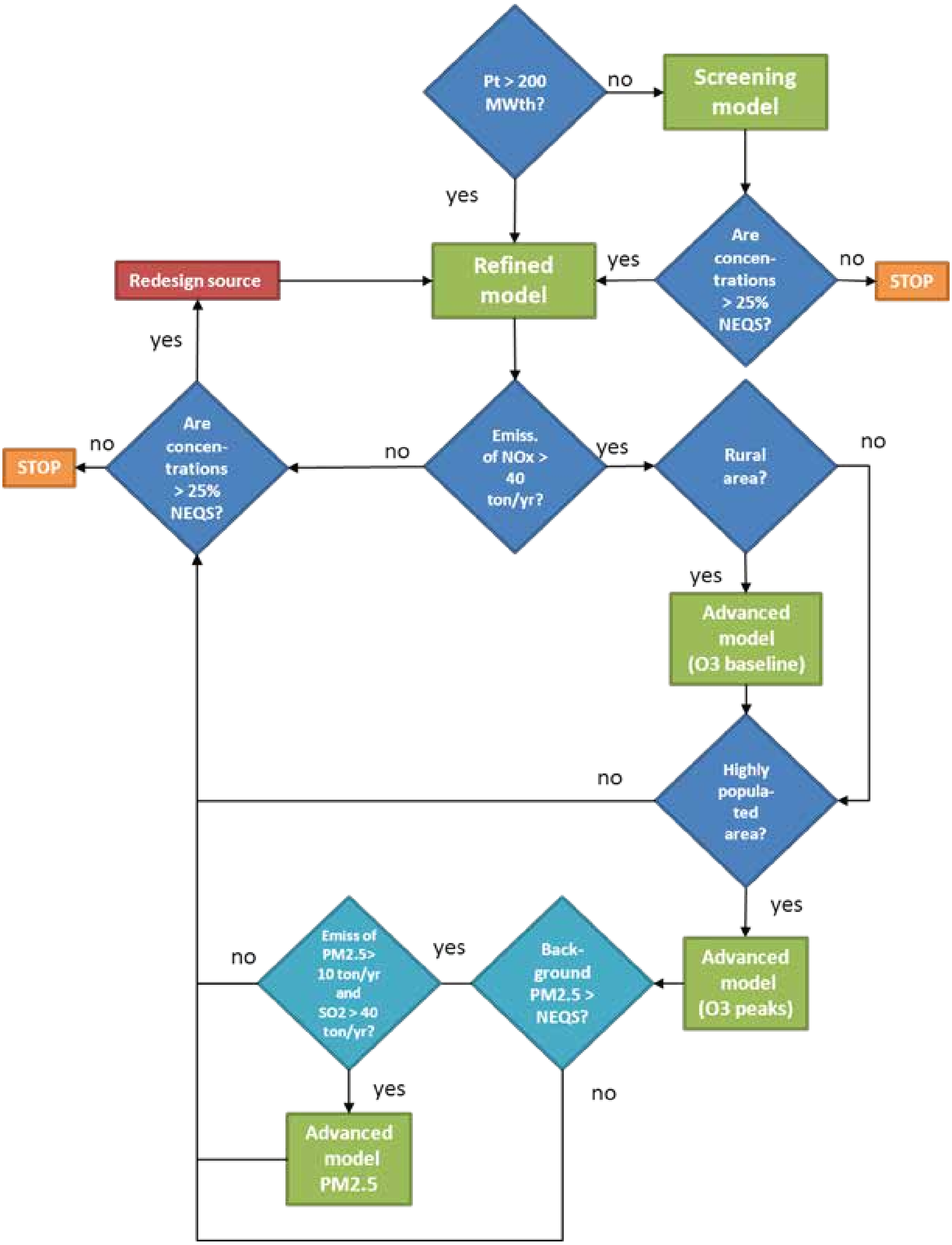


Figure 6-3 Flow chart indicating situations in which different categories of dispersion models might be used.

5. **Meteorological pre-processors:** Often meteorological data does not contain the required information for the dispersion model or the output from a NWP model has to be adapted to the requirements of the chemical transport model in terms of grids and variables. The meteorological pre-processors, or interface models, estimate all relevant meteorological variables for the calculation of concentrations and provide consistency between the meteorological and the chemical transport models.

The need for meteorological data is strongly dependent on the application. Usually Eulerian based air quality models have a prognostic model as meteorological driver, while Lagrangian models may be driven by a diagnostic wind model and a relevant meteorological pre-processor. Gaussian based models can generally be applied using both diagnostic and prognostic fields. Local scale models may require only a single observational site as input.

According to the National Institute of Water and Atmospheric Research (2004), for a screening model that handles only a single source at a time, wind direction is not a factor in determining worst-case conditions in flat terrain in the case where buildings do not exist. For multiple-source combinations, use of a variety of wind directions is important.

For refined and advanced assessments, actual near-site data is used. The representativeness of the actual data depends on the proximity of the meteorological monitoring site to the activity, the complexity of the terrain, the exposure of the instruments, the time of data collection, and the data recording method. Data for these types of modeling must be shown to be temporally and spatially representative of the site of the facility.

A minimum of 1 year of site-specific meteorology should be used. Site-specific data must be related to the longer-term (seasonal or annual) by statistical methods. Relating site-specific meteorology to data from climate or meteorological stations having longer collection periods ensures that site data are temporally representative. The upper air sounding data should be taken from the most representative or closest upper air monitoring station.

Missing meteorological data must be processed prior to being utilized in a model. There are numerous methods of processing missing data. Generally a data set should not be used if less than 90% of the annual data is available.

Complex terrain

Terrain elevations can have a large impact on the air quality dispersion modeling results and therefore on the estimates of ground level concentrations. Terrain elevation is the elevation relative to the facility base elevation.

In fact, in situations of complex terrain, significant changes in meteorological conditions can occur over short distances. Refined and advanced models can simulate these effects on pollutant transport and dispersion in a much more realistic way than a screening model, which assumes spatial uniformity in the meteorology. Clearly this means that more detail is required for modeling and for input data.

Evaluation of the terrain within a given study area is the responsibility of the modeler.

Local Buildings

Buildings and other structures near a stack can have a substantial effect on plume transport and dispersion, and on the resulting ground-level concentrations that are observed.

Airflow around buildings is often very complicated and may create zones of strong turbulence and downward mixing on the lee side of a building (Figure 6-4). This effect is known as building downwash. In such cases, the entrainment of exhaust gases released by short stacks in the wake of a building can result in much higher ground-level concentrations close to the source than the model would otherwise predict. A well-designed stack can minimize building downwash effects. It is generally accepted that if a stack complies with the criteria in the Good Engineering Practice (i.e. 2.5 times higher than any nearby building), then building downwash is unlikely to occur (AENV, 2009; EPA, 1985).

The cooling towers of coal-fired power plants are usually the buildings that bring up building downwash problems in this type of air quality modeling.

To take account local building effects, models generally require information related to the dimensions and location of the structures with respect to the stack.

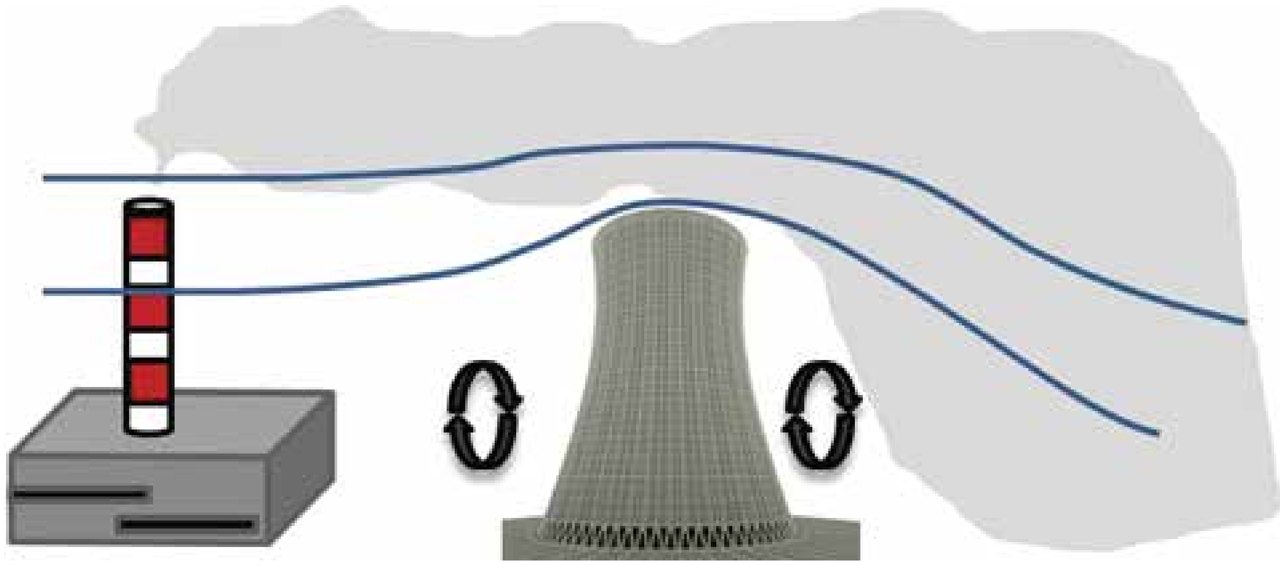


Figure 6-4 Schematic of building downwash for a cooling tower of a coal-fired power plant.

Emission input data

A source input data example for coal-fired power plants dispersion modelling is presented in Table 6-11.

Because emission rates and stack parameters can vary over a range of operating conditions, the modelling analysis must also consider various operating load scenarios for a proposed project. When modelling multiple flues, or multiple stacks that are close together, take account of the effect of enhanced plume buoyancy.

If sources exhibit variable emission rates, either over short- or longer-term periods, it may be important to consider programming the model to simulate the variation in the emissions. This would reduce the possibility of the model over-predicting long-term (longer than one-hour) averages, which could occur if the maximum emission rate was assumed to apply for 24 hours per day, 365 days per year.

For areas with multiple facilities, the emissions of all of the other sources in the airshed should be included.

Type of source	CFPP example	Parameters needed
Point	Discharges from stacks	Coordinates Release height (i.e., stack height) Exit velocity Stack diameter Exit temperature Mass emission rates of the pollutants
Area	Source with a large surface area, such as contaminated site, a pile of solid material, or a liquid surface (pond, tank, lagoon)	Coordinates of the area perimeter Release height Mass emission flux rate (i.e., mass Emission rate per unit of area, $g/s.m^2$)
Line	Sources where emissions are in linear form such conveyor belt, or roofline vent along a long, narrow building (usually a line source must be redefined as a chain of volume sources for modelling)	Dimensions of the line Release height Mass emission rates
Volume	3D sources such as area sources distributed with a vertical depth, for example, diffuse source such as emissions from within a building.	Coordinates Dimensions (3D) Mass emission rates

Table 6-11 Example Input Data for Characterizing Emissions Sources for a coal-fired power plant.

Models output

The main objective of a modelling study is to determine the significance of the impacts of pollutants discharged from the coal-fired power plant. The results must therefore be reported effectively and concisely in a manner suitable for the purpose for which they were produced.

This means the results must be communicated in a way that can be understood by other people who may not be experienced in interpreting model output.

All aspects of an air quality impact analysis should be thoroughly documented prior to submission for regulatory review. Documentation should address all assumptions and procedures, and provide the following information:

- The state of current air quality in the project impact area;
- The selection of air quality models;
- The selection of modelled scenarios;
- The input data: grid, emission inputs, including any temporal or spatial apportionment, meteorological data, including data quality and representativeness, air pollutant concentration input data, including data quality and representativeness;
- Air pollutant concentration output data and any other model outputs, including: interpretive limitations associated with procedural assumptions, input data, or theoretical basis of the model;
- All model input files, including the model source code, should be available, if requested.

In this scope, first it is important to report the modelling results in an easy-to-understand manner and second, to evaluate the implications of the results in terms of the potential effects of the predicted ground-level concentrations on people's health and the environment also in an easy-to-understand manner.

Model Results

Most models allow results to be assimilated and reported in a variety of formats to allow statistical analysis. These include the maximum predicted concentration at each or any receptor, or up to the nth highest predictions (such as the 99.5 percentile, which is the highest ground-level concentration at each receptor after the highest 0.5% of predictions have been discarded).

Some models also allow record the number of exceedances of a user-specified threshold value at each receptor. This function allows, for example, the production of graphs or tables showing the percentage of time that model results exceed the evaluation criteria.

Statistics

For the purpose of comparing modelling results to the national standards:

- Run the model for the minimum period of one full year of meteorological data where possible (i.e. 8760 hours).
- Show a map with the study area identifying the receptor(s) that are most highly impacted and those that is most sensitive.
- Report the maximum national standards values predicted ground-level concentrations for the receptor(s).
- Use the frequency of exceedances to indicate the frequency of 'pollution events' that exceed the national standards used.

Maps

- Present modelling results graphically whenever it is helpful and appropriate.
- Use sufficient labelling and include legends to allow people to understand the data.
- Present contour plots with:

- Indication of the sources, site property boundary and potentially sensitive receptors.
- Keep the number of concentration contours to the minimum necessary for assigning the information.
- Include in the legend the national standards limits.
- The contours should be over a map or photograph of the study area.

- Calculate the area of a receptor grid that is impacted by concentrations above the national standards limits. This is a useful tool to explore the extent of impact as well as the magnitude and significance.

- Present a percentage occurrence analysis for sensitive receptors.

- Present graphs showing the daily and seasonal variation of the ground-level concentrations caused by the pollutants discharged from the power plant.

6.2.4 Climate change

Climate change is already a concern in Asia and its impacts are projected to intensify in the decades to come, threatening the development and security of the region. Countries in Asia are among the most vulnerable globally to the adverse impacts of climate change, with poor and marginalized communities likely to suffer the most heavily (ADB, 2013).

An earlier ADB report (2008) based on 2007 IPCC[16] projections mentions that in Pakistan climate change studies forecast increased flooding, rock avalanches, and water resource disruptions as the Himalayan glaciers continue to melt. Floods exceeding design parameters could destroy the dams, barrages, and other fixed-capacity irrigation infrastructure on which the country's agriculture depends. The risk of hunger will also increase because of declining crop productivity owing to heat stress. Other areas of concern include the further intrusion of saline water along the Sindh coastal zone due to an accelerated rise in sea level; more and stronger cyclones caused by rising sea surface temperatures that will affect Karachi and other coastal settlements; heat strokes brought on by summer temperature spikes and the spread of disease vectors encouraged to breed in stagnant water bodies during mild winters.

Most recent report published by IPCC (2013) reaffirms the above mentioned trends confirming a high confidence in projected rise in temperature and medium confidence in summer monsoon precipitation increase in future over South Asia.

In September 2012, the Ministry of Climate Change of Pakistan published the National Climate Change Policy (MCCPAK, 2012) where the important climate change threats to the country are identified:

- Considerable increase in the frequency and intensity of extreme weather events, coupled with erratic monsoon rains causing frequent and intense floods and droughts;

- Projected recession of the Hindu Kush-Karakoram-Himalayan glaciers due to global warming and carbon soot deposits from trans-boundary pollution sources, threatening water inflows into the Indus River system;

- Increased siltation of major dams caused by more frequent and intense floods;

- Rising temperatures resulting in enhanced heat and water-stressed conditions, particularly in arid and semi-arid regions, leading to reducing agricultural productivity;

- Further decrease in the already scanty forest cover, from too rapid a change in climatic conditions to allow natural migration of adversely affected plant species;

- Increased intrusion of saline water in the Indus Delta, adversely affecting coastal agriculture, mangroves and the breeding grounds of fish;

- Threat to coastal areas due to projected sea level rise and increased cyclone activity due to higher sea surface temperature;

- Increase stress between upper riparian and lower riparian regions in relation to sharing of water resources;

- Increased health risks and climate change induced migration.

As far as greenhouse gases emission are concerned, Pakistan emissions in 2010 (313.47 $MtCO_2eq$/year) signify 0.7% of total world emissions. Pakistan per capita emissions of 2.3 tonnes CO_2eq/year (149th in world ranking) represent circa 1/3 of world average . However, due to its large population, total GHG emissions rank Pakistan as 25th in a list of 185 countries, between Argentina and Nigeria.

[16] IPCC – Intergovernamental Panel on Climate Change.

6.2.4.1 Potential Impacts

Since January 1st, 2012, the International Finance Corporation (IFC, 2012) has decided that the risks and impacts identification process will consider the emissions of greenhouse gases, as well as the relevant risks associated with a changing climate and the adaptation opportunities.

Responses to climate change can be divided into two aspects:

- **Mitigation** — the term used to describe the process of reducing GHG emissions that contribute to climate change. It includes strategies to reduce GHG emissions and enhance GHG sinks.

- **Adaptation** — is a process, or set of initiatives and measures, to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Adaptation can also be thought of as learning how to live with the consequences of climate change.

Climate change adaptation and mitigation are closely interrelated. While they are often considered as separate topics or policy fields, it is critical to consider the links between them. Certain adaptation responses have clear mitigation benefits, but some actions can result in 'maladaptation' — i.e. instead of reducing vulnerability to climate change, they actually increase it or reduce the adaptive capacity. Some actions can also distribute the benefits of adaptation unequally across society (for example, the prevention of climate-change-induced diseases only for affluent people). One of the roles of EIA is to seek to manage these conflicts and potential synergies. This can be done by comprehensively assessing the synergies between climate change mitigation, adaptation and other environmental issues and policy concerns, in order to avoid negative synergies and missed opportunities for promoting positive synergies.

Coal-fired power plants are an important source of greenhouse gases at the worldwide level, namely CO2. In fact coal-fired power plants are the largest contributor to greenhouse gas emissions that cause climate change (Ailun and Cui, 2012).

The burning of fossil fuels for electricity and heat supply is the largest single source of global greenhouse gas emissions at a global level.

In 2004 energy supply represented a share of 26% of global greenhouse gas emissions (IPCC, 2007). In a recent report, the International Energy Agency states that in 2010, 43% of CO_2 emissions from fuel combustion were produced from coal (IEA, 2012). Between 2009 and 2010, worldwide CO_2 emissions from the combustion of coal increased by 4.9% and represented 13.1 Gt CO_2. Currently, coal fills much of the growing energy demand of those developing countries (such as China and India) where energy-intensive industrial production is growing rapidly and large coal reserves exist with limited reserves of other energy sources.

As mentioned earlier, several greenhouse gases are associated with power generation and transmission, including CO_2, N_2O, methane (CH_4), hydrofluorocarbons, perfluorocarbons, and SF_6. CO_2, one of the major greenhouse gases under the United Nations Framework Convention on Climate Change, and N_2O are emitted from the combustion of coal. Methane can be released at coal storage facilities.

Energy production and distribution infrastructure can be highly vulnerable to the impacts of climate change. According to ADB (2013) these impacts will have consequences for the design, construction, location, and operations of power infrastructure. Inadequate attention to these impacts can increase the long-term costs of energy sector investments and reduce the likelihood that these investments deliver intended benefits.

The power sector is generally viewed in the context of greenhouse gas emissions mitigation. However, it is also the case that the sector is itself significantly vulnerable to projected changes in climate. The coal-fired power sector's vulnerability to projected climate changes includes the following:

- Increases in water temperature are likely to reduce generation efficiency, especially where water availability is also affected.

- Increases in air temperature will reduce generation efficiency and output as well as increase customers' cooling demands, stressing the capacity of generation and grid networks.

- Changes in precipitation patterns and surface water discharge, as well as an increasing frequency and/or intensity of droughts, may reduce water availability for cooling purposes to thermal power plants.

- Extreme weather events, such as stronger and/ or more frequent storms, can reduce the supply and potentially the quality of coal, damage generation and grid infrastructure, reduce output, and affect security of supply. This may be of particular significance in regions where projects are located or planned in water-stressed areas or where water is scarce.

- Sea level rise can affect energy infrastructure in general and limit areas appropriate for the location of power plants and grids.

6.2.4.2 Baseline survey

EA is an effective means to incorporate climate change considerations in project planning; yet challenges remain. The EA process cannot consider the bulk of GHG emitted from already existing developments. Furthermore, unlike most project-related environmental effects, the contribution of an individual project to climate change cannot be measured (FPTC, 2003).

The environmental importance of a particular project can be assessed by placing it in the context of the policy objectives or regulations. This would enable practitioners and decision makers to place the predicted GHG emissions associated with an individual project within a provincial or federal context. When incorporating climate change considerations in a project EA, practitioners should consult with relevant authorities on climate change and EA-related policies, knowledge and practices.

Similar challenges confront the consideration of climate change impacts on individual projects. While research is ongoing, sufficiently detailed information may not be available on local changes in climatic factors, to be able to accurately predict climate change impacts on a specific project.

When addressing climate change adaptation concerns the EIA should not only consider the historical data on climate, but also clearly identify and present the climate change scenario that should be considered in the assessment process. Scenarios based on climate model projections, existing climate data and local experiences, can contribute to the identification of climate change considerations, and assist risk-based decisions.

A clear description of the climate change scenario facilitates discussion on whether the expected climatic factors should be considered in the project design and how they may affect the project's environmental context. EIA should outline extreme climate situations to be considered as part of the environmental baseline analysis.

Any existing adaptation strategies, risk management plans and other national or sub-regional studies on the effects of climate variability and climate change should be reviewed, as well as proposed responses and available information on expected climate-related effects relevant to the project.

6.2.4.3 Methods for impact assessment

Incorporation of climate change considerations in EA requires two practical approaches:

- Climate mitigation concerns: determining whether the project may significantly change GHG emissions and defining the scope of any necessary GHG assessment;

- Climate change adaptation concerns: being clear about climate change scenarios used in the EIA and identifying the key climate change adaptation concerns and how they interact with the other issues to be assessed in EIA.

Most projects may include different components that might be more closely associated with one or the other climate change consideration. For example, the first consideration may be applicable to a coal-fired power plant project, while the adaptation concern may be more relevant to assess the adequateness of its cooling system.

When it comes to mitigation, the main concerns focus on GHG emissions. Implementing a project may lead to, for example:

- A direct increase in GHG emissions:

- Will the proposed project emit greenhouse gases?

- Does the proposed project entail any land use, land-use change or forestry activities (e.g. deforestation) that may lead to increased emissions?

- Does it entail other activities (e.g. afforestation) that may act as emission sinks?

- An increase in energy demand leading to an indirect increase in GHG emissions:

- Will the proposed project significantly influence demand for energy?

- Is it possible to use renewable energy sources?

• Embedded GHG emissions, e.g. due to energy use in material production, transport, etc.;

• Loss of habitats that provide carbon sequestration, (e.g. through land-use change).

In the case of coal-fired power plants the first question is one of major relevance. For combustion sources such as coal-fired power plants, the GHG of concern are CO_2 (carbon dioxide), CH_4 (methane) and N_2O (nitrous oxide).

The World Bank Group's (WB) Strategic Framework for Development and Climate Change adopted in October 2008 lays out the criteria that a coal plant project should meet to receive traditional financing from any of the entities within the WB, including the International Finance Corporation (IFC) and Multilateral Investment Guarantee Agency (MIGA). Specifically, it requires, among others, that coal projects be designed to use the best appropriate available technology to allow for high efficiency and therefore lower GHG emissions intensity, after full consideration of viable alternatives to the least-cost (including environmental externalities) options and when the additional financing from donors for their incremental costs is not available.

The European Investment Bank (EIB) developed a pilot methodology for calculating absolute and relative GHG emissions (EIB, 2012). Emission factors to calculate GHG emission in coal-fired power plant are presented in Table 6-12.

In Latin America and the Caribbean region, IDB will support those coal-fired power plants that are designed to meet minimum performance criteria in terms of efficiency and GHG emissions intensity, and to use the best appropriate available technology to allow for high efficiency and therefore lower GHG emissions intensity. Table 6-13 provides minimum performance criteria for IDB financing of acceptable technologies. Such minimum performance criteria are based on (i) performance of model Coal Plants as defined by the US EPA and DoE, (ii) typical performance of Coal Plants specified by the International Energy Agency (IEA), and (iii) the EU Best Available Techniques Reference Document for Large Combustion Plants. IDB performance criteria might be used as references by other multilateral development banks such as the ADB.

Fuel Name	Units	kg CO_2	kg CH_4	kg N_2O
Anthracite	1 metric tonne (t)	2625	0.0	0.0
Anthracite	1 TJ	98300	1.0	1.5
Bitumen	1 metric tonne (t)	3244	0.1	0.0
Bitumen	1 TJ	80700	3.0	0.6
Lignite	1 metric tonne (t)	1202	0.0	0.0
Lignite	1 TJ	101000	1.0	1.5
Other bituminous coal	1 metric tonne (t)	2441	0.0	0.0
Other bituminous coal	1 TJ	94600	1.0	1.5
Sub bituminous coal	1 metric tonne (t)	1816	0.0	0.0
Sub bituminous coal	1 TJ	96100	1.0	1.5
Brown coal briquettes	1 metric tonne (t)	2018	0.0	0.0
Brown coal briquettes	1 TJ	97500	1.0	1.5
Coking coal	1 metric tonne (t)	2668	0.0	0.0
Coking coal	1 TJ	94600	1.0	1.5

Table 6-12 Default GHG Emissions Factors for coal-fired power plants.TJ factors from IPCC (2006) assume no unoxidized carbon. To account for unoxidized carbon, IPCC suggests multiplying by 0.98. Other factors are from WRI/WBCSD GHG protocol.[18]

[18] *http://www.ghgprotocol.org/*

Technology	Pulverized Coal Combustion Supercritical	Pulverized Coal Combustion Ultra-Supercritical	Circulating Fluidized Bed Combustion	Integrated Gasification Combined Cycle
Net Plant Higher Heat Value Efficiency (%) (Bituminous coal)	> 38.3	> 42.7	> 36.0	> 38.2
Net CO_2 Emissions Intensity (kg CO_2/net MWh)	< 832	<748	<890	<832

Table 6-13 Minimum performance criteria of new coal-fired power plants that may be supported by the IDB (IDB, 2009).

The EIA process should consider, early in the process, not only the impact of a project on climate change (i.e. mitigation aspects) but also the impact of climate change on the project and its implementation (i.e. adaptation aspects):

- How might implementing the project be affected by climate change?
- How might the project need to adapt to a changing climate and possible extreme events?

The EIA should be able to answer some basic questions that should be asked when identifying major climate change adaptation concerns:

• Heat waves:

- Will it absorb or generate heat?

- Can it be affected by heat waves?

- Will it increase energy and water demand for cooling?

- Can the materials used during construction withstand higher temperatures (or will they experience, for example, material fatigue or surface degradation)?

• Droughts due to long-term changes in precipitation patterns (also consider possible synergistic effects with flood management actions that enhance water retention capacity in the watershed):

- Is the proposed project vulnerable to low river flows or higher water temperatures?

- Will it worsen water pollution — especially during periods of drought with reduced dilution rates, increased temperatures and turbidity?

- Will it change the vulnerability of landscapes or woodlands to wildfires? Is the proposed project located in an area vulnerable to wildfires?

- Can the materials used during construction withstand higher temperatures?

• Extreme rainfall, riverine flooding and flash floods:

- Will the proposed project be at risk because it is located in a riverine flooding zone?

- Will it change the capacity of existing flood plains for natural flood management?

- Will it alter the water retention capacity in the watershed?

- Are embankments stable enough to withstand flooding?

• Storms and winds:

- Will the proposed project be at risk because of storms and strong winds?

- Is the project’s connectivity to energy, water, transport and ICT networks ensured during high storms?

• Landslides:

- Is the project located in an area that could be affected by extreme precipitation or landslides?

• Rising sea levels:

- Is the proposed project located in areas that may be affected by rising sea levels?

- Can seawater surges caused by storms affect the project?

- Is the proposed project located in an area at risk of coastal erosion? Will it reduce or enhance the risk of coastal erosion?

- Is it located in areas that may be affected by saline intrusion?

- Can seawater intrusion lead to leakage of polluting substances (e.g. waste)?

6.2.5 Noise and vibration

6.2.5.1 Potential Impacts

Noise and vibration at coal-fired power plants are generated during several phases of the project. Table 6-14 lists main noise emission sources by activity and phase.

Phase	Activity	Emission sources
Site preparation and construction	Land clearing, earth moving, terrain shaping	Heavy equipment Disruption and blast Increased traffic
	Construction and landscaping of onsite facilities, structures and buildings	Heavy equipment Use onsite of tools
Construction camp and onsite housing	Existence of structures	Transformers and switches
Operation	Coal transport and processing	Transportation of coal by trucks or trains Pulverisers and choppers
	On-site equipment	Turbines and generators Boilers Pumps, fans and ductworks, piping and valves Cooling towers Other equipment Emission control equipment
	Fuel combustion	Emission control equipment
	Existence of structures	Transformers and switches
Decommissioning	Removal and transport of machinery and equipment	Use of heavy equipment, transport of equipment and machinery from site Use onsite of tools
	Removal or decommissioning of structures and buildings	Use of heavy equipment, transport of equipment and machinery from site Use onsite of tools

Table 6-14 Potential noise emission sources

Noise and vibration at energy generation and transmission projects are generated during construction and decommissioning activities from blasting, construction equipment, and the transport of equipment and materials. Energy projects have associated transformers and switches, which are a source of noise.

Principal sources of noise in coal-fired power plants include the turbine generators and auxiliaries; boilers and auxiliaries; fans and ductwork; pumps; compressors; condensers; precipitators, including rappers and plate vibrators; piping and valves; reciprocating engines; motors; radiators; and cooling towers. At coal-fired thermal plants the transportation of fuel via trucks or trains and its preparation (e.g., pulverizers, choppers) are also sources of noise. In most circumstances coal-fired power plants (> 50 MWth) are used for base load operation. As such, this type of power plant typically operates continually representing a continuous source of noise.

6.2.5.2 Baseline survey

If there are nearby (<500 m) receptors, baseline noise measurements should be included in the Environmental Setting section of the EIA. If these measurements do not exist, they should be taken at representative points of reception prior to start of construction. Noise levels in and around sensitive habitats and areas of human habitation also should be taken.

A point of reception or receptor may be defined as any point on or near the premises occupied by persons or animals where extraneous noise and/or vibration are received. Examples of receptor locations include: permanent or seasonal residences; hotels/motels; schools and daycare facilities; hospitals and nursing homes; places of worship; parks and campgrounds; sensitive habitats such as breeding, birthing or nesting areas.

6.2.5.3 Methods for impact assessment

To estimate noise emissions during construction and operation of a power project, baseline monitoring and operational monitoring is necessary. Noise propagation models may be effective tools to help evaluate noise management options such as alternative plant locations, general arrangement of the plant and auxiliary equipment, building enclosure design, and, together with the results of a baseline noise assessment, expected

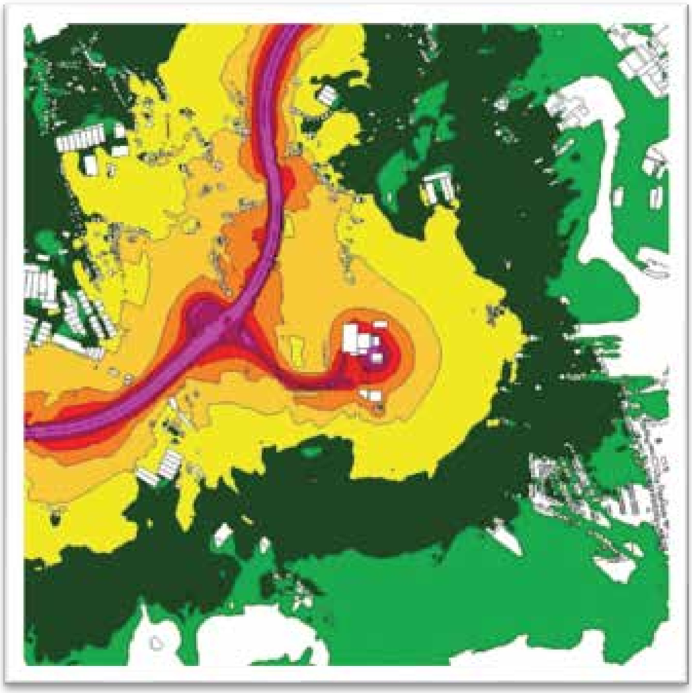


Figure 6-5 Noise map of an industrial facility.

compliance with the applicable community noise requirements. This information can be obtained using empirical or numerical modeling technique. Point source propagation can be analyzed using basic analytical equations based on attenuation of sound energy as the inverse of the square of the distance from the noise source. Numerical modeling techniques have also been developed for the additive effect of multiple sources. The results of the models are then compared to the appropriate standards. Most advanced models provide graphic output of noise impacts or isophons (see example on Figure 6-5), which can then be overlaid on maps with land use and locations of critical receptors.

Noise impacts should not exceed the levels represented in the Pakistani National Environmental Quality Standards (see Annex A Table A-5) or result in a maximum increase in background levels of 3 dB at the nearest receptor location off-site.

6.2.6 Aesthetic resources

6.2.6.1 Potential Impacts

Impacts of coal-fired power plants and auxiliary transmission projects on landscape and aesthetic resources include (see Table 6-15):

Activity	Activity description	Environmental concern
Site preparation and construction activities	Land clearing, earthmoving, terrain shaping	Disruption of view Degradation of landscape Use of nighttime lighting
	Construction and landscaping of onsite facilities, structures and buildings	Disruption and degradation of views Use of nighttime lighting
	Construction and/or upgrade of access roads. Construction of power line connections	Disruption and degradation of view Use of nighttime lighting
Construction camp and onsite housing activities	Existence of structures	Disruption or degradation of views Light pollution
Operation	Existence of structures	Disruption or degradation of views Light pollution
Decommissioning	Removal or decommissioning of structures and buildings	Effect on view (positive or negative)
	Restoration of terrain and vegetation	Effects on view (positive and negative)

Table 6-15 List of potential impacts on aesthetic resources**.**

- Impacts on visual resources and landscapes: Visual impacts are highly variable, depending on the project layout, location, lines of sight, and scenic vistas that may exist in the project area. Visual impacts may include the power plant itself, smoke stacks, cooling towers, dams, roads, and right of ways.

- Impacts on visibility: Combustion power plants can degrade ability to view vistas from a distance due to air emissions generated from combustion and from the water vapor plume caused by the cooling towers.

- Increases in light contamination: Light pollution is excessive or obtrusive artificial light and can be a problem at power plants projects and at substations associated with transmission projects. Light pollution is a broad term that refers to multiple problems, all of which are caused by inefficient, unappealing, or unnecessary use of artificial light. Light pollution sources from power projects include:

- Lights used during construction to enable work at night or during low light conditions;

- Building and structure exterior and interior lighting;

- Nighttime security lighting;

- On-site streetlights;

- Vehicular lighting associated with traffic to and from the site.

6.2.6.2 Baseline survey

Baseline information on views and vistas that could be impacted by the proposed project should be identified in the Environmental Setting. Vistas and views include, but are not limited to mountains, waterfalls, skylines including sunrises and sunsets, and cultural, archeological, and historical structures.

The location of these views and vistas can be documented by presenting panoramic views of them from potential viewpoints such as communities, roads, and designated scenic viewing areas. Narrative descriptions of existing visual assets are also useful as the specific importance of a view may not be obvious to a non-local viewer. In addition, this subsection should present information on existing visibility in the project area.

This subsection should present panoramic photos of the proposed facility site from potential viewpoints such as communities, roads, and designated scenic viewing areas. These photos can be used to establish the views without the facility and provide a baseline on which the facility can be overlaid.

Information should also be presented in the subsection on light pollution from existing sources in the project area including communities, factories, streetlights, etc.

6.2.6.3 Methods for impact assessment

It is recommended that a project be graphically superimposed on baseline panoramic views of the proposed project site from different potential viewpoints such as communities, roads, and designated scenic viewing areas, to provide a better understanding of potential visual impacts as a function of direction, distance and time of day.

The potential for visibility impacts should be assessed using appropriate air quality models. Zone of Visual Influence maps show the extent of visibility of a proposed development from the surrounding landscape. They can also be used to assess the cumulative visual impact of similar developments within an area. Wireframe views give an outline image of the contours of the land from a selected viewpoint. This gives a picture of the proposed development without obstruction from surrounding buildings and vegetation. Photomontages are computer aided 'photographs' of a proposed development, showing a picture of how a development will appear after construction.

The color photomontage is probably the most frequently used technique. Such a technique has the advantage of accurately portraying the landscape in a meaningful and easily recognizable form. Video montage techniques have recently been developed to demonstrate the important effects of movement.

6.2.7 Biological environment

Pakistan covers a land area of 882,000 km^2 almost all of which might be considered part of the watershed of the River Indus. From the northern boundary of the Arabian Seacoast and the mouth of the Indus near the tropic of Cancer, Pakistan extends some 1,700 km northward to the origins of the Indus among the mountains of the Himalayas, Hindu Kush and Karakorum.

With its dramatic geological history, broad latitudinal spread and immense altitudinal range, Pakistan spans a remarkable number of the world's ecological regions and supports a wide array of ecosystems (GoP, 2000). However, any description of the natural ecological zones of Pakistan must be qualified by the statement that these zones have been so widely affected by human activity that very few truly natural habitats remain. Natural terrestrial ecosystems range from the permanent snowfields and cold deserts of the mountainous north to the arid sub-tropical zones of Sindh and Balochistan; from the dry temperate coniferous forests of the inner Himalayas to the tropical deciduous forests of the Himalayan foothills, from the steppe forests of the Sulaiman Range to the thorn

	Total reported	Endemics	Threatened
Mammals	174	6	20
Birds	668	?	25
Reptiles	177	13	6
Amphibians	22	9	1
Fish			
Freshwater	198	29	1
Marine	788	-	5
Invertebrates			
Echinoderms	25	-	2
Marine Molluscs	769	-	8
Marine Crustaceans	287	-	6
Marine Annelids	101	-	1
Insects	>5000	-	-
Plants			
Angiosperms	5700	380	?
Gymnosperms	21	-	?
Pteridophytes	189	-	?
Fungi	>4500	2	?
Algae	775	20	?

Table 6-16 Species richness and endemism in major plant and animal groups on Pakistan (GoP, 2000)

forests of the Indus plains; and from the swamps and riverine communities of the Indus and its tributaries to the mangrove forests lining the Indus Delta and Arabian Sea.

Because Pakistan is largely bounded by manmade borders and does not comprise an isolated entity in biogeographic terms, relatively few species are found only in this country (Table 6-16). Thus, Pakistan has relatively low rates of endemism – about 7% for flowering plants and reptiles, and 3% for mammals – but higher for freshwater fish, 15%. However, the proportion of 'restricted range' species occurring in Pakistan is much higher, and for many of these species, Pakistan contains the bulk of the global population.

The ecological trend of greatest concern in Pakistan today is the continuing loss, fragmentation and degradation of natural habitats. This is affecting without exception forests, rangelands, freshwater and marine ecosystems. Of equal concern is the continuing decline in many native species of animals and plants. Some species are already extinct, many are internationally threatened, and more still are of national concern. The degradation of agro-ecosystems and the accelerating loss of domestic genetic diversity are areas that need to be looked into.

Ecosystem	Characteristics	Significance	Threats
Indus Delta and coastal wetlands	Extensive mangroves and mudflats Inadequate protected area coverage	Rich avian and marine fauna Diverse mangrove habitat Marine turtle habitat	Reduced freshwater flow from diversions upstream Cutting mangroves for fuelwood Drainage of coastal wetlands
Indus River and wetlands	Extensive wetlands	Migratory flyway of global importance Habitat for Indus River dolphin	Water diversion/drainage Agricultural intensification Toxic pollutants
Chagai Desert	A desert of great antiquity	Many endemic and unique species	Proposed mining Hunting parties from the Gulf
Balochistan juniper forest	Huge and ancient junipers	Largest remaining juniper forest in the world Unique flora and fauna	Fuelwood cutting and overgrazing Habitat fragmentation
Chilgoza forest (Sulaiman range)	Rock outcrops with shallow mountain soils	Important wildlife habitat for several species at risk	Fuelwood cutting and overgrazing Illegal hunting
Balochistan sub-tropical forests	Mid-altitude forests with sparse canopy but rich associated flora	Very few areas now remain Important wildlife habitat	Fuelwood cutting and overgrazing
Balochistan rivers	Not connects with the Indus river system	Unique aquatic fauna and flora with high levels of endemism	Water diversion/drainage Overfishing
Tropical deciduous forests (Himalaya foothills)	Extend from the Margalla Hills National Park east to Azad Kashmir	Perhaps the most floristically rich ecosystem of Pakistan	Fuelwood cutting and overgrazing
Moist and dry temperate Himalayan forests	Important forest tracts now becoming increasingly fragmented	Global hotspot for avian diversity Important wildlife habitat	Commercial logging Fuelwood cutting and overgrazing
Trans-Himalayan alps and plateaux	Spectacular mountain scenery	Unique flora and fauna Center of endemism	Fuelwood cutting and overgrazing Illegal hunting Unregulated tourism Habitat fragmentation

Table 6-17 Critically threatened ecosystems of Pakistan (GOVPAK, 2000).

In Pakistan, given the widespread historic conversion of natural ecosystems to agriculture, the already highly advanced and rapidly accelerating degradation of habitats, and the continuing depletion of populations, almost all remaining natural or modified ecosystems are now critically threatened.

The Biodiversity Action Plan (GoP, 2000) identified at least 10 ecosystems of particular value for their species richness and/or unique communities of flora and fauna are threatened with habitat loss and degradation (Table 6-17). Given their biodiversity importance and the high level of threat, these ecosystems are considered to be of critical concern for conservation.

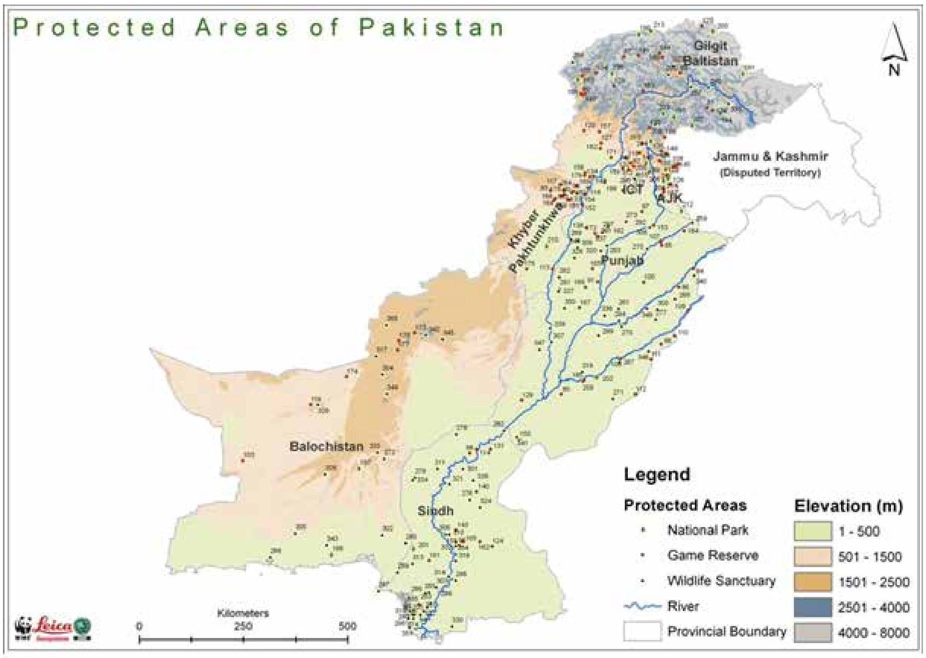


Figure 6-6 Geographical distribution of naturally protected areas of Pakistan (information provided by WWF-Pakistan).

According to data provided recently by WWF-Pakistan, Pakistan has a total of 351 of naturally protected areas (see Table 6-18). Almost 60% of the protected areas are game reserves defined either at public (provincial or community scale) or private level. There are a total of 26 national parks distributed within the country (see Figure 6-6) with a high concentration in the northern part of the country (AJK and K-P). More than a quarter of the protected areas are wildlife sanctuaries concentrated in Punjab, Sindh and Balochistan.

Province	Protected Area Category								
	National Park	**Wildlife Sanctuary**	**Wildlife Refuge**	**Wildlife Park**	**Game Reserve**	**Private Game Reserve**	**Community Game Reserve**	**Unclassified**	**Total**
AJK	7	0	0	0	3	0	0	0	**10**
Balochistan	2	15	0	0	6	0	0	6	**29**
Punjab	4	38	0	0	26	1	0	4	**73**
K-P	7	3	4	5	49	16	61	3	**148**
Sindh	1	33	0	0	15	0	0	2	**51**
Federal Territory	1	2	0	0	1	0	0	0	**4**
GB	4	5	0	0	9	0	18	0	**36**
Total	**26**	**96**	**4**	**5**	**109**	**17**	**79**	**15**	**351**

6-18 Number and type of naturally protected areas in Pakistan (data provided by WWF-Pakistan)

6.2.7.1 Potential impacts

The primary pathways of impacts from a coal-fired power plant project on the biological environment will be potential contamination of soil, water and air and alteration of flow in surface water. Biological resources can also be affected by land use conversions, increased human activity in the vicinity of the power plant, and increased pressure on natural resources in the area of influence due to human population increases associated with the project.

It is imperative that no endangered or threatened species or designated protected areas be adversely impacted by the power or transmission line project. These species should receive particular attention during the assessment of impacts on flora and fauna, striving for no net loss. All activities proposed for the project should be overlaid on maps of the habitats for endangered and threatened species as well a protected areas, to identify any potential impacts.

Terrestrial species and associated ecosystems

Terrestrial species are those which may occur on land, including mammals, birds, reptiles, amphibians, invertebrates, trees, shrubs, forbs, grasses, fungi, mosses and microbes. Impacts on terrestrial species and the ecosystems associated with them (including wetlands and riparian areas) include (see Table 6-19):

• Destruction, modification or fragmentation of habitat;

• Disruption of behavior, including feeding, migration, breeding, nesting, and calving;

• Direct impacts:

- Poisoning from direct contact with hazardous substances or contamination of watering holes;

- Electrocution;

- Increased collection and hunting.

Destruction or fragmentation of terrestrial ecosystems is largely associated with land clearing, earthmoving and terrain shaping at the facility site and along access roads and right-of-ways. However, the creation of water impoundments can also flood ecosystems which in the case of power plant cooling ponds will be of relatively small area. Excessive collection of fuelwood by workers during construction or operation can also lead to deforestation. Destruction of ecosystems can also be caused indirectly if emissions from a coal-fired power plant reduce productivity of vegetation downwind from the facility.

The construction of access roads and right-of-ways can fragment existing ecosystems and interrupt migratory corridors. Access roads and right-of-ways can also open to human activities areas that had previously been relatively wild, disturbing the species in those areas and creating opportunities for increased collection or harvest of plant life and collection or hunting of animals.

Some ecosystems are more critical to species' survival than others. These include migratory routes or corridors, watering holes, salt licks, and breeding, nesting and calving areas. These areas should have been identified in the preparation of the Environmental Setting. Any impacts in these areas should receive special attention.

Alteration of terrestrial habitat for construction of transmission and distribution associated projects may also yield benefits for wildlife such as the creation of protective nesting, rearing, and foraging habitat for certain species; the establishment of travel and foraging corridors for ungulates and other large mammals; and nesting and perching opportunities for large bird species atop transmission towers and associated infrastructures.

Impacts on aquatic ecosystems caused by water contamination and water flows are derived directly from the surface water quantity and quality impacts identified in subsection 4.2.2 Water Resources. For example, discharges with elevated temperature and chemical contaminants can affect phytoplankton, zooplankton, fish, crustaceans, shellfish, and many other forms of aquatic life. These types of ecosystem changes can often lead to invasion by non-native species. These impacts and others caused by changes in water quality and quantity should be investigated and characterized.

Direct aquatic habitat alteration can occur during construction or upgrading of access roads and right-of-ways. If such activities require construction across wetlands or streams; on the borders of ponds or lakes estuaries; or on coastlines, they can disrupt watercourses and wetland flow regimes, impact water quality and cause bank erosion all of which impact aquatic habitats.

If the project involves a construction camp or onsite

Activity	Activity description	Environmental concern	Affected environment
Site preparation and construction activities	Land clearing, earthmoving, terrain shaping	Deforestation, wetland destruction and other vegetation.	Flora and associated ecosystems
		Loss of habitat; Habitat fragmentation; Disruption and dislocation of local and/or migratory wildlife, including disturbance of migratory corridors and breeding, spawning, nesting and calving areas; Poisoning via contamination of waste and spills and leaks of hazardous materials;	Fauna
		Reductions in species and habitats	Threatened and endangered species
	Construction and landscaping of onsite facilities, structures and buildings	Spread of invasive species	Flora and associated ecosystems
		Disruption and dislocation of local and/or migratory wildlife, including disturbance of migratory corridors and breeding, spawning, nesting and calving areas	Fauna
	Construction and/or upgrade of access roads. Construction of power line connections	Spread of invasive species	Flora and associated ecosystems
		Disruption and dislocation of local and/or migratory wildlife, including disturbance of migratory corridors and breeding, spawning, nesting and calving areas	Fauna
		Increase road access in remote areas may lead to increase use of natural resources and to invasion of previously inaccessible areas	Flora and fauna and associated ecosystems; Threatened and endangered species; Protected areas

Table 6-19 Terrestrial flora, fauna and ecosystems.

Activity	Activity description	Environmental concern	Affected environment
Construction camp and onsite housing activities	Camp management	Animals attracted to garbage and food waste; Disruption and dislocation of local and/or migratory wildlife, including disturbance of migratory corridors and breeding, spawning, nesting and calving areas; Degradation of ecosystems from fuel wood gathering; Increased collecting, hunting and fishing (food for workers)	Terrestrial and aquatic fauna and associated ecosystems
	Solid and human waste disposal	Attraction of pests and vectors	Fauna
	Fuel and chemical storage and handling	Poisoning via spills and leaks	Fauna
	Existence of structures	Electrocution	Fauna
Operation	Dams for cooling ponds	Destruction of ecosystems by inundation	Flora and associated ecosystems
	On-site equipment	Disruption and dislocation of local and/or migratory wildlife, including disturbance of migrator corridors and breeding, spawning, nesting and calving areas	Fauna
	Fuel combustion	Destruction or degradation of ecosystems downwind from stack emissions	Flora and associated ecosystems
	Solid and human waste disposal	Attraction of pests and vectors	Fauna
	Fuel and chemical storage and handling	Poisoning via spills and leaks	Fauna
Decommissioning	Removal or decommissioning of structures and buildings	Disruption and dislocation of local and/or migratory wildlife, including disturbance of migratory corridors and breeding, spawning, nesting and calving areas; Wildfire	Fauna

Table 6-19 Terrestrial flora, fauna and ecosystems.

housing during operation, animals can be attracted to garbage and food waste thus changing their feeding habits and their interactions with humans. Regular maintenance of right-of-ways to control vegetation may involve the use of mechanical methods, such as mowing or pruning machinery, in addition to manual hand clearing and herbicide use, all of which can disrupt wildlife and their habitats. Noise, vibration, illumination, and vehicular movement can disrupt animal activities. These are particularly of concern if animals are disrupted in sensitive habitats, such as migratory routes or corridors, watering holes, salt licks, and breeding, nesting and calving areas.

Light pollution poses a serious threat to wildlife, having negative impacts on plant and animal physiology. Light pollution can confuse animal navigation, alter competitive interactions, change predator-prey relations, and cause physiological harm. The rhythm of life is orchestrated by the natural diurnal patterns of light and dark, so disruption to these patterns impacts the ecological dynamics.

Direct impacts to wildlife can be caused by increased hunting, improper solid or liquid waste disposal and direct contact by animals with project components. Increased collection and hunting can be stimulated by increased human activity in the area by workers and

Activity	Activity description	Environmental concern
Site preparation and construction activities	Land clearing, earthmoving, terrain shaping	Wetland destruction; Run-off carrying sediments and associated contaminants; Poisoning via contamination of waste and spills and leaks of hazardous materials
	Construction and landscaping of onsite facilities, structures and buildings	Run-off carrying sediments and associated contaminants
	Construction and/or upgrade of access roads. Construction of power line connections	Run-off carrying sediments and associated contaminants
Construction camp and onsite housing activities	Solid and human waste disposal	Run-off carrying associated contaminants
	Fuel and chemical storage and handling	Contamination from spills and leaks
Operation	Dams for cooling ponds	Individuals killed, damaged or entrapped by intake structures, cooling systems or turbines
	Cooling systems	Habitat alteration from discharges of cooling tower
	Maintenance	Habitat alteration from water contamination from disposal of dredged or removed material
	Fuel washing and preparation	Habitat alteration from water contamination from residue disposal
	Fuel combustion	Habitat alteration from water contamination from ash and sludge disposal
	Solid and human waste disposal	Run-off carrying associated contaminants
	Fuel and chemical storage and handling	Contamination from spills and leaks
Decommissioning	Removal or decommissioning of structures and buildings	Run-off carrying sediments and associated contaminants

Table 6-20. Aquatic species and associated ecosystems

the population that grows to meet those worker's needs. Improper waste disposal can bring animals into direct contact with hazardous substances or poison watering holes.

The combination of the height of transmission towers and the electricity carried by transmission lines can pose a potentially fatal hazard to birds and bats through collisions and electrocutions. Avian collisions with power lines can occur in large numbers if located within daily flyways or migration corridors, or if groups are traveling at night or during low light conditions (e.g., dense fog). In addition, bird and bat collisions with power lines may result in power outages and fires.

Aquatic species and associated ecosystems

Aquatic species are those species that may live in marine water as well as freshwater. Impacts (see Table 6-20) that can affect aquatic species and the ecosystems associated with them include:

• Water contamination;

• Changes in water flows or water levels in surface water;

• Direct aquatic habitat alteration;

• Injury or mortality from:

• Direct contact with in-water technologies;

- Increased collection or fishing;

- Habitat avoidance due to noise or visual disturbances.

For coal-fired power plants projects that divert surface water to use in cooling and in boilers aquatic organisms can be drawn into intake structures and entrained in the system. In either case, aquatic organisms may be killed or subjected to significant harm. In some cases (e.g., sea turtles), organisms are entrapped in intake canals.

6.2.7.2 Baseline survey

The Environmental Setting information for biological resources should include information on aquatic, terrestrial and wetland ecosystems in the vicinity of the project. The challenge for development of an EIA for energy projects is to qualitatively evaluate and record the local ecosystems and their biodiversity, often in the absence of clear protective designations. This involves looking at a range of criteria to determine whether the site is of local, regional, national or international importance.

In evaluating baseline conditions of aquatic, terrestrial and wetlands ecosystems (as appropriate for the project area) the following steps should be taken:

• Obtain readily available information on biodiversity through review of maps, reports and publications available from government agencies, universities, NGOs or online.

• Produce maps of all habitats and key species locations, protected areas, migration corridors, seasonal use areas (mating, nesting, etc.).

• Describe timing of important seasonal activities (nesting, breeding, migration, etc.) for species that could be affected by the energy project activities.

• Determine the following ecological characteristics of the project area:

- Size of each habitat;

- Existing condition of each habitat and its value;

- Species/habitat richness;

- Fragility of the ecosystem;

- Population size for important species or species of concern;

- Rarity of any species or habitat.

• Identify whether the site or surrounding area falls within a protected area – that is, whether it is a natural area designated by the government as having special protection.

• Identify whether the site or surrounding area is not currently protected but has been identified by governments or other stakeholders as having a high biodiversity conservation priority.

• Identify whether the site or surrounding area has particular species that may be under threat.

• Review and summarize relevant legal provisions relating to biodiversity, species protection and protected area management (including requirements of any management plans that exist for designated protected areas).

• Elicit the views of stakeholders on whether the site or surrounding area has rare, threatened, or culturally important species.

The evaluation of any ecosystem whether aquatic, terrestrial, or wetland is dependent upon professional judgment and requires the involvement of trained ecologists. In areas where there is little or no information available, considerable field work is required to collect the information listed above.

Flora

An inventory of flora within the project boundaries and project area of influence should be conducted during the collection of baseline information for the Environmental Setting. The best sources of data on local flora are local peoples, relevant ministries and academia.

The results of the inventory should be presented as vegetative maps of the area, which will usually also serve to provide a map of the relevant ecosystems. Narrative descriptions of vegetative types should also be included, identifying species endemism, keystone species (species that play a critical role in maintaining the structure of an ecological community and whose impact on the community is greater than would be expected based on its relative abundance or total biomass) and species rarity including identification of those that may be threatened or endangered.

Of particular importance is the delineation of wetlands as they are sensitive habitats and quite important with respect to cleaning water that passes through them as well as serving as buffers against flooding elsewhere in the hydrological basin. Already identified in surface water subsection, in this subsection the ecological characteristics should be presented.

Fauna

An inventory of aquatic and terrestrial fauna within the project boundaries and project area of influence should also be conducted during the collection of baseline information for the Environmental Setting.

As in the previous case, the best sources of data on local fauna are local peoples, relevant ministries (forestry, agriculture and environment), and academia.

The results of the inventory should present information on the status (i.e. endemic, migratory, exotic, keystone, threatened, endangered, etc.) and life history characteristics (mating and breeding seasons, migratory patterns, etc.) of the species identified as residing in the area. For terrestrial species, maps should be included identifying:

- Breeding areas;
- Nesting and calving areas;
- Migratory corridors (if applicable).

Ecosystems

Beyond looking at flora and fauna independently, an EIA needs to be integrated, i.e. to address the relationships between biophysical, social and economic aspects in assessing project impacts (IAIA 1999).

Addressing these relationships relies on an integrated description of ecosystems in the Environmental Setting as well as integrated impact assessment. It is often challenging to describe complex interactions between flora and fauna, physical and human threats, and key trends in the structure and functions of the ecosystems. Methodologies for describing ecosystem interactions are included in the impact assessment sub-chapter.

Endangered or Threatened Species and Habitats

Threatened and endangered flora and fauna are a subset of the complete inventory of flora and fauna in the project area and its area of impact. This involves:

- Review of local, national, regional and global literature on the range and domain of endangered or threatened species.

- Consultation with local and national government agencies, NGOs and academic institutions to determine what species may be in the project area.

- Cross-referencing this list with national lists of threatened and endangered species as well as international lists such as the Red List[19] of the International Union for Conservation of Nature and the species in the appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).[20]

- Conducting a thorough physical survey of the project area and inquiring of local residents and authorities to determine if those species are present.

[19] *http://www.iucnredlist.org/*
[20] *http://www.cites.org/*

These guidelines suggest that the endangered and threatened species and habitats be covered separately under flora and fauna, and then summarized in this subsection to highlight particularly sensitive areas of concern in evaluating impacts. This separate subsection is not intended to duplicate the information under Flora and Fauna, but rather to pull it together in an integrated manner.

Protected Areas

Protected areas should be highlighted in the EIA as areas which have already been identified as significant and needing special protection. One of the challenges in preparing the EIA is the fact that boundaries of protected areas may be imprecise on available maps. Within the area of influence of the project, steps should be taken to better define these boundaries, to ensure that the proposed project will not encroach on the protected area. The Environmental Setting should also report on the status of management plans for the protected areas, and where applicable, identify the allowed uses in each management zone. The project should not be inconsistent with the allowable uses in a designated protected area.

It is also important to identify areas in area of influence that are not currently designated as protected areas, but have been identified by governments or other stakeholders as having a high biodiversity conservation priority.

6.2.7.3 Methods for impact assessment

Biological impact assessment is based on studies, literature review and professional judgment. Results of soil, water, air, and noise impact modelling or other means of quantification should be overlaid on maps showing location of flora, fauna, ecosystems, threatened and endangered species habitats, and protected areas, to determine the possibility of adverse impacts.

Terrestrial resources

Predicted impacts on air and water quality, mechanical impacts on flora and fauna, and impacts of noise and light should then be graphically overlaid on the documented domains and ranges of plants and animals to assure that impacts are not likely to exceed those which might interfere with the long-term health of impacted populations.

Aquatic Resources

Assessment of aquatic resource impacts must primarily be focused toward establishing relationships between river flow and fish habitat quantity. Flow versus fish habitat models have generally been applied in situations of proposals for seasonal water storage and release associated with flood control, water diversions and other water uses.

Ecosystems Services

The goal of an environmental and social impact assessment is to identify, predict, evaluate, and mitigate “the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made” (IAIA 1999).

Some aspects of project dependence on ecosystems might be covered by the risk assessment but this assessment is often limited to ecosystem services that constitute operational inputs such as freshwater. As a consequence, certain aspects of project impacts and dependencies may be overlooked. Standard EA assesses environmental and social impacts separately or with limited interdisciplinary analysis. As a consequence it is necessary to develop an approach that facilitates integration of the environmental and social assessments focusing attention on both the socio-economic dimensions of a project’s environmental impacts and the implications of ecosystem change for project performance.

Since January 1st, 2012, the International Finance Corporation (IFC, 2012) has incorporated “ecosystems services” in its Performance Standards. The new IFC Performance Standards require projects to “maintain the benefits from ecosystem services” and “conduct a systematic review to identify (…) those services on which the project is directly dependent for its operation”. IFC (2012) defines ecosystem services as the benefits that people, including businesses, derive from ecosystems.

Ecosystem services are organized into four types:

- Provisioning services, which are the products people obtain from ecosystems - provisioning services may include food (crops, livestock, capture fisheries, aquaculture and wild foods), biological raw materials (timber, fibers, animal skins, ornamental resources), freshwater, biomass fuel, genetic resources and medicinal plants;

- Regulating services, which are the benefits people obtain from the regulation of ecosystem processes - regulating services may include air quality regulation, surface water purification and flow regulation, carbon storage and sequestration, climate regulation, protection from natural hazards, pollination, etc.;

- Cultural services, which are the non-material benefits people obtain from ecosystems - cultural services may include natural areas that are sacred sites and areas of importance for recreation and ecotourism, ethical and spiritual values, educational and inspirational values;

- Supporting services, which are the natural processes that maintain the other services - may include habitat, soil formation, nutrient cycling, primary production.

An ecosystem services approach recognizes the intrinsic and complex relationship between biophysical and socio-economic environments. It integrates these aspects by explicitly linking ecosystem services (the benefits people derive from ecosystems), their contribution to human well-being, and the ways in which people impact an ecosystems' capacity to provide those services. In the context of environmental impact assessments, the ecosystem services approach provides a more systematic and integrated assessment of project impacts and dependencies on ecosystem services and the consequence for the people who benefit from these services. It helps EIA practitioners to go beyond biodiversity and ecosystems to identify and understand the ways natural and human environment interrelates. This holistic understanding, from description of the Environmental Setting to the impact assessment, will lead the EIA practitioner through a new set of questions:

- What ecosystem services are important for local communities?

- Which services will the project potentially impact in a significant way?

- How does the impact on one ecosystem service affect the supply and use of other ecosystem services?

- What is the underlying level of biodiversity and the current capacity of the ecosystems to continue to provide ecosystem services?

- What are the consequences of these ecosystem service impacts on human well-being, for example what are the effects on livelihood, income, and security?

- What are the direct and indirect drivers of ecosystem change affecting the supply and use of ecosystem services? How will the project contribute to these direct and indirect drivers of change?

"The Ecosystem Services Review for Impact Assessment" recently developed by the World Resources Institute (Landberg et al., 2013) addresses this set of questions by providing a structured methodology to facilitate integration of the environmental and social assessments.

This methodology has two objectives. From an impact point of view, it aims to mitigate project impacts on the benefits provided by ecosystems. From a dependence point of view, it aims to provide measures to manage operations that depend on ecosystems to achieve planned performance. WRI method aims integrating ecosystem services into EA though six steps embedded in the scoping, baseline and impact analysis, and mitigation stages of an EIA:

- **Scoping stage:**

- **Step 1:** Identify relevant ecosystem services: Identify ecosystem services the project may impact and/or on which the project depends.

- **Baseline and impact analysis stage:**

- **Step 2:** Prioritize relevant ecosystem services: Prioritize ecosystem services by identifying which of the relevant ecosystem services, if altered, could affect the livelihood, health, safety, or culture of their beneficiaries or the operational performance of the project. Only priority ecosystem services are carried forward to subsequent steps. All projects that require an ESIA should, at a minimum, undertake Steps 1 and 2 to determine whether any ecosystem services should be prioritized and assessed in further stages of the ESIA.

- **Step 3:** Define the scope and information needs of the ecosystem service assessment. Define the boundaries of and identify indicators for the impact and dependence assessments to clarify priority ecosystem services data and analysis requirements for environmental and social practitioners.

- **Step 4:** Establish the base line for priority ecosystem services. Evaluate the condition of priority ecosystem services in the absence of the project.

- **Step 5:** Assess project impacts and dependencies on

Activity	Activity description	Environmental concern	Affected environment
Site preparation and construction activities	Land clearing, earthmoving, terrain shaping	Destruction of cultural heritage	Cultural resources
		Displacement and relocation of current settlements	Resettlement and relocation
		Disruption of people livelihoods (use of natural resources)	Socio-economic conditions; Gender
Operation	Cooling systems	Water-related vector diseases	Health
	Fuel combustion	Visibility	Landscape
	Manpower	Individual income increase by direct and indirect employment; Increase purchases and other economic activities from local business	Socio-economic conditions; Gender
		Hazardous jobs; Occupational diseases due to exposure to dust	Health
		Increased tax base; Electric power reliability	Socio-economic conditions
Decomissioning	Manpower	Same as before	Same as before

Table 6-21 Social-economic-cultural impacts.

priority ecosystem services. Predict the changes in priority ecosystem services over the life of the project.

- **Mitigation stage:**

- **Step 6:** Mitigate impacts and manage dependencies of project on priority ecosystem services. Identify measures to at least achieve no loss of the benefits people derive from ecosystems affected by the project and to ensure planned operational performance where the project depends on ecosystem services.

This approach requires input from both environmental and social practitioners of the ESIA team. The ecosystem service lead has the responsibility of guiding, coordinating, and integrating the analyses of these practitioners. Ideally, this leader is an ecosystem service specialist.

Alternatively, the role can be assumed by an ecologist familiar with the work of social practitioners or a social practitioner comfortable with the ecological component of impact assessments.

6.2.8 Social-economical-cultural environment

6.2.8.1 Potential impacts

Social-economic-cultural impacts from power generation and or transmission projects are highly variable and dependent on the project type, project size, project footprint, energy source(s), existing land use patterns, proximity of population, local livelihoods, and presence of cultural and religious assets. Further, different types of impacts will occur during project preparation, construction, operation and decommissioning.

Socio-economic conditions

The social and economic impacts of coal-fired power plant and associated transmission projects will be both positive and negative. Socio-economic impacts will vary by location and size of the project, length of the project from construction to closure, manpower requirements, the opportunities the company has for the local community employment and involvement, and the existing character and structure of the nearby communities.

Positive impacts can include:

• Increased individual income:

- Direct employment on the project;
- Indirect employment generated by project activities;
- Increased purchases from local businesses;
- Other economic activities stimulated in the community as a result of the project.

• Employment opportunities for local residents (short- and long-term);

• Increased tax base;

• Less expensive and more reliable electric power.

Negative impacts can include:

• Displacement and relocation of current settlements, residents or community resources;

• Displacement or disruption of people's livelihood (e.g., fishing, hunting, grazing, farming, forestry and tourism);

• Public finance requirements – more infrastructure and services needed to meet the demands of increased population (e.g., public education, policing, fire protection, water, sanitation, roads);

• Increased traffic and truck trips (safety, noise, exhaust);

• Reduction in quality of life for residents from visual and noise impacts;

• Impacts on public health:

- Creation of new electromagnetic fields near residences;

- Water-related vector diseases (malaria, dengue, etc.).

• Impacts on worker health and safety:

- Identification of hazardous jobs and number of workers exposed with duration of exposure;

- Occupational diseases due to exposure to dust and other project-related activities such as handling of explosives, solvents, petroleum products, etc.;

- Identification of physical risks and safety aspects.

Some impacts have the potential to be positive and/or negative such as:

• Change in population:

- Change in character of community;

- Change in religious, ethnic or cultural makeup of community;

- Change in crime rates (drugs, alcohol, prostitution, etc.).

One of the primary socio-economic concerns is displacement of people through: involuntary or forced taking of land, relocation or loss of shelter, loss of assets (farmlands, forests, fisheries, etc.), and/or loss of income sources or means of livelihood. Involuntary resettlement under development projects, if unmitigated, often gives rise to severe economic, social and environmental risks arising from a chain of actions following displacement. Production systems are dismantled and people face impoverishment. People are relocated to environments where their productive skills may be less applicable and the competition for resources greater. Community institutions and social networks are weakened. Kin groups are dispersed. Cultural identity, traditional authority and the potential for mutual help are diminished or lost.

The impacts on public health will vary with the type of project. Coal-fired power plants that require the use of cooling ponds can create habitats for mosquitoes. If dengue fever or malaria is prevalent in the area, these impoundments could increase the population of mosquitoes that carry these diseases. Air pollutant emissions can impact health in downwind communities, depending upon the concentrations and the distance to the communities.

Any project that runs transmission lines near residences can create electromagnetic fields (EMF). Although there is public concern over the potential health effects associated with exposure to EMF (not only high voltage power lines and substations, but also from everyday household uses of electricity), empirical data is insufficient to demonstrate adverse health effects from exposure to typical EMF levels from power transmissions lines and equipment. However, while the evidence of adverse health risks is weak, it is prudent to limit public exposure to EMF to the extent practicable.

Infrastructure

The impacts on infrastructure of energy generation and transmission projects can also be neutral, positive or negative, varying with the location and size of the project, manpower requirements, economic benefits to the community, impact on availability of public funds and the existing infrastructure. The impacted infrastructure can include:

• Transportation Infrastructure

- Existing roads

- Associated structures (bridges, tunnels, traffic controls, etc.)

- Airports

- Railroads

• Public Health Infrastructure

- Drinking water supplies and treatment

- Wastewater treatment and management

-Solid and hazardous waste management and treatment

• Communications Infrastructure

- Telephone services (fixed lines and mobile)

• Associated transmission facilities

- Radio stations

- Television stations

• Energy Infrastructure

- Electrical power

- Fuel stations and storage facilities

For all of these types of infrastructure, the question for the EIA is to assess if this infrastructure has the capacity to meet the demands the project will create, or if it has to be altered, improved or expanded. Additionally, the EIA should determine if the project will alter the condition of the infrastructure. If the existing infrastructure will not meet the demand of the project, or if the project will affect the condition of the infrastructure, then the project has an impact on that infrastructure.

For transportation infrastructure, this subsection should addresses impacts of transportation and traffic patterns on existing roads. It should identify any anticipated changes in traffic patterns, densities, and traffic safety. If such changes are identified, the EIA should also estimate their impact on traffic accidents, congestion and noise.

Cultural, archeological, ceremonial and historic resources

Impacts on cultural, archeological, ceremonial and historic resources include any direct or indirect alteration of sites, structures, landmarks or traditional cultural lifestyles and resources associated with those lifestyles. Cultural, archeological, ceremonial and historic resources include: archeological sites, historic buildings, burial grounds, sacred or ceremonial sites, areas used for the collection of materials used in ceremonies or traditional lifestyles, and sites that are important because of their roles in traditional stories. Examples of adverse effects to cultural and historical resources from energy projects include:

• Destruction during construction;

• Damage and alteration;

• Removal from historic location;

• Introduction of visual or audible elements that diminish integrity;

• Neglect that causes deterioration;

• Loss of medicinal plants;

• Loss of access to traditional use areas;

• Impacts to previously inaccessible areas from development/improvement of roads.

Land use

Energy projects will impact local land use because land use on the project site itself will be modified for the life of the project. This impact, however, varies greatly with the size of the facility site which in the case of coal-fired power plants will have a maximum of 1-3 km^2 including the coal and ash storage facilities. Other long-term impacts can include those associated with roads, rails and other ancillary facilities that may stay in place and be used for many years, possibly even after the project's life.

Projects can impact land use on properties adjacent to the facilities as well as properties through which roads and right-of-ways may pass. Land use in these areas can be impacted by visibility, noise, odor, air pollution, and water contamination. The development of new roads also may open up previously inaccessible areas to development.

Land use in communities near the facility can experience changes due to increased population, demanding more housing, schools, churches, and commercial and public services. For energy generation and transmission projects these impacts may be short-lived, occurring only during construction when the number of workers is highest.

Coal-fired power plant projects can negatively impact existing tourism land use because they can detract from the visual experience and thereby impact the tourist experience.

6.2.8.2 Baseline survey

Socio-economic conditions

This subsection should include descriptive and quantitative information for the area surrounding the project site on:

• Population, including age, gender, ethnic composition, religions, languages spoken and educational level;

• Economic activities, including industrial and commercial activities, employers, employment, incomes and distribution of income, tax base and skills, services and goods availability in the communities;

• Crime rates;

• Literacy rates;

• Community organizations;

• Public Health and Safety:
- Diseases in the project area (including the sources of data and the methodology used to collect and analyze the data);
- Existing practice for assessment of occupational health;
- Existing electromagnetic fields (primarily associated with high voltage electric power lines);
- Local perceptions of the proposed project.

Transportation infrastructure

The information on the transportation infrastructure should addresses baseline conditions of transportation and traffic patterns on existing roads. This should include:

• Maps showing the location of all existing roads, railroads, air strips, airports and pipelines.

• Condition:

- Surface materials
- Erosion and sediment problems and controls
- Maintenance programs (what, when and whom)

• Description of anticipated third-party improvements (government or entity other than the proponent).

• Traffic patterns and densities on roads that may experience significant increased use during construction or operation of the project.

• Safety levels and current circulation issues, and capacity.

Public health infrastructures

The information presented on the public health infrastructure includes information on the existing drinking water, wastewater and solid waste management systems. The Environmental Setting should provide maps and quantitative information on the existing infrastructure for these systems, their capacities and any plans for expansion or change in technology or management of the systems. For drinking water system(s), this should include:

• Sources of drinking water;
• Quality (before and after treatment);
• Access;
• Trends in availability of potable water.

Information on the wastewater system(s) should be presented on maps as well as in narrative and tabular forms and include:

• Quantity (inflow and discharges);
• Treatment;
• Sludge disposal, if applicable;
• Discharge points;
• Trends.

Information on the solid waste management system(s) should include:

- Quantity (daily quantities generated, collected and disposed of);
- Collection systems;
- Recycling programs;
- Disposal facilities (locations, sizes and management).

Communications and energy infrastructures

Information on communications should include the types of communications systems in the project area and their associated infrastructure such as transmission lines and microwave towers. Information on energy should include the types and sources of energy in the project area including:

- Generating facilities;
- Transmission and distribution lines;
- Storage facilities (including fuel storage facilities).

Cultural, archeological, ceremonial and historic resources

All cultural, archeological, ceremonial and historic resources within the project boundaries and within the area of direct impact should be inventoried and mapped. Excellent sources of information on location of such assets usually include authorities responsible for such assets, local religious institutions and scholars, and the UNESCO World Heritage site.[21] During the preparation of the EIA, views should be solicited from stakeholders on whether any sites or surrounding areas have important traditional or cultural value. This subsection should also include information on any indigenous people or other traditional cultures in the project area.

Land use

The land use subsection of the Environmental Setting should include information on actual and potential land use in and around the proposed project. It should indicate trends in land use and patterns of land use. The information should be presented as a land use map showing location, size and proximity of:

- Population centers
- Agricultural lands
- Forested lands
- Flood plains and water bodies
- Coastal zones
- Protected areas
- Wetlands
- Other environmentally sensitive areas
- Recreational or tourist areas
- Culturally sensitive areas
- Other land uses as appropriate

The information on population centers should include information on the numbers, sizes and locations of:

- Schools
- Cemeteries
- Mosques
- Other public buildings
- Housing (including housing density)

The information on the tourism and recreation areas should include the numbers, sizes and locations of recreation facilities and eco-cultural-tourist locations. This subsection should also include information on the current and projected future employment opportunities associated with tourism based on natural or cultural resources.

6.2.8.3 Methods for impact assessment

Socio-economic conditions, infrastructure and land use

When an activity, such as development or expansion of a power project, or extension or upgrading of power transmission, is expected to accelerate social change at the local level, it is necessary to have detailed (sometimes household level) socio-economic and cultural data from the directly affected communities for the baseline, and to develop trend data to assess whether anticipated impacts will continue or alter those trends in a significant way.

Social impacts cannot usually be assessed through secondary data on infrastructure and social services. The results from detailed family level surveys, focus group discussions and key informant interviews, participant observation, stakeholder consultations, secondary data, and other direct data collection methods should be analyzed carefully (Joyce, 2001).

As data is collected, trends based on gender, age groups, economic status, proximity to the projects should be analyzed. This analysis can be accomplished using statistical models or, as what has been found more recently to be effective, the use of Geographical Information Systems (GIS). According to Joyce et. al. (2001), the problem with using a strictly qualitative approach has issues:

[21] *http://whc.unesco.org/*

- There is a greater difficulty of predicting social behavior and response as compared to impacts on the biophysical or biological elements, such as water or animals.

- The fact that social impacts are as much to do with the perceptions people or groups have about an activity as they are to do with the actual facts and substantive reality of a situation, and

- The fabric of social interactions and social well-being (today being recognized and labeled as "social capital", which are in the end where many social impacts take place, can only be measured or evaluated through qualitative and participatory processes.

- As the causation gets more distant, it is less clear how directly responsible a given project or activity is for that impact and required environmental measures, and less clear how effective environmental measures taken by one player would be.

Again, according to Joyce, the measure of significance is the most difficult/critical part of socio-economic impact assessment. Impacts should be described in terms of the level of intensity of an impact, the directionality (positive or negative), the duration, and its geographic extension. Significance is necessarily defined using professional judgment. Towards this end, categories of impacts are defined and a determination can be made as to what constitutes a short, medium and long-term impact, and the reasons for the designation. This is where participation by locals becomes important in determining what is significant to them. Based on the significance of the impact(s) conclusions can be drawn and environmental measures can be designed.

Other socio-economic impacts which should be assessed include:

- **Land use** - To understand the impacts of power and transmission projects on land use, it is important to be able to visualize and calculate potential changes which may occur. This can be done by developing maps which show pre-construction, operational and post-closure land use. GIS captures, stores, analyzes, manages, and presents data that is linked to location. GIS applications are tools that allow users to create interactive queries (user created searches), analyze spatial information, edit data, maps, and present the results of all these operations. A GIS includes mapping software and its application with remote sensing, land surveying, aerial photography, mathematics, photogrammetry, geography, and other tools.

- **Population and housing** - The key to understanding the potential impact on the local population and housing is having a good understanding of the work force required for the operation. Simple calculations can then be made to determine changes in demographics over the life of the project.

- **Infrastructure capacity** - Simple calculations comparing demands on roads, hospitals, wastewater treatment, water supply and waste management against capacity. However, these calculations should take into account direct demands from the project for every phase of the project including construction, operation and closure, demands from anticipated induced growth as an indirect impact of the proposed project and demands into the future in the absence of the project.

- **Employment** - Having a good understanding of the work force required for each phase (construction, operation and closure) of a coal-fired power plant or transmission line project is required to determine what additional labor may be required for schools, hospitals, support industries, etc.

- **Transportation** - Transportation studies are required to determine impacts on traffic and roads due to commuting and the hauling of construction materials to the project site, delivery of fuel and removal of wastes if by rail, water or road, and increases in traffic associated with the work force servicing the project and providing support to that work force.

Cultural, archeological, ceremonial and historic resources

Impacts are usually defined as direct or indirect alterations to characteristics of a cultural archeological, ceremonial or historic site or traditional use of a resource. Effects are adverse when the integrity is affected or the quality diminished. Impact assessment begins with overlaying all project activities on the map of cultural archeological, ceremonial or historic site sites developed for the Environmental Setting, to identify all sites that may be directly impacted. In addition, noise, vibration and visibility (of and from the sites) impacts need to be estimated, using the results of the noise, vibration and visibility assessments discussed above. Impacts to historical and archeological sites and cultural resources are evaluated with respect to their magnitude and significance. For cultural resources, it is important to consider impacts that may affect the transmission and retention of local values. These potential impacts to the transmission and retention of local values may be caused by impacts to plants, animals, fish, geology and water resources that may be used for cultural purposes by certain populations for traditional purposes, as well as visual impacts.

6.3 Environmental management and monitoring

In the following subchapters environmental management and monitoring measures of coal-fired power plants are described. Monitoring information is described for the following components:

- Geology and soils;
- Water resources including surface water and groundwater;
- Air quality (including ambient air and stack emissions testing);
- Noise and vibrations.

For each component, when possible, the monitoring program should provide the following information:

- Actual impacts;
- Early warning information;
- Actual impacts compared to predicted impacts.

Monitoring plans should address all phases of the project: siting, construction, operation, closure and site reclamation. Monitoring should begin before design and construction to determine the baseline conditions. The length of monitoring during the different phases will depend on the environmental resource that is being affected, as well as the expected duration of the impact. Specific monitoring programs will be required depending on the type of plant and type of resources affected.

Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards, so that any corrective actions can be taken if necessary. Records of monitoring results should be maintained in an acceptable format and reported to the responsible authorities and relevant parties, as required.

6.3.1 Geology and soils

There are no specific monitoring measures for geology and soil except in the case of a potential soil contamination where soil sampling should be conducted based on types of materials stored and handled. Land is considered contaminated when it contains hazardous materials or oil concentrations above background or naturally occurring levels.

Contaminated lands may involve surficial soils or subsurface soils that, through leaching and transport, may affect groundwater, surface water, and adjacent sites. Where subsurface contaminant sources include volatile substances, soil vapor may also become a transport and exposure medium, and create potential for contaminant infiltration of indoor air spaces of buildings.

6.3.2 Water resources

6.3.2.1 Surface water

Prior to implementing any baseline monitoring program, a "Sampling and Analysis Plan" should be developed. This plan would define sample locations, sampling techniques, chemical parameters, and analytical methods. Sample locations should be located upstream and immediately downstream of potential pollutant sources (including dam and diversion outlets). The selection of chemical parameters to be monitored is dependent on the nature of the pollutants to be discharged to surface water.

Monitored parameters may include: field parameters (pH, specific conductance, temperature, etc.) and laboratory analyzed parameters (total dissolved solids, total suspended solids, selected trace metals, major cations/anions), and perhaps other parameters depending on the nature of the operation.

6.3.2.2 Groundwater

For projects that can potentially have impacts on groundwater quality, if data for existing wells and springs is not available, a "Sampling and Analysis Plan" should be prepared and a sampling program implemented. The sampling should include water levels and flow rates as well as other parameters such as pH, temperature, and specific conductance. The selection of chemical parameters to be monitored is dependent on the nature of the activity and its potential to contaminate the aquifer.

6.3.2.3 Water monitoring and management

The essential elements of a water management program involve:

- Identification, regular measurement, and recording of principal flows within a facility;
- Definition and regular review of performance targets, which are adjusted to account for changes in major factors affecting water use (e.g. industrial production rate);
- Regular comparison of water flows with performance targets to identify where action should be taken to reduce water use.

Water measurement (metering) should emphasize areas of greatest water use. Based on review of metering data, 'unaccounted' use – indicating major leaks at industrial facilities – could be identified.

A wastewater and water quality monitoring program with adequate resources and management oversight should be developed and implemented to meet the objective(s) of the monitoring program.

The wastewater and water quality monitoring program should consider the following elements:

- Monitoring parameters: The parameters selected for monitoring should be indicative of the pollutants of concern from the process, and should include parameters that are regulated under compliance requirements.
- Monitoring type and frequency: Wastewater monitoring should take into consideration the discharge characteristics from the process over time. Monitoring of discharges from processes with batch manufacturing or seasonal process variations should take into consideration of time-dependent variations in discharges and, therefore, is more complex than monitoring of continuous discharges. Effluents from highly variable processes may need to be sampled more frequently or through composite methods. Grab samples or, if automated equipment permits, composite samples may offer more insight on average concentrations of pollutants over a 24-hour period. Composite samplers may not be appropriate where analytes of concern are short-lived (e.g., quickly degraded or volatile).
- Monitoring locations: The monitoring location should be selected with the objective of providing representative monitoring data. Effluent sampling stations may be located at the final discharge, as well as at strategic upstream points prior to merging of different discharges. Process discharges should not be diluted prior or after treatment with the objective of meeting the discharge or ambient water quality standards.
- Data quality: Monitoring programs should apply internationally approved methods for sample collection, preservation and analysis. Sampling should be conducted by or under the supervision of trained individuals. Analysis should be conducted by entities permitted or certified for this purpose. Sampling and Analysis Quality Assurance/Quality Control (QA/QC) plans should be prepared and, implemented. QA/QC documentation should be included monitoring reports.

6.3.3 Air quality

6.3.3.1 Ambient air

Automatic air quality monitoring systems measuring ambient levels outside the plant boundary should be installed in a minimum of 2 locations to cover:

- Predicted maximum ground level concentration point
- Sensitive receptor and
- Background point

The number of air quality monitoring stations should be greater if the area in which the power plant is located is subjected to meteorological conditions which could lead to high levels of air pollutants affecting nearby populations or sensitive ecosystems.

Meteorological conditions need to be characterized for air modeling purposes. If appropriate data is unavailable, then monitoring of meteorological parameters will be necessary.

Ambient air quality monitoring guidelines recommended for power plants are provided in Table 6-22.

Effectiveness of the ambient air quality monitoring program should be reviewed regularly. It could be simplified or reduced if an alternative program is developed (e.g., local government's monitoring network). Continuation of the program is recommended during the life of the project if there are sensitive receptors or if monitored levels are not far below the relevant ambient air quality standards.

Incremental impacts predicted	Ambient air quality monitoring parameters
If incremental impacts predicted by EA >/= 25 % of relevant short-term ambient air quality standards or if the plant >/= 1,200 MWth	Monitor parameters (e.g. PM10/PM2.5/SO_2/NO_x/O_3/CO to be consistent with the relevant ambient air quality standards) by continuous ambient air quality monitoring system (typically a minimum 2 systems to cover predicted maximum ground level concentration point / sensitive receptor / background point).
If incremental impacts predicted by EA < 25% of relevant short term ambient air quality standards and if the facility < 1,200 MWth but ≥ 100 MWth	Monitor parameters either by passive samplers (monthly average) or by seasonal manual sampling (e.g., 1 week/season) for parameters consistent with the relevant air quality standards.

Table 6-22 Ambient air quality monitoring parameters (based on IFC, 2008

6.3.3.2 Emission monitoring and testing

An annual stack emission testing for PM, SO_2, NO_x and heavy metals must be performed at each stack. The calibration of the continuous emissions monitoring systems should also be performed every 12 months. Emissions measurements should be compared with national emission limit values shown in Table A-3 and A-4, assuring that project emissions are below legislated emission limits. It is also recommendable to compare project emission with the emission guidelines for solid fuels specified by the IFC (2008) and listed in Table 6-9 (subchapter 6.2.3.3). Table 6-23 presents an example of an air pollutant emission monitoring plan.

Note that continuous or indicative means, “Continuously monitor emissions or continuously monitor indicative parameters”. The aim of stack emission testing is to have direct measurement of emission levels to countercheck the emission monitoring system.

6.3.4 Noise

If EA predicts noise levels at residential receptors or other sensitive receptors are close to the relevant ambient noise standards/guidelines, or if there are such receptors close to the plant boundary (e.g., within 100m) then, conduct ambient noise monitoring every year to three years depending on the project circumstances.

Noise monitoring programs should be designed and conducted by trained specialists. Typical monitoring periods should be sufficient for statistical analysis and may last 48 hours with the use of noise monitors that should be capable of logging data continuously over this time period, or hourly, or more frequently, as appropriate (or else cover differing time periods within several days, including weekday and weekend workdays). The type of acoustic indices recorded depends on the type of noise being monitored, as established by a noise expert. Monitors should be located approximately 1.5 m above the ground and no closer than 3 m to any reflecting surface (e.g., wall). In general, the noise level limit is represented by the background or ambient noise levels that would be present in the absence of the facility or noise source(s) under investigation.

	Parameter	CFPP (>50 - 600 MWth)	CFPP (≥ 600 MWth)
Emission monitoring	Particulate Matter (PM)	Continuous or indicative	Continuous or indicative
	Sulphur Dioxide (SO_2)	Continuous if FGD or monitor by S content	Continuous
	Nitrogen Oxides (NO_x)	Continuous or indicative	Continuous
Stack emission testing	PM, SO_2, NOx, Heavy metals	Annual	Annual

Table 6-23 Typical air emission monitoring parameters and frequency (IFC, 2008)

7 - How can impacts be mitigated?

7.1 Geology and soils

Erosion and soil compaction

- Schedule land disturbing activities to avoid periods of heavy rainfall and reduce or halt construction activities during heavy rainfall episodes.

- Remove, store and reuse topsoil to reclaim disturbed areas.

- Contour exposed slopes.

- Reestablish the original grade and drainage pattern to the extent practicable.

- Restore or apply protective covering on disturbed soils as quickly as possible.

- Mulch or cover exposed areas.

- Promptly revegetate exposed areas with fast growing indigenous grasses.

Soil contamination from spills and fuel leaks

- Prepare a comprehensive list of all hazardous materials to be used, stored, transported, or disposed of during all phases of activity.

- Design containment for storage, handling and dispensing of hazardous materials, including fuels, oils, greases, solvents and residues.

- Prepare a Spill Prevention and Response Plan for storage, use and transfer of fuel and hazardous materials.

- Train workers on the Spill Prevention and Response Plan.

- Provide onsite portable spill management, control and cleanup equipment and materials.

- Containerize and periodically remove wastes for disposal at appropriate off-site permitted disposal facilities, if available.

- Document accidental releases as to cause, corrective actions taken, and resulting environmental or health and safety impacts.

Waste production and disposal

The high-volume wastes generated by coal-fired power plants are typically managed in landfills or surface impoundments or, increasingly, may be applied to a variety of beneficial uses. Low-volume wastes are also managed in landfills or surface impoundments, but are more frequently managed in surface impoundments. Many coal-fired plants co-manage large-volume and low-volume wastes.

Recommended measures to prevent, minimize, and control the volume of solid wastes from thermal power plants include:

- Dry handling of the coal combustion wastes (CCWs), in particular fly ash. Dry handling methods do not involve surface impoundments and, therefore, do not present the ecological risks identified for impoundments (e.g., metal uptake by wildlife);

- Recycling of CCWs in uses such as cement and other concrete products, construction fills (including structural fill, flowable fill, and road base), agricultural uses such as calcium fertilizers (provided trace metals or other potentially hazardous materials levels are within accepted thresholds), waste management applications, mining applications, construction materials (e.g., synthetic gypsum for plasterboard), and incorporation into other products provided the residues (such as trace metals and radioactivity) are not considered hazardous. Ensuring consistent quality of fuels and additives helps to ensure the CCWs can be recycled. If beneficial reuse is not feasible, disposal of CCW in permitted landfills with environmental controls such as run-on/run-off controls, liners, leachate collection systems, ground-water monitoring, closure controls, daily (or other operational) cover, and fugitive dust controls is recommended;

- Management of ash disposal and reclamation so as to minimize environmental impacts – especially the migration of toxic metals, if present, to nearby surface and groundwater bodies, in addition to the transport of suspended solids in surface run-off due to seasonal precipitation and flooding. In particular, construction, operation, and maintenance of surface impoundments should be conducted in accordance with internationally recognized standards;

- Reuse of sludge from treatment of wastewater from FGD plants. This sludge may be re-used in the FGD plant due to the calcium components. It can also be used as an additive in coal-fired plant combustion to improve the ash melting behavior.

7.2 Water resources

Water conservation

Water conservation programs should be implemented commensurate with the magnitude and cost of water use. These programs should promote the continuous reduction in water consumption and achieve savings in the water pumping, treatment and disposal costs. Water conservation measures may include water monitoring/management techniques; process and cooling/heating water recycling, reuse, and other techniques; and sanitary water conservation techniques. General recommendations for coal-fired power plants include:

- Storm/Rainwater harvesting and use;

- Zero discharge design/Use of treated waste water to be included in project design processes;

- Recycling of wastewater in coal-fired plants for use as Flue Gas Desulphurization (FGD) makeup. This practice conserves water and reduces the number of wastewater streams requiring treatment and discharge. Suitable wastewater streams for reuse include gypsum wash water, which is a different wastewater stream than the FGD wastewater. In plants that produce marketable gypsum, the gypsum is rinsed to remove chloride and other undesirable trace elements;

- Alternatively, if feasible, use of SOx removal systems that generate less wastewater; however, the environmental and cost characteristics of both inputs and wastes should be assessed on a case-by-case basis;

- Use of localized recirculation systems in plant/facility/shops (as opposed to centralized recirculation system), with provision only for makeup water;

- Use of dry process technologies such as dry quenching, collection of fly ash in dry form and bottom ash in drag chain conveyor systems;

- Consider use of soot blowers or other dry methods to remove fireside wastes from heat transfer surfaces so as to minimize the frequency and amount of water used in fireside washes;

- Process water system pressure management;

- Project design to have measures for adequate water collection, spill control and leakage control system.

Water conservation opportunities in cooling systems include:

- Use of closed circuit cooling systems with cooling towers rather than once-through cooling systems;

- Limiting condenser or cooling tower blowdown to the minimum required to prevent unacceptable accumulation of dissolved solids;

- Use of air cooling rather than evaporative cooling, although this may increase electricity use in the cooling system;

- Use of treated waste water for cooling towers;

- Reusing/recycling cooling tower blowdown.

The following techniques have all been used successfully for water saving in industrial processes:

- Washing Machines: Many washing machines use large quantities of hot water. Use can increase as nozzles become enlarged due to repeated cleaning and /or wear. Monitor machine water use, compare with specification, and replace nozzles when water and heat use reaches levels warranting such work.

- Water reuse: Common water reuse applications include countercurrent rinsing, for example in multi-stage washing and rinsing processes, or reusing waste water from one process for another with less exacting water requirements. For example, using bleaching rinse water for textile washing, or bottle-washer rinse water for bottle crate washing, or even washing the floor. More sophisticated reuse projects requiring treatment of water before reuse are also sometimes practical.

- Water jets/sprays: If processes use water jets or sprays (e.g. to keep conveyors clean or to cool product) review the accuracy of the spray pattern to prevent unnecessary water loss.

- Flow control optimization: Industrial processes sometimes require the use of tanks, which are refilled to control losses. It is often possible to reduce the rate of water supply to such tanks, and sometimes to reduce tank levels to reduce spillage. If the process uses water cooling sprays, it may be possible to reduce flow while maintaining cooling performance. Testing can determine the optimum balance.

- If hoses are used in cleaning, use flow controls to restrict wasteful water flow;

- Consider the use of high pressure, low volume cleaning systems rather than using large volumes of water sprayed from hosepipes;

- Using flow timers and limit switches to control water use;

- Using 'clean-up' practices rather than hosing down.

Consumption of building and sanitary water is typically less than that used in industrial processes. However, savings can readily be identified, as outlined below:

- Compare daily water use per employee to existing benchmarks taking into consideration the primary use at the facility, whether sanitary or including other activities such as showering or catering;

- Regularly maintain plumbing, and identify and repair leaks;

- Shut off water to unused areas;

- Install self-closing taps, automatic shut-off valves, spray nozzles, pressure reducing valves, and water conserving fixtures (e.g. low flow shower heads, faucets, toilets, urinals; and spring loaded or sensored faucets);

- Operate dishwashers and laundries on full loads, and only when needed;

- Install water-saving equipment in lavatories, such as lowflow toilets.

Heating systems based on the circulation of low or medium pressure hot water (which do not consume water) should be closed. If they do consume water, regular maintenance should be conducted to check for leaks. However, large quantities of water may be used by steam systems, and this can be reduced by the following measures:

- Repair of steam and condensate leaks, and repair of all failed steam traps;

- Return of condensate to the boilerhouse, and use of heat exchangers (with condensate return) rather than direct steam injection where process permits;

- Flash steam recovery;

- Minimizing boiler blowdown consistent with maintaining acceptably low dissolved solids in boiler water. Use of reverse osmosis boiler feed water treatment substantially reduces the need for boiler blowdown;

- Minimizing deaerator heating.

Thermal discharge

Recommendations to prevent, minimize, and control thermal discharges include:

- Use of multi-port diffusers;
- Adjustment of the discharge temperature, flow, outfall location, and outfall design to minimize impacts to acceptable level (i.e., extend length of discharge channel before reaching the surface water body for pre-cooling or change location of discharge point to minimize the elevated temperature areas);

- Use of a closed-cycle, recirculating cooling water system (e.g., natural or forced draft cooling tower), or closed circuit dry cooling system (e.g., air cooled condensers) if necessary to prevent unacceptable adverse impacts. Cooling ponds or cooling towers are the primary technologies for a recirculating cooling water system.

Water quality

In the context of their overall environmental management system, facilities should:

- Understand the quality, quantity, frequency and sources of liquid effluents in its installations. This includes knowledge about the locations, routes and integrity of internal drainage systems and discharge points;

- Plan and implement the segregation of liquid effluents principally along industrial, utility, sanitary, and stormwater categories, in order to limit the volume of water requiring specialized treatment. Characteristics of individual streams may also be used for source segregation.

- Identify opportunities to prevent or reduce wastewater pollution through such measures as recycle/reuse within their facility, input substitution, or process modification (e.g., change of technology or operating conditions/modes).

- Use of infiltration and run-off control measures such as compacted soils, protective liners, and sedimentation controls for run-off from coal piles;

- Spraying of coal piles with anionic detergents to inhibit bacterial growth and minimize acidity of leachate. If coal pile run-off will be used as makeup to the FGD system, anionic detergents may increase or create foaming within the scrubber system. Therefore, use of anionic surfactants on coal piles should be evaluated on a case-by-case basis.

- Treatment of low-volume wastewater streams that are typically collected in the boiler and turbine room sumps in conventional oil-water separators before discharge;

- Treatment of acidic low-volume wastewater streams, such as those associated with the regeneration of makeup demineralizer and deep-bed condensate polishing systems, by chemical neutralization in-situ before discharge;

- Pretreatment of cooling tower makeup water, installation of automated bleed/feed controllers, and use of inert construction materials to reduce chemical treatment requirements for cooling towers;

- Elimination of metals such as chromium and zinc from chemical additives used to control scaling and corrosion in cooling towers;

- Use the minimum required quantities of chlorinated biocides in place of brominated biocides or alternatively apply intermittent shock dosing of chlorine as opposed to continuous low level feed.

Additionally, the generation and discharge of wastewater of any type should be managed through a combination of:

- Water use efficiency to reduce the amount of wastewater generation;

- Process modification, including waste minimization, and reducing the use of hazardous materials to reduce the load of pollutants requiring treatment;

- If needed, application of wastewater treatment techniques to further reduce the load of contaminants prior to discharge, taking into consideration potential impacts of cross-media transfer of contaminants during treatment (e.g., from water to air or land).

When wastewater treatment is required prior to discharge, the level of treatment should be based on:

- Whether wastewater is being discharged to a sanitary sewer system, or to surface waters;

- National and local standards as reflected in permit requirements and sewer system capacity to convey and treat wastewater if discharge is to sanitary sewer;

- Assimilative capacity of the receiving water for the load of contaminant being discharged wastewater if discharge is to surface water;

- Intended use of the receiving water body (e.g., as a source of drinking water, recreation, irrigation, navigation, or other);

- Presence of sensitive receptors (e.g., endangered species) or habitats;

- Good International Industry Practice (GIIP) for the relevant industry sector.

Liquid effluents quality objectives depend on the characteristics of the environmental media where they are discharged:

- Assess compliance of their wastewater discharges with the applicable discharge standard: Comply with national standards for discharge into inland waters or into sea as specified in S.R.O. 549 (I)/2000;

- Discharge to sanitary sewer systems: Discharges of industrial wastewater, sanitary wastewater, wastewater from utility operations or stormwater into public or private wastewater treatment systems should:

  - Comply with national standards for discharge into sewage treatment as specified in S.R.O. 549 (I)/2000;

  - Meet the pretreatment and monitoring requirements of the sewer treatment system into which it discharges.

- Not interfere, directly or indirectly, with the operation and maintenance of the collection and treatment systems, or pose a risk to worker health and safety, or adversely impact characteristics of residuals from wastewater treatment operations.

- Be discharged into municipal or centralized wastewater treatment systems that have adequate capacity to meet local regulatory requirements for treatment of wastewater generated from the project. Pretreatment of wastewater to meet regulatory requirements before discharge from the project site is required if the municipal or centralized wastewater treatment system receiving wastewater from the project does not have adequate capacity to maintain regulatory compliance.

• Land application of treated effluent: The quality of treated process wastewater, wastewater from utility operations or stormwater discharged on land, including wetlands, should be established based on local regulatory requirements. Where land is used as part of the treatment system and the ultimate receptor is surface water, water quality guidelines for surface water discharges specific to the industry sector process should apply. Additional guidance on water quality considerations for land application is available in WHO (2006).

Potential impact on soil, groundwater, and surface water, in the context of protection, conservation and long-term sustainability of water and land resources should be assessed when land is used as part of any wastewater treatment system.

• Septic systems: Septic systems are commonly used for treatment and disposal of domestic sanitary sewage in areas with no sewerage collection networks, Septic systems should only be used for treatment of sanitary sewage, and unsuitable for industrial wastewater treatment. When septic systems are the selected form of wastewater disposal and treatment, they should be:

- Properly designed and installed in accordance with local regulations and guidance to prevent any hazard to public health or contamination of land, surface or groundwater.

- Well-maintained to allow effective operation.

- Installed in areas with sufficient soil percolation for the design wastewater loading rate.

- Installed in areas of stable soils that are nearly level, well drained, and permeable, with enough separation between the drain field and the groundwater table or other receiving waters.

7.3 Air quality

Coal-fired power plant projects should prevent or minimize impacts on ambient air quality by ensuring that:

• Emissions do not result in pollutant concentrations that reach or exceed national legislated standards (S.R.O. 1062(I)/2010) (see Table A-4).

• Emissions do not contribute a significant portion to the attainment of relevant ambient air quality guidelines or standards. As a general rule, it is suggested a maximum 25% increase of the applicable air quality standards to allow additional, future sustainable development in the same airshed (IFC, 2007).

Facilities or projects located within poor quality airsheds, and within or next to areas established as ecologically sensitive (e.g., national parks), should ensure that any increase in pollution levels is as small as feasible, and amounts to a fraction of the applicable short-term and annual average air quality guidelines or standards as established in the project-specific environmental assessment.

Suitable mitigation measures may also include the relocation of significant sources of emissions outside the airshed in question, use of cleaner fuels or technologies, application of comprehensive pollution control measures, offset activities at installations controlled by the project sponsor or other facilities within the same airshed, and buy-down of emissions within the same airshed. Specific provisions for minimizing emissions and their impacts in poor air quality or ecologically sensitive airsheds should be established on a project-by-project or industry-specific basis. Offset provisions outside the immediate control of the project sponsor or buy-downs should be monitored and enforced by the local agency responsible for granting and monitoring emission permits. Such provisions should be in place prior to final commissioning of the facility/project.

The stack height for all point sources of emissions should be designed according to good international industry practice (GIIP) to avoid excessive ground level concentrations due to downwash, wakes, and eddy effects, and to ensure reasonable diffusion to minimize impacts (see Figure 6-7). IFC (2007) suggests using GIIP based on United States 40 CFR, part 51.100 (ii) that defines that the stack height should be the greater of:

1. 65 m, measured from the ground-level elevation at the base of the stack:

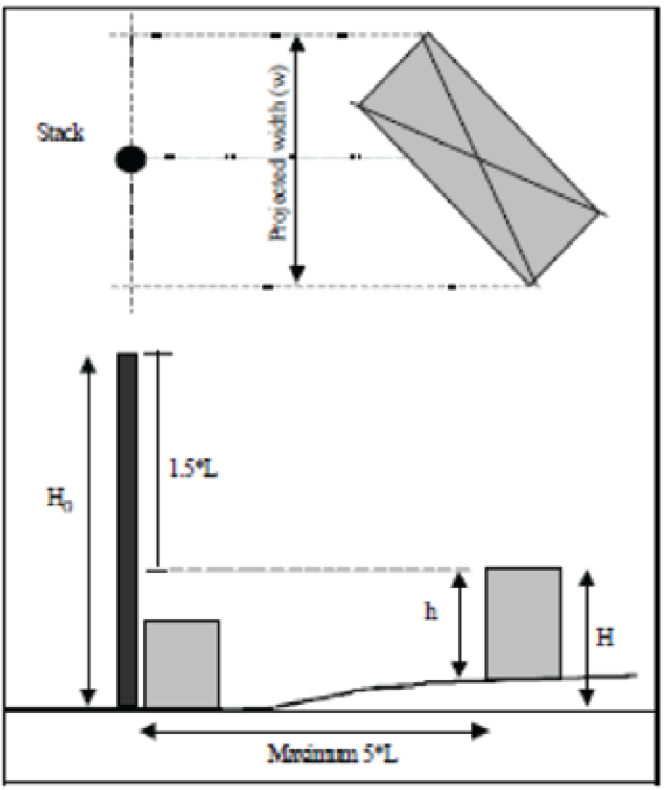
2. HG = H + 1.5L; where

- HG = stack height measured from the ground level elevation at the base of the stack.

- H = Height of nearby structure(s) above the base of the stack.

- L = Lesser dimension, height (h) or width (w), of nearby structures ("Nearby structures" = Structures within/touching a radius of 5L but less than 800 m).

Figure 6-7 Good international industry practice for stack height dimensioning.



The main pollutants from coal-fired power plants are particulate matter (PM), sulphur dioxide (SO_2), nitrogen oxides (NO_x) and carbon dioxide (CO_2). Control techniques for these pollutants generally fall into three broad categories:

- Fuel substitution/treatment: burning a cleaner fuel.

- Combustion modification: any physical or operational change in the furnace or boiler and is applied primarily for NO_x control purposes.

- Post-combustion control: a device placed after the combustion of the fuel to control emissions of PM, SO_2, and NO_x.

Some measures, such as choice of fuel and use of measures to increase energy conversion efficiency, will reduce emissions of multiple air pollutants, including CO_2, per unit of energy generation. Optimizing energy utilization efficiency of the generation process depends on a variety of factors, including the nature and quality of fuel, the type of combustion system, the operating temperature of the combustion turbines, the operating pressure and temperature of steam turbines, the local climate conditions, the type of cooling system used, etc. Recommended measures to prevent, minimize, and control air emissions include:

- Giving preference to high-heat-content, low-ash, and low-sulphur coal;

- Considering beneficiation to reduce ash content, especially for high ash coal. If sulphur is inorganically bound to the ash this will also reduce sulphur content;

- Selection of the best power generation technology for the fuel chosen to balance the environmental and economic benefits. The choice of technology and pollution control systems will be based on the site-specific environmental assessment (some examples include the use of energy-efficient systems, such as supercritical, ultrasupercritical or integrated coal gasification combined cycle (IGCC) technology for coal-fired units). Additional information in this topic is included in sub-chapter 3.2. Mitigation measures for reducing emissions via combustion modification and post-combustion control for each of the pollutants of concern are discussed in detail in sub-chapter 3.2.3.

7.4 Climate change

In general for climate change mitigation, it is important to investigate and use options to eliminate GHG emissions as a precautionary approach in the first place, rather than having to deal with mitigating their effects after they have been released. This is not possible in the case of coal-fired power plants because combustion itself is a major but unavoidable source of GHG. Nevertheless mitigation measures identified and introduced as a result of an EIA, e.g., construction and operational activities that use energy and resources more efficiently, may contribute to climate change mitigation as well.

Bear in mind that some EIA mitigation measures that address climate change can themselves have significant environmental impact and may need to be taken into account (e.g., renewable energy generation or tree planting may have adverse impacts on biodiversity).

Examples of alternatives and mitigation measures related to climate change mitigation concerns in coal-fired power plants include:

• Direct GHG emissions:

- Consider different technologies, materials, supply modes, etc. to avoid or reduce emissions.

• It is worthwhile to remember that the Pakistani National Climate Change Policy (MCCPAK, 2012) defines the need of "exploring the possibility of obtaining technological know-how and its transfer for installation of clean coal technologies such as Pressurized-Fluidized-Bed Combustion and Near-Zero Emission Technology for the Thar coal reserves, and their inclusion in the future pulverized coal Integrated Gasification Combined Cycle (IGCC) systems."

• Moreover, a new coal-fired power plant should perform at high efficiency level and should be designed in such a way that it can be easily retro-fitted for Carbon Dioxide Capture and Storage (CCS) (MCCPAK, 2012);

- Protect natural carbon sinks that could be endangered by the project, such as peat soils, woodlands, wetland areas, forests;

- Plan possible carbon off-set measures, available through existing off-set schemes or incorporated into the project (e.g., planting trees).

• GHG emissions related to energy consumption:

- Use recycled/reclaimed and low-carbon construction materials;

- Build energy efficiency into the design of a project (e.g., passive ventilation and low-energy light bulbs);

- Use energy-efficient machinery;

- Make use of renewable energy sources.

• GHG emissions related to transport:

- Choose a site that is linked to a public transport system or put in place transport arrangements;

- Provide low-emission infrastructure for transport (e.g., electric charging bays, cycling facilities).

In terms of climate change adaptation, different types of EIA alternatives and mitigation measures are available for decision-makers to use in planning the adaptation of coal-fired power plant projects to climate change. The most appropriate mix of alternatives and/or mitigation measures will depend on the nature of the decision being made and the sensitivity of that decision to specific climate impacts and the level of tolerated risk.

Adaptation measures can generally be divided into engineering and non-engineering options. In a number of circumstances, it may be best to promote "no-regret" or "low-regret" adaptation strategies that deliver development benefits regardless of the nature and extent of changes in climate. This is a useful and practical approach wherever uncertainty is high regarding climate change, and where large climate-proofing capital investments cannot be easily justified.

In general, engineering adaptation measures include more robust design specifications that will allow structures to withstand more extreme conditions and function effectively under higher air and/or water temperatures. In some circumstances, it may also be necessary to consider relocating or retrofitting extremely vulnerable existing infrastructure. Furthermore, decentralized generation systems may reduce the need for large facilities in high-risk areas and minimize climate risk. Finally, the reliability of control systems and information and communications technology components may improve from redundancy in their design and from being certified as resilient to higher temperatures and humidity. For thermal power facilities, enlarged or retrofitted cooling systems (including air cooling) may be considered where water is expected to be increasingly scarce; designing facilities to be waterproofed may be an option where increased flooding is expected.

From a non-engineering adaptation perspective, it may be cost-effective to put in place more robust operational and maintenance procedures, improved and better-coordinated land use planning (e.g., rezoning land use so future power infrastructure is in less vulnerable areas), policies and enforceable regulations to improve energy security, decentralized local planning and generation, integration of adaptation and mitigation planning, integration of climate change and disaster management planning, improving forecasting of demand changes and supply – demand balance with climate change, integrating power sector planning with that of other sectors (including water supply), and improving localized models used to predict storms and flood hazards. It may be of interest to set up rapid emergency repair teams to repair damaged facilities quickly.

Potential alternatives and mitigation measures related to climate change adaptation concerns applicable to coal-fired power plant projects include:

• Heat waves:

- Ensure that the proposed project is protected from heat exhaustion;

- Encourage design optimal for environmental performance and reduce the need for cooling;

- Reduce thermal storage in a proposed project (e.g., by using different materials and coloring).

• Droughts:

- Ensure that the proposed project is protected from the effects of droughts (e.g., use water-efficient processes and materials that can withstand high temperatures);

- Introduce technologies and methods for capturing storm water;

- Put in place state-of-the-art wastewater treatment systems that make reusing water possible.

• Extreme rainfall, riverine flooding and flash floods:

- Consider changes in construction design that allow for rising water levels and ground water levels (e.g., build on pillars, surround any flood-vulnerable or flood-critical infrastructure with flood barriers that use the lifting power of approaching floodwater to automatically rise, set up backwater valves in drainage-related systems to protect interiors from flooding caused by backflow of wastewater, etc.);

- Improve the project's drainage.

• Storms and winds:

- Ensure a design that can withstand increased high winds and storms.

• Landslides:

- Protect surfaces and control surface erosion (e.g., by quickly establishing vegetation - hydroseeding, turfing, trees);

- Put in place designs that control erosion (e.g., appropriate drainage channels and culverts).

• Rising sea levels:

- Consider changes in construction design to allow for rising sea levels (e.g., building on pillars, etc.).

7.5 Noise and vibration

Noise prevention and mitigation measures should be applied where predicted or measured noise impacts from a project facility or operations exceed the applicable noise level guideline at the most sensitive point of reception. The preferred method for controlling noise from stationary sources is to implement noise control measures at source. Methods for prevention and control of sources of noise emissions depend on the source and proximity of receptors.

Noise reduction options that should be considered include:

• Selecting equipment with lower sound power levels;

• Installing silencers for fans;

• Installing suitable mufflers or silencers in intake and exhaust channels, on engine exhausts and compressor components;

• Using sound absorptive materials in walls and ceilings;

- Using vibration isolators and flexible connections (e.g., helical steel springs and rubber elements);
- Installing acoustic enclosures for equipment casing radiating noise;
- Improving the acoustic performance of constructed buildings and apply sound insulation;
- Applying a carefully detailed design to prevent possible noise leakage through openings or to minimize pressure variations in piping;
- Selecting structures according to their noise isolation effect to envelop the building;
- Installing acoustic barriers without gaps and with a continuous minimum surface density of 10 kg/m^2 in order to minimize the transmission of sound through the barrier. Barriers should be located as close to the source or to the receptor location to be effective;
- Installing vibration isolation for mechanical equipment;
- Limiting the hours of operation for specific pieces of equipment or operations, especially mobile sources operating through community areas;
- Modification of the plant configuration or use of noise barriers such as berms and vegetation to limit ambient noise at plant property lines, especially where sensitive noise receptors may be present;
- Re-locating noise sources to less sensitive areas to take advantage of distance and shielding;
- Siting permanent facilities away from community areas if possible;
- Taking advantage of the natural topography as a noise buffer during facility design;
- Reducing project traffic routing through community areas wherever possible;
- Developing a mechanism to record and respond to complaints.

7.6 Aesthetic resources

During construction activities such as land clearing, earthmoving and terrain shaping:

- Avoid locating structures on ridgelines, summits or other locations where they would be silhouetted against the sky from important viewing locations.
- Locate linear features to follow natural land contours rather than straight lines, particularly up slopes.
- Locate facilities to take advantage of both topography and vegetation as screening devices to restrict views of projects from visually sensitive areas.
- Design and locate structures and roads to minimize and balance cuts and fills.
- Light pollution:

- Avoid to the extent practicable locations valued for unspoiled dark skies.

- Limit night-time lighting to avoid spill onto nearby residences.

During construction and landscaping of onsite facilities, structures and buildings:

- Low-profile structures should be chosen whenever possible to reduce their visibility.
- Minimize the profile of all structures located within 0.4 km of scenic highways so that views from the highway are preserved.
- Minimize the number of structures and co-locate structures where possible to minimize the need for additional pads, fences, access roads, lighting and other project features.
- Design facilities, structures, roads and other project elements to match and repeat the form, line, color and texture of the existing landscape.
- Design natural looking earthwork berms and vegetative or architectural screening where screening topography and vegetation are absent.
- Paint grouped structures the same color to reduce visual complexity and color contrast.
- Plant vegetative screens to block views of facilities and right-of-ways.

During operations stage:

- Prepare a Lighting Plan including actions to minimize the need for and amount of lighting on structures. Project developers should design and commit to install all permanent exterior lighting such that:

- Light fixtures do not cause spill light beyond the project site.

- Lighting does not cause reflected glare.

- Direct lighting does not illuminate the night-time sky.

- Illumination of the project and its immediate vicinity is minimized by including use of motion detectors or other controls to have lights turned off unless needed for security or safety.

7.7 Biological environment

As a matter of priority, any project should seek to avoid impacts on biodiversity and ecosystem services (IFC, 2012). In the specific case of coal-fired power plants significant impacts on biodiversity can be almost always avoided if an adequate site selection process was followed.

However when avoidance of impacts is not possible, measures to minimize impacts and restore biodiversity and ecosystem services should be implemented. Given the complexity in predicting project impacts on biodiversity and ecosystem services over the long-term, the project proponent should adopt a practice of adaptive management in which the implementation of mitigation and management measures are responsive to changing conditions and the results of monitoring throughout the project's lifecycle.

For the protection and conservation of biodiversity, the mitigation hierarchy includes biodiversity offsets, which may be considered only after appropriate avoidance, minimization, and restoration measures have been applied. Biodiversity offsets are measurable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts arising from project development and persisting after appropriate avoidance, minimization and restoration measures have been taken. A biodiversity offset should be designed and implemented to achieve measurable conservation outcomes that can reasonably be expected to result in no net loss and preferably a net gain of biodiversity; however, a net gain is required in critical habitats (definition below). Measurable conservation outcomes for biodiversity must be demonstrated in situ (on-the-ground) and on an appropriate geographic scale (e.g., local, landscape-level, national, regional).

IFC (2012) defines habitat as a terrestrial, freshwater, or marine geographical unit or airway that supports assemblages of living organisms and their interactions with the non-living environment. For the purposes of implementation of mitigation measures, habitats are divided into modified, natural, and critical. Critical habitats are a subset of modified or natural habitats.

- Modified habitats: areas that may contain a large proportion of plant and/or animal species of non-native origin, and/or where human activity has substantially modified an area's primary ecological functions and species composition. Modified habitats may include areas managed for agriculture, forest plantations, reclaimed coastal zones, and reclaimed wetlands. Projects should minimize impacts on biodiversity values and implement mitigation measures as appropriate.

- Natural habitats: areas composed of viable assemblages of plant and/or animal species of largely native origin, and/or where human activity has not essentially modified an area's primary ecological functions and species composition. Any power plant project should not significantly convert or degrade[22] natural habitats, unless all of the following are demonstrated:

- No other viable alternatives within the region exist for development of the project on modified habitat;

- Consultation has established the views of stakeholders, including affected communities, with respect to the extent of conversion and degradation; and

- Any conversion or degradation is mitigated according to the mitigation hierarchy.

[22] Significant conversion or degradation is (i) the elimination or severe diminution of the integrity of a habitat caused by a major and/or long-term change in land or water use; or (ii) a modification that substantially minimizes the habitat's ability to maintain viable populations of its native species.

In areas of natural habitat, mitigation measures will be designed to achieve no net loss[23] of biodiversity where feasible. Appropriate actions include:

- Avoiding impacts on biodiversity through the identification and protection of set-asides;[24]

- Implementing measures to minimize habitat fragmentation, such as biological corridors;

- Restoring habitats during operations and/or after operations; and

- Implementing biodiversity offsets.

• Critical habitats: areas with high biodiversity value, including (i) habitat of significant importance to Critically Endangered and/or Endangered species; (ii) habitat of significant importance to endemic and/or restricted-range species; (iii) habitat supporting globally significant concentrations of migratory species and/or congregatory species; (iv) highly threatened and/or unique ecosystems; and/or (v) areas associated with key evolutionary processes. In areas of critical habitat, the Environmental Assessment should analyze the following:

- If no other viable alternatives within the region exist for development of the project on modified or natural habitats that are not critical;

- If the project does not lead to measurable adverse impacts on those biodiversity values for which the critical habitat was designated, and on the ecological processes supporting those biodiversity values;

- If the project does not lead to a net reduction in the global and/or national/regional population[25] of any Critically Endangered or Endangered species over a reasonable period of time;

The EA should include a robust, appropriately designed, and long-term biodiversity monitoring and evaluation program integrated into the project management program. When a project is able to meet all the above mentioned requirements, the project's mitigation strategy will be described in a Biodiversity Action Plan and will be designed to achieve net gains[26] of those biodiversity values for which the critical habitat was designated.

The EA should include a robust, appropriately designed, and long-term biodiversity monitoring and evaluation program integrated into the project management program. When a project is able to meet all the above mentioned requirements, the project's mitigation strategy will be described in a Biodiversity Action Plan and will be designed to achieve net gains of those biodiversity values for which the critical habitat was designated.

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[23] No net loss is defined as the point at which project-related impacts on biodiversity are balanced by measures taken to avoid and minimize the project's impacts, to undertake on-site restoration and finally to offset significant residual impacts, if any, on an appropriate geographic scale (e.g., local, landscape-level, national, regional).

[24]Set-asides are land areas within the project site, or areas over which the client has management control, that are excluded from development and are targeted for the implementation of conservation enhancement measures. Set-asides will likely contain significant biodiversity values and/or provide ecosystem services of significance at the local, national and/or regional level. Set-asides should be defined using internationally recognized approaches or methodologies (e.g., High Conservation Value, systematic conservation planning).

[25] Net reduction is a singular or cumulative loss of individuals that impacts on the species' ability to persist at the global and/or regional/national scales for many generations or over a long period of time. The scale (i.e., global and/or regional/national) of the potential net reduction is determined based on the species' listing on either the (global) IUCN Red List and/or on regional/national lists. For species listed on both the (global) IUCN Red List and the national/regional lists, the net reduction will be based on the national/regional population.

[26] Net gains are additional conservation outcomes that can be achieved for the biodiversity values for which the critical habitat was designated. Net gains may be achieved through the development of a biodiversity offset and/or through the implementation of programs that could be implemented in situ (on-the-ground) to enhance habitat, and protect and conserve biodiversity.

7.8 Socio-economic-cultural environment

Table 7-1 presents mitigation measures for impacts on the socia-economic-cultural environment. Table 7-1 presents mitigation measures for impacts on the socia-economic-cultural environment.

Table 7-1 Mitigation measures for impacts to the socia-economic-cultural-environment

Affected environment		Location and design	Operational, best practices and monitoring
Socio-economic conditions	Displacement and relocation	▪ Locate facilities to avoid displacement and relocation. ▪ Develop a compensation plan for land owners. ▪ Develop a compensation plan for displaced and relocated people.	▪ Assure that new locations are culturally compatible ▪ Assure that proper training and job opportunities are available or are created. ▪ Provide counseling to assist in adaptation to the new surroundings.
Affected environment		**Location and design**	**Operational, best practices and monitoring**
	Changes in character of the community and crime rates	▪ Locate construction camps away from local communities.	▪ Implement a program to instruct employees, contractors, and site visitors to avoid harassment and disturbance of local residents. ▪ Ensure adequate security to protect residents from construction camp workers, and to protect the construction camp workers from themselves.
	Public health	▪ Limit stray voltage from transmission lines by grounding, installation or, if necessary, isolation. ▪ Route transmission lines to avoid residential areas. ▪ Place line conductors closer together to lower EMF.	▪ Assure proper clearance of area to be inundated before beginning reservoir filling. ▪ Restrict of access to project facilities, especially high risk areas, through use of signs, fences and communication of risk to the local community. ▪ Avoid creation of standing, stagnate water.

Affected environment		Location and design	Operational, best practices and monitoring
	Worker health and safety	▪ To the extent practicable locate the proposed project site relative to fire hazard severity zones. ▪ Conduct a safety assessment to describe potential safety issues (e.g., site access, construction, work practices, security, emergency procedures, and fire control and management). ▪ Develop a worker safety program to address all of the safety issues identified in the assessment and all applicable safety standards set forth by local governments and the relevant safety and health administration.	▪ Implement worker safety program. ▪ Require periodic safety inspections of all vehicles.
Infrastructure	Transportation Infrastructure	**Roads** ▪ Consult with local planning authorities regarding traffic, in general and specific issues (such as school bus routes). ▪ Develop a Traffic Management Plan for site access roads and for use of main public roads to mitigate impacts of the project on traffic. ▪ Provide for safe ingress and egress to/from the proposed project site. **Aviation** ▪ Avoid locating any portion of a facility within a designated airport safety zone, airport influence area or airport referral area.	**Roads** ▪ Limit traffic to roads indicated specifically for the project. ▪ Instruct and require all personnel and contractors to adhere to speed limits to ensure safe and efficient traffic flow.
		▪ Avoid introducing a thermal plume, visible plume, glare, or electrical interference into navigable airspace on or near an airport. ▪ Limit structure height to less than 61 meters above ground level. ▪ Limit the height of objects in the vicinity of the runways. ▪ Bury transmission lines near runways, if necessary for safety.	
	Public health infrastructure	▪ Locate facilities so as not to directly impact or disturb activities at public infrastructure.	
	Communications infrastructure	▪ Locate facilities so as not to directly impact or disturb activities at communications infrastructure. ▪ Design the project to reduce electromagnetic interference (e.g., impacts to radar, microwave, television, and radio transmissions) and comply with any applicable regulations. ▪ Signal strength studies should be conducted when proposed locations have the potential to interfere with public safety communication systems.	

Cultural, archeological, ceremonial and historic resources		▪ Use existing roads to the maximum extent feasible to avoid additional surface disturbance. ▪ Locate facilities to avoid significant cultural, archeological, ceremonial and historic resources. ▪ Prepare a Cultural Resources Management Plan, if cultural resources are present in the project area.	▪ If avoidance is not possible, conduct appropriate cultural resource recovery operations or alternate mitigations. ▪ During all phases of the project, keep equipment and vehicles within the limits of the initially disturbed areas. ▪ Educate workers on identification of cultural, archeological, ceremonial and historic resources. ▪ Stop work in the area of an unexpected discovery of a cultural, archeological, ceremonial and historic resource during any phase of the project until the resource can be evaluated by a professional archaeologist and an appropriate response undertaken. ▪ Educate workers and the public on the consequences of unauthorized collection of artifacts. ▪ Periodically monitor the condition of significant resources in the vicinity of the project and associated roads and right-of-ways and report to authorities on any degradation, looting and vandalism.
Land use		▪ Contact local stakeholders early in the process to identify sensitive land uses, issues and local plans and ordinances. ▪ Avoid the conversion of unique farmland or farmland of national importance. ▪ Compensate farmers and ranchers for crop or forage losses. ▪ Work with agricultural landowners to determine optimal electricity pole heights, pole locations, and other significant land use issues. ▪ Use larger structures with longer spans to cross agricultural fields. ▪ Use single poles where conflicts with land use are significant. ▪ Orient multiple-pole structures with the plowing pattern. ▪ Keep guy wires outside crop land and have highly visible shield guards. ▪ Locate the line along fence lines or adjacent to roads ▪ Use shorter poles with markers on the shield wires in areas where aerial spraying and seeding are common.	▪ Restrict work on rights-of-way to dry season and fallow periods in agricultural areas. ▪ Mitigate windbreak damages by trimming windbreaks selectively, replanting lower growing trees and brushes beneath the line, or creating a new windbreak elsewhere.
Tourism and recreation		▪ Locate facilities so as not to directly impact or disturb activities at tourism or recreation areas or facilities.	

8 - Practitioner Tools

8.1 Draft TOR for a EIA consultant team

1. Objectives and scope of the EIA

The TOR should start with a statement of the objectives and scope of the EIA and why it is required.

It should provide a brief description of the coal-fired power plant project. This should include a plan of the proposed scheme and a map of area that will be affected either indirectly or directly. It should also include approximate alignments of access roads and transmission lines if these are available.

2. Legal Framework

Pakistan has EIA legislation in place regarding large-scale projects such as the coal-fired power plant projects, and the country's provinces have additional legislation. There are also a number of policies and guidance documents that must be taken into account in conducting the EIA. The EIA needs to contain a review of the current and impending legal requirements relevant to this project.

3. Institutional set-up

A brief description should be given of the most important institutions, including those responsible for the EIA, the project executing agency and future managers. This may be presented in the form of an organogram.

4. Description of the work

A description of the work to be undertaken should give a general set of requirements for determining the potential impacts of, and impacts on, the proposed project. It should outline the need for:

- Scoping of the impacts and preparation of a preliminary scoping report;
- Stakeholder consultation and information disclosure requirements;
- Baseline studies that are known to be required, with provision for other studies that may emerge as a result of the scoping. If field studies are required at different times of year, this should be stated;
- Development of the impact assessment and mitigation measures;
- Preparation of the Environmental Management Plan (EMP) and Resettlement Action Plan (if required), as well as subsidiary plans (if required);
- Monitoring and compliance requirements.

The TOR should require the consultants to cover the following points:

- Alternatives to be considered and a comparison of environmental and social impacts;
- Influence of projected climate change upon the project, and risks of any seismic events;
- The main impacts during construction, operation and decommissioning phases;
- The main environmental effects of the proposed project, both in the project area and in the surrounding area and the timescale of the impacts; this should include a clear definition of the different impact zones and distinction of the different impacts;
- The size and extent of the impacts based as much as possible on quantitative data rather than qualitative assessment. It may be necessary to highlight certain topics (such as the hydrological changes, soil contamination, air pollution) when a particular issue is known to be of concern. In most cases, however, it may be preferable not to mention any specific topic and make the consultant responsible for a complete review of all topics;
- Those groups that will benefit and those disadvantaged by the project;
- The impact on protected areas and any rare species of plant or animal in the area;
- The impact on human health;
- Cumulative impacts;
- Provincial and national transboundary impacts should be assessed;
- The control and management aspects of the project to determine if they will be effective;

- The present policy, institutional and legislative situation and future needs;
- The mitigating measures needed and how they should be incorporated into the project design;
- The monitoring and evaluation activities that are required to ensure that mitigating measures are implemented and future problems are avoided.

5. Main methods or techniques to be used

The TOR should require the consultant to propose the most appropriate methods of survey, consultation and impact assessment that they expect to use. They should also be asked to highlight any limitations or constraints involved with the application of these methods. The method statement in the proposals may be an important criterion for comparison between them and selection.

6. Scope of work

The EIA will be conducted in the following two phases:

- Scoping – which will enable the client, authorities and the Consultants to fine-tune these TOR. One of the most critical aspects of scoping is comparing alternative locations, as choosing the best location (from an environmental perspective) will significantly improve the possibility of avoiding and/or reducing the main environmental impacts
- Environmental Impact Assessment including guidelines to develop a project-specific Environmental Management Plan.

Scoping: It is recommended that the Scoping Report be based on:

- Existing literature, data, maps and analytical documents pertaining to the project area;
- Initial consultation with Interested and Affected Parties and key stakeholders;
- Discussions with the techno/economic consultants, particularly with regards to design options and operational issues;
- Expert opinion and professional judgment within the consultant team;
- Analysis of environmental laws, regulations and policies;
- Analysis of the lending agency guidelines;
- Preliminary definition of the areas that will be influenced by the project;
- Site selection analysis.

The main objective of the Scoping Report is to advise on the best location (from an environmental perspective), refine the TOR and to develop a comprehensive and realistic Work Plan that is likely to deliver the required outputs.

The site selection, revised TORs and Work Plan will be endorsed by the relevant authorities after a thorough, interactive review.

Environmental Impact Assessment: This phase shall provide meaningful input, based on scientific fact or best available knowledge, into the decision making process regarding the construction, operation and decommissioning. As noted earlier, the aim of the EIA is to provide decision-makers and stakeholders with a comprehensive evaluation of the impacts of the project on the environment, as well as the effects of the environment on the project, to a high level of confidence. The EIA report must be a stand-alone document, which can be included in the overall bankable feasibility study report for the project.

In order to assess the baseline situation, best alternative location and the possible impacts of the project, the consultant is required to utilize, and where necessary, update previous studies to a sufficient level of detail on the following:

- Climate, including future climatic change scenarios;
- Water resources (quantity and quality) including surface water and groundwater;
- Biological resources (flora and fauna occurrence, status, trends), including the potential for the spread of invasive and alien species, rare and threatened species, ecosystems and habitats in the local/regional context;

- Air quality;
- Noise and vibrations;
- Soils;
- Geology and hazards;
- Aesthetic resources;
- Socio-economic and cultural aspects.

The consultants must adopt an integrated systems approach to the EIA study. The aim of this approach is to ensure that the complex inter-relationships which exist in the environment (both biotic and abiotic) are clearly understood at local, national and regional levels. The key drivers of the system and the indicators must be identified. It will only be possible to properly predict the impacts of the proposed project once the affected ecosystems have been comprehensively described.

The impacts should be evaluated in terms of their local, regional, national and international importance. The positive and negative impacts should be assessed in terms of the magnitude, significance, frequency of occurrence, duration and probability. The confidence level in each prediction must be stated. In the initial stage of the EIA, a summary table showing the impacts and their ratings must be provided, together with general recommendations for avoidance and/or mitigation. The later stages of the EIA will provide much more detailed information for the preferred option.

The study should consider secondary, synergistic and cumulative effects where relevant and should consider at least a 20-year time frame.

The environmental study must also include guidelines for an Environmental Management Plan, to be developed in a future phase. This plan has to take into account desired outcomes (e.g., ongoing land use) and the required institutional capacity for implementation.

The specialist studies and all documentation relating to the public consultation process must be included in a separate volume or volumes.

All maps must be in GIS format, linked to those used in the techno-economic study. The same base-maps must be used for both the techno/economic and EIA studies, so that there are no inconsistencies as regards to mapping.

7. Required qualifications of the team

Completing the work as required needs a multi-disciplinary team. It is suggested that at least the following disciplines be included:

- Team leader (essential that this person has broad understanding of EIA, and a proven ability to integrate specialist studies);
- Geological engineer;
- Soils scientist;
- Water quality specialist;
- Hydrologist;
- Environmental engineer;
- Archaeologist;
- Biologist/ecologist (botanical, zoological)
- Economist (with special knowledge of resource economics)
- Sociologists/social anthropologist
- GIS Specialist

The expertise may be sourced both internationally and nationally according to the level and complexity of the EIA, in which case the TOR should specify these requirements. The TOR should also specify the expected tasks to be undertaken by each team member. The required qualifications of each team member should be identified for comparisons of expertise provided in each proposal. These may include academic qualifications, previous experience with coal-fired power plants EIAs, previous experience in the area and with the local groups, their culture and language.

8. Time schedule & reporting

The time schedule of the EIA should be provided with specific milestone dates expected for:

- Public procurement started;
- Deadline for proposals;
- Inform EIA consultants of selection;
- Scoping consultation meetings with stakeholders;
- Presentation of Scoping report (if necessary);
- Baseline surveys, information gathering and analysis;
- Progress meetings between developer and EIA team, and with regulators (if necessary);
- Presentation of Draft EIA report and EMP;
- Presentation of the findings at stakeholder meetings;
- Presentation of Final EIA report and EMP.

The expected format of the EIA report and EMP may be provided in an Annex.

9. Public Participation Programme

The completion of the EIA must include a comprehensive public participation programme. The aim of public participation is to obtain broad public opinion of the project and to ensure that the concerns of the Interested and Affected Peoples are adequately addressed in the EIA and in the EMP and RAP. The proposals must provide detail of how such a programme will be designed and implemented.

10. Available information

The Terms of Reference should contain a review of the current status of information on the project and its effects. This will include which documents are available, what analysis has already taken place and some brief extracts when needed to prepare a good proposal. Furthermore, it is important to mention if certain information/data is not available and will have to be collected by the evaluator to ensure a realistic calculation of the offer. If a Strategic Environmental Assessment in the area or sector has already been carried out, this should be made available.

11. Indicative budget

The indicative budget for the EIA may be provided to help the consultants frame their proposals appropriately. The budgets proposed will be an important criterion for selection, but if there is a fixed maximum budget, the quality of the proposal in terms of method and expertise will be more important. There should be an additional budget set aside for surveys or studies that may emerge during the course of the EIA.

8.2. Outline of a typical Environmental Impact Assessment report

Volume 1: Environmental Impact Assessment Report

Acronyms and Abbreviations

Executive Summary

1. Context of the Project
1.1. Objectives and justifications of the proposed project
1.2. Related Projects and Development
1.3. Project proponents
1.4. EIA Consultant(s)
1.5. Structure of the EIA Report

2. Policy, Legal and Institutional Framework
2.1. Corporate Environmental and Social Policies
2.2. Policy and Legal Framework
2.3. International Conventions, Treaties and Agreements
2.4. Pakistan Government Institutional Framework
2.5. International Policies, Guidelines and Standards (if applicable)
2.6. Project Environmental and Social Standards

3. Project and Alternatives Description
3.1 Presentation of the Project and Description of Strategic Alternatives
3.1.1 Project Rationale and Background
3.1.2 Project Location
3.1.3 Project Infrastructure
3.2 Comparison and Selection of within-project alternatives
3.2.1 Methodology
3.2.2 Comparison and Selection of Alternative
3.3 Description of the Selected Alternative
3.3.1 Type and nature of the project
3.3.2 Fuel
3.3.3 Design and engineering features of the power plant
3.3.4 Access
3.3.5 Technical Description of the Selected Alternative
3.3.2.1 Pre-Construction Activities
3.3.2.2 Construction Activities
3.3.2.3 Operation Activities
3.3.2.4 Decommissioning, closure and post-closure Activities
3.3.6 Onsite support facilities

4. Environmental Setting
4.1 Setting the Study Limits
4.2 Methodology
4.2 Geology and Hazards
4.2.1 Geologic characteristics
4.2.2 Topography and geomorphology
4.2.3 Geologic hazards
4.3 Soil Resources
4.2.1 Types, capacity and uses
4.2.2 Fertility and potential uses of the land for agriculture
4.2.3 Stability and permeability
4.2.4 Erosion and sedimentation potential
4.4 Water Resources
4.4.1 Surface water
4.4.1.1 Hydrography
4.4.1.2 Hydrology
4.4.1.3 Water uses
4.4.1.4 Water quality

4.4.2 Groundwater
4.4.2.1 Hydrogeological characteristics
4.4.2 2 Groundwater recharge data and potential yield
4.4.2.3 Water uses
4.4.2.4 Water quality
4.5 Air Quality
4.5.1 Climate and meteorology
4.5.2 Air quality monitoring data
4.5.3 Emission data and inventories
4.6 Climate Change
4.6.1 Climatic scenarios
4.6.2 Expected impacts of climate change on baseline conditions
4.7 Noise and Vibration
4.7.1 Sensitive areas
4.7.2 Noise levels
4.8 Aesthetic resources
4.8.1 Points of Interest
4.8.2 Landscape units
4.8.3 Visibilities
4.9 Biological environment
4.9.1 Protected Areas
4.9.2 Ecosystems
4.9.3 Flora and vegetation
4.9.4 Fauna
4.9.5 Endangered or Threatened Species and Habitats
4.10 Socio-economical-cultural environment
4.10.1 Administrative Organizations and Limits
4.10.2 Land Use
4.10.3 Socio-economic conditions
4.10.3.1 Population
4.10.3.2 Crime rates
4.10.3.3 Literacy rates
4.10.3.4 Community organizations
4.10.3.5 Public Health and Safety
4.10.3.6 Economic activities
4.10.4 Infrastructure Facilities
4.10.4.1 Transportations infrastructures
4.10.4.1 Public Health Infrastructures
4.10.4.1 Communication infrastructures
4.10.4.1 Energy Infrastructures
4.10.5 Cultural components
4.10.5.1 Archaeology
4.10.5.2 Temples and monuments
4.10.5.3 Indigenous people and traditional cultures

5. Impact Assessment and Mitigation Measures
5.1 Impact Assessment Methodology
5.1.1 Scope of Assessment
5.1.2 Geographical Scope: Study Area Boundaries
5.1.3 Temporal Scope
5.1.4 Methodology
5.1.5 Modeling Requirements
5.2 Impacts, Mitigation Measures and Residual Impacts
(Pre-Construction, Construction, Operation Decommissioning, closure and post-closure)
5.3.1 Geology
5.3.2 Soil Resources
5.3.3 Water Resources
5.3.4 Air Quality
5.3.5 Climate Change
5.3.6 Noise and Vibration
5.3.7 Aesthetic resources
5.3.8 Biological environment
5.3.9 Socio-economical-cultural environment
6. Risk Assessment
6.1 Context of the Qualitative Risk Assessment
6.2 Methodology
6.3 Results of the Qualitative Risk Assessment
6.3.1 Pre-Construction Phase
6.3.2 Construction Phase
6.3.3 Operation Phase
6.3.4 Decommissioning, closure and post-closure Phase (if applicable)
6.4 Results of the Quantitative Risk Assessment
7. Cumulative Impact Assessment
7.1 Methodology and Approach
7.2 Determination of Valued Ecosystem Components
7.3 Determination of a Spatial and Temporal Framework
7.4 Cumulative Impact Assessment
7.5 Development of a Management Framework
8. Environmental Management and Monitoring Plan

Only a Summary of the EMP should be presented in that section to ensure that the EMP is in line with the impact assessment and proposed mitigation measures. The full EMP should be presented in Volume 2.

9. Conclusions
10. References

Appendices: (for example, could be a separate Volume)

Appendix 1: Mapping
Project Description
Description of the Environment
Impacts and Mitigation Measures
Appendix 2: Description of the Project
Flow Diagrams
Layouts
Others
Appendix 3: Technical Reports (if required)
Appendix 4: Modeling Reports (if required)

Air Quality
Noise
Others

Appendix 5: Public Consultation
(public consultation plan, summary of public outreach activities, summary of response to comments, copies of written comments)

8.3 Outline of a typical Environmental Management Plan

Volume 2: Environmental Management Plan

PART I GENERAL MATTERS

0.0 Acronyms and Abbreviations
1.0 General Overview
2.0 Project developer's environmental and social policies and commitments
3.0 Legal Requirements and Environmental and Social Policies and Commitments
3.1 Applicable Laws
3.2 Contractual and Corporate Commitments
3.3 Governing Parameters
4.0 EMP Organizational Structure, Roles and Responsibilities
5.0 Authorities and other Stakeholders

PART II PLANS AND PROGRAMS

6.0 Construction Phase
6.1 Description of Construction Works
6.2 Management and Monitoring Plans
7.0 Operational Phase
7.1 Description of Operations
7.2 Management and Monitoring Plans
8.0 Decommissioning, Closure and Post-closure
8.1 Description of Decommissioning, Closure and Post-closure
8.2 Management and Monitoring Plans

PART III: PROCEDURES AND SUPPORT PROGRAMS

9.0 Management Procedures
9.1 Competence, training and awareness
9.2 Internal and External Communication
9.3 Documentation (GIS, GPS, photos, video recording, forms and reports, etc.)
9.4 Control of Documents
9.5 Operational Control
9.6 Emergency preparedness and response
10.0 Checking
10.1 Monitoring, measurements
10.2 Evaluation of Compliance
10.3 Non-compliance, corrective action and prevention action

10.3.1 Non-compliance Level and Communication
10.3.2 Non-compliance procedure
10.4 Control of Records
10.5 Internal Audit
10.6 External Audit
11.0 Management review
12.0 Cross Reference of ISO 14001:2004 Requirements and Sections in the ESMMPOP
13.0 Cross Reference to Standards

Volume 3: Development Plans (if required)

- Watershed Management Plan
- Biomass Removal Plan
- Resettlement Action Plan
- Stakeholder Engagement Plan
- Livelihood Restoration Plan
- Community Development Plan
- Vulnerable Groups Development Plan
- Others

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Annex A – National Environmental Quality Standards

Table A-1 National Environmental Quality Standards (S.R.O. 549 (I)/2000 Annex-I) for municipal and liquid industrial effluents (mg/L unless otherwise defined). Note that dilution of liquid effluents to bring them to the NEQS limiting values is not permissible through fresh water mixing with the effluent before discharging into the environment and that the concentration of pollutants in water being used will be subtracted from the effluent for calculating the NEQS limits.

Parameter	Into inland waters	Into sewage treatment[27]	Into sea[28]
Temperature increase[29]	3ºC	3ºC	3ºC
pH value	6-9	6-9	6-9
Biochemical Oxygen Demand (BOD_5) at 20ºC[30]	80	250	80 (municipal) 200 (industrial)
Chemical Oxygen Demand (COD) at 20ºC[3]	150	400	400
Total Suspended Solid (TSS) at 20ºC[3]	200	400	200
Total Dissolved Solids (TDS)	3500	3500	3500
Oil and Grease	10	10	10
Phenolic compounds (as phenol)	0.1	0.3	0.3
Chloride (as Cl^-)	1000	1000	≤ sea concentration
Fluoride (as F^-)	10	10	10
Cyanide (as CN^-) total	1.0	1.0	1.0
Anionic detergents (as MBAS)[31]	20	20	20
Sulphate (SO_4^{2-})	600	1000	≤ sea concentration
Sulphide (S^{2-})	1.0	1.0	1.0
Ammonia (NH_3)	40	40	40
Pesticides[32]	0.15	0.15	0.15
Zinc	5.0	5.0	5.0
Iron	8.0	8.0	8.0
Manganese	1.5	1.5	1.5
Chlorine	1.0	1.0	1.0
Total toxic metals	2.0	2.0	2.0
Toxic metals			
Arsenic	1.0	1.0	1.0
Barium	1.5	1.5	1.5
Boron	6.0	6.0	6.0
Cadmium	0.1	0.1	0.1
Chromium (trivalent and hexavalent)	1.0	1.0	1.0
Copper	1.0	1.0	1.0
Lead	0.5	0.5	0.5
Mercury	0.01	0.01	0.01
Nickel	**1.0**	**1.0**	**1.0**
Selenium	0.5	0.5	0.5
Silver	1.0	1.0	1.0

[27]Applicable only when and where sewage treatment is operational and BOD5 ≤ 80 mg/L is achieved by the sewage system.
[28]Provided discharge is not at shore and not within 10 miles of mangrove or other important estuaries.
[29]The effluent should not result in a temperature increase of more than 3ºC at the edge of the zone where initial mixing an dilution take place in the receiving body. In case this zone is not defined, use 100 m from the point of discharge.
[30]Assuming minimum dilution 1:10 on discharge. A lower dilution ration would attract progressively stringent standards to be determined by the Federal Environmental Protection Agency. 1:10 dilution means, for example that for each one cubic meter of treated effluent, the recipient water body should have 10 cubic meter of water for dilution of this effluent.
[31]Methylene Blue Active Substances; assuming surfactant as biodegradable.
[32]Pesticides include herbicides, fungicides and insecticides.

Table A-2 National Environmental Quality Standards for Ambient Air (S.R.O. 1062(I)/2010). Note that annual arithmetic average is only valid with a minimum of 104 measurements in a year sampled twice a week 24 hourly at uniform intervals. 24 hourly and 8 hourly average values should be met 98% of the year – in 2% of the time it may exceed but not in consecutive days.

Pollutant	Time-weighted average	Concentration in ambient air	Method of measurement
Sulphur dioxide (SO_2)	Annual	80 µg/m³	Ultraviolet fluorescence method
	24 hours	120 µg/m³	
Nitrogen Oxides (as NO)	Annual	40 µg/m³	Gas phase chemiluminescence
	24 hours	40 µg/m³	
Nitrogen Oxides (as NO_2)	Annual	40 µg/m³	Gas phase chemiluminescence
	24 hours	80 µg/m³	
Ozone (O_3)	1 hour	130 µg/m³	Non-dispersive UV absorption method
Suspended particle matter (SPM)	Annual	360 µg/m³	High volume sampling[33]
	24 hours	500 µg/m³	
Respirable particulate matter (PM10)	Annual	120 µg/m³	β ray absorption method
	24 hours	150 µg/m³	
Respirable particulate matter (PM2.5)	Annual	15 µg/m³	β ray absorption method
	24 hours	35 µg/m³	
	1 hour	15 µg/m³ [34]	
Lead (Pb)	Annual	1 µg/m³	ASS method using EPM2000 or equivalent filter paper
	24 hours	1.5 µg/m³	
Carbon monoxide (CO)	8 hours	5 mg/m³	Non-Dispersive Infrared (NDIR) method
	1 hour	10 mg/m³	

[33] Average flow rate not less than 1.1 m³/minute.
[34] The National Environmental Quality Standard for the hourly concentration of PM2.5 is not correct. Hourly limit value has to be higher than the daily limit value.

Table A-3 National Environmental Quality Standards for Coal-Fired Power Plants gaseous emission (mg/Nm^3 unless otherwise defined) (S.R.O. 549 (I)/2000 Annex-II. Note that dilution of gaseous emissions to bring them to NEQS limiting value is not permissible though excess air mixing blowing before emitting into the atmosphere.

Parameter	Source	Present standard
Smoke		40% or 2 in the Ringleman Scale or equivalent smoke number
Particulate matter (based on the assumption that the size of the particulate is 10 µm or more)	Coal fired boiler	500
	Other processes	500
Hydrogen Chloride	Any	400
Chlorine	Any	150
Hydrogen Fluoride	Any	150
Hydrogen Sulphide	Any	10
Sulphur Oxides		See table A-4.
Nitrogen Oxides[35] (expressed as NO_X)	Lignite	260 ng/J (heat input)
	Other types of coal	300 ng/J (heat input)
Carbon Monoxide	Any	800
Lead	Any	50
Mercury	Any	10
Cadmium	Any	20
Arsenic	Any	20
Copper	Any	50
Antimony	Any	20
Zinc	Any	200

Table A-4 National Environmental Quality Standards for Coal-Fired Power Plants SO_2 emissions (S.R.O. 549 (I)/2000 Annex-II). Note that dilution of gaseous emissions to bring them to NEQS limiting value is not permissible though excess air mixing blowing before emitting into the atmosphere.

Background air quality	Annual SO_2 average (µg/m^3)	Maximum 24 hr SO_2 average (µg/m^3)	Criterion I Max emission (SO_2 tonnes/day per plant)	Criterion II Max. allowable ground level increment (µg/m^3)
Unpolluted	<50	<200	500	50
Low polluted	50	200	500	50
Moderately polluted	50-100		Linear interpolation between 500 and 100	Linear interpolation between 50 and 10
High polluted	100	400	100	10
Very polluted	>100	>400	100	10
			No projects with sulphur dioxide emissions will be recommended	

[35] Annual average ambient air concentration of Nitrogen Oxides, expressed as NO_X, should not exceed 100 µg/m^3 (0.05 ppm)

Table A-5 National Environmental Quality Standards for Noise (S.R.O. 1064(I)/2010). Limits in dB(A) Leq: time weighted average of the level of sound in decibel on scale A which is relatable to human hearing.

Category of Area / Zone	Day Time 6 am to 10 pm	Night Time 10 pm to 6 am
Residential Area (A)	55	45
Commercial Area (B)	65	55
Industrial Area (C)	75	65
Silence Zone (D)	50	45

According to the Pakistani legislation, silence zones are zones that are declared as such by the competent authority: an area comprising not less than 100 m around hospitals, educational institutions and courts. Note that mixed categories of areas may be declared as one of the four above mentioned categories by the competent authority.

Annex B – List of experts consulted

Table B-1 List of people consulted during the preparation of the present guidance.

Name	Organization
Aatif Alvi	ISGS
Abdul Jabbar Memon	Ministry of Petroleum & Natural Resources
Abdul Rasool	GENCO
Abida Ayub	NIAP
Adeel Ahmad	Mott Macdonald Pakistan
Ahmad Saeed	NIAP-IUCN
Ali Nawaz	PPIB, Ministry of Water & Power
Amir Shaikh	Sindh Engro Coal Mining Company
Arfa Zaheer Azmat	NIAP-IUCN
Arshad Ali Langha	Sindh EPA
Asif Shuja Khan	Director General - Pakistan EPA (Former)
Asim Hanif	Freelance Consultant
Atta ur Rehman	Government of Balochistan
Azfar Ansari	NIAP-IUCN
Azhar Khan	Ministry of Petroleum & Natural Resources
Azheruddin Khan	National Environmental Consultants
Bobbi Schijf	NCEA
David Annandale	NIAP
Eisa Bin Bashir	PPIB, Ministry of Water & Power
Faisal Saleem	ISGS
Farhan Gohar	NIAP-IUCN
Farooq Hameed Sheikh	Punjab EPA
Fouad Khan	World Bank
Hafiz Abdul Basit	Government of Balochistan
Hamid Marwat	Planning Commission
Hamza Khalid Butt	NIAP-IUCN
Hidayat Hasan	Hagler Bailly Pakistan
Huma Batool	SBKWU, Quetta
Humaira Kanwal	Mott Macdonald Pakistan
Ihsan Ullah	ISGS
Ijlal Hussain	IUCN - CCD
Imran Ali Abro	ISGS
Imran-ul-Haq	NESPAK
Irfan Tariq	CCD
Irfan ul Haq	NESPAK
Javed Malik	Planning Commission of Pakistan
Khalid Waheed Khan	Chief Energy Planning Commission of Pakistan
M. Imran Sabir	EPA Sindh
M. Mansoor Khan	IUCN - CCD
M. Shahid Saleem	NTDC
Mahr Khalid Mehmood	NTDC
Mohammed Ali Shishmahal	Mott Macdonald Pakistan
Muhammad Aqib Uddin	Freelance Consultant
Muhammad Husnain	AJK EPA/ IUCN

Name	Organization
Muhammad Iqbal	Ministry of Petroleum & Natural Resources
Muhammad Yahaya Musa Khel	WWF-Pak, Balochistan
Nadeem Aslam Chaudhry	Chief Minister Office, Punjab
Naseem ur Rehman	Punjab EPA
Nasir Khan Kashani	EPA - Balochistan
Nelofer Jamil	SBKWU, Quetta
Prof. Shafiq-ur-Rehman	University of Peshawar
Rafia Mahmood	NIAP-IUCN
Rana Ijaz Ahmad	ISGS
Sadia Waseem	RCCI, SARRAC
Salman Ahmed	ISGS
Samina Bilal	NTDC
Shahab Alam	Ministry of Petroleum & Natural Resources
Sher Bahadur	KDM, Quetta
Waqar Phulphoto	Sindh EPA
Zahoor Ahmed	UoB

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House No. 2, Street 83
Embassy Road, G-6/4, Islamabad
Tel: +92 (51) 2271027-34
Fax: +92 (51) 2271017
Email: niap@iucn.org
Web: www.niap.pk

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