Accounting for unsustainable mineral extraction in Madhya Pradesh and West Bengal

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CHAPTER 1 Introduction

This study aims to estimate the extent of and value the depletion of mineral resources and environmental costs of mining in two states of India - Madhya Pradesh and West Bengal. The study was commissioned by the Central Statistical Organization with the objective of developing a methodology and data framework for accounting for unsustainable mineral extraction in the country, which can be used to supplement and/or adjust the conventional national income accounts.

At a broad level, the study was guided by the United Nations System of Integrated Economic and Environmental Accounting, the UNSEEA. However, a review of the literature on natural resource accounting and valuation of sub-soil assets in particular, was undertaken at the outset to draw and build on specific studies done in this area.

There is a range of metallic, non-metallic and fuel minerals being mined in the two states. While Madhya Pradesh ranks high in the country in the production of copper concentrates, diamond, limestone and pyrophyllite, West Bengal leads in the production of apatite. In both states, however, coal production accounts for the lion's share of the value of total mineral production. In 2002/03, coal accounted for about 85% and 98% of the total value of mineral production in MP and WB respectively. The states make up for about 7.5% and 11% of the total coal resources available in the country, respectively. Therefore, the study decided to focus on the coal sector in both states.

The next chapter presents a review of the literature on the subject. The following chapters provide an overview of the coal industry in the country, followed by a discussion of the trends in coal availability (i.e. asset accounts for coal resources) in physical and monetary terms. The next two chapters document the environmental impacts of coal mining and propose and illustrate a methodology for placing a value on these. The final chapter summarizes the main results and discusses data gaps, future research ideas and policy implications of such an exercise.

It is hoped that the project will be useful in furthering methodological research and identifying information gaps in the area of natural resource accounting for sub-soil assets.

CHAPTER 2 Survey of literature: accounting for minerals and environmental degradation

Introduction

Economic growth is widely considered as one of the means for enhancing social welfare. Economic activity could however, be unsustainable and welfare reducing for several reasons. Many countries are therefore increasing their efforts towards addressing the problems with the existing system of national accounts, commonly used to indicate the level of economic activity and development in the country. This chapt er surveys current and past views on natural resource accounting - integrating the costs of resource depletion and degradation in conventional economic aggregates - both theoretical developments and work attempting to apply some of these theories in differen t countries, with a focus on mineral resources.

The chapter also discusses methods to integrate economic and environmental accounts as suggested by the UN SEEA (United Nations System for integrated Environmental and Economic Accounting), particularly for mineral resources and environmental degradation.

The survey is organized as follows. It begins with a brief discussion on the need for national income accounting and for incorporating sustainability concerns within it. Section 2 describes the theory of v aluing depletion of natural resources and discusses some papers which lay the groundwork for its application. In section 3, the efforts towards accounting for degradation are surveyed, along with a discussion on defensive expenditures. The section also looks into the development of environmental protection expenditure accounts by countries. While discussing both depletion and degradation, the related SEEA approaches are examined in detail.

National accounts and sustainability

Since early 1930's economists and policy makers have felt the need for an integrated accounting system for an economy. Dasgupta and Mäler (2000) list three reasons for an interest in the national income accounts. 1) Society requires an index of aggregate economic activity, 2) it is desirable to have an index of social welfare for spatial and temporal comparisons and for evaluating policy, and 3) academics have been seeking an index of sustainable income. As a result, national accounting measures were developed in the 40's and 50's as an indicator of economic activity for guiding macroeconomic policies. GDP (gross domestic product) was devised and considered to be the indicator of the value of total goods and services generated in an economy. Alongside, the NDP (net domestic product) w as formulated, obtained by deducting the depreciation of fixed or manmade capital from GDP. It became a measure of sustainable income as it gave an estimate of the maximum value that could be consumed while staying as well off at the end of the period as in the beginning. Samuelson (1981) and Weitzman (1976) contended that NNP was the best measure of welfare under the standard national income accounting framework.

In time it was recognized that such a measure captured economic concerns of employment, outpu t and consumption but not sustainability concerns of the environment or natural resources. It did not account for depletion of natural resources or environmental damage resulting from economic activity. Economists have since argued that calculated change in GDP bears little relation to real growth, particularly in resource-based economies. Specifically, they have argued that it is not possible to determine from the national accounts whether an economy is genuinely growing or merely living off its capital (Repetto 1986; 1989). Early studies in the field pointed two sources of difficulty in the SNA. One is the non -imputation of the value of environmental goods and services (Peskin 1981; Hueting 1987; Repetto 1989). The other is the absence of any allowance for depreciation, depletion or degradation of environmental assets (Harrison 1989; Elf Serafy 1989; El Serafy and Lutz 1989).

El Serafy and Lutz (1989) pointed out that GDP was essentially a short-term measure of economic activity for which exchange occured in monetary terms. It was of limited usefulness to gauge long-term sustainable growth; partly because natural resource depletion and degradation were being ignored under current practices. Similarly, Bartelmus and Tongeren (1994) emphasized the need for inclusion of natural resource degradation in national income accounting: Conventional national accounts in their assessment neglected the new scarcities of natural resources that threatened the sustained productivity of the economy and the degradation of environmental quality, mainly from pollution and consequences of human health and welfare.

Thus, exclusion of environmental degradation from NDP gives an overestimation of the growth rate of the economy and future consumption possibilities. Environmental and natural resources make an important contribution to long-term economic performance and can be considered economic assets, even when they do not enter the market transactions directly. When economic policy decisions are based on the omission of environmental costs, including the value of natural resource depletion, economic activities can be encouraged to the detriment of the environment and natural resource base.

In response to such concerns, efforts to extend the measure or develop an alternative to the System of national accounts are increasing in several countries. In many of these countries alternatives to the existing SNA has already been proposed, as suggested by SEEA or ENRAP. The literature that has developed in this area suggests adjustments to national accounts in order to include the value of environmental services, deduct defensive expenditures since these do not contribute to net well being and deduct the value of environmental damages (Peskin 1989).

Valuation of mineral depletion

Green accounting is a measure of economic performance by maximising the social welfare function after incorporating the services of natural capital. The standard measure of current well being in the national accounts is the aggregate market value of consumption of good and services,

$$C(t) = \sum_{i=1}^{n} p_i(t) c_i(t)$$

where $p_i(t)$ is the price of the ith good at time t, $c_i(t)$ is the consumption of the ith good in time t and c(t) is the total vale of consumption for the same period. One aspect of green accounting is the effort to expand the definition, and the measurement of consumption to include non -market values, in particular ones associated with environmental goods and services.

The standard definition of net national product (NNP) is $g(t) = c(t) + Q(t)\, k(t)$, where net investment, k (t), p ertains to all capital stocks, including natural resources, consumption is the numeraire and Q(t) is a vector of prices of capital goods.

According to Hartwick (1990) there is explicit depreciation of natural resource capital, which should be deducted fr om GNP to arrive at the correct estimate of NNP. In order to arrive at a good aggregate of economic activity, the GNP of an economy should incorporate priced resource input flows and these flows from capital stocks should be 'off-set' by deductions from (or possibly supplements to) GNP to incorporate declines (or possibly increases) in natural resource stocks.

For example, air sheds and watersheds are stocks whose flows of services 'enter' the economy but are generally un - or underpriced. Thus, the correct approach would be to re-price the environmental services by appropriate scarcity or shadow prices and revise GNP upward. Then any annual declines (increases) in the corresponding stocks should be valued and netted out (added to) of GNP to obtain NNP.

From theory to practice

Over the last fifteen years, several countries have attempted adjustments to their national income accounts, beginning with Robert Repetto in the late 1980s. These studies have arrived at estimates for depletion and depreciation of natural capital based on the theory and the constraints of data inadequacy.

The estimation of economic depreciation and the value of changes in stock has been dealt with in empirical studies largely by using three methods 1) Net Present Value method 2) User Cost method or the El Serafy approach or 3) Net Price Method.

Net present value: The method is based on the opportunity cost principle – economic assets will be acquired and put to a particular use in production, assuming rational behaviour, if their discounted expected net returns exceed the discounted returns from any other investment option available.

User cost method: El Serafy suggests that total resource rent cannot be deducted from GDP, acknowledging the fact that a resource rich country has a real income advantage in comparison with a resource poor country. A portion of the rent should be counted as value added, the reward for human effort. The idea is to convert a time-bound stream of (net) revenues from the sales of an exhaustible natural resource into a permanent income stream by investing a part of the revenue, that is, the 'user cost' allowance over the lifetime of the resource. Only the remaining amount of revenues should be considered 'true income' (El Serafy as cited Bartelmus et al. 2001).

Net price method: This method determines the value of a resource at the beginning of a period as the volume of the proven reserve times the difference between the average market value per unit of the resource and the per unit cost of extraction, development and exploration (including a normal rate of return on invested produced capital). In the case of non-renewable resources, this stock comprises only the 'proven reserves that are exploitable under present economic conditions, and therefore have a positive net price' (Bartelmus et al. 2001). The net price method is based on the Hotelling rent assumption i.e. in a perfectly competitive market the net price of a natural resource rises at the rate of interest of alternative investment, offsetting the discount rate. In principle the net price effective at the time of the resource use should be applied.

A number of studies have applied variation of these methods. In a recent paper Sara (2002) stressed the need for broadening the definition of capital to include natural capital and human capital before preparing a green account for Venezuela and tried to construct a sustainability indicator for Venezuela. The study focuses on the estimation of the oil capital, as part of the natural capital, in a small open economy dependent on oil rents. The concept of oil capital covers only the proven reserves and excludes resources with lesser biological certainty. Instead of marginal cost, average costs are used and natural gas a by - product of oil extraction is excluded. This study shows that the assumptions made on exploration costs and allocation mechanism can make a huge difference in the estimates of oil capital value. It also reveals that changes in the economic environment of the producer affect the country's capital formation and explains changes in oil proven reserves.

Davis and Moore (2003) investigate the theory and practice of adjusting national income and product accounts for the stock and depletion of mineral assets. One of the current methods of calculating mineral depletion, the net price method, is upwardly biased. This is because it takes the quantity extracted and multiplies it by price less average cost, while the marginal cost may be rising. The valuation equations given in this paper can be used to calculate an accurate estimate of mineral depletion, through their equation and parameter value.[1] The result of these adjustments would be a lower stock value than typically calculated using the Hotelling valuation principle, and less depletion than typically charged using the total rent method.

The study by Eugenio and others (2002) estimate the green measures of Chile's mining sector for the period 1977-96. The study adopts the equation given by Davis and Moore for adjustments to derive the net domestic product. This paper also raises issues regarding fixed and current price for estimating net price and uses both the methods.

Blignaut, Hassan and Lange's (2003) discuss natural resource accounting in Southern Africa, particularly for non-renewable resources. The paper describes the efforts of Southern Africa in this direction and also shows some empirical estimates for mineral resources of Botswana, Namibia and South Africa. The NRASA (Natural Resource Accounting in Southern Africa) Project and RANESA (Resource Accounting Network for Eastern and Southern Africa) are two major examples of endeavours by African countries towards NRA (Natural Resource Accounting) and sustainable management of resources in these natural resource dependent economies.

The formative work by Perrings, Gilbert, Pearce, and Harrison (1989) in Africa, tried to extend national accounts to cover non-marketed resource based activities and proceeds to construct natural resource accounts for Botswana. The

[1] Depletion calculation at time t is given by $\Delta(t) = [P(t) - a(t)]q(t) - 0.6r[P(t) - a(t)]R(t)$ for petroleum extraction where P(t) is spot price of the mineral, q(t) is the output level, a(t) is the average cost and R(t) is the remaining economic reserves.

construction of a Social Accounting Matrix (SAM) from the national accounts shows the interaction between production, consumption, and capital accumulation, but it does not provide adequate data on changes in the stocks of Botswana's natural capital. Values in SAM are generally imputed for those inputs and outputs, which are traded under the existing structure of property rights. This paper stresses on the need of a construction of stock accounts, because they can be of interest to macroeconomic planners. In this paper the issue of treating new discoveries is unresolved and it is suggested that discoveries should be treated as analogous to capital transfers.

In India, TERI's study (1994) attempted to develop physical and monetary accounts for coal. The study discusses the physical and monetary accounts at an all-India level and for the major coal producing states of Andhra Pradesh, Bihar, Maharashtra, Madhya Pradesh, North-Eastern States, Orissa and West Bengal. The change of stock is valued using the net price method and GDP at factor cost is adjusted by the value of coal depletion. The study takes the net value-added from the resource as the economic rent and then separates it from value-added by physical capital to extract the resource. The value added from the resource is defined as the net revenue from the resource less all factor payments including normal return to capital. The value of the natural resource stock is estimated as the discounted present value of the net revenue.

Another TERI study (TERI 2001) aimed at preparing physical and monetary accounts for select resources in Goa, used the net price and user cost methods for valuing the stock and depletion of iron-ore in Goa and adjusted the value added by the mining sector accordingly.

Valuation of environmental degradation

According to SEEA (2003), trying to put a value on environmental valuation is not the same as trying to value environmental goods. SEEA (2003) recommends two major valuation techniques.

(i) Cost-based valuation methods
(ii) Damage-based valuation methods

Costs based valuation techniques are based on the costs of mitigating and abating environmental damages from production processes. There are three ways in which emissions can be controlled. Steps can be taken to avoid the emissions in the first place, either by abstaining from the activity -giving rise to the emissions or by substituting less damaging inputs and outputs. The second solution is to secure the emissions and make them less harmful. The third option is to restore the environment by means of clean-up activities. Within this broad framework of cost based valuation, the abatement cost method is the most commonly used valuation technique. The pollution abatement approach is attractive for several reasons: it is consistent with the polluter pays principle; abatement technology has dominated technological solutions to controlling pollution; and in many instances, abatement cost is relatively easy to measure than other approaches.

The use of distance functions to estimate shadow price of the pollutant is one of the widely used methodologies within this category. The literature on the estimation of the air pollution abatement costs and technical efficiencies using distance functions is growing. Some of the selected studies are reviewed below.

Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977) independently proposed the estimation of a stochastic frontier production function, where noise is accounted for by adding a symmetric error term. Fare & Grosskopf (1990) have employed a dual Shephard's lemma (1970) to the output distance function which yields the revenue deflated shadow prices of all the outputs. Fare et al. (1993), have used the output distance function approach to derive the shadow prices of the pollutants for the USA. They show how efficiency measures can be adjusted in the presence of undesirable outputs and also how the output distance functions can be estimated as frontiers in order to generate the shadow prices of the undesirable outputs. Coggins & Swinton (1996), estimate the shadow price of the SO2 abatement for Wisconsin coal burning utility plants of USA by using the output distance function approach. Hartman, Wheeler and Singh (1997), Gupta & Kumar (2003) have all analysed and estimated costs for air pollution abatement for U.S.A. Gupta and Kumar (2003) have measured the resource use efficiency of the electricity generating units in the USA under SO2 trading regime. Using the output distance function, they have compared three methods for the calculation of resource use efficiency, namely, stochastic frontiers analysis, deterministic parametric programming and non -parametric linear programming. Wang (2002) has estimated the same using the output distance function technique for air polluting Chinese industries. Hailu (2003) has estimated pollution abatement and productivity performance of regional Canadian pulp and paper industries in Canada. Literature on output distance function approach is rare in India. Kumar (1999) and Shanmugam & Kulshreshtha (2002) have estimated the abatement cost especially for the Thermal Power Plants in India using output distance functions.

Damage-based valuation methods are based on two sets of information. The first is to assess the extent of the damage, which has occurred. The most important damage to be considered is that caused to health by pollution. To assess this damage a common methodology considered is the dose response functions. This is a technique where the existence of correlation between the pollutant and the illness is measured. Once the extent of the damage is calculated it is necessary to find a way of putting a monetary valuation to it. For that, some of the pricing techniques used in the cost based methods can be can be used for this valuation. Each can be seen as the respondents 'willingness to pay' for a given service. For this extensive surveys on 'willingness to pay' can be carried out. Finally another method that can be applied is the method of 'benefit transfer'. It is a method used to estimate economic values for ecosystem services by transferring the available valuation information from existing studies to other studies.

Defensive expenditures

Environmental protection expenditure or defensive expenditure measure the cost of compliance to environmental regulations or the financial burden on the economy which could have been diverted to other uses. Thus defensive expenditure and degradation are closely linked since the former helps to prevent the latter. According to SEEA (2003) environment protection expenditure is a measure of the value of preserving environment and is inferred from what people spend to prevent its degradation or to restore it to its original state after it has been damaged.

Environmental protection expenditure

SEEA (2003) divides the environment protection expenditure into capital and current expenditures.

Expenditure, which will help combat environmental degradation in both current and future periods is considered as fixed capital formation. Since it forms a part of the final demand side of the national accounts, it needs to be adjusted to reach a value of net domestic product or net national income.

Expenditure undertaken by producers, which affects the level of environment degradation only in the accounting period in question, is treated as current expenditure, e.g. compensation to the employees and intermediate consumption. When the producer is the government sector and the production is for collective consumption, the environment protection expenditure automatically gets added in the government consumption expenditure and thus to the level of GDP (SEEA, 2003).

The environmental protection expenditure component of the SEEA differs from the others in that it doesn't add any new information to the national accounts but reorganizes expenditures in the conventional SNA that are closely related to environmental protection and resource management. The purpose is to make these expenditures more explicit, and thus, more useful for policy analysis. In this sense, they are similar to other satellite accounts, such as transportation or tourism accounts, which do not necessarily add new information, but reorganize existing information. This set of accounts has three quite distinct components: (SEEA 2003).

- Expenditures for environmental protection and resource management, by public and private sectors
- The activities of industries that provide environmental protection services
- Environmental and resource taxes subsidies

There have been several methods of classifying the environmental protection expenditures by the industry. One of them as suggested by the SEEA is the CEPA. The CEPA (Classification of Environmental Protection Activities) classifies expenditure on environment protection according to characteristics of activities as:

- Protection of ambient air and climate
- Waste water management
- Waste management
- Protection of soil and groundwater
- Noise and vibration abatement
- Protection of biodiversity and landscape
- Protection against radiation
- Research and development for environmental protection
- Other environmental protection activities

Adjustments using defensive expenditure as suggested by SEEA

According to SEEA if defensive expenditure is used for estimating environmental costs, there is a need for symmetric treatment of such expenditure by gov ernment and industry. The SEES suggests the "gross gross" approach as one way to achieve this symmetry. In this approach, all repairs and maintenance are considered as part of gross capital formation and current repairs are treated as a form of consumption of fixed capital thus eliminating the double counting. This change in classification will not alter GDP in case of government sector but some of the final consumption is reclassified as fixed capital consumption. In case of industry the net domestic product remains unchanged but GDP increases by environmental protection expenditure undertaken. The difference between GDP and NDP is increased by the total current expendit ure on environmental protection (SEEA 2003).

It is important to separate the environ mental protection expenditure or the defensive expenditure into current and capital expenditure to distinguish between how far the burden is on going rather than one time. Current expenditure would include spending on environmental protection activities a nd external expenditure likes wasting disposal, wasting water treatment etc. Capital expenditure comprises of both expenditure on end-of-pipe technologies and integrated investments or clean technologies. Integrated investments refer to modification of existing equipments to reduce pollutants output or purchase of new equipment for industrial purpose, which also control pollution. A TERI study (1994) used the data on capital and revenue costs by coal producing companies towards environmental protection. The study used the control-cost approach to arrive at estimates of environmental cost per tonne of coal produced by mines. In this study the capital costs were annualised to arrive at an estimate of the cost of producing the fuel mineral in India.

Conclusion

Over the last quarter-century, official statistical agencies and individual researchers have responded to the deficiencies in current accounting approaches by developing alternative approaches and novel systems of accounts. The first approached by individual researchers, tested wholly new frameworks that often included major aspects of nonmarket activities. Later, official statistical agencies began to take incremental steps toward including some activities that are near-market in nature. The differ ences in approach generally reflect varying emphasis on the deficiencies discussed earlier, differing views on the functions of national accounting, and differences in what are considered the appropriate functions of official statistical agencies. While economists are often critical of green accounting systems proposed by national accountants, national accountants contend that the real world data constraints impose restrictions in valuation. The discipline of environmental economics working in tandem with national accountants is slowly beginning to arrive at a coherent, alternative set of operational guidelines for natural resource accounting. The survey of literature here attempted to summarise the developments over the years in natural resource accounting, particularly in the context of mineral resources. This review will be used in the following chapters to assess the costs of mineral depletion and environmental degradation due to mining in the study states.

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CHAPTER 3 Coal sector in India

Introduction

Coal is the primary source of commercial energy in India and meets about 56% of the energy requirements of the country. The coal industry's importance was recognized since the inception of the planning process in the country. The industry largely remained in the private sector until it was nationalised in the early seventies.

The industry was nationalized in two stages: coking coalmines were taken over in October 1971 and all other coal mines in May 1973. The nationalization was done, apart from other considerations, with a view to ensure that the production of coal, which is the primary source of energy, should be properly planned to meet the increasing energy requirements in the industrial development of the country. In 1975, the industry was reorganized with CIL (Coal India Limited) as the holding company. At present CIL has seven coal-producing subsidiaries, based mostly on geographical location, and one planning and design institute. With the relaxing of the import duties and increasing coal demand the monopoly of the Indian coal industry is slowly being breached in the last decade.

This chapter discusses the evolution of the coal industry in India beginning with the first section on coal classification and grading. The second section discusses the structure of the Indian coal industry and peeks into some of the inefficiencies in the sector. The third section discusses the pricing of coal in India while the fourth gives an overall view of the current demand and supply scenario for the industry. Finally the chapter concludes by noting the changes in the sector over the years and expected reforms in the future.

Coal quality: grading classification

Geologically Indian coal is of mostly sub-bituminous rank, followed by bituminous[1] and lignite (brown coal). Grading of coal was conceived in India in the year 1917. According to the report of the Coalfields Committee 1920, coal was then graded for marketing purposes, not according to its class, but by the name or the designation of the seam and by the name of the colliery producing it. Subsequently, the Coal Grading Board was established in 1924. In 1926 Grading scheme was based

[1] Bituminous coal is a soft coal containing a tar-like substance called *bitumen*. It is of better quality than lignite coal but of poorer quality than anthracite coal.

upon ash, moisture, and calorific value as the three factors governing the evaluation of the quality in coal and used to classify the coal of Barakar and Raniganj series in Bengal and Bihar fields.

Systematic grading started in 1944 based on ash plus moisture at 60% relative humidity and 40 deg Celsius. In 1956, the Coal Board was formed, which categorized coal on associated ash and moisture content (a) low moisture coal for moisture content of 2% or below (b) coal having moisture content above 2%. The ash content in Indian coal usually ranges from 35% to 50%.

Coal grading on basis of heat value

In accord with the recommendations of the Central Fuel Research Institute, post nationalisation the prices of coal were related to the UHV (useful heat value). As discussed in the previous paragraph, low moisture and high moisture coals were categorised separately and priced accordingly prior to nationalisation. Under revised grading post nationalisation, moisture wise distinction coals and their separate pricing no longer existed and low moisture and high moisture coals were treated on par. Under this grading system that is still in practice, UHV was to be the grade -determining factor.

Post nationalization the coal companies were empowered (under clause 3 A of Colliery Control Order 1944) to declare the grades of coal seams mined by them. The CCO (Coal Controller's Organization) was given the following additional responsibilities.

- Lay down the procedure and method for sampling and analysis of coal for the purpose of declaration and maintenance of grades of coal mines in a colliery
- Carry out test checks wherever felt necessary for verification of grades notified by coal companies for different coal seams mined by different collieries every year and
- Act as an appellate authority for looking into complaints by consumers on coal quality

The coal companies are empowered to declare the classes, grades, and sizes of the coal of any seam or section of a seam in a colliery in accordance with the prescribed procedure as laid down by the Coal Controller. All the coal companies declare the grades of coal seams being mined by their collieries at the beginning of every financial year. Some companies (Central Coalfields Limited, South Eastern Coalfields Limited, and Western Coalfields Limited) also declare the coal grades at their railway sidings (loading points). The declared grade of coal seams being mined is of less interest to the consumers and what is more important is the "declared dispatch grade" of coal from a loading point.

According to the prevailing grading system non -coking coal is classified into seven grades (A-G) based on its UHV,[2] (see Table 1 below). The gradation of coking coal as shown in Table 2, is based on ash content while for semi coking / weakly coking coal it is based on ash plus moisture content. The UHV is assessed on the basis of a prescribed formula, by imposing a penalty for different percentages of ash and moisture content. This is not in consonance with the internationally used grading system based on gross calorific value[3] that is based on the actual heat value. It was developed by CFRI to facilitate easy calculation by coal companies.

UHV is defined by the formula:
UHV (Kcal/Kg) = 8900 – 138 (A+M)
A and M being percentages of ash and moisture in the coal sample at 60% relative humidity & temperature of 40 deg. Celsius.

Table 1 Grades of non-coking coal

Grade	*Useful Heat Value (UHV) (Kcal/Kg) UHV= 8900-138(A+M)*	*Corresponding Ash% + Moisture % at (60% RH & 40O C)*	*Gross Calorific Value GCV (Kcal/ Kg) (at 5% moisture level)*
A	Exceeding 6200	Not exceeding 19.5	Exceeding 6454
B	Exceeding 5600 but not exceeding 6200	19.6 to 23.8	Exceeding 6049 but not exceeding 6454
C	Exceeding 4940 but not exceeding 5600	23.9 to 28.6	Exceeding 5597 but not exceeding. 6049
D	Exceeding 4200 but not exceeding 4940	28.7 to 34.0	Exceeding 5089 but not Exceeding 5597
E	Exceeding 3360 but not exceeding 4200	34.1 to 40.0	Exceeding 4324 but not exceeding 5089
F	Exceeding 2400 but not exceeding 3360	40.1 to 47.0	Exceeding 3865 but not exceeding. 4324
G	Exceeding 1300 but not exceeding 2400	47.1 to 55.0	Exceeding 3113 but not exceeding 3865

Table 2a Grades of coking coal

Grade	*Ash Content*
Steel Grade –I	Not exceeding 15%
Steel Grade -II	Exceeding 15% but not exceeding 18%
Washery Grade -I	Exceeding 18% but not exceeding 21%
Washery Grade -II	Exceeding 21% but not exceeding 24%
Washery Grade -III	Exceeding 24% but not exceeding 28%
Washery Grade -IV	Exceeding 28% but not exceeding 35%

[2] As against Gross calorific value in the internationally traded coal.
[3] The calorific value or heat of combustion or heating value of a sample of fuel is defined as the amount of heat evolved when a unit weight (or volume in the case of a sample of gaseous fuels) of the fuel is completely burnt and the products of combustion cooled to a standard temperature of 298 degree K. It is usually expressed in Gross Calorific Value (GCV).

Table 2b Grades of semi-coking coal

Grade	*Ash + Moisture Content*
Semi coking grade – I	Not exceeding 19%
Semi coking grade – II	Exceeding 19% but not exceeding 24%

Demerits of UHV system

In the GCV (gross calorific value) system of grading of non-coking coal, which is internationally in use, it is possible to determine the exact value of non-coking coal grades supplied to consumers whereas in the existing UHV system, the heat value cannot be determined directly but computed by using an empirical formula based on ash and moisture content. The band variation in GCV grades of non-coking coal is narrower than the existing variation of heat value in the UHV system (Table 1). Most of the international coal pricing is based on GCV and Indian users of imported coal also buy it on GCV basis. Even the thermal power plants in India, the main consumers of non-coking coal, follow the GCV system in all their monitoring and recording practices as well as computation of heat value for operational controls.

The move from the existing system of grading of non-coking coal on the basis of UHV to the more internationally comparable GCV is currently under review by government.

Structure of the industry

Coal mines were nationalized in the early seventies in view of the then existing unsatisfactory mining conditions e.g. violation of mine safety laws, industrial unrest, failure to make investments in mine development etc., In India the Department of Coal under the Ministry of Coal & Mines, has the overall responsibility of determining policies and strategies in respect of exploration and development of coal and lignite reserves. These key functions are exercised through its public sector undertakings, namely, Coal India Limited and Neyveli Lignite Corporation Limited and Singareni Collieries Company Limited, which is a joint sector undertaking of Government of Andhra Pradesh and Government of India.

CIL has eight subsidiary companies namely: 1) Bharat Coking Coal Limited (BCCL) 2) Central Coalfields limited (CCL) 3) Eastern Coalfields limited (ECL) 4) Western Coalfields limited (WCL) 5) South Eastern Coalfields limited (SECL) 6) Northern Coalfields limited (NCL) 7) Mahanadi Coalfields limited (MCL) 8) Central Mine Planning and Design Institute Limited (CMPDIL).

While the first seven of the subsidiary companies listed above are coal-producing companies, the last is an engineering design exploration company. CMPDIL was set up for preparing perspective plans, rendering consultancy services and undertaking exploration and drilling work to establish coal reserves in the country and collection of detailed data for preparation of projects for actual mining.

The Coal Controller's Organisation is also a subordinate office of the Ministry of Coal and Mines, Department of Coal and discharges various statutory functions in addition to attending the legal matters arising out of various statutes which the Coal controller has been made responsible to administer.

CIL the holding company, has collectively been able to achieve profits over the years largely due to its four profit making subsidiaries namely, NCL, WCL, MCL and SECL. The other three coal producing companies ECL, BCCL, CCL have been consistently making a loss over the last few years. The mines of these companies are some of the oldest in the country and located in the states of West Bengal and Jharkhand. One of the reasons for loss making is that the coal reserves falling in these mines are located in deep seams resulting in difficult geo-mining conditions. The second reason is the large share of old underground mines and surplus manpower. These result in very low productivity measured in terms of OMS (output per manshift) and explain the consistent loss made by these subsidiaries.

Type of mining

Coal mining operation in India can be considered under two main headings: 1) underground mining – coal is extracted from the seam without removal of overlying strata, 2) strip, or opencast mining – the strata's overlying the coal seam (overburden) are removed and coal is extracted from the exposed seam. The type of mining depends on the geo-mining conditions of coal, the thickness and inclination of the seam and overlying strata, the value of surface land and other economic factors. Open cast coal production in India has rapidly increased year after year, whereas underground coal production has been stagnating at approximately 50-60 million tonnes for several years. Its share in total production has fallen to less than 20% in 2002-03. Currently about 80% of India's coal comes from opencast mines, some of them being large, highly mechanized opencast operations (See Figure 1). These operations require less labour, can be implemented faster and involve lower production costs than underground mines. Productivity in opencast mines is generally much higher than underground mines.

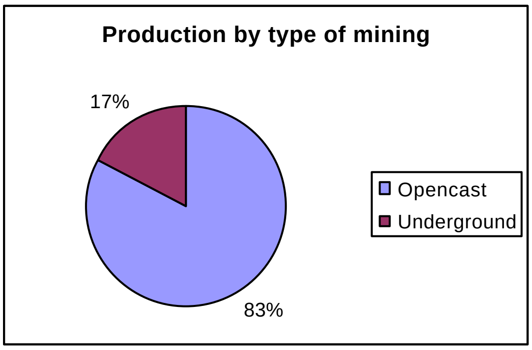

Figure 1 Production share by type in 2003-04

The cost of production per tonne of coal from underground mines could be as high as five times that of opencast mines. Since the coal is priced according to grade and not on a cost plus basis, some of the coal produced from underground mines is sold below their cost of production. The loss making by the three subsidiaries are explained by the fact that their coalfields usually have a high share of underground mines with very high cost of production.

Coal pricing

In India, monopoly in the coal sector meant the government was required to determine and declare prices. Before deregulation of prices, coal prices announced by the Government of India were based on the BICP (Bureau of Industrial Costs and Prices) Report on Coal Industry (1987) and the report on Singareni Collieries Co. Ltd (BICP 1988) and the escalation formula that was recommended. Coal prices have been completely deregulated since January 2000 and CIL is free to determine prices. CIL is ex pected to continue to rely partly on the BICP method.

The BICP pricing method is based on various input costs, which are in turn related to their price indices. The BICP had recommended that there should be an annual review of coal prices depending on the cost of inputs and rise in wages. The BICP formula basically aims at neutralizing the impact of increase in price of input used in coal production. These were calculated on movement of relevant price indices from the base level of Jan.1987 and were considered by BICP for arriving at basic prices or pithead prices. Thus it does not involve the cost of sizing, transportation from pithead, loading, cess, royalty, sales tax, stowing excise duty etc. The prices as notified by CIL, are pithead prices and not the delivered cost of coal. The delivered cost may be quite different from the pithead price due to the cost of transport as coal is located largely in the eastern and central regions. The demand for coal is however, spread across the country, and from sector s ranging from power stations, steel plants, cement etc. The load centre power plants have been complaining about the increasing landed cost of coal, which sometimes is three times the pithead price of coal. The pricing mechanism has of late come under the microscope for several reasons.

Bhattacharya (1995), in his paper has summarized some of the problems with the BICP pricing mechanism, as below:

- Since the production costs of all mines are averaged, it is difficult to identify those incurring losses; thus, the uneconomic units may exist at the cost of the better performing ones. Some of the pithead power plants contend that this results in the price of coal being almost three times the cost of production, which is unreasonably high.
- The method does not give any incentive to improving performance, as no attention is paid to the existing inefficiencies.
- The delivered cost at the user's end is not considered.
- Since the cost of production does not take into account user cost or scarcity costs, these prices do not really represent economic prices.

The other issue is related to the unique system of grading of coal in India. Grading and pricing of non -coking coal can be done either by GCV / NCV (Net Calorific Value) or UHV. In the former system, it is possible to determine the exact value of non -coking coal grades supplied to consumers. The band variation in GCV grades of non -coking coal is narrower than the existing variation of heat value in the UHV system. Under the GCV system, the consumer has the benefit of paying for the specific quality of non -coking coal received by him and the producer has an incentive to improve the quality of his production. In India, companies notify the rates of coal in terms of UHV. As the coal price remains the same over a broad range of UHV, there is no incentive for incremental improvements in coal quality.

On the demand side, increase in coal prices has been a cause of concern to major coal consumers, particularly the largest consumer of coal - the power sector. On the other hand, the financial performance of the coal sector is poor as the pricing mechanism, which not just allows inefficiency, but sets coal prices substantially below international prices.

Coal India was allowed to revise the price of coal every six months based on the BICP formula. At that point, the pithead price of coal of a particular grade was same for all coalfields. However, with each price increase, it became apparent that such parity is impossible to maintain, and regional adjustments in price are essential partly to maintain the competitiveness of domestic coal against the imported coal and partly to charge a premium for the geographical location of coal production. For example, today the price of Grade E coal from Mahanadi Coal fields Ltd with all coast -based consumers is the cheapest at 675 rupees per tonne and that of Western Coalfields Ltd is the most expensive at 1065 rupees per tonne, where the regional demand is much higher than the supplies. The price of the grades of coal as notified vary for the subsidiaries and even within ECL, based on the coalfields. For instance the price of grade A coal ranges from Rs. 1870 per tonne in SP mines, ECL to Rs. 1350 for other mines in ECL. The price of A grade coal from MCL is notified as Rs. 1050 per tonne and of the inferior G grade from MCL is Rs. 290 per tonne. The grade wise prices notified by CIL are given in Annexure 1.

The price of power coal has gone up by 15% to 20% and that of coking coal by 20% to 50%, the average price increase being 16.7% during the revision on 15th June 2004. In the past, increased costs of inputs were given as the justification of such increases. However, there is an effort to link the recent increase of coal price to international prices. There is also a hint that the basis of calculation of such increases in future may be different.

Demand and supply scenario

Coal has been the most important component of India’s energy matrix for a long time, accounting for nearly 50% of the total supplies (TERI 2004). India holds about 90 billion tonnes of proven coal reserves accounting for 8.6% of the world total. However, according to the Planning Commission (2002) only 17.96 billion tonnes of the proven reserves are extractable. The largest consumers of coal in India are the electricity sector (67%), followed by the iron and steel sector (13%) and the cement sector (4%), and others industries like sponge iron, fertilizer, brick kilns, paper, etc. Currently, India is the third-largest coal producer. At the same time, it is the eighth-largest importer of coal in the world (TERI 2005)[4]. While the Ninth Five-year Plan was formulated with a long-term perspective of augmenting domestic coal production to meet the increasing demand, the Tenth Plan accepted a shortage condition to prevail in supply of domestic coal. The domestic demand for coal is estimated to grow from 340.1 MT

[4] Coal Import and Captive Mining - Indian Scenario, An ongoing study in TERI (The Energy & Resources Institute), Prepared for Calcutta Electric Supply Corporation Ltd.

(million tonnes) in 2002/03 to 460.5 MT by 2006/07, and 620 MT by 2011/12. As against this demand, the availability of indigenous coal is estimated to grow from 341.3 MT in 2002/03 to 405 MT in 2006/07 and 515 MT in 2011/12, thereby leaving a gap of 55 MT in 2006/07 and this gap is expected to increase to 105 MT in 2011/12 (TERI 2004).

The most conspicuous fact about India's coal sector over the last decade is the persistent presence of demand supply gap. This has induced coal-consuming industries to go for increasing amounts of imported coal.

Table 3 Present Coal demand-supply gap (**million tonne- MT**)

	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04
(a) Total indigenous coal supply (offtake)*	299.69	291.02	306.27	318.38	329.04	340.09	359.23
(b) Total indigenous demand	323.32	325.34	330.96	333.81	354.22	363.3	380.9
(c) Demand - Supply (i.e. b-a) (indigenous gap)	23.63	34.32	24.69	15.43	25.18	23.21	21.67
(d) Materialisa tion through import#	16.44	16.54	19.70	20.93	20.55	23.26	21.68
(e) Total supply or availability i.e. a+d	316.13	307.55	325.97	339.31	349.59	363.35	380.9
Overall gap i.e. b-e	7.19	17.79	4.99	-5.49	4.64	-0.05	0.00

SOURCE MoCM (2004)

*excluding export & middling. # excluding coke

Table 3 shows that the indigenous demand supply gap is not met fully even by imports in case of some years. This implies that domestic users are not getting coal as per their needs, thereby indicating a below -capacity performance. The demand supply gap peaked during the recession of 1998-99. The relatively smaller indigenous gaps witnessed in 2000-01 and 2003-04 is due to increase in supply more than the increase in demand.

Sector demand for coal

The demand for coal in India is driven by the power sector being the largest consumer. The total power generation capacity as on 31 March 2002 was 1, 04,917 MW out of which coal based generating capacity was 59,386 MW and that of lignite was 2,745 MW totaling to 62, 131MW or 59%. In the Tenth Plan there is a proposal for addition of 41,110MW generating capacity with the total generating capacity increasing to 1, 46,027 MW. The coal's contribution in this is estimated at 18,308MW with a planned coal consumption of 317 MT. The captive pow er plants are expected to consume over 27 MT thus totaling to 345 MT. The demand for coal by power sector alone in likely to cross 400 MT by the end of 11th Plan (TERI 2004).

The coal production in the year 2003-04 was recorded at 355.72 MT[5] thus achieving a growth of 5.6 % over the previous year's production of 336.87 MT. Against this; the supply of coal to various consumers has been 352.32 MT. Power utilities were supplied with over 75% of the total dispatches, amounting to almost 265 MT. This does not include supplies to captive power units of core sector and various other industries, which may even, be more than 25 MT. The overall imports were lower at 23.50 MT due to increased prices and ocean freight. Though there was a lot of hue and cry from the non-core sector consumers, the supplies from CIL alone to this sector has been increasing over the last couple of years and was over 54 MT in 2003/04. However, the brick sector which uses over 25 million tonne of coal to produce over 110 billion bricks annually was officially supplied with not more than a couple of million tonne. As a result, the open market price of coal from where the brick sector sources balance of its coal requirement was extraordinarily high this year (TERI 2004).

Coal imports and international prices

In the face of low production from the captive mines[6], along with favorable import policy in recent years, import is increasingly becoming a viable option for procuring coal. Coking coal was being imported by our steel sector since liberalization in 1991. Non-coking coal imports began in 1995-96 and since import has been increasing, particularly in the coal-consuming industries located in the coastal regions given the price and quality advantage of internationally traded coal.

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[5] Provisional and Excluding Meghalaya, MOC annual report 2003/04
[6] On the captive mining front, 143 captive blocks have been identified and in comparison to last year's 27 blocks, 50 of these have been allotted so far while only four mines continue to produce coal. This is also hindered by difficulties in amending the Coal Mines (Nationalization) Act 1973 that allows commercial mining of coal.

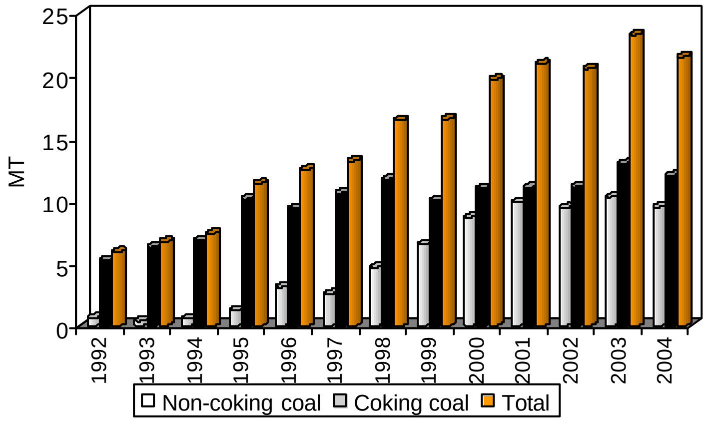

Figure **2** Import of coal by India
SOURCE TERI (2004)

From the Figure 2, it can be inferred that coking coal accounts for bulk of imports in the country. Thereby, steel industry is the biggest importer of coking coal - a key input for steel manufacturers. India imports high quantity of coking coal because of both inadequate reserves of coking coal and poor quality of indigenous coking coal in India.

Non-coking coal imports have increased since 2000 due to the cement industry and power sector imports. Even though India has substantial reserves of non-coking coal, however, the coal is of inferior quality with high ash content. Further, domestic coal reserves are concentrated in the eastern India and transportation of coal to other parts of India constitutes a significant add up to the delivered costs of coal.

Although coking coal largely constitutes Indian imports catering to the steel sector, there has been a trend recently for coal-based industries in the coast to import non-coking or steam coal, if the price is competitive. The rise in steam coal price from 2003 to 2005 along with the increasing freight rates has kept the steam coal imports at a low volume though. The international coal prices have ranged between $ 30 – 35 (free on board) over 2004-5. The cost would increase considerably with the inclusion of freight to India. The CIF price of imported coal from Australia or Indonesia costs around $60-70 per tonne. The price band of Indian coal of varying heat value ranges widely. For instance $38 for A grade coal from Raniganj coalfield and $20 for similar grade coal from a MCL coalfield. Even if the Indian coal is adjusted for the difference in heat value, it costs around $35-40, which renders it competitive to the coal consuming industries. Only small amounts of non -coking coal are imported by coast based consumer or purposes of blending or due to non -availability of indigenous supply, although such imports have been increasing over the years.

Besides India has been importing small quantities of coke since 1988-89. From 0.13 MT that year,[7] the coke import has increased to 2.41 MT during 1999 -00 and 2000-01, and then marginally dropped to 1.89 MT in 2003-04.

Table 4 Import of coal and coke during the last five years (type wise)

Coal (MT)	*1999-00*	*2000-01*	*2001-02*	*2002-03*	*2003-04*	*2004-05 (Provisional)*
Coking Coal	10.99	11.06	11.11	12.95	12.9	14.84
Non-coking Coal	8.71	9.87	9.44	10.31	8.7	10.47
Coke	2.41	2.42	2.28	2.25	1.89	2.78
Total Import	22.11	23.35	22.83	25.51	23.5	28.09

SOURCE http://coal.nic.in/eximp.html ; Coal Directory of India 2003-04

The marginal fall in total imports in 2003 -04 cannot necessarily be attributed to a fall in demand from Indian users, as there are several external and supply -side factors that affected the international market in 2003 and 2004.

Table 5 Trend in coking coal prices in international markets

Country of origin	US $ per tonne				
	2001	*2002*	*2003*	*2004*	*2005 (Estimate)*
Australia					
Queensland					
(Hard Coking Coal)	40	44	43	58-178	115-135
USA	48	52	57	72-150	125-150
Canada	38	41	41	57-95	110-130
China	39	39	39	70-95	115-125
Russia	45	45	46	70-95	105-120
Index (over all the countries)	100	105	108	155-290	271-312

SOURCE www.unece.org/ie/se/pdfs/cmm/sess7dec/cmr/Maiello_CokingCoal.pdf [8]

As regards trends in international prices, price of coal in international market rose steeply during 2004. The price of exported coking coal in Australia, from which India is regularly importing more than 80% of its total coking coal imports, has increased throughout 2004. The price that

[7] Steel Scenario, vol.13, December 2003

[8] As accessed on 30 March 2005. Free-on-board price (at the load-port). Price stands for typical export value (representative average of all qualities).

averaged around US $43 per tonne during 2003 was in the higher range of US $ 58-178 per tonne during 2004[9]

During 2003 and 2004, there was a rise in freight charges, along with capacity constraint in shipments. Large demand from China for iron ore, which compete directly with coal for space on dry-bulk cargoes, raised freight rates to a very high level throughout 2004.

There was a sudden huge surge in demand for coal from China that has reduced the quantity for other countries. China, which was till 2003 the second largest exporter of coal, became one of the biggest importers of coal in 2004. In the second half of 2003, China, which is a main source of coke and non-coking coal for India,[10] stopped supply to meet its own demand thereby increasing the demand supply gap.[11]

Import policy of government

The growing imbalance between demand and supply has prompted liberalization of the coal market. As per the present policy, coal can be freely imported (under Open General License) by the consumers themselves. Import quotas were lifted in 1993 and import duties have been steadily reduced.[12] The current duty structure is as under:

Table 6 Import Duty structure for coal (as on March 31, 2005)

Type of coal		*Effective Import Duty*
Coking	Having upto 12% ash	0%
Coal	Having ash 12% and more	5%
Coke		5%
Non-Coking Coal		5%

SOURCE Ministry of Coal, with effect from 28.2.2004

With effect from 9.1.2004 the Central Government has withdrawn the 4% Special Additional Duty from all types of coal. Custom duty on low ash coal is already done away with (since 1.3.2004).

A reason for slow increase in import of non-coking coal and coking coal with ash content more than 12% is the high customs duty, as compared to the duty on low ash (<12%) coking coal. Budget 2005-06 has proposed a reduction of customs duty on high ash coal from current 15% to 5%. This is expected to induce more import of coal with more than 12% ash. It can be added that coking coal with ash content 13-19% can be used by steel plants to manufacture hard coke.[13]

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[9] Average price of indigenous coking coal during first three quarters of 2004 was around Rs. 2270

[10] India imports around 1 MT of low ash coke and 1.4 MT non-coking coal from China per year

[11] Steel Scenario, vol.13, December 2003

[12] www.coal.nic.in/chap80102.pdf (accessed on 19 March '05)

[13] If it also has low sulphur and phosphorus

Conclusion

As we can see the deregulation of prices in the Indian coal sector, the opening up and favorable import policy by the government is slowly bringing competitiveness in the coal sector in India. With expected positive developments like commercial mining and increasing import viability our sector must necessarily increase productivity and be economically efficient to be a competitive source of energy. The infusion of fresh capital and technology is imperative to augur reforms in the coal sector, given the increasing supply/demand gap. Captive mining, which is still in its initial stages, must be given a boost by the government by reducing the bottlenecks. Similarly the linkages between coal producers and coal consumers must be based on cost minimization objective. Pricing issues are crucial to the sector and given the monopoly the industry avails of, a careful exercise is required to correct the anomalies. It is imperative to address the issue of privatization and closure of loss making units to ensure efficiency in the coal sector. As discussed, efforts are being made by the Indian government to make suitable changes in the existing legal and regulatory framework. More than 30 years of command and control has slowed the process. Despite this, there are indications that it may ultimately happen in a few years from now.

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Annexure 1: Gradewise Basic Price of coal

Gradewise Basic Price of coal at the Pit-head excluding statutory levies for Run-of-mine (ROM) Non-Long-Flame Coal, as notified by CIL on 15.06.2004 for the subsidiaries are tabled below:

Basic Price of Run of Mine Non-Long-Flame Non-Coking Coal (in Rs/tonne)							
Field/ Co.	A	B	C	D	E	F	G
ECL/ Raniganj	1740	1640	1440	1240	770	570	380
ECL	1350	1220	1020	820	620	480	340
ECL/ Mugma	1550	1380	1180	980	780	580	380
ECL/ SP Mines	1870	1670	1470	1270	850	650	450
ECL/ Rajmahal	-	-	-	-	810	690	550
BCCL	1310	1190	990	820	650	520	370
CCL	1340	1210	1010	830	650	520	370
NCL	1230	1110	910	760	610	480	350
WCL	1320	1250	1160	1100	900	710	540
SECL	1080	1010	860	730	600	470	350
MCL	1050	940	780	650	510	400	290

CHAPTER 4 Physical accounts for coal resources

The objective of preparing physical accounts is to study whether the current levels of a given resource are declining and if so, at what pace. Though minerals and energy resources are not renewable on a human time scale, "proven" reserves may appear to be sustainable if the rate of discoveries or reappraisals keep pace with extractions (UN, EC, IMF, OECD, WB 2003). Even when this is not so, changes in the rate of extraction may be indicative of changes in demand patterns and the efficiency of resource extraction or use, which in themselves are issues of interest. Further, the issue of estimating the resource rent and assessing whether it is being reinvested to develop alternatives to the exhaustible resources is an important one in the debate on sustainability of non -replenishable resources like minerals.

Classification of coal resources

For the compilation of physical accounts, it is first necessary to classify the existing stock of a mineral on the basis of the certainty of knowledge concerning their occurrence or economic viability. A useful way of looking at sub-soil resources is the McKelvey Box (Figure 1). The vertical axis of the box represents the degree of economic recovery and the horizontal axis measures the degree of geologic certainty of the mineral resources. The boundary between identified (discovered) and undiscovered resources fluctuates as the result of a mining company's investment in exploration and development, and differing geological conditions. The boundary between economic *reserves* and sub-economic *resources* is affected by the relationship between prices and extraction costs, and technological improvements.

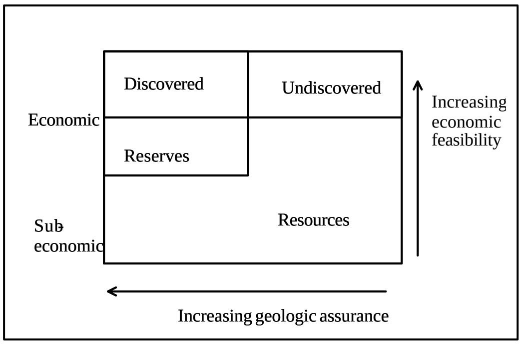

Figure **1** Mc Kelvey's Box

The McKelvey Box illustrates the distinction between mineral 'resources' and 'reserves'. Simply put, mineral 'reserves' constitute the economically mineable part of the 'resource'. A more sophisticated way of looking at resources and reserves is the United Nations Framework Classification for minerals. This is discussed in more detail below.

United Nations Framework Classification for energy and mineral resources

The United Nations Framework Classification (UNFC) for energy and mineral resources is a universally accepted scheme for classifying/ evaluating energy and mineral reserves/resources. Total remaining resources are categorized using three essential criteria affecting their recoverability:

- Geological assessment (G)
- Feasibility assessment (F)
- Economic viability (E)

The sub-classification under these criteria is shown in Table 1.

Table 1 United Nations Framework Classification for coal, uranium and other solid minerals

Categories and subcategories		
Geological assessment (G)		
G4		Reconnaissance study
G3		Prospecting
G2		General exploration
G1		Detailed exploration
Feasibility assessment (F)		
F3		Geological study
F2		Pre-feasibility study
F1		Mining report and/or feasibility study
	F1.2	Feasibility study
	F1.1	Mining report
Economic viability (E)		
E3		Intrinsically economic
E2		Potentially economic
	E2.2	Sub-Marginal economic
	E2.1	Marginal economic
E1		Economic
	E1.2	Exceptional economic
	E1.1	Normal economic

The process of geological assessment is generally conducted in stages of increasing details. The typical stages of geological investigation i.e. reconnaissance, prospecting, general exploration and detailed exploration generate data with clearly defined degrees of geological assurance and are used as the geological assessment categories in the UNFC. The categories under "feasibility assessment" reflect the successive stages of a feasibility assessment - geological study at initial stage followed by a prefeasibility study and a feasibility study/mining report. The degree of economic viability is assessed in the course of the prefeasibility and feasibility studies. The three criteria and their categories can be visualized in three dimensions with economic viability, feasibility, and geological estimates forming the three axes as in Figure 2.

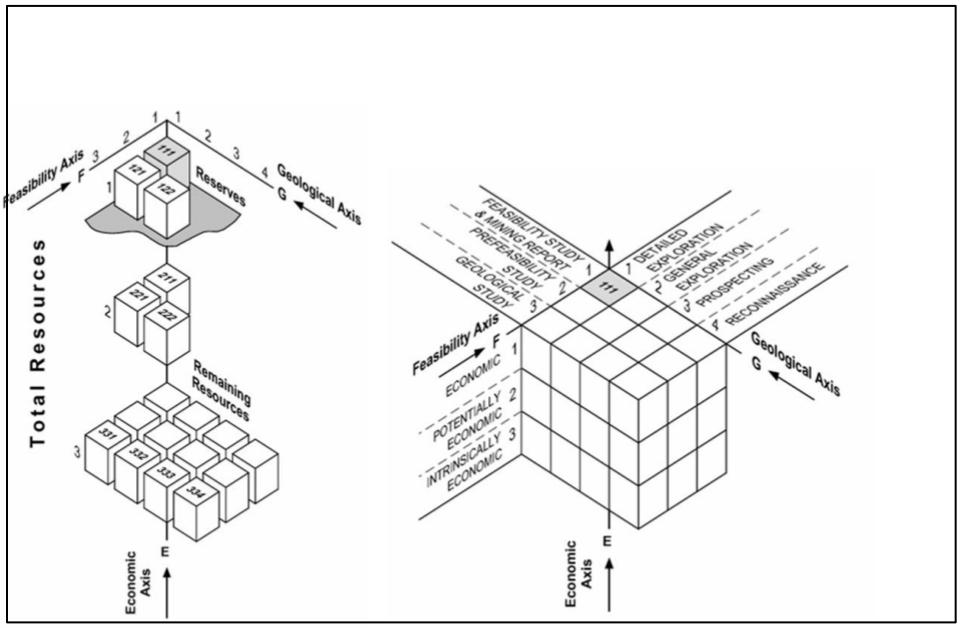

Figure **2** United Nations Framework Classification for coal and other solid minerals
SOURCE (http://www.unece.org/ie/se/pdfs/UNFC/UNFCemr.pdf, Accessed on 13 Aug 2004)

The classification of minerals in the UNFC is based on a three digit coding system, in which reserves are classified using codes to designate each of the E (economic), F(feasibility) and G(geological) categories in that order. The number 1, for example, refers to the highest degree of economic viability on the E axis, the most advanced project status on the F axis and the highest quality assessment on the G axis, respectively. Thus, Class 111, used to denote 'proved reserves', would refer to quantities that are economically and commercially recoverable; have been justified by means of a feasibility study or actual production to be technically recoverable and are based on reasonably assured geology. On the other hand, the lowest category of resources will have the code 334. The various categories of resources/reserves can be codified in this framework as shown in Table 2.

Table 2 Codification of coal resources/ reserves in the United Nations Framework Classification

S No.	*Type of reserve / resource*	*Code*
1.	Mineral reserves including:	
	- Proved mineral reserves	111
	- Probable mineral reserves	121 + 122
2.	Mineral resources (Additional or remaining resources) including:	
	- Feasibility mineral resources	211
	- Pre-feasibility mineral resources	221 + 222
	- Measured mineral resources	331
	- Indicated mineral resources	332
	- Inferred mineral resources	333
	- Reconnaissance mineral resources	334

SOURCE (http://www.unece.org/ie/se/pdfs/UNFC/UNFCemr.pdf, Accessed on 13 Aug 2004)

Indian system for coal classification

Estimates of the GSI (Geological Survey of India) and CMPDIL (Central Mine Planning and Design Institute Limited) indicate that India had about 240.75 billion tonnes of coal resources as of January 2003. Coal resources in the country are classified as being proved, inferred and indicated. The norms for estimation and classification of Indian coal reserves are primarily based on the Indian Standards Procedure (ISP), formulated by the Committee on Assessment of Resources set up by the Coal Council of India in 1956. The Procedure requires that reserves be reported according to the coal to overburden ratio, the depth from the surface and by the thickness range. It lays down the classification of proved, indicated and inferred reserves based on the relative reliability of the reserves[1].

The ISP was modified by the Task Force on Assessment of Coal Resources constituted at the Central Geological Programming Board Meeting in 1986 as follows:

- Proved reserves will be assessed only from the data emanating out of detailed exploration. Regional exploration, carried out by GSI will lead to estimations of 'indicated' and 'inferred' reserves on the basis of the stipulations of the ISP
- Reserves assessed through regional exploration over influence areas upto 1000 m from the central point will be under 'indicated' category and those within 1000-2000m will be under 'inferred' category. Thus, the inferred reserves will be limited upto 2000m from the central point.

[1] The 1957 ISP defines required that 'proved' reserves should be established from dimensions revealed in outcrops, trenches, mine working and boreholes and the extensions of the same for reasonable distance not exceeding 200 metres on geological evidence; for indicated reserves, the points of observation were stipulated to be 1000 m apart but may be 2000 m for beds of known geological continuity; finally for inferred reserves, quantitative estimates were to be based largely on broad knowledge of geological evidence

Table 3 shows the extent of coal resources in each of these categories.

Table 3 Coal resources in India (as on 1/1/ 2003)(**in million tonnes**)

Proved	Indicated	Inferred	Total
90085	112613	38050	240748

SOURCE MoCM (2004)

Each of these categories reflects the degree to which the resources have been explored. In the first stage, the GSI and various State Directorates of Geology and Mining undertake a regional ex ploration for making a general assessment of the 'geological resources' of coal under the 'inferred' and 'indicated' categories. In the second stage, detailed exploration is carried out by CMPDIL, a subsidiary of Coal India Limited directly as well as through MECL (Mineral Exploration Corporation Limited), state governments and private agencies for upgradation of coal reserves into the 'proved' category by accurately delineating the geometry of coal seams and determining the quality/grade of coal in potential coal blocks. Based on the findings of detailed exploration, detailed geological reports and project reports for coalmines are formulated (MoCM. 2004, Planning Commission 2002). The various stages in coal exploration, their purpose and the agencies responsible are summarized in Table 4 below:

Table 4 Different stages of coal exploration

S No	*Exploration stage*	*Purpose*	*Agency responsible*	*Contribution to coal inventory categories*
1	Preliminary	Broad prognostication of coal occurenecs	GSI (Geological Survey of India), State Directorates of Geology and Mining	Prognosticated resources
2	Regional	Firm identification of coal occurrences with 1-2 drill holes per sq. km	GSI, CMPDI (Central Mine Planning and design Institute), MECL (Mineral Exploration Corporation Ltd)	Indicated and inferred
3	Detailed	Detailed proving of deposit with more than 8-9 drill holes per sq. km	CMPDI, MECL, private companies etc.	Proved
4	Developmental	Geological support to working mines	Coal companies through CMPDI	None

The economies of coal production in any coalfield would depend on various geo-technical parameters e.g. depth and thickness of coal seam. Since coal is not a homogenous material, its quality is another parameter that plays an important role in decisions regarding its production. The two major categories of Indian coal are ‘coking’ and non-coking. These in turn are further classified into various grades as discussed in detail in the previous chapter on the Indian coal indu stry.

Tables 5 and 6 summarise coal availability by quality. As can be inferred, almost 87% of Indian coals are non -coking type. Of these, D,E,F and G grade power coal constitute about 80% in the proved category and 85% in the indicated category.

Table 5 Inventory of geological reserve of coal by type as on 1st January 2003

Type of coal	*Reserve (Mill. Tonnes)*			
	Proved	*Indicated*	*Inferred*	*Total*
Prime coking	4614	699	0	5313
Medium coking	11325	11839	1889	25053
Blendable / Semi coking	482	907	222	1610
Non coking (including high sulphur)	73664	99168	35940	208772
Total	90085	112613	38050	240748

SOURCE MoCM (2004)

Table 6 Grade-wise geological reserves of non-coking coal in Gondwana coalfields of India (as on 1/1/2003)(**in million tonnes**)

GR-A	*GR-B*	*GR-C*	*GR-D*	*GR-EFG*	*Total*
Proved					
1207.72	4119.99	8931.18	11276.07	47697.20	73232.16
Indicated					
1142.58	4071.35	10523.60	19103.98	64220.43	99061.94
Inferred					35570.76
Grand total					207864.86

SOURCE MoCM (2004)

Mineability / extractability of coal resources

There are concerns about the reserve classification system followed in India and whether it gives the true picture of coal reserves in the country. According to the UNFC system, a mineral ‘reserve’ is the economically viable and technically feasible part of the ‘resource’. Thus only those reserves can be considered mineable for which detailed geological exploration and a feasibility study have been conducted, a mining report has been prepared, and the economics of mining established.

India does not follow the UNFC system yet and the figures of reserves reported by the GSI are based on the Indian Standards Procedures as discussed earlier. According to these procedures, even “indicated’ and ‘inferred’ deposits get classified as “reserves”. Such reporting has resulted in misplaced confidence in long -term availability of coal in India (Chand 2004). On the other hand, going by the UNFC even ‘proved reserves’ as defined in India need to be scaled down, on the basis of techno-economic feasibility of a particular deposit and the degree of recoverability.

The CMPDIL is currently working on adapting the UNFC for a more realistic assessment of reserves. In 2000, the Ministry of Mines constituted a committee comprising members from various government organizations and the mining industry to formulate field guidelines for implementation of the UNFC in exploration and mineral resource estimation in India (MoM 2001). In 2001, the Ministry published these guidelines after a consultative process with the mining and exploration agencies. The guidelines relevant for coal resources in the country are provided in Annexure 1. Meanwhile, it has reported that the total mineable reserves of India (based on the method accepted by the Association of German Metallurgical and Mining Engineers) may not be more than 40BT (Table 7). This estimate takes into account all resources up to a depth of 1200 m and 143 BT of 'prognosticated' resources, which may become available in the future.

Table 7 Estimated mineable / extractable reserves (**Bt**)

Depth ranges in m.	*Assured resources*	*R:P ratio considered**	*Extractable reserves*
0-300	113.3	4.7	24.1
300-600	47.7	5.7	8.4
0-600 (Jharia)	14.0	5.2	2.7
600-1200 m	29.5	6.7	4.4
Total: 0-1200	204.5	5.2	39.6

* For creating 1 Mt of mine capacity and assuming 85% of capacity utilisation, it was estimated that about 140 Mt are, on an average, required to be established in the ground through detailed exploration. Taking an average mine life of 30 years, this translates into the requirement of about 4.7 t of coal for producing 1 t in one year or an annual Reserve to Production (R:P) ratio of 4.7: 1 in the 0-300 m depth range. This ratio was projected for other depth ranges.

SOURCE CMPDIL (2001)

Out of this, more than 8 BT of coal has already been depleted, leaving behind 32 BT. The Tenth Plan reports extractable coal reserves of 17.96 BT, which is 21% of the proved reserves of 84.4 BT as estimated by GSI and CMPDI in 2001.

In addition to the limited reserves of coal, there are several other factors that could limit the increase in coal production in future. Land requirement for mining will be an important one especially in view of the large dependence on opencast mining. The issue of rehabilitation and resettlement of people displaced by mines and the rising concern for the environment, both at the local and global levels, would make large scale expansion of coal mining, in particular open cast mining, a difficult proposition.

Physical accounts for coal resources in Madhya Pradesh and West Bengal

Both Madhya Pradesh and West Bengal are richly endowed with coal resources, accounting for 7.5% and 11.0% of the total coal resources in the country as in 2003. Table 8 gives the share of the two states in national coking and non -coking coal resources in 2003.

Table 8 Share of Madhya Pradesh and West Bengal in national coal resources (percent) in 2003

	Share of MP	Share of WB
Prime coking	0.00	0.00
Medium coking	8.70	0.91
Blendable / Semi coking	0.00	48.99
Non coking	7.68	12.57
Total	7.56	11.32

Continuous assessments have been adding to the coal availability in the states. It is not clear from the data whether the increase in proved reserves is due to reappraisals or new discoveries. While in some cases, reappraisals might have added to proved reserves, there has been a net addition in the total resource stock over the period.

Figure 3 shows the trend in total proved, indicated, and inferred coal resources in the two states between 2000 and 2003.

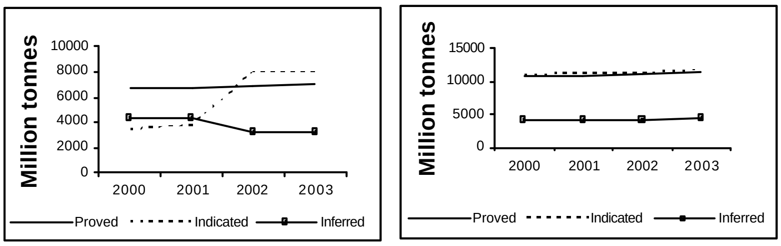

Figure **3** Madhya Pradesh ɔal reserves in Madh West Bengal
(**Million**

While in the case of WB, there was a steady gradual increase over the period, MP recorded a sharp rise in indicated resources in 2002, the year in which separate reporting for MP and Chattisgarh started[2]. This kink is seen in the case of Chattisgarh as well, indicating that both states recorded a sharp increase in 'indicated' resources in 2002.

[2] Till 2001, coal resources were reported for undivided MP. To estimate coal resources in the "newly formed" MP for previous years, resources were aggregated at the coalfield level. Except in the case of Sohagpur, all coalfields lie entirely either in MP or Chattisgarh. In the case of Sohagpur, estimates for 2002 indicate that about 82% of all non -coking coal in the depthrange 0-300m and 100% in 300-600m, and all coking coal resources fall in the new MP. These shares were used to estimate the shares of Sohagpur coal for the MP and Chattisgarh before their division in 2000.

As noted, it is important to study Indian coal by depth and coal quality. A detailed classification of coal resources - both coking and non -coking - in Madhya Pradesh and West Bengal using these parameters is provided in Annexure 2 .

The knowledge on reserves along with information on production can be put together to prepare a mineral asset account of the type recommended in SEEA (Figure 4). These accounts make use of the following basic identity.

Closing stock = opening stock + reserve accretion – production (depletion)

	Proven	*Probable*	*Possible*	*Other*	*Total*
Opening stock					
Reappraisals due to • New information • New technology • Price change					
New discoveries					
Extractions					
Closing stocks					

Figure **4** Format for Physical Asset accounts - SEEA
SOURCE UN, EC, IMF, OECD, WB (2003)

While extractions lead to a decline in the available reserves, additions could occur due to reappraisals in the same field due to new knowledge. This may revise the total level of the reserves or reserves of higher certainty. Downward revisions are also possible, both in absolute size and from one classification to a less certain one. A completely new discovery is more likely to be recorded as probable/possible (indicated/inferred as per the Indian classification) since it is only after extensive investigation that the validity of proven (or proved) reserves can be established.

While such accounts will be informative, they are very data intensive and in practice some simplification may be required. On the other hand, certain other characteristics may need to be included - for instance, in the case of Indian coal it would be appropriate to construct these accounts by grade, as has been attempted in this exercise. If detailed accounts cannot be prepared by the grade of coal, using a physical unit such as tonne for aggregate accounts may give a misleading picture. Instead, accounts prepared by tonnes of oil equivalent may be more appropriate in pr eparing physical accounts.

In the absence of estimates of extractable reserves at the state level, ‘proved reserves’ have been used to estimate the opening stock of coal in each state. It needs to be cautioned, however, that these estimates are on the h igher side. To give an idea of the recoverability factor, if the reserves to production ratios in Table 7 are applied to corresponding coal resources by depth, the estimated mineable coal reserves were less than 20% of the reported proved reserves in both in Madhya Pradesh and West Bengal in 2003. Further, this figure does not take into account depletion due to past production.

Accounts for non-coking coal

As the data in Table 9 indicates (also see Figure 5), there has been a net increase in the stock of all grades of non -coking coal in Madhya Pradesh over the period 2000/01 and 2002/03[3]. It is interesting to note that the increase has been generally higher for the more inferior varieties of coal. Proved reserves of coal of grades EFG (combined) and D grew by about 7% and 7.4% respectively as against lower rates of growth for grades C (3.3%), B (2.4%) and A (1.7%).

In West Bengal, except in the case of Grade A where there has been a marginal decline in stock over the period (1.1%), other grades have noted a net increase in stock (Table 10 and Figure 6). The highest increase has been in the stock of Grade D (6.7%), followed by about 2.4% for both Grades EFG (combined) and C, and 0.5% for Grade B. On the whole, there has been a net addition to the stock of non -coking coal reserves in WB. Thus, by and large, discoveries/ reappraisals have more than compensated for the decline in the stock of non -coking coal due to its production in both states.

[3] Madhya Pradesh refers to the newly formed state (i.e. excluding Chattisgarh). Wherever data was available only for the undivided state, the shares of MP and Chattisgarh were estimated using data for more recent years.

Table 9 Physical asset accounts for non-coking coal reserves in Madhya Pradesh (**million tonnes**)

	Grade A	Grade B	Grade C	Grade D	Grade EFG	Total
2000/01						
Opening Stock	177.18	438.70	1278.92	1404.35	2961.04	6260.42
Discoveries/Reappraisals	1.08	4.33	21.56	4.98	0.00	31.95
Extraction	0.80	1.83	20.30	6.00	12.63	41.55
Closing Stock	177.46	441.20	1280.19	1403.32	2948.41	6250.81
2001/02						
Opening Stock	177.46	441.20	1280.19	1403.32	2948.41	6250.81
Discoveries/Reappraisals	3.81	9.89	55.18	61.67	80.02	210.34
Extraction	0.79	2.54	18.60	6.55	15.15	43.62
Closing Stock	180.49	448.55	1316.77	1458.45	3013.28	6417.54
2002/03						
Opening Stock	180.49	448.55	1316.77	1458.45	3013.28	6417.54
Discoveries/Reappraisals	0.54	6.25	21.71	54.77	159.79	243.06
Extraction	0.63	3.14	16.51	5.74	16.52	0.00
Closing Stock	180.40	451.67	1321.97	1507.48	3156.55	6660.60

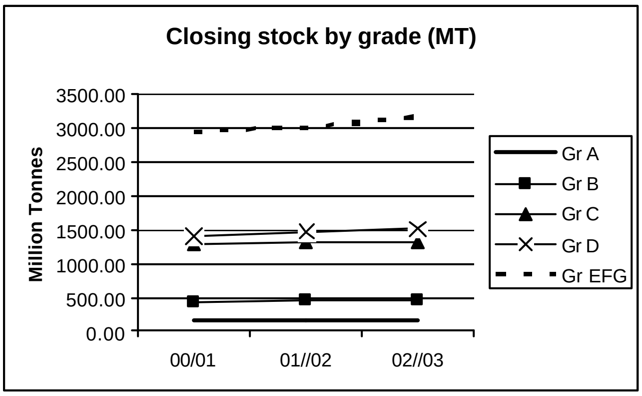

Figure **5** Trend in reserves of proved non-coking coal in Madhya Pradesh by grade (**million tonnes**)

Table 10 Physical asset accounts for non-coking coal reserves in West Bengal (**million tonnes**)

	Grade A	Grade B	Grade C	Grade D	Grade EFG	Total
2000/01						
Opening Stock	157.95	2009.54	3577.79	2617.86	2017.75	10380.53
Discoveries/Reappraisals	0.00	0.00	0.00	7.96	58.72	67.04
Extraction	0.96	11.03	6.08	0.90	0.65	19.63
Closing Stock	156.99	1998.51	3571.71	2624.92	2075.82	10427.95
2001/02						
Opening Stock	156.99	1998.51	3571.71	2624.92	2075.82	10427.95
Discoveries/Reappraisals	0.35	1.81	70.16	145.64	35.90	253.86
Extraction	1.02	11.65	6.42	0.90	0.72	20.70
Closing Stock	156.32	1988.68	3635.45	2769.66	2111.00	10661.11
2002/03						
Opening Stock	156.32	1988.68	3635.45	2769.66	2111.00	10661.11
Discoveries/Reappraisals	0.00	30.63	29.68	30.52	16.29	107.12
Extraction	1.11	11.07	5.94	0.61	0.85	19.57
Closing Stock	155.22	2008.23	3659.19	2799.57	2126.44	10748.65

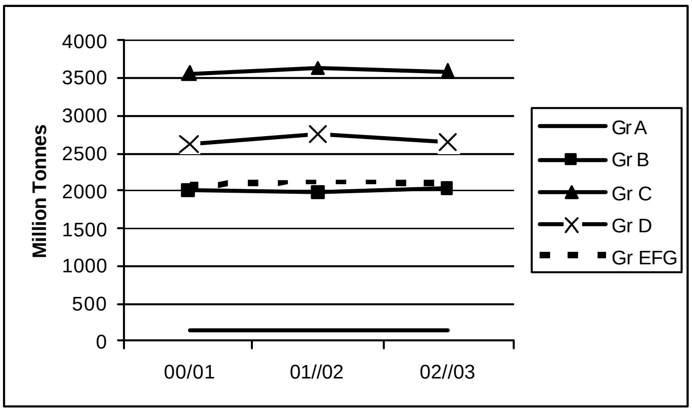

Figure **6** Trend in reserves of proved non-coking coal in West Bengal by grade (**million tonnes**)

Accounts for coking coal

Coking coal makes up for a small share of coal resources in the country. As can be seen from Table 11 , proven reserves of coking coal in MP noted a marginal drop over the period concerned. All of the coal in the state is of the medium coking variety. Both medium and semi-coking coal is found in West Bengal. Both these varieties registered a small decline in the period of the study (Table 11).

Table 11 Physical asset accounts for coking coal reserves in Madhya Pradesh and West Bengal (**million tonnes**)

Madhya Pradesh	Medium coking
2000/01	
Opening Stock	352.69
Discoveries/ Reappraisals	1.80
Extraction	0.95
Closing Stock	353.54
2001/02	
Opening Stock	353.54
Discoveries/ Reappraisals	0.00
Extraction	0.54
Closing Stock	353.00
2002/03	
Opening Stock	353.00
Discoveries/ Reappraisals	0.00
Extraction	0.59
Closing Stock	352.41

West Bengal	Medium coking	Semi coking
2000/01		
Opening Stock	210.00	188.05
Discoveries/ Reappraisals	0.00	0.00
Extraction	0.24	0.21
Closing Stock	209.76	187.84
2001/02		
Opening Stock	209.76	187.84
Discoveries/ Reappraisals	0.00	0.00
Extraction	0.32	0.38
Closing Stock	209.45	187.46
2002/03		
Opening Stock	209.45	187.46
Discoveries/ Reappraisals	0.00	0.00
Extraction	0.31	0.21
Closing Stock	209.14	187.25

Accounts for 'mineable' coal

As discussed earlier, only a fraction of the reported resources of coal are recoverable/mineable reserves. To that extent, the physical accounts built in the previous section overestimate the assets of coal available in the two states. An attempt was made to estimate recoverable reserves in the two states using the depth-wise recoverability factors discussed earlier (Table 7). These factors were applied to coal resources of different grades, varying depth and different classes of geological certainty. The results are summarized in following tables.

Table 12 Mineable reserves by grade (non-coking) in MP – **as percentage of reported resources**

	Grade A	Grade B	Grade C	Grade D	Grades EFG	Total
Proved	20.92	20.94	21.10	21.09	21.15	21.10
Indicated	19.92	19.17	19.85	18.79	19.12	19.26
Inferred						19.74
Total						20.13

Table 13 Mineable reserves by grade (cok ing) in MP – **as percentage of reported resources**

	Medium coking
Proved	20.20%
Indicated	18.55%
Inferred	17.59%
Total	18.70%

As can be seen, mineable reserves constitute only 17 -20% of the total reported resources in each category of coal in MP. Going by these estimates of reserves, closing stock s of grade A, B, and C coal record a decline over the study period, while the increase in grades D and EFG(combined) is 4.0% and 3.0% (compared to about 7% when looking at the corresponding change in coal resources). Likewise coking coal reserves fall by about 2.4% as compared to 0.8% fall in coking coal resources.

The case is similar in West Bengal (Tables 14 and 15 below). Reserves make up only about 15-21% of resources. Grades A and B of non -coking coal show a decline while C, D, and EFG show an increase that is smaller than the changes in corresponding grades of reported resources.

Table 14 Mineable reserves by grade (non-coking) in WB – **as percentage of reported resources**

	Grade A	Grade B	Grade C	Grade D	Grades EFG	Total
Proved	20.14	20.28	20.87	20.91	20.66	20.72
Indicated	16.64	17.45	17.71	17.72	18.10	17.76
Inferred						16.76
Total						18.81

Table 15 Mineable reserves by grade (coking) in WB – **as percentage of reported resources**

	Medium coking	Semi coking	Total
Proved	21.00	18.00	19.58
Indicated	17.87	15.82	15.90
Inferred		15.29	15.29
Total	20.75	16.23	17.24

Thus, with more realistic estimates of coal reserves in the country, the decline in available coal reserves appea rs to be faster (or the rise slower) than indicated by estimates of reported resources. In other words, the life of coal in the country may not be as promising as can be inferred by officially reported resources of coal. Further, the estimated reserves may still be on the higher side considering that some of the deposits of coal may exist in protected/ecologically sensitive or inhabited areas where its exploitation may be difficult.

Conclusion

This chapter attempted to study the trends in coal reserves in MP and WB for the period 2000/01 till 2002/03. The states are two of the major coal producing states in the country. Since the coal classification system in the country does not distinguish between reserves and resources, "proved coal" resources in the states were taken to represent "reserves". The analysis found that over all, non-coking reserves noted a net increase, with the rise generally being higher for lower grades. In the case of coking coal, which is available in smaller quantities compared to non-coking coal, there was a marginal drop in available reserves in both states.

Available recoverability factors indicate that only 15-20% of the coal resources of varying grades may be recoverable. Physical accounts based on recoverable reserves suggest that the long-term availability of coal in the country is not as promising as suggested by estimates of reported resources.

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Annexure 1: Field guidelines for adoption of United Nations Framework Classification

I. Stratiform, Stratabound and Tabular deposits of regular habit

Characteristics of deposits

Of regular habit with predictable change in trend with sharp to moderate physical contrast with bounded surfaces, low dipping to moderately steep, simply folded and faulted. Also as blanket cappings and surficial tabular bodies.

Geological Axis

G4 (Reconnaissance)	G3 (Prospecting)	G2 (General exploration)	G1 (Detailed exploration)
1. **Aerial reconnaissance**: Remote sensing, airborne geophysical survey etc. 2. **Geological survey**: Mapping on 1:50,000 or smaller scales 3. **Geochemical survey**: (i) Grab/chip sampling of rocks or weathered profiles (Nil for coal/lignite; (ii) Recording of broad geomorphology, drainage, etc. 4. **Geophysical survey**: Ground geophysical survey 5. **Technological survey**: (i) Trenching – One or two to expose mineralized Zone at ideal locations only; (ii) Pitting/drilling – Up to 5 test pits/boreholes per 100 sq.km. area; (iii) Scout drilling – A few to know the existence of coal/lignite; (iv) Sampling – Regional and random grab/chip sampling 6. **Petrographic and mineragraphic studies**: Determination of principal rock types, mineral assemblage, identification of minerals of interest (especially of metallic minerals and gangues) 7. Synthesis of all available data/concepts 8. the activities as above or	1. **Geological survey**: (i) Mapping on 1:50,000 to 1:25,000 scale (for coal, lignite exploration – mapping on 1:10,000) (ii) Linking of maps so prepared with topogrids; (iii) Assessment of lithology, structure, surface mineralization, analysis of old history of mining 2. **Geochemical survey**: Geochemical sampling, rock typewise and if necessary, rock type-cum-skeletal soil-domain-wise (for all metallic mineral exploration) 3. **Geophysical survey**: Detailed ground geophysical work; bore-hole geophysical logging, if possible 4. **Technological survey**: a) Pitting/trenching to explore bed rock/mineralized zone; b) Drilling; Preliminary drilling (dry drilling for bauxite and in formation vulnerable to wash); Bore-hole spacing - (i) Coal, gypsum, near surface potash and salt-beds- 1000 to 2000 meters; (ii) Iron and manganese ore– 200 to 400 m; (iii) Limestone and dolomite – 400 to 500 m	1. **Geological survey**: (i) Mapping on 1:25,000 to 1:5,000 or larger scale with triangulation points, benchmarks, if any shown. For coal, mapping on 1:10,000 scale (ii) Linking of maps so prepared with topogrid; (iii) Assessment of lithology, structure, surface mineralization, analysis of old history of mining 2. **Geochemical survey**: (i) Detailed litho-geochemical channel sampling from fresh rock exposures, trenches, pits; (ii) Recording of deleterious elements, likely by-product elements (e.g Ga in bauxite, Ni, PGE etc. in chromite, Au in Fe ore, etc. (Nil for cooal/ lignite exploration); (iii) In coal/lignite exploration, geo-chemical sampling of coal and water to be done for environmental study 3. **Geophysical survey**: (i) Borehold geophysical survey; (ii) Special geophysical traverses for problem solving, if required 4. **Technological survey**: a) Pitting/trenching:	1. **Geological survey**: (i) Mapping– For coal, mapping 1:5000; for other minerals 1: 1000 scale (ii) Preparation of detailed topographical-cum- geological map including all surface geological features, extent of deposit, structure, location of boreholes, assay plan and sections of exploratory mine development and borehold data; (iii) Topogrid/triangulation stations/ identified fiducials linking in the maps 2. **Geochemical survey:** Detailed grid pattern sampling and analysis 3. **Geophysical survey**: Detailed and specific borehold geophysical survey 4. **Technological**: (i) Pitting – 2 to 5 per sq.km. for simple deposits; (ii) Trenching – At spacing of 200-300 m; (iii) Drilling – closer spaced (with definite grid pattern) than that for G2 category; For coal: (i) Density of boreholes to be 12 to 15 per sq. km. Depending on the complexities for geostructural proving; (ii) For opencast project grid spacing may be 100m x 50m depending on the

less than that required for G3	(iv) Bauxite of thick capping – 300 to 400 m (v) Chromite as regional lode – 300 m; (vi) Barytes formations – 400 t0 500 m c) Sampling: Sampling at well-defined locations at surface and also from pits/trenches, boreholes and existing mine openings 5. **Petrographic/ mineragraphic studies:** (i) Petrographic study of rocks of the deposit and its surroundings, alterations (if any) connected with mineralization; (ii) Determination of phase in which mineral of interest occur; (iii) Mineralogical studies including paragenesis, identification of zones of oxidation and primary zones, grain size distribution, overall characteristics of useful minerals	systematic pitting/trenching for deciphering extent of mineralization at surface b) Drilling: grid reduction needed: spacing (i) for coal, gypsum near surface pota sh and salt beds – 400 to 1000 m; (ii) Iron and manganese ore– 100 to 200 m; (iii) Limestone and dolomite and barites – 200 to 400 m up to a depth of at least 30 m; (iv) bauxite of thick cappings and chromite as regional lode - 100 to 300 m c) Sampling: (i) Systematic pit and trench sampling, deep pitting if necessary; (ii) Core sampling: Lithology and strength of mineralization wise (check sampling – 10%) d) Laboratory scale scanning / chemical analysis, e) Bulk sampling if necessary for testing processing technology, f) Collection abiotic geo - environmental parameters 5. **Petrographic** : Study of petrographic character of rocks including grain size, texture etc.	geology, weather mantle cover, burning nature of coal seams (iv) Exploratory ming and check drilling results if possible; (v) Sampling – systematic pit and trench sampling, core and sludge sampling for laboratory scale and bulk sample for the pilot plant scale beneficiation studies. 5. **Petrographic and mineragraphic study:** Refining of data on the petrographic character of rocks of the deposit and its surroundings, alterations (if any), including study of grain size texture gangue and its liberation characteristics for further refining of data 6) **Geostatistical analysis** of borehold data, thickness of ore: Waste encountered in holes, assay values of samples if considered necessary

Feasibility Axis

F3 (Geological study)	F2 (Pre-feasibility study)	F1 (Feasibility study)
1. **Geological and related study:** (i) Geological, mineralogical and chemical analysis data; (ii) Topographical setting and nature of land; (iii) Infrastructure; (iv) Meteorological and preliminary ecology data if possible	1. **Geology:** Local geology, mineralogy, identification of ore types and geometry 2. **Mining:** Methods, pre -production plan, development plan, manpower (rough estimate) 3. **Environment:** Base the data on environment 4. **Processing:** Proven laboratory scale/pilot scale beneficiation,	1. **Geology:** Geology of area and project, detailed exploration, closed spaced drilling, ore body modeling, bulk samples for beneficiation, geotechnical and ground water & surface waters studies. However for coal, beneficiation studies to be carried out depending upon coal qualities 2. **Mining:** Mining plan, mine recoveries and efficiencies, equipment selection,

2. The activities as above or less than that required for F 2.	investigation data, likely establishment 5. **Infrastructure and services, construction activities:** brief details 6. **Costing:** Capital and operating cost – rough estimates based on comparable mining operations 7. **Marketing:** Overview like industrial structure, demand supply relation, pricing, etc. 8. **Economic viability:** Preliminary study of cash flow forecasts 9. **Other factors:** Statutory provisions relating to labour, land, mining, taxation, etc.	manpower requirement 3. **Environment:** EIA studies and EMP including socio-economic impact, rehabilitation of project affected persons, waste disposal/reclamation, detailed land use data 4. **Processing:** Pilot scale/industrial scale investigation data, list of equipment, manpower and environmental considerations like waste disposal of tailing, etc. 5. **Infrastructure and services, construction activities**: Full details 6. **Costing**: Detailed break-up of capital cost, operating cost, details of working capital 7. **Marketing**: Overview, specific market aspects 8. **Economic viability**: Cash flow forecast, inflation effects, sensitivity studies 9. **Other factors:** Statutory provisions relating to labour, land, mining, taxation, etc.

Economic Axis

E3 (Intrinsically economic)	E2 (Potentially economic)	E1 (Economic)
1. Reconnaissance to detailed geological study, rough estimates of grades (may be below economic cut-off), general idea about forest/non-forest and land use status 2. The activities as above or less than that required for E 2.	1. General and detailed exploration 2. Specific end-use grades of reserves (above/marginally below economic cut-off grade) 3. General knowledge of forest/non-forest and other land use data	1. Detailed exploration 2. Mining report/mining plan/working mines 3. Specific end-use grades of reserves (above economic cut-off grade) 4. Specific knowledge of forest/non-forest and other land use data

II. Stratiform, Stratabound and Tabular deposits of irregular habit

Characteristics of deposit

Of irregular habit and/or with faults of large measures, shear zones, solution cavities, irregular erosion and weathering (oxidation) features, partings and bifurcations, igneous intrusives, facies changes, etc.

Geological Axis

G4 (Reconnaissance)	G3 (Prospecting)	G2 (General exploration)	G1 (Detailed exploration)
1. **Aerial reconnaissance**: Remote sensing, airborne geophysical survey etc. 2. **Geological survey**: Mapping on 1:50,000 or smaller scales 3. **Geochemical survey**: (i) Grab/chip sampling of rocks or weathered profiles (Nil for coal/ligniteexploration; (ii) Recording of broad geomorphology, drainage, etc. 4. **Geophysical survey**: Ground geophysical survey 5. **Technological survey**: (i) Trenching – One or two to expose mineralized Zone at ideal locations only; (ii) Pitting/drilling – Up to 5 test pits/boreholes per 100 sq.km. area; (iii) Scout drilling – A few to know the existence of coal/lignite; (iv) Sampling – Regional and random grab/chip sampling 6. **Petrographic and mineragraphic studies**: Determination of principal rock types, mineral assemblage, identification of minerals of interest (especially of metallic minerals and gangues) 7. Synthesis of all available data/concepts 8. the activities as above or less than that required for G3	1. **Geological survey**: (i) Mapping on 1:50,000 to 1:25,000 scale (for coal, lignite exploration – mapping on 1:10,000) (ii) Linking of maps so prepared with topogrids; (iii) Assessment of detailed statigraphy, lithology, structure, surface mineralization, analysis of old history of mining 2. **Geochemical survey**: Grid geochemical sampling, rock type wise and if necessary, soil-domain-wise (for all metallic mineral exploration) 3. **Geophysical survey**: Detailed ground geophysical work 4. **Technological survey**: (i) Pitting/trenching/drilling depending on variability; (ii) Selection of drilling sties best suited to unravel the lithological/structural complexities 5. **Petrographic/ mineragraphic studies**: (i) Petrographic study of rocks of the deposit and its surroundings, alterations (if any) connected with mineralization; (ii) Determination of phase in which mineral of interest occur; (iii) Mineralogical studies including paragenesis,	1. **Geological survey**: (i) Mapping on 1:25,000 to 1:1,000 or larger scale with triangulation points, benchmarks, if any shown. For coal, mapping on 1:10,000 scale (ii) Linking of maps so prepared with topogrid; 2. **Geochemical survey**: (i) Detailed litho-geochemical channel sampling from fresh rock exposures, trenches, pits; (ii) Recording of deleterious elements, likely by-product elements (e.g Ga in bauxite, Ni, PGE etc. in chromite, Au in Fe ore, etc. (Nil for coal/lignite exploration); 3. **Geophysical survey**: (i) Borehold geophysical survey; (ii) Special geophysical traverses for problem solving, if required; (iii) Concurrent synthesis of multidisciplinary data. Bore-hole geophysical logging, if possible 4. **Technological survey**: (i) Pitting/trenching: Pitting/trenching for helping surface and subsurface correlation of mineralized zones; (ii) Drilling: close spaced at 200 x 200m grid to decipher the ore-shoot behaviour atleast at two level. In general, spacing of probe	1. **Geological survey**: (i) Mapping a) Coal -1:5000 s b) For other minerals 1: 1000 or larger scale; (ii) Preparation of detailed topographical-cum- geological map including all surface geological features, extent of deposit, structure, location of boreholes, assay plan and sections of exploratory mine development and borehold data; 2. **Geochemical survey**: Detailed lithogeochemical analysis 3. **Geophysical survey**: Detailed borehold geophysical survey 4. **Technological**: (i) Pitting – 3 to 5 nos. for every mass body or at 100 - 200 meter grid interval; (ii) Trenching – At spacing of 50-200 meters; (iii) Drilling – closer spaced than that for G2 at 3-4 levels down to a workable depth; (iv) Sampling–Core and sludge, pits samples for grade analysis or beneficiation, bulk samples for laboratory scale/pilot plant investigation (v) Collection of abiotic geo-environmental data – its further refining and analysis 5. **Petrographic**: Study of petrographic character of rock and study of useful minerals

	identification of zones of oxidation and primary zones, grain size distribution, overall characteristics of useful minerals	points along strike may be 100 m but in specific cases depending on the necessity it may be brought down to 50 m. especially for precious metals. A few probe points for deeper intersections; (iii) Detailed core sampling, bulk sampling for testing of processing technology; (iv) Collection of abiotic geo-environmental parameters 5. **Petrographic**: Refining of data on the petrographic character of rocks including study of grain size, texture and liberation characteristics	6) **Geostatistical analysis** of borehold data, thickness of ore: Waste encountered in holes, assay values of samples if considered necessary

Feasibility Axis

F3 (Geological study)	F2 (Pre-feasibility study)	F1 (Feasibility study)
1. **Geological and related study:** (i) Reconnaissance prospecting by geochemical, geophysical scout drilling to understand controls of mineralisations/general and detailed exploration; (ii) Geological maps showing extent and persistence of mineralisations; guides, controls, hostrock, lithology, etc.; (iii) Infrastructure; (iv) Preliminary ecological and meteorological data, if possible 2. The activities as above or less than that required for F 2.	1. **Geology:** (i) Geology of area; (ii) General and detailed exploration guided by surface and sub-surface geochemical and geophysical data, exploratory mining details 2. **Mining:** Mine recoveries estimates, man power details, pre-production plan 3. **Environment:** Baseline data, potential constraints on project 4. **Processing:** Proven laboratory scale/pilot scale investigations on bulk samples; likely establishment of plant; possibilities of cost estimates 5. **Infrastructure, construction services etc.:** brief details 6. **Costing:** Capital and operating cost – rough estimates based on comparable mining operations 7. **Marketing:** An overview, demand and supply relations, industry structure, pricing, etc. 8. **Economic viability:** Preliminary study of cash flow forecasts 9. **Other factors:** Statutory provisions relating to land, labour, mining, taxation, etc.	1. **Geology:** Geology of project, detailed exploration with larger inputs of exploratory mining, deep pitting, trenching/benching, underground boreholes, closed spaced drilling 2. **Mining:** Mining plan, meticulous methods with special emphasis on geotechnical, production aspects; safety measures, mine recoveries, efficiency variability due to various controls 3. **Environment:** EIA/EMP including socio-economic impact, rehabilitation of project affected persons, waste disposal/reclamation, detailed land use data 4. **Processing:** Proven details of pilot plant scale investigation, appended with layout, plant design, manpower requirements, fuel/power consumption, disposal effluents and present/future remedial measures 5. **Infrastructure, construction, and service**: Full details 6. **Costing**: Detailed break-up of capital cost and operating cost and details of working capital 7. **Marketing**: An overview, specific market aspects 8. **Economic viability**: Cash flow forecast, inflation effects, sensitivity studies 9. **Other factors:** Statutory provisions relating to land, labour, mining, taxation, etc.

Economic Axis

E3 (Intrinsically economic)	E2 (Potentially economic)	E1 (Economic)
1. Reconnaissance to detailed geological study, rough estimates of grades (may be below economic cut-off), general idea about forest/non-forest and land use status 2. The activities as above or less than that required for E 2.	1. General and detailed exploration 2. Specific end-use grades of reserves (above/marginally below economic cut-off grade) 3. General knowledge of forest/non-forest and other land use data	1. Detailed exploration 2. Mining report/mining plan/working mines 3. Specific end-use grades of reserves (above economic cut-off grade) 4. Specific knowledge of forest/non-forest and other land use data

Annexure 2 Availability of coking and non-coking coal in Madhya Pradesh and West Bengal

Table 1 Field wise inventory of Geological Reserves of Coal in Madhya Pradesh (As on 01.01.2003)

Field	Type of coal	Depth (metre)	Reserve (Million. tonnes			
			Proved	Indicated	Inferred	Total
Johilla	Non coking	0-300	185.08	104.09	32.83	322
Umaria	Non coking	0-300	177.7	3.59	0	181.29
Pench-Kanhan	Medium coking	0-300	67.54	263.11	16.41	347.06
	Medium coking	300-600	40.29	127.87	142.17	310.33
	Non coking	0-300	1057.31	161.72	35.8	1254.83
	Non coking	300-600	210.84	165.82	122.4	499.06
	Total		1375.98	718.52	316.78	2411.28
Pathakhera	Non coking	0-300	261.08	24.76	0	285.84
	Non coking	300-600	29.72	0	103	132.72
	Total		290.8	24.76	103	418.56
Gurgunda	Non coking	0-300	0	47.39	0	47.39
Mohpani	Non coking	0-300	7.83	0	0	7.83
Sohagpur	Medium coking	0-300	184.57	211.38	2.01	397.96
	Medium coking	300-600	62.09	866.78	90.54	1019.41
	Medium coking	600-1200	0	81.94	21.7	103.64
	Non coking	0-300	1190.48	828.19	56.62	2074.29
	Non coking	300-600	1.27	149.56	12.28	163.11
	Total		1438.41	2137.85	182.15	3758.41
Singrauli	Non coking	0-300	3554.81	1769.68	1604.12	6928.61
	Non coking	300-600	69.65	3057.39	978.02	4105.06
	Non coking	600-1200	0	24.99	0	24.99
	Total		3624.46	4852.06	2582.14	11058.66
Total	*Medium coking*	*0-1200*	*354.49*	*1551.08*	*272.83*	*2178.4*
total	*Non coking*	*0-1200*	*6745.77*	*6337.18*	*2944.07*	*16027.02*
Total	***All***	***0-1200***	***7100.26***	***7888.26***	***3216.9***	***18205.42***

SOURCE MoCM (2004)

Table 2 Grade-wise resource of non-coking coal in Madhya Pradesh (As on 01-01-2003)

Depth Range	Proved						Indicated							
	Gr A	Gr B	Gr C	Gr D	Gr EFG	Total	Gr A	Gr B	Gr C	Gr D	Gr E FG	Total	Inferred	Grand Total
Johilla														
0-300	0.31	36.17	70.29	44.33	33.98	185.08	0	32.52	32.59	17.25	21.73	104.09	32.83	322
Umaria														
0-300	0.5	11.63	39.02	59.69	66.86	177.7	0.11	0.49	1.02	1.36	0.61	3.59	0	181.29
Pench Kanhan														
0-300	53.48	149.68	281.66	269.49	303	1057.31	2.96	19.9	44.54	63.79	30.53	161.72	35.80	1254.83
300-600	17.45	40.91	60.59	59.38	32.51	210.84	3.84	63.13	72.45	6.57	19.83	165.82	122.40	499.06
0-600	70.93	190.59	342.25	328.87	335.51	1268.15	6.8	83.03	116.99	70.36	50.36	327.54	158.20	1753.89
Pathakhera														
0-300	1.08	13.12	63.51	87.45	95.92	261.08	0	2.76	4.36	5.75	11.89	24.76	0	285.84
300-600	0	0.22	4.73	13.63	11.14	29.72	0	0	0	0	0	0	103.00	132.72
0-600	1.08	13.34	68.24	101.08	107.06	290.8	0	2.76	4.36	5.75	11.89	24.76	103.00	418.56
Gurgunda														
0-300	0	0	0	0	0	0	0	0	0	0	47.39	47.39	0	47.39
Mohpani														
0-300	0	0	0	0	7.83	7.83	0	0	0	0	0	0	0	7.83
Sohagpur														
0-300	109.79	207.21	344.08	276.73	252.67	1190.48	41.9	169.58	299.31	158.33	159.07	828.19	55.62	2074.29
300-600	0	0	0.4	0.27	0.6	1.27	11.08	56.45	53.95	13.87	14.21	149.56	12.28	163.11
0-600	109.79	207.21	344.48	277	253.27	1191.75	52.98	226.03	353.26	172.2	173.28	977.75	67.9	2237.4
Singrauli														
0-300	0	0.23	513.06	712.28	2329.24	3554.81	19.45	97.8	774.48	336.03	541.92	1769.68	1604.12	6928.61
300-600	0	0	0.03	2.52	67.1	69.65	21.7	277.21	577.2	1120.62	1060.66	3057.39	978.02	4105.06
600-1200	0	0	0	0	0	0	0	7.81	4.97	4.92	7.29	24.99	0	24.99
0-1200	0	0.23	513.09	714.8	2396.34	3624.46	41.15	382.82	1356.65	1461.57	1609.87	4852.06	2582.14	11058.66
Total	**182.61**	**459.17**	**1377.37**	**1525.77**	**3200.85**	**6745.77**	**101.04**	**727.65**	**1864.87**	**1728.49**	**1915.13**	**6337.18**	**2944.07**	**16027.02**

SOURCE MoCM (2004)

Table 3 Field wise inventory of Geological Reserves of Coal in West Bengal (As on 01.01.2003)

Field	Type of coal	Depth (metre)	Reserve (Mill. Tonees			
			Proved	Indicated	Inferred	Total
Raniganj	Medium coking	0-300	194.70	1.60	0	196.30
	Medium coking	300-600	15.30	16.90	0	32.20
	Semi coking	0-300	45.75	14.19	0	59.94
	Semi coking	300-600	109.51	113.23	23.48	246.22
	Semi coking	600-1200	32.79	305.07	144.75	482.61
	Non coking	0-300	9083.98	2249.43	228.63	11562.04
	Non coking	300-600	1597.08	3413.17	1860.89	6871.14
	Non coking	600-1200	13.22	1829.23	1655.76	3498.21
	Total		11092.33	7942.82	3913.51	22948.66
Barjora	Non coking	0-300	114.27	0		114.27
Birbhum	Non coking	0-300	0	331.75	39.43	371.18
	Non coking	300-600	0	2372.43	464.51	2836.94
	Non coking	600-1200	0	923.12	42.80	965.92
	Total		0	3627.3	546.74	4174.04
Darjeeling	Non coking	0-300	0	0	15	15
Total	*Medium coking*	*0-1200*	*210*	*18.50*	*0*	*228.50*
Total	*Semi coking*	*0-1200*	*188.05*	*432.49*	*168.23*	*788.77*
Total	*Non coking*	*0-1200*	*10808.55*	*11119.13*	*4307.02*	*26234.7*
Total	***All***	***0-1200***	***11206.6***	***11570.12***	***4475.25***	***27251.97***

SOURCE MoCM (2004)

Table 4 Grade-wise resource of non-coking coal in West Bengal (As on 01-01-2003)

Depth Range			Proved						Indicated					
	Gr A	**Gr B**	**Gr C**	**Gr D**	**Gr EFG**	**Total**	**Gr A**	**Gr B**	**Gr C**	**Gr D**	**Gr E FG**	**Total**	**Inferred**	**Grand Total**
Raniganj														
0-300	109-98	1503.16	3276.3	2528.63	1665.91	9083.98	37.1	251.39	752.3	617.57	591.07	2249.43	228.63	11562.04
300-600	48.32	529.37	400.43	272.05	346.91	1597.08	105.78	775.28	1326.38	665.02	540.71	3413.17	1860.89	6871.14
600-1200	0	9.45	0.9	1.3	1.57	13.22	156.63	390.83	554.69	393.42	333.66	1829.23	1655.76	3498.21
0-1200	158.3	2041.98	3677.63	2801.98	2014.39	10694.28	299.51	1417.5	2633.37	1676.01	1465.44	7491.83	3745.28	21931.39
Barjora														
0-300	0	0	0	0	114.27	11427	0	0	0	0	0	0	0	114.27
Darjeeling														
0-300	0	0	0	0	0	0	0	0	0	0	0	0	15	15
Birbhum														
0-300	0	0	0	0	0	0	0	0	0.97	25.42	305.36	331.75	39.43	371.18
300-600	0	0	0	0	0	0	0	27.29	732.36	368.32	1244.46	2372.43	464.51	2836.94
600-1200	0	0	0	0	0	0	0	18.6	288.03	361.12	255.37	923.12	42.8	965.92
0-1200	0	0	0	0	0	0	0	45.89	1021.36	754.86	1805.19	3627.3	546.74	4174.04
Total	**158.3**	**2041.98**	**3677.63**	**2801.98**	**2128.66**	**10808.55**	**299.51**	**1463.39**	**3654.73**	**2430.87**	**3270.63**	**11119.13**	**4307.02**	**26234.7**

SOURCE MoCM (2004)

CHAPTER 5 Valuation of mineral resources

The system of national accounts (SNA) recommends the use of market prices for valuing assets. This is possible in the case of produced assets and land. In many countries, including India, major sub-soil deposits are the property of the government and not sold. When market prices do not exist, one of the alternatives is to estimate the value of the asset as being equal to the value of future income streams to be provided by the asset discounted to the present period.

Related to the value of an asset is the decline in its value overtime. For produced assets, this decline is measured in SNA as the consumption of fixed capital, being the difference between net and gross capital formation. Income is defined classically as the amount, which can be spent in a period while remaining as well off at the end of the period as at the beginning. The depreciation allowance ensures that the run down of fixed capital is taken into account while calculating income according to this definition.

In the past, natural resources have been regarded as free gifts of nature available in abundance, their depletion or depreciation not being a concern. The 1993 SNA recognized this anomaly. It defined assets as an entity (1) over which rights are enforced by institutional units, individually or collectively, and (2) from which economic benefits may be derived by the owners from holding them or using them over a period of time. This definition was wide enough to bring within its fold several environmental assets including mineral deposits and land, cultivated biological stocks and some non-cultivated biological stocks such as fish stocks and natural forests. However resources like remote land or unprofitable mineral stocks are left out from this definition. The SEEA expands the scope of asset definition to include all environmental assets that are of interest and measurable. Implementation of the SEEA can be expected to take a long time since many countries including India have yet to integrate the limited environmental asset base as proposed in the 1993 SNA.

Having discussed the coal mineral assets in physical terms in the previous chapter, this chapter discusses how these assets and their depreciation can be valued and integrated in the SNA[1].

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[1] Since data was not available for 2002/03, the monetary analysis is only upto the year 2001/02. However, analysis for 1999/2000 has been included to provide a longer time series.

Valuing mineral assets: conceptual issues

The estimation of this economic depreciation and the value of changes in stock has been dealt with in empirical studies largely by using three methods 1) Net Present Value method 2) User Cost method or the El Serafy approach or 3) Net Price Method.

The Net present value is based on the opportunity cost principle – economic assets will be acquired and put to a particular use in production, assuming rational behaviour, if their discounted expected net returns exceed the discounted returns from any other investment option available.

The n et price method is a simplified version of the NPV method in which thevalue of a resource at the beginning of a period is estimated as the volume of the proven reserve times the difference between the average market value per unit of the resource and the per unit cost of extraction, development and exploration (including a normal rate of return on invested produced capital). In the case of non -renewable resources, this stock comprises only the 'proven reserves that are exploitable under present economic conditions, and therefore have a positive net price' (Bartelmus et al. 2001). The net price method is based on the Hotelling rent assumption i.e. in a perfectly competitive market the net price of a natural resource rises at the rate of interest of alternative investment, offsetting the discount rate.

However, El Serafy suggests that total resource rent cannot be deducted from GDP, acknowledging the fact that a resource rich country h as a real income advantage in comparison with a resource poor country. A portion of the resource rent should be counted as value added, the reward for human effort. The idea is to convert a time-bound stream of (net) revenues from the sales of an exhaustib le natural resource into a permanent income stream by investing a part of the revenue, that is, the 'user cost' allowance over the lifetime of the resource. Only the remaining amount of revenues should be considered 'true income' (El Serafy as cited Bartelmus et al. 2001).

The main attraction of the El Serafy approach is that it is easier to compute. All that is required are the estimates of the receipts per period, the rate of interest and the life of the asset. In practice, some of these estimates can be tricky. Moreover it is assumed that the net receipts are constant over time, which is highly restrictive, and in many cases unrealistic.

This study uses the net present value (NPV) method for the estimation of the value of mineral assets, as recommended by SEEA. The user cost approach is used to adjust value added by the mining sector for the cost of depletion.

Net present value method for estimating the value of minerals

Broadly speaking, there are three steps in the NPV estimation. The first step requires the estimation of resource rent in the current period. This then needs to be projected into the future. Finally, the set of future resource rents must be discounted to a value in the present period. These steps are elaborated in the following sections.

Estimating resource rent

Resource rent can be estimated by factoring out an estimate of the return to produced capital (i.e. that element of the economic rent that represents the return to produced or man-made capital) from the net operating surplus. The return to produced capital can be estimated by applying an appropriate rate of interest to the stock of produced capital. The steps in estimating the resource rent are shown in Figure 1.

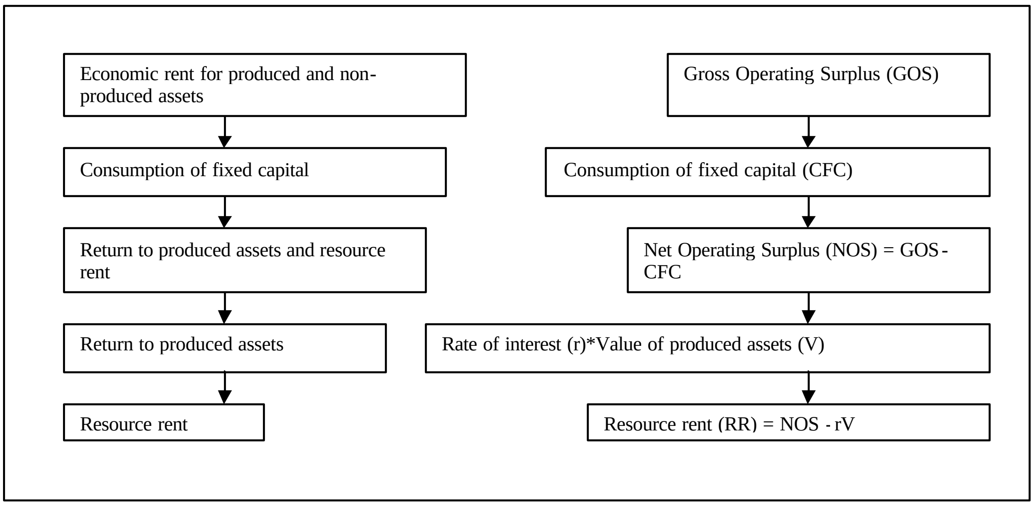

Figure **1** Derivation of resource rent
SOURCE UN, EC, IMF, OECD, WB (2003)

Assessing the value of the asset

Once the unit resource rent has been estimated, the value of the resource can be estimated as the discounted net present value of the future stream of rents that the resource will yield until it is exhausted. The resource value is thus a function of the unit resource rent, the years the resource is expected to last until exhaustion and the rate of discount. Assuming that the rate of extraction remains constant, the value of the resource rent in constant price terms can be written as follows:

$$RV = RR\sum_{K=1}^{n}\frac{1}{(1+r)^{k}} = RR\left[\frac{(1+r)^{n}-1}{r(1+r)^{n}}\right]$$

Where
RV: Value of the resource;
RR: Resource Rent;
n: life of the deposit in years. This in turn can be expressed as S/E where S is the stock of the resource in physical terms and E, the annual rate of extraction, assumed to remain constant; and r the rate of discount.

Valuing mineral assets: application to coal resources of Madhya Pradesh and West Bengal

Each of the factors required for estimating the asset value, along with corresponding data issues in the study states of Madhya Pradesh and West Bengal, a re discussed in this section.

Approach, assumptions and data sources

Resource rent

Resource rent is estimated as a residual of GOS (gross operating surplus) after adjusting for consumption of fixed capital and return to produced capital. GOS was estimated as the residue in gross value of output after adjusting for value of intermediate consumption and compensation of employees. Two scenarios were worked out based on the alternative sources of data as explained below.

Gross value of coal output
In current and constant (1993/94) prices was available from the statistics departments of the two states[2].

Value of intermediate consumption
Two scenarios were worked out:

- Option I: Intermediate consumption estimated as % share in the value of total output as available from the Central Statistical Organization, Ministry of Statistics and Programme Implementation.
- Option II: Intermediate consumption (IC) estimated from company wise data on intermediate consumption. IC per tonne for each state was estimated as the weighted average of per tonne IC of companies operating in the

[2] Bureau of Applied Economics and Statistics (BAES), in West Bengal, and the Directorate of Economics and Statistics in Madhya Pradesh

state, using production as weights. Aggregate IC was estimated as the product of weighted p er tonne IC and total production of coal in the state.

Company wise IC per tonne was estimated as follows. First, company wise aggregate intermediate consumption was estimated from the company accounts of all major coal companies in India. Cost categorie s included under IC are energy purchase, insurance, godown rent/lease rental, royalty (other than natural resources), repair and maintenance (of buildings, other construction, plant and machinery, and others), transport charges, and other intermediate consumption. IC per tonne was estimated using company wise production data (from the annual Coal Directory, Coal India). This was converted into constant price series using 'All India Mining and Quarrying" price deflator (estimated from all India GDP series by economic activity in current and constant prices).

Compensation of employees

CoE (compensation of employees) was estimated in a way similar to Option II for estimating IC. Company wise compensation of employees per tonne was estimated from the books of accounts and production data. This was converted into a constant price series using all India mining and quarrying price deflator . Per tonne compensation of employees in the state was estimated as the weighted average of CoE in companies operating in it. Finally, aggregate compensation was derived by multiplying weighted per tonne cost by the aggregate coal production in the state.

Consumption of fixed capital

Two options were worked out as follows:

- Option I: Consumption of fixed capital (CFC) estimated as % share in the value of total output as available from CSO.
- Option II: CFC estimated using all India CFC data for the mining sector as calculated by CSO. This is explained below.

For the purpose of calculating national income aggregates, CSO calculates the 'consumption of fixed capital' for each industry at the national level. The method followed in India to calculate capital stock and depreciation is the PIM (perpetual inventory model) approach. The method entails accumulating past capital formation and deducting the value of assets that have reached the end of their service life. The approach is outlined in Appendix 1. All India CFC in current prices for the mining sector is available from CSO. This was apportioned across states depending on the sh are of the states' mining sector in the national mining sector. All India income for 'mining and quarrying' sector was obtained from CSO under current and constant prices. Corresponding values for the study states under current and constant prices was also available from CSO.

Finally CFC for the coal sector was obtained by multiplying the total mining CFC for the state by the percentage share of the value of coal production in the value of total mining production in the state.

CFC estimates turn out to be much higher in Option II. As a share of the value of output, CFC ranged from 10-13% in MP to 29-31% in WB in Option II as against the 9.35% norm in Option I.

Value of produced capital

The value of produced capital in the mining and quarrying sector of the states of West Bengal and Madhya Pradesh was estimated similar to the estimation of CFC as explained above. At the all India level, the Net Fixed Capital Stock by industry is estimated by CSO in current and constant prices, following the PIM approach. The NFCS is obtained in a similar fashion as that of CFC.

SEEA provides three alternatives on the choice of the rate of interest needed to estimate the return to the capital stock. The first approach is to use the rate of return in the specific industry i. e. by the ratio of the net operating surplus and the capital stock employed in that industry. The second approach is to use the rate that covers the cost of financing the acquisition of the produced capital stock i.e. by using the interest rate on bonds issued by the resource companies. Finally, the rate may be interpreted as the opportunity cost of investment in the produced capital stock i.e. average real rate if return on investment elsewhere in the economy, usually estimated from long term government bond rates.

It was planned that a sensitivity analysis could be attempted with various rates of discount. However, as will be discussed later, even at the lowest rates of discount, the resource rent in West Bengal was negative. Thus a low rate of 3% was chosen to demonstrate the methodology.

NPV of resource rent

Life of the resource

The life of the resource is estimated as the reserve (including new discoveries) to production ratio. In other words, the life of the resource each year may be calculated as t he existing stock less production level plus fresh discoveries divided by the volume extracted. The SEEA recommends the use of proven reserves or proven and probable taken together if the former is not available. Given the difference in classification in India and that estimates of proved reserves are available; these were used for the analysis. This data is available from the Coal Controller's Office and is published in an annual Coal Directory of India. Data on production was also sourced from the Coal Directory of India.

A case was also worked out with 'mineable proved' reserves instead of proved resources. This is discussed in a separate section later in the chapter.

Rate of discount

The rate of discount expresses a time preference for income today rather than in the future. This will depend on the ownership of the asset. In general, individuals and businesses will have higher rates of time preference than governments. It is argued that a social rate of discount, closer to zero, better takes into account inter-generational equity and should be used to derive the net present value. In this analysis, a sensitivity analysis was undertaken with two rates of discount - 3% and 6%.

Findings and analysis

The resource rent was estimated for both states using the above methodology. This is discussed in the following sections.

Madhya Pradesh

Tables 1 and 2 below show the detailed calculation of the resource rent for the state of Madhya Pradesh under both the options. IN both options, the resource rent is first found to decrease under current and constant prices and then increases. The higher resource rent in Option 1 is on account of the lower depreciation allowance.

The fluctuation in the value of resource rent in current prices is due to the erratic behavior of the value of coal and compensation of employees. It can be seen that the gross value of output declined and then increased while compensation to the employees behaved in the opposite direction.

Table 1 Asset accounts for Madhya Pradesh under Option I

			Current prices (Rs/tonne)			Constant (1993/94) prices (Rs/tonne)		
			1999/2000	2000/01	2001/02	1999/2000	2000/01	2001/02
i	Gross value of coal output		679.12	609.90	718.02	386.07	386.07	386.07
ii	Gross value added	Assuming intermediate consumption at 24.68% of value of output	503.36	459.37	540.81	286.16	290.79	290.79
iii	Compensation of employees		159.04	223.02	178.71	105.02	137.15	106.68
iv	Gross operating surplus	ii-iii	344.32	236.36	362.10	181.14	153.64	184.11
v	Net operating surplus	Assuming consumption of fixed capital at 9.35% of value of output	280.82	179.33	294.96	145.04	117.54	148.01
vi	Net fixed capital stock		1667.35	1420.37	1628.70	788.94	813.97	754.32
vii	Return to produced capital	3%*vi	50.02	42.61	48.86	23.67	24.42	22.63
viii	Resource rent	v-vii	**230.80**	**136.72**	**246.10**	**121.37**	**93.12**	**125.38**
ix	Resource life (in years)	Based on the reserve to production ratio	151.16	155.08	154.35	151.16	155.08	154.35
x	Net present value (6%)	At 6% rate of discount	3846.07	2278.39	4101.18	2022.57	1551.85	2089.42
xi	Net present value (3%)	At 3% rate of discount	7605.06	4510.78	8117.76	3999.36	3072.37	4135.73

Table 2 Asset accounts for Madhya Pradesh under Option II

			Current prices (Rs/tonne)			Constant (1993/94) prices (Rs/tonne)		
			1999-2000	2000-2001	2001-2002	1999-2000	2000-2001	2001-2002
i	Gross value of coal output		679.12	609.90	718.02	386.07	386.07	386.07
ii	Gross value added		432.53	381.75	466.13	223.25	245.77	235.71
iii	Compensation of employees		159.04	223.02	178.71	105.02	137.15	106.68
iv	Gross operating surplus	ii-iii	273.48	158.73	287.42	118.23	108.62	129.03
v	Net operating surplus		157.65	58.47	171.55	59.46	46.69	71.56
vi	Net fixed capital stock		1667.35	1420.37	1628.70	788.94	813.97	754.32
vii	Return to produced capital	3%*vi	50.02	42.61	48.86	23.67	24.42	22.63
viii	Resource rent	v-vii	**107.63**	**15.85**	**122.69**	**35.79**	**22.28**	**48.93**
ix	Resource life (in years)	Based on the reserve to production ratio	151.16	155.08	154.35	151.16	155.08	154.35
x	Net present value (6%)	At 6% rate of discount	1793.60	264.21	2044.56	596.42	371.21	815.35
xi	Net present value (3%)	At 3% rate of discount	3546.59	523.09	4046.93	1179.33	734.93	1613.89

West Bengal

Resource rent estimates for West Bengal from 1999 - 2000 to 2001-02 under both the options are provided in the following tables.

Table 3 Asset accounts for West Bengal under Option I

			Current prices (Rs/tonne)			Constant (1993/94) prices (Rs/tonne)		
			1999-2000	2000-2001	2001-2002	1999-2000	2000-2001	2001-2002
i	Gross value of coal output		1029.83	1098.88	1172.28	712.19	712.19	712.09
ii	Gross value added	Assuming intermediate consumption at 24.68% of value of output	775.66	827.68	882.96	536.42	536.42	536.35
iii	Compensation of employees		657.90	811.53	722.15	434.42	499.07	431.08
iv	Gross operating surplus	ii-iii	117.75	16.14	160.81	102.01	37.35	105.27
v	Net operating surplus		21.47	-86.60	51.20	35.42	-29.24	38.69
vi	Net fixed capital stock		1704.03	2281.53	2465.40	1129.29	1133.53	1101.30
vii	Return to produced capital	3%*vi	51.12	68.44	73.96	33.88	34.01	33.04
viii	Resource rent	v-vii	**-29.65**	**-155.04**	**-22.75**	**1.54**	**-63.24**	**5.65**
ix	Resource life (in years)	Based on the reserve to production ratio	598.42	538.76	517.85	598.42	538.76	517.85
x	Net present value (6%)	At 6% rate of discount	-494.18	-2584.11	-379.27	25.61	-1054.06	94.20
xi	Net present value (3%)	At 3% rate of discount	-988.36	-516822	-758.54	51.22	-2108.12	188.41

Table 4 Asset accounts for West Bengal under Option II

			Current prices (Rs/tonne)			Constant (1993/94) prices (Rs/tonne)		
			1999-2000	2000-2001	2001-2002	1999-2000	2000-2001	2001-2002
i	Gross value of coal output		1029.83	1098.89	1172.29	712.19	712.19	712.09
ii	Gross value added		719.77	855.86	883.99	507.46	562.74	540.00
iii	Compensation of employees		657.91	811.54	722.15	434.42	499.07	431.08
iv	Gross operating surplus	ii-iii	61.86	44.32	161.84	73.04	63.67	108.9 2
v	Net operating surplus		-56.52	-116.73	-13.55	-11.09	-22.57	25.01
vi	Net fixed capital stock		1704.03	2281.53	2465.41	1129.29	1133.53	1101.30
vii	Return to produced capital	3%*vi	51.12	68.45	73.96	33.88	34.01	33.04
viii	Resource rent	v-vii	**-107.64**	**-185.18**	**-87.51**	**-44.96**	**-56.57**	**-8.03**
ix	Resource life (in years)	Based on the reserve to production ratio	598.42	538.76	517.85	598.42	538.76	517.85
x	Net present value (6%)	At 6% rate of discount	-1794.00	-3086.29	-1458.56	-749.41	-942.87	-133.79
xi	Net present value (3%)	At 3% rate of discount	-3588.00	-6172.57	-2917.13	-1498.82	-1885.75	-267.57

The striking feature of the above analysis (for West Bengal) is the existence of negative resource rents for most years. The negative rents are higher in absolute terms in Option 2 as compared to Option 1, due to the higher values of CFC in the second option as discussed earlier.

In theory, resource rent could be negative for several reasons. First, where prices are determined based on international prices, negative rent may be explained by the fluctuations in international prices while costs (which are locally determined) remain relatively constant. This, however, cannot explain negative resource rent in India where prices are determined within the country as explained in chapter 1. It is more likely that in this case negative resource rent could result from the peculiarities of the industry structure. In India development of coal resources comes under the public sector and many units, that are uneconomic, continue to operate out of political compulsions. This is particularly true for West Bengal. The largest coal producer in the state, producing over 80% of the coal is a heavy loss maker, as reflected in a negative operating surplus in the last few years.

It is interesting to note that the output per man shift for underground mines (which make up for 43% of the total coal production in the state) is lowest for the state of West Bengal, (Table 5). Output in terms of raw coal raised in tonnes, per man per shift (OMS) is treated as a measure of man productivity.

Table 5 Coal produced in tonnes per man per shift

State	*Average OMS (underground) in tonnes*	*Average OMS (opencast) in tonnes*
West Bengal	0.425	7.695
Jharkhand	0.672	3.239
Madhya Pradesh	0.921	5.363
Chattisgarh	1.069	8.971
Maharastra	0.794	4.545
Andhra Pradesh	0.822	8.248
Orrissa	0.764	16.026

SOURCE MoCM (2004)

OMS for the open cast mines in West Bengal is comparable to other states. The average value for open cast mines in West Bengal is high because the mines are relatively new and highly mechanized.

As a result of the lower productivity in underground mines, the compensation to employees per tonne of coal produced is highest for ECL compared to other companies (Table 6).

Table 6 Compensation of employees in 2001/02

Company	*Estimated compensation of employees (Rs/tonne)*
Bharat Coking Coal Ltd.	779.39
Northern Coalfields Ltd.	110.12
Central Coalfields Ltd.	398.27
Eastern Coalfields Ltd.	795.18
South Eastern Coalfields Ltd.	229.12
Western Coalfields Ltd.	371.90
Singareni Coalfields Ltd.	484.92
Mahanadi Coalfields Ltd.	79.08

Compensation of employees, as a share of estimated total production costs is as high as 88% in WB, as compared to59% in MP. Thus, lower productivity undermines the true value of the resources in the state.

In order to get a better estimate of the shadow price or resource rent of coal in WB, it is necessary to work out an efficient level of compensation of employees. In order to do so, an attempt is made to estimate the production efficiencies of inputs of individual underground mines compared to a notional efficiency frontier, using the theory of the input distance function. The method is explained in detail below.

Input distance function for estimating the shadow price of inputs

A firm's production technology could be modeled in different ways: the production function, profit function or the cost function. Then Hotelling's Theorem and Shephard's Lemma allow one to derive compatible input shadow prices, demands and output offers with optimisation behaviour from the inpu t distance function. The input distance function completely describes multiple output technology and is dual to the cost function.

The input distance function has the obvious advantage over production functions in allowing for the possibility of multiple outputs and joint production. One advantage of the input distance function over the cost function is that no information on input prices is required, nor is the maintained hypothesis of cost minimisation required. In fact, no specific behaviour goal is embedded in the input distance function. Moreover, the distance functions allow one to calculate the shadow prices of the inputs, as the observed prices of inputs in the developing countries are not market clearing prices. Kumar (2004) has carried out a very g ood application of this method for calculating the technical efficiencies of intensive water using manufacturing units as well as the shadow prices of water. In our analysis we will be using the input distance function technique to calculate the technical efficiencies of the mines in the West Bengal. We will also calculate the efficient wage level per tonne of production and the return to scale of the individual mines. In the next section a brief theoretical description of the model is given.

Economic model

Let us consider a firm employs a vector of inputs x e $\Re^{N+}$ to produce a vector of outputs y e $\Re^{M+}$, $\Re^{N+}$, $\Re^{M+}$ are non - negative N - and M-dimensional Euclidean spaces, respectively. Let P (x) be the feasible output set for the given input vector x and L (y) is the input requirement set for a given output vector y. Now the technology set is defined as

$$T = \{(y, x) \in \Re^{M+N} + y \in P(x)\} \text{.................................} (1)$$

The conventional production function defines the maximum output that can be produced from an exogenously given input vector, while the cost function defines the minimum cost to produce the exogenously given output. The output and input distance functions generalise these notions to a multi -output case. The input distance function describes "how far" an ***input*** vector is from the boundary of the representative input set, given the fixed output vector. Formally, the input distance function is defined as

$$D(y, x) = \min [\lambda : (\mathbf{x} / \lambda, \mathbf{y}) \in T\} \text{..................}(2)$$

Equation (2) characterises the input possibility set by the maximum equi-proportional contraction of all inputs consistent with the technology set (1). The input distance functions can be used to measure the Debreu -Farrell technical efficiency. The input distance function is

- homogeneous of degree one in inputs,
- concave in inputs,
- convex in outputs
- nondecreasing in inputs

It is dual to the cost function. The distance functions can be computed either non -parametrically using the Data Envelope Analysis (DEA) or parametrically. Here we adopt the parametric approach for the computation of distance functions, the advantage of this approach is that it is differentiable. We employ the translog form of input distance function that is twice differentiable and flexible. The form is given by ln D (x, y) = a_0 + S a_m lnx_m S $ß_n$ lny_n + 1/2 S $ß_{nn'}$(lny_n) (ln$y_{n'}$) + 1/2 S a $_{mm'}$ (lnx_m)(ln$x_{m'}$) + S ? $_{nm}$ (lny_n) (lnx_m)..(3)

In the above formulation, symbols 'x' and 'y' represent the input and the output variables. The subscript m represents a particular input and m a particular output.

To compute the parameters of equation (3), we use the linear programming approach developed by Aigner and Chu (1968), that is

$$\text{Min} \quad \sum_{k=1}^{K} \{\ln D_k(x, y) - ln 1\}$$

Subject to

i) $\quad \text{Ln } D_k\ (x, y) \geq 0 \ \ldots\ldots\ k = 1\ldots K$

ii) $\dfrac{d \ln D_k(x, y)}{d \ln yn} \leq 0 \ \ldots\ldots\ n = 1\ldots N$

iii) $\dfrac{d \ln D_k(x, y)}{d \ln xm} \geq 0 \ \ldots\ n = 1\ldots M$

iv) $\displaystyle\sum_{m=1}^{M} a_m = 1$

v) $\displaystyle\sum_{m=1}^{M}\sum_{m'=1}^{M} a_{mm'} = \sum_{n=1}^{N}\sum_{m=1}^{M} g_{mn} = 0$

vi) $\alpha_{mm'} = \alpha_{m'm},\ \beta_{mm'} = \beta_{m'm}$

Where, K denotes the number of observations. The restrictions in (i) ensures that the value of input distance function is greater than or equal to one as the logarithm of this function are restricted to be greater than or equal to zero. Restriction in (ii) enforces the monotonocity condition of non - increasing of input distance function in good outputs, whereas the restriction in (iii) enforces that the input distance function is non -decreasing in inputs. Restriction (iv) and (v) impose the homogeneity and symmetry conditions respectively as required by the theory.

In other words, the input distance function gives an aggregate productive inefficiency factor (of inputs) for each mine relative to a notional efficient frontier. For the purpose of this analysis, this factor has been used to estimate the amount by which the factors of production should be reduced while ensuring that the same level of output is produced. The efficient values of inputs can be obtained by multiplying the productive efficiency factor for each mine with the existing levels of inputs. In this case, the estimation is carried out only for labour in underground mines. This was done since the average OMS of underground mines for the state is lowest when compared with the other states of India (Table 5) while the compensation to the employees is highest. The average OMS for the open cast mines is however comparable with the better performing mines of India (Table 6).

Data

For estimating the parameters of the model, all the underground mines of the state of West Bengal have been considered. Input data has been divided into four major variables, viz. labour, raw material, capital, and others. Raw materials include stores, power and transport. Capital includes interest payment and depreciation. Finally 'Others' include components of administration and other costs. All the variables have the same unit (Rs lakh). Finally the data set belongs to year 2001-2002.

Estimation and results

Using the data set, the model was run in the GAMS (General Algebraic Modeling System) software. The parameter estimates were obtained and using those estimates the input use efficiencies were calculated. The average efficiency for all the underground mines was found to be 74%. This means that on an average the firms can reduce their inputs by 26% in order to maintain the existing level of output. This inefficiency in production can be due to various reasons. Low levels of labour productivity, as compared to other states, can be one of the major factors. Vintages of capital also play an important role. Other factors such as geological conditions could also be important.

The revised or efficient compensation to employees is obtained by multiplying the firm specific efficiency levels with the existing compensation to the employees. The average per tonne CoE for all mines (underground and opencast) in 2001/02 was estimated as the weighted average per tonne CoE using production weights for opencast and underground mines. This wage rate works out at Rs 430 and Rs 256 in current and constant (1993/94) prices. Corresponding values in Option II discussed earlier were Rs 722 and Rs 430 per tonne of coal produced.

Revised resource rent calculation

Using the 'efficient level' of CoE for West Bengal, the value of resource rent was re-estimated. The new results under Option 2 are given in Table 7.

Table 7 Asset accounts for West Bengal under Option II for 2001-02

			Current prices (Rs/tonne	Constant (93/94) prices (Rs/tonne)
i	Gross value of coal output		1172.29	712.09
ii	Gross value added		883.99	540.00
iii	Compensation of employees		430.00	256.37
iv	Gross operating surplus	ii-iii	453.99	283.63
v	Net operating surplus		278.60	199.72
vi	Net fixed capital stock		2465.41	1101.30
vii	Return to produced capital	3%*vi	73.96	33.04
viii	Resource rent	v-vii	**204.64**	**166.68**
ix	Resource life (in years)	Based on the reserve to production ratio	517.85	517.85
x	Net present value (6%)	At 6% rate of discount	3410.63	2777.97
xi	Net prese nt value (3%)	At 3% rate of discount	6821.26	5555.94

With the revised estimates of compensation of employees, the resource rent per tonne comes to about Rs 204 and Rs 166 at current and constant prices respectively as compared to Rs –87 and Rs –8 under option II considered earlier. Thus, the reduction in CoE improves the net operating surplus enough to make the resource rent positive.

Adjusting the mining sector SDP for depletion

The study uses the User Cost method for adjust income from the mining sector for depletion/accretion . As discussed earlier, in the net price method, extraction of the resource is valued at the difference between the market price and unit cost of extraction, development and exploration (including a normal rate of return on invested produced capital). The User Cost (Repetto 1989) method is based on the premise that a part of net receipts from an exhaustible resource should be reinvested to ensure a perpetual stream of income from the resource. The difference between the actual revenue on the basis of the current exploitation rate minus the revenue from a hypothetical extraction rate based on an infinite horizon, comprises the user cost element. The user cost component is given by the following formula.

$R - X = R/(1+r)^{T+1}$

where

R = p - c = unit value of the resource less the costs of extraction, development, and exploration (in each time period)

X= annual income ensured in perpetuity

r= rate of discount

T= life time of the resource

The user cost component was estimated at two discount rates- 6% and 3% (at 0%, the user cost is the same as the cost estimated using the net price method). While 6% approximates the real rate of interest, 3% reflects a higher weight being attached to the interests of future generations.

The depletion component of rent, however, turned out to be negligible as percent of the SDP from the mining sector in both states. Partly, this was due to the life of reported coal reserves on the country, which are expected to last for more than 151 years in MP and over 500 years in WB.

Estimation of user cost with mineable reserves (proved) gave a more realistic picture. In 2001/02 (at constant 1993/94 prices), the user cost component for coal as percentage of mining sector SDP in MP varied from 2.5% (at 6% rate of discount) to over 15% (at 0% rate of discount) (Figure 2). In WB, the share of user cost in mining sector SDP in 2001/02 (using estimates of efficient wages), varied from about 0.1% (at 6% rate of discount) and 2% (3% rate of discount) to 42% (at 0% rate of discount).

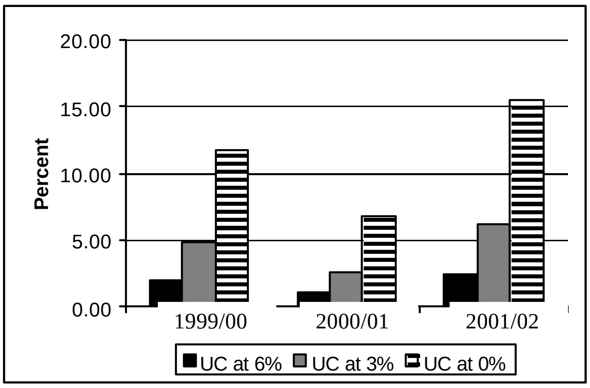

Figure **2** User cost as share of mining sector SDP in Madhya Pradesh

Summary and conclusion

The analysis for the estimation of resource rent in this chapter made use of the net present value method. For the purpose of adjusting national income accounts, the 'user cost' or depletion component of the resource rent was estimated. Various options were worked out using different data sources.

In case of MP, the resource rent, in constant 1993/94 prices, falls from Rs 121/tonne of coal produced in 1999/00 to Rs 93/tonne in 00/01 and then rises to Rs 125/tonne in 01/02. This picture is obtained under option I, based on norms (percentage of output) used by CSO for estimating the values of intermediate consumption and consumption of fixed capital. In option II, based on actual company-wise data on intermediate consumption and all India data on consumption of fixed capital in the mining sector, a similar trend is observed. The resource rent falls from Rs 35/ tonne of coal produced to Rs 22 and then increases to Rs 48.

In the case of WB, the striking finding is the existence of negative resource rents for coal for most of the years being studied. It is postulated that the negative resource rents are on account of the presence of several uneconomic mines in the state. Inefficiencies in production are apparent from the lower levels of output per man shift and resulting higher CoE (compensation of employees) per tonne as compared to other states for underground mines.

In order to eliminate the biases in resource rent arising out of these inefficiencies, an attempt was made to estimate "efficient" level of CoE for the state. This was done using the input distance function, which estimates the distance of each mine from a notional efficient production frontier. The efficient CoE was estimated for each mine by multiplying the efficiency factor with the existing CoE and an average for the state was worked out. Based on these estimates, the resource rent per tonne comes to out to be about Rs 205 and Rs 167 at current and constant prices respectively as compared to negative figures of about Rs –88 and Rs –8 under the inefficient option II scenario. With this level of efficient wages, the depletion premium or user cost component as a share of mining sector SDP in WB varied from to 0.1% (at 6% rate of discount) to 2% (3% rate of discount) in 2001/02. For Madhya Pradesh, the estimates of depletion as share of mining sector SDP for the same year varied from 2.5% (at 6% rate of discount) to 6% (at 3% rate of discount).

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Annexure 1: Perpetual Inventory Model to determine the capital stock

The PIM (perpetual inventory model) seeks to derive an estimate of capital stock at any point in time by accumulating past capital formation and deducting the value of assets that have reached the end of their service life. The approach is also used to estimate the consumption of fixed capital. The various steps in PIM estimation are as follows: -

1. The average length of life of each class of assets (i.e. buildings, other construction, roads and bridges, transport equipment, and machinery and equipments) is assumed separately. The CSO has come up with norms for age of different assets based on detailed discussions with concerned agencies, along with depreciation provisions under Income Tax Rules and Company Act.

2. The GFCF (gross fixed capital formation) is then estimated for each class of assets for L years prior to Y years where L is the average life of assets and Y is the year for which CFC (consumption of fixed capital) and stock are to be estimated.

3. Appropriate price indices are applied to the estimates of GFCF at current prices to convert these to constant prices.

4. The estimates of GFCF at constant prices are then aggregated for L years to obtain the estimates of GFCS at constant prices at the end of the year. For assets that have lived their service life, the investment made in the original year is deducted from GFCS.

5. The GFCS of an asset is then divided by L to obtain the estimates of CFC at constant prices i.e. assuming straight line depreciation. CFC is used for calculating estimates of net domestic product, net capital formation, net fixed capital stock, and net saving. CFC is currently being calculated for all fixed assets. It is, however, not estimated for non-produced assets.

6. Having arrived at the capital stock at the end of the year Y, it is maintained year-by year by the same procedure as outlined above.

This process is outlined as follows:

- GFCF (Y)=GFCF (Y) at current prices *{100/index (y)}
- GFCS (Y) =GFCF (Y)+GFCS (Y-1)-GFCF (Y-L)
- CFC (Y)=GFCS(y)/L
- Cumulative CFC (Y)= Cumulative CFC(y -1)+CFC (Y) -GFCF(Y-L)
- NFCS (Y)=GFCS (Y) -Cumulative CFC (Y)

Where
L is the average life of assets and Y is the year for which CFC or GFCS have to be estimated.

SOURCE Discussions with CSO

CHAPTER 6 Coal mining and the environment: impact and abatement measures

Introduction

Coal mining - both underground and opencast - can cause extensive damage to the environment if adequate environmental protection and remediation measures are not adopted.

This chapter examines major environmental issues related to the coal mining industry. It begins with the environmental legislations governing the mining industry in India. It outlines the potential environmental impacts of coal mining in the country. In the light of the various legislations governing the environmental performance of the mining industry in India, the mines are required to and have undertaken several mitigation and abatement measures. These are discussed in last section of the chapter.

Environmental policy and legislation for the mining sector in India

There is gamut of legislation governing the environmental performance of mining in the country. The establishment and functioning of any industry, including mining are governed by the following environmental acts/regulations besides the local zoning and land use laws of the States and Union Territories (Singh 1997).

1) The Water (Prevention and control of Pollution) Act, 1974 as amended from time to time (Water Act)
2) The Water (Prevention and Control of Pollution) Cess Act, 1977, as amended (Water cess Act)
3) The Air (Prevention and Control of Pollution) Act, 1981 as amended (Air act).
4) The Environment (Protection) Act, 1986 (EPA)
5) The Wildlife (Protection) Act, 1972 as amended
6) The Forest (Conservation) Act, 1980 as amended
7) The Public Liability Insurance Act, 1991
8) The Mines and Minerals (Regulation and Development) Act, 1957, as amended (MMRD Act)
9) Circulars issued by the Director -General Mines Safety (DGMS)

The Environmental Impact Assessment of Development Projects Notification (1994 as amended) under the EPA 1986 requires all mining projects to obtain environmental clearance from Ministry of Environment and Forests (MoEF) (since mining is listed under Schedule I of the Notification). Mining projects being site-specific also have to obtain separate site clearance from the Government as specified in the EIA notification. Forest clearance under Forest (Conservation) Act 1980 is also specifically required if the project involves forestland. The Act is the primary legislation for conservation of forests in the country. The Act, and a number of judicial decisions interpreting it, have made the prior approval of the central government mandatory before a lease can be granted covering any reserved forest or any forest land for use for non-forest purposes.

Over the life of the mine, it is required to meet the ambient standards of air, water and noise as laid out in the respective acts. Similarly, the mine has to comply with safety standards according to circulars issued by the Director-General Mines Safety.

A later section will discuss in more detail the specific guidelines that the industry needs to follow in order to conform to these legislations.

Environmental issues at different phases of mining

Mining may affect all aspects of environment at different stages of the process. The impacts on environment begin in the pre mining phase and continue into the operation and post mining phases.

At the pre-mining stage, there could be displacement of people, cutting of forestland, removal of vegetation and several other impacts due to the acquisition of land. Apart from the mining activity itself, these impacts are caused by the large-scale in-migration of construction workers and the transport of heavy mining equipment for construction, trial shipments of mine products and bulk samples. The existing infrastructure including roads is often not upgraded to cope with the heavy load. Vehicular emissions and dust contribute to SO_2 (sulphur dioxide), NOx (oxides of nitrogen) and SPM (suspended particulate matter), causing air pollution even before active mining begins. The various adverse impacts of mining are represented in the Figure 1. It shows the impacts associated with major pre mining activities viz. land acquisition, site clearance, construction of infrastructure and transport of equipments to and sample products from the mine area.

The environmental impacts of mining during the operational phase are likely to be greater than those in the pre mining phase. These range from the impact on land, ground water quality and levels, air and water pollution and solid waste generation. The environmental impacts of underground and opencast mining are summarized in Figures 2 and 3 respectively.

The post-mining phase has long-term implications for the ecology of the area. Negligence in planning of long-term water management, safety and stability of mining voids, and final rehabilitation can render the mining area uninhabitable. Abandoned and closed mines are often associated with ongoing ground- and surface water contamination, which may continue for a long period.

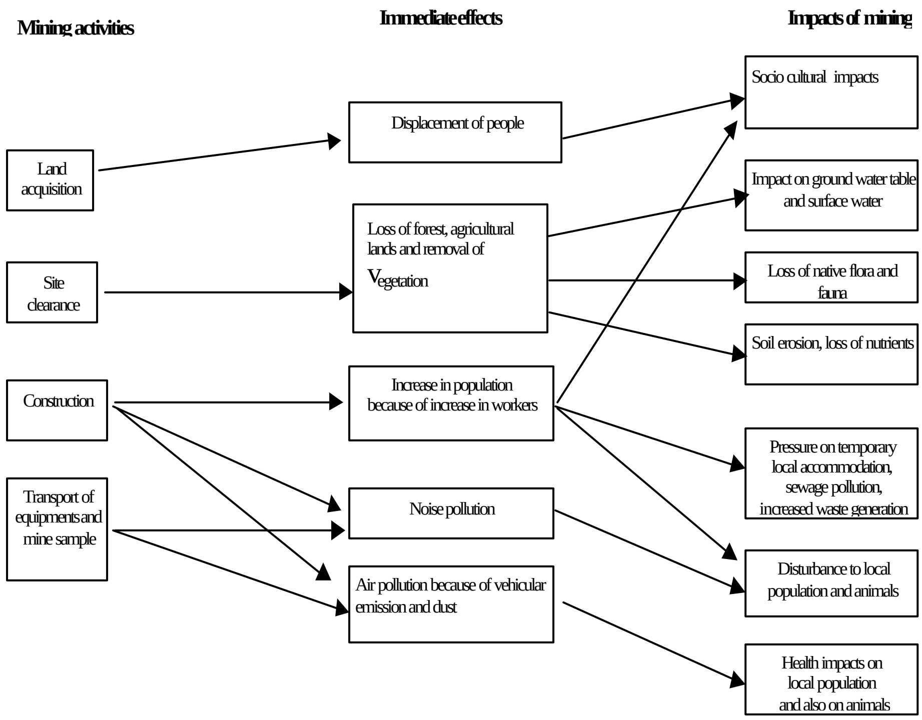

Figure **1** Environmental impacts in the pre-mining phase

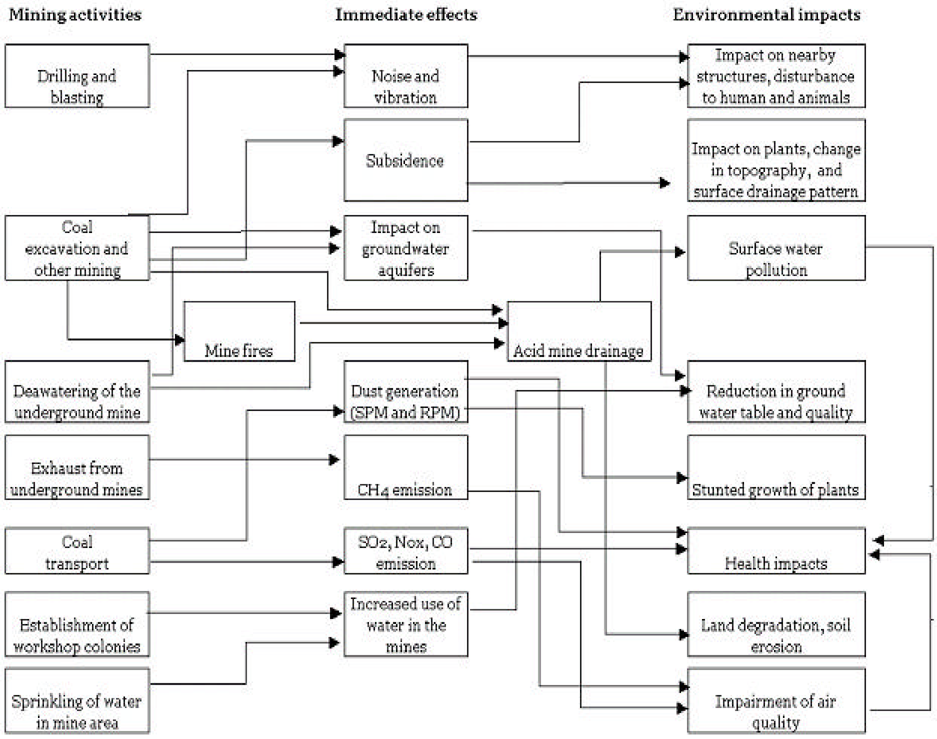

Figure 2 Environmental impacts of underground coalmines

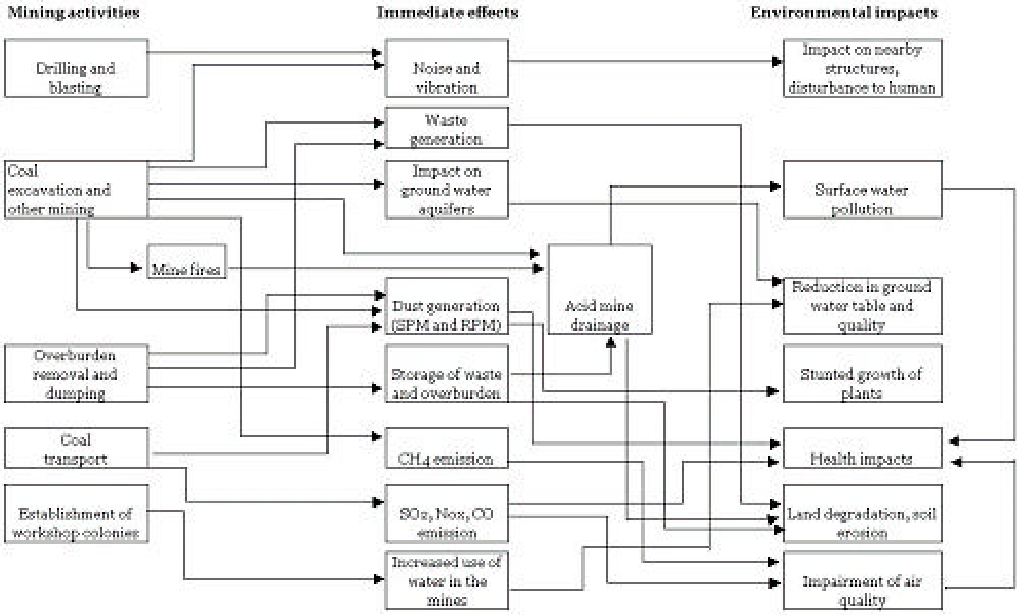

Figure **3** Environmental impacts of opencast coal mining

Impacts of mining on resources

This section discusses some of the major environmental, health and socio economic impacts of coal mining on various resources.

Impact on land

The extent of disturbances on the land depends upon the method of mining. However, irrespective of the method, mining results in land-surface disturbances. While open cast mining produces large-scale disturbances on the earth's surface, underground mining usually causes less significant land disturbances.

Impacts due to surface mining

Surface mining involves the removal of the precious topsoil and overburden, which are then moved away from the pit. This results in widesprea d changes in the topography, streams and vegetations, and loss of flora and fauna. The disturbed area can be much larger than the mine area because of land requirement for disposal of overburden, mining ponds and settlement tanks.

The area needed for over burden dumping can vary widely depending on the technology used for mining. Destruction of natural soil stratum, heaping and piling of overburden can degrade adjoining land. Changes in the soil microflora, which play a vital role in controlling various natural ecological cycles of nitrogen, carbon sulphur, mineralization and assimilation, may add to the loss of productivity. The dust generated during mining activities deposits on the existing vegetation and can stunt their growth.

Apart from overburden, the disposal of other waste without adequate rehabilitation can have long lasting environmental and socio-economic consequences. These waste include rocks without any extractable coal content, slimes, mud, and tailings from coal preparation plants, spent reagent solutions, sewage and liquid wastes from workshop colonies.

After mining is completed, the land usually remains barren unless special precautions are taken to ensure that proper topsoil is used when the area is replanted. If the low -grade coal that is not extracted is left at the quarry site, the land could be rendered unproductive.

Impacts due to underground mining

In underground mining, the roof of the mined area behind the roof support may progressively collapse under the weight of the layers of earth above the coal seam. This results in a phenomenon called subsidence. Long wall panel mining results in a depression on the surface of the ground described as a subsidence trough. Slopes on the surface created by the subsidence trough are gentle and typically less than 2% (i.e. 1 metre drop over a 50 metre length). Subsidence troughs occur relative to the existing ground surface and are therefore less noticeable on rolling topography than on flatter areas. Surface subsidence can pose potential damage to houses, sheds, roads, dams and other man-made structures. Surface subsidence can also create surface cracks and humps and affect surface drainage by altering drainage paths or forming ponds. Subsidence can also change natural landforms making the land more prone to flood and the water logging soils.

Another problem particularly in underground coalmines can be that of mine fires. As coal has high carbon content, under certain conditions natural or otherwise, it tends to ignite or burn spontaneously, even at rather low temperatures. In Jharia coalfields in Jharkhand alone 70 active coal fires spread over 1732 ha were reported in 1988. A project to recover burning mines saved some 100Mt of coal from uncontrolled burning in the Jharia mining area. This shows the magnitude of coal destroyed by mine fires. Apart from the economic loss from burning of coal, reclamation of land under mine fire could be practically impossible.

Toxic pollutants like carbon monoxide; oxides of nitrogen, sulphur and unburnt hydrocarbons are released into the atmosphere, which affect the microenvironment of the local region. Loss of vegetation also aggravates this problem. Mine fires severely affects the quality of water bodies during monsoons or when water used for fire control operations passes over areas where active distillation is causing upward movement of gases/ steam.

Impacts on water resources

Water is used in coalmines for several functions including washing, spraying, in tailing-ponds and for coal preparation. This can cause a conflict with other water users and environmental requirement. Mines can dewater groundwater aquifers some distance from shafts or pits, which reduce the water table in the area adversely affecting other activities including agriculture.

The major source of water pollution due to mining include pumped out mine water, spent water from coal handling plants, dust extraction and dust suppression systems, wash offs from overburden dumps, workshops and domestic effluents and effluents from washery. There are a few mines with acid mine drainage problems that could exacerbate the problem. Chronic leaks from waste dumps or direct disposal of waste in the water bodies result in severe pollution of ground and surface water.

Water pollution can affect the area even after the closure of the mine if the pits are not filled properly. Water in contact with the left over coal in the pits becomes toxic and unfit for any use. Also run off from abandoned waste dumps and pits, becomes acidic resulting in soil erosion, and contamination in the water bodies.

Impacts on air

Air pollution from underground mining is negligible, but open cast mining can adversely affect the ambient air quality. Major pollutants are NOx, CO and suspended particulate matter. But the main pollutant in most cases is dust (SPM and RPM-respirable particulate matter). Dust generation occurs within the mine pit, over haul roads as well as dumping areas.

The major causes of dust during mining are excavation, drilling, blasting, coal handling, and operation of heavy earth moving machinery. The emission factors for various mining activities for a proposed opencast coal mine at Baranj block, Chandrapur district, Maharashtra, as calculated by Chaulya et al. (2000), are given in Table 1. The table identifies coal-handling plant as the major source of SPM followed by haul roads and transport roads. Ghose and Majee (2001) used such emission factors to estimate the dust generated in opencast mine of Bharat Coking Coal Limited in Jharia Coalfield. Their study showed that the mine produced 2500 tonnes of coal per day, generated overburden of the magnitude 9950 m3/day and dust generated was 9.36 tonnes/day.

Table 1 Emission rate of suspended particulate matter for different mining activities

	Emission activities	Emission rate
1	Drilling	0.3825 g s^{-1}
2	Overburden loading	0.4826 g s^{-1}
3	Coal loading	0.4872 g s^{-1}
4	Haul road	.0132 g s^{-1} m^{-1}
5	Transport road	0.0140 g s^{-1} m^{-1}
6	Overburden unloading	1.1103 g s^{-1}
7	Coal unloading	0.7618 g s^{-1}
8	Exposed overburden dump	0.00003675 g s^{-1} m^{-2}
9	Stockyard	0.0002066 g s^{-1} m^{-2}
10	Coal handling plant	0.000647 g s^{-1} m^{-2}
11	Workshop	0.000111 g s^{-1} m^{-2}
12	Exposed pit surface	0.00001528 g s^{-1} m^{-2}

SOURCE Chaulya and others (2000)

Another toxic pollutant emitted from coalmines is methane. Methane emission from coal mining depends on the mining methods, depth of coal mining, coal quality and entrapped gas content in coal seams. Methane emission occurs both in opencast and underground mines, but it can be more acute in case of underground mines. Methane being highly explosive can cause accidents and mine fires. Thus it needs to be removed during underground mining for safety and efficiency. An estimate of methane gas emission per tonne of coal production is given in Table 2. This estimate suggests that assuming all underground mines in India belong to degree I seams, then 336.87 M cum of methane was emitted in 2002 -03 and 355.72 M cum in 2003-04 (provisional). The actual emission would be much larger as underground mines of degree II and degree III emit 10 and 23 times respectively more of methane than that of degree I mines. Methane as a GHG (green house gas) is 21 times more potent than carbon dioxide.

Table 2 Estimate of methane emission in coal mining

Type of coal production	*CH4 emission (CuM/ tonne)*	
	During mining	*Post mining*
Opencast mining	1	0.09
Underground mining		
Degree I*	1	0.09
Degree II*	10	1.07
Degree III*	23.03	3.5

SOURCE TERI (2004)

* Degree I: A seam in which the inflammable gas in the general body of air at any place in the underground working exceed 0.1% and rate of emission of gas is less than 1 m3 per tonne of coal mined.

Degree II: A seam in which the inflammable gas in the gen eral body of air at any place in the underground working exceed 0.1% and rate of emission of gas is less than 1 m3 per tonne of coal mined or rate of emission of gas 1 m3 per tonne or more but less than 10 m3 per tonne of coal mined.

Degree III: A seam in which the rate of emission of gas in more than 10 m3 per tonne of coal mined.

Noise pollution and vibrations

Blasting, heavy earth moving machinery, drills, cutter loaders, material handling, crushing etc generate a lot of noise during mining that is higher than human tolerance level. If no control measures are adopted, then the high level of noise affects the health of the working force and people staying in the vicinity of the mine area. These vibrations also disturb animals in the vicinity of the mine, forcing them to migrate.

Socio economic and health impacts

All the impacts discussed above can adversely affect the health and well being of the people at the project site. At the first stage, the displacement of people due to mining can have social, economic and psychological impacts on them. In the period 1982-83 to 1992-93 Coal India used 35236ha of land to develop coalfields and had to settle 3790 families (IEA 2002). Most of the population is deprived of its traditional livelihood like agriculture or fishing. Women workers are more seriously affected, as they are mostly absorbed as unorganised daily wage labour or casual labour.

Environmental impacts of mining may lead to a reduction in the quality of life due to loss of livelihoods and natural resources like forests, fisheries, water, and fertile land. Even communities living near the mine area are vulnerable to accidents caused by mining activities. The blasting and drilling activities lead to weakening of nearby structures and increase the chance of their collapse.

Coal dust generated due to blasting, coal cutting, and loading operations can cause serious respiratory ailments and pneumoconiosis amongst the workers. The DGMS (Directorate

General of Mine Safety) has prescribed the average maximum tolerable intake of dust by mine workers to be 32mg/m3 and a threshold limit value of 3 mg/m3 per hour. But in practice the incidence of dust is much higher than this value. A case study in the East Parej coal fields conducted by Priyadarshi (1997) showed that the most common diseases suffered by people due to the dust from the coal mines are tuberculosis, cough and cold, malaria, skin diseases, diarrhoea, staining of teeth, joints pain, arthritis, lethargy. The study assessed that, metals like arsenic, mercury, fluoride, nickel and chromium may cause problems even if they are present in trace amount in the drinking water. As a result of these toxic wastes in the water and soils, and high level of exposure to dust it was found that the longev ity of the communities living in the coalmines has reduced drastically. The average longevity of women was found to be 45 and that of male was estimated to be 55 at the time of study in 1993. This can be compared against the All India life expectancy of 60.13 in 1991-95. In the same area most of the children were found to be lethargic because of toxic dust and contaminated water consumption.

Coal dust can also interfere with visibility and the functioning of danger alarms in mine area and pose safety hazards. The high level of noise in the coalmines can affect the hearing and the neurological system of the workers. If the noise level exceeds 85 decibels for a prolonged period, it may result in permanent hearing loss.

In a University of Delhi's CMHE Damodar river survey [1] it was found that heavy metals from coal washeries are being accumulated in fish in Damodar River. Heavy metals like mercury can damage the kidneys, the brain and nervous system.

Besides health impacts, workers in the mines are vulnerable to accidents. One of the major reasons of nationalising coal industry was given as its poor safety record. The causes of major hazards are roof falls in underground mines, and incidents of workers being run over by machinery in open cast mines.

The environmental control measures prescribed for the coal mines are expected to address all the facets of environmental and socio-economic impacts. The next section discusses the pollution control and mitigative actions required to be taken up by coalmines in India to meet the environmental standards laid down by CPCB. The discussion is based on a study of EMPs of several mines and other relevant literature along with consultation with experts.

[1] Aquatic Ecology Studies, Centre for inter-Disciplinary Studies of Mountain and Hill Environments, University of Delhi, "Feasibility Report of Pollution Abatement Schemes for River Damodar", 1996.

Environmental protection and mitigation measures in coal mining

The environmental control measures required to be adopted vary according to the type of mining method, equipment used, geophysical characteristics, and climatic conditions in the mine area. This section discusses the type of environmental control measures required to be adopted by different coalmines in India. To begin with, the section discusses the specific requirements for preparing environmental impacts assessment and management reports for coal mining.

Requirements for preparing environmental management plans

All coal-mining projects are required to obtain an environmental clearance from the central government. Under this requirement, the project authorities need to prepare an EIA (environmental impact assessment) report and an EMP (environmental management plan). The EIA documents provide anticipated impacts on the environment, on the basis of which the mitigative and protective measures to be undertaken are designed in the EMP. The EMP is required to establish the baseline environment scenario and recommend appropriate control measures. The report is required to generate baseline data on the following parameters:

a. Socio-economic profile: Data on socio-economic profile like population, literacy rate, proportion of population belonging to scheduled caste and tribe, ratio of male to female, availability of educational and medical facilities, availability of power supply, post and telegraph, communication, access to drinking water, occupational structure, land use pattern are to be collected for both the mining area and buffer zone.

b. Air quality: The meteorological trends and micro meteorological study of air quality with respect to wind direction, speed, temperature, humidity in all four seasons (winter, pre monsoon, monsoon and post monsoon) is required. The air quality sampling stations are to be located in suitable places to assess the air quality of the core and buffer zone. The parameters to be studied are SPM, RPM, SO_2, NOx, CO.

c. Water quality: The physico-chemical and bacteriological parameters of the water bodies are to be studied in all four seasons. The pH (power of hydrogen), Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), oil and grease in the streams, nallah or rivers in the mining area are to be collected. The data on pH, calcium, chloride, fluoride, sulphate, iron, total hardness, coliform count in the drinking water source like well or river is also required. Hydrogeology parameters like the drainage pattern in the area, type of existing aquifers in the area, transmissivity, permeability, storage coefficient of thereof are to be collected. The trends of groundwater level in all seasons, and data about its potential, balance, recharge and pattern of water use is required.

d. Noise levels: The ambient noise level in dB (A) (decibels) is required to be collected from different sampling stations at industrial, commercial, residential and silence area in all the four seasons for day and night time.
e. Soil quality: Pre mining soil quality in mining and bu ffer zone at different sampling stations is required to be collected. Data for grain size distribution, pH, electrical conductivity, bulk density, nitrogen, phosphorus, potassium, moisture content of the soil in summer and post monsoon is required.
f. Land use pattern: The land use pattern in the pre mining phase in terms of forest land, tenancy land, also forest area, irrigated, non -irrigated agricultural land, cultivable waste land, pasture land, total habitable area are to be collected.
g. Forest, flora and fauna: The type of endemic and native species of terrestrial, aquatic, and avian flora and fauna in the mining and buffer area are to be listed.

The EMPs are required to furnish an Environmental Impact Matrix showing positive or negative impact when protective measures are considered. The net impact matrix is then calculated. The next section discusses the types of environmental control measures required to be adopted by coalmines in India.

Pollution control and environmental protection measures

The environmental standards as directed by the CPCB (Central Pollution Control Board) for air quality, effluent discharge, and noise levels are given in Annexure 1. The type of environmental control measures adopted by coalmines as dictated by norms of CPCB and State Governments can be categorized into:

1. Socio-economic rehabilitation
2. Measures for land degradation
3. Measures for air pollution
4. Measures for water pollution
5. Measures for noise pollution
6. Disaster management

The CPCB (Central Pollution Control Board) has developed the National Environmental Standards and Code of practice for coalmines for abatement of associated pollution problems. These are under consideration of the Ministry of Environment & Forests for notification under the Environment (Protection) Act, 1986.[1]

[1] These guidelines specify environmental standards for coalmines that are more stringent than the currently mandated standards.

Socio-economic rehabilitation

If the proposed coalmine involves areas where there is habitation, the displaced population needs to be compensated according to norms of the State Government. The displaced families are required to be suitably relocated to a mutually agreed site, as per norms. The resettlement and rehabilitation of villagers should be carried out in consultation with Gram Panchayats of the affected villages. The landowners are to be given cash compen sation and land losers are to be offered monetary compensation in lieu of employment. As landless labourers and homeless persons lose earnings they are also required to be suitably rehabilitated by providing them training and infrastructural support for self-employment or alternative source of income.

The rehabilitation norms also require the coalmine project to develop and improve the civic amenities like road, streetlight, school, health centre, drinking water facts, entertainment, ponds, well, playground, park, shopping centre in the mine area. Various social developments of the surrounding villagers such as assistance to adult education and vocational training, assistance to schools, assistance to improve health care facilities, road repairing, plantations, environment awareness programmes are also suggested to be taken up by the project. All these are to be identified on priority basis in consultation with village Panchayats.

Compensatory afforestation

The Forest conservation Act 1980 is the primary legislation for conservation of forests. Under the provisions of the Act, the mining company has to obtain approval both from the central and state governments to obtain a mining lease in forestland. While sanctioning the diversion of forestland for non -forestry purposes, the Government of India stipulates the condition of compensatory afforestation either on equal area of non -forest land or on double the degraded forestland. The mining companies are required to pay the state forest departments an amount stipulated for the district/division under which the mining land falls, which is to be used for appropriate compensatory afforestation[1].

[1] Recently, the state governments including Madhya Pradesh and West Bengal are working on the Net Present Value of forest services to be charged to mining companies in addition to compensation for afforestation. The present value is to be recovered at the rate of Rs. 5.8 lakh per hectare to Rs. 9.20 lakh per hectare of forestland acquired depending upon the quantity and density of forest, according to a Supreme Court order in 2002. In 2005, the supreme court has upheld the government's notification constituting the Compensatory Afforestation Fund Management and Planning Authority (CAMPA) for managing money to be used for compensatory afforestation. It has also ordered th e constitution of an expert committee to identify and define

Measures for control of land degradation

Land reclamation is a crucial measure to ensure that the mine area is capable of some productive use after mining is over. In opencast mines land reclamation involves measures to make land quality suitable for some productive use like agriculture, forestry or recreational purposes besides backfilling of overburden into excavated voids. Land reclamation can be divided into two stages, (a) technical reclamation and (b) biological reclamation.

The various stages of technical land reclamation are

1. Backfilling in the excavated area
2. Levelling the backfilled area
3. Carpeting with top soil
4. Foot drains or catch drains to capture surface runoff .
5. Measures taken for plantation and fodder growth

The land is gradually upgraded for making it fit for agricultural purposes in consultation with department of agriculture. The technically reclaimed backfilled area is then subject to biological reclamation that will involve the following steps:

1. Spreading the topsoil to a recommended thickness of 0.5 to 1.0m in the backfilled area and as far as practicable with minimum time lag.
2. Planting and growing of grass and legumes for at least 2 -3 years, so that it can be suitable for growing fodder inter space with a few local varieties of trees. This would help in binding the soil and prevent their runoff from the slope and this would upgrade the soil.
3. Creating small shallow water bodies, which will help make water available to the plantation.
4. Experts' opinion should be taken along with soil test before actual implementation. The backfilled areas should be converted into a grazing pasture and later to agricultural land.

For external overburden dumps, the technical reclamation would involve stabilising the dump to an appropriate slope (mostly about 30 degree). The top surface of the dump would need to be dressed to a 'saucer shape' for collecting rainwater and prevent water from rushing from the sides. The top of the dumps is to be vegetated and biological reclamation is required to follow.

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parameters under each category of values of forestlands should be estimated.

Topsoil is the most vital component of land reclamation, which needs to be protected. Suitable protective measures are to be taken by coalmines to preserve the topsoil otherwise it can suffer irreversible damages. For retaining fertility beyond one season a vegetation cover is to be created by growing local grass and shrubs. The soil is directly to be replaced, initially on the embankment and over external OB dump and later into backfilled area. The reclamation programme is to be taken up as early as possible so that topsoil is not stored for long. Backfilled area must be graded and levelled as per requirements to restore the original landscape as far as possible. While carpeting topsoil and sub-soil should be amended for proper vegetation growth. In the final stage afforestation/ revegetation/ development of forestry or pastureland is required to be undertaken.

In underground mining the land use pattern usually may not undergo much changes. In this case land reclamation mainly comprises subsidence management. For subsidence management the following measures are to be undertaken:

1. Important features on the land like metalled roads, ponds, and habitations are to be protected by leaving coal pillars unextracted vertically below and within the subsidence influence area.
2. All around depillaring area, co-related on the surface, protective bunds and garland drains are proposed, so that no water from surface enters the subsidence area.
3. Surface cracks are to be sealed by using clay or stone chips or any other suitable material.

Measures for control of air pollution

Almost all mining activities would contribute towards air pollution. Drilling, blasting, activities in the CHP (coal handling plant), transportation of coal and overburden contribute to the dust load in the area. The mines are required to adopt preventive and suppressive measures to control air dust production.

The following measures are recommended in the environmental management to control dust generation in drilling operations:

1. Drilling devices are to be used with adequate dust collectors and disposal arrangements.
2. Water is to be sprinkled before and after the dry season.
3. Sharp drill bits[1] and bits of proper shape are to be used for drilling holes. Suitable water flushing system is to be used by keeping appropriate air pressure on the bit and separating cuttings from the bit.

[1] Drill bits are drill accessories that are used as rotary cutting tools for drilling holes

Blasting activities are required to adopt the following measures to control air pollution generated:

1. Use of proper amount of explosives for blasting has been suggested to reduce generation of dust to the minimum. Sprinkling water before dr illing and blasting would mitigate dust.
2. Proper spacing of blast hole is recommended.
3. Blasting is required to be done during shift change time when minimum number of workers are present around the mine area and during favourable weather condition.

Loading and transportation of coal and OB is also a significant source of dust generation. To control dust generation from these sources the following measures are required to be undertaken:

1. Regular wetting of the surface OB dumps and regular water sprinkling on haul roads. Haul roads are to be regularly cleaned.
2. All service roads are required to be black topped.
3. Overloading of dumpers and trucks is to be avoided as spillage generates dust. Dust generation is to be minimised by covering all trucks with tarpaulin. The speed limit of vehicles is to be controlled to control generation of dust.
4. Operators cabin are to be air -conditioned and dust free.
5. Smoke emission of HEMM are to conform to notified Motor Vehicle Rules, 1989.
6. Regular maintenance of HEMM engines are to be undertaken to control emission of exhaust fumes and their composition.

Washery and coal handling plant will have to adopt the following measures for dust suppression:

1. Crusher house to be enclosed and provided with dust suppression and extraction systems like wet cyclones, centralised suction arrangement followed by bag filter, water sprinklers. The dust emission should not be more than 150mg/Nm^3.
2. Transfer points in the mines are to be provided with proper dust suppression system either wet or dry and it should be enclosed.
3. Broken pieces of coals are to be wetted prior to their loading into dumpers. It is recommended to minimise height of coal fall at transfer points and dust suppression system at these points.
4. Coalbunkers are to be provided with dust collection system like bag filters.
5. Belt conveyors are to be enclosed.
6. Washeries are to be provided with close circuit water utilization from the tailing points.

Apart from the above measures the coalmines are required to develop green barriers around mine, infrastructure, colony, along the approach roads, even around mechanical ventilators. It is estimated that plants of 10, 20 and 30m heights can reduce pollution by 50%, 70% and 80% respectively. This can be an effective dust trapping system apart from absorbing noise to a great extent. It is also suggested that plantations should be done in the area, which would not be required immediately for mining and infrastructure facilities.

Measures for control of water pollution

The sources of water pollution in coalmines are the pumped out mine water, water discharge from coal handling plant and mine, effluents from domestic sources, washeries and workshops. The following measures are to be undertaken for controlling water pollution:

1. Discharged mine water is to be stagnated in a settling pond at surface. The water after stagnation is expected to be suitable for industrial consumption.
2. Settling tank is to be constructed in such a way that the mine water loaded with suspended solids pass through it before being discharged to the nearby natural water courses or used for industrial consumption.
3. Domestic effluent and sanitary sewage from plant and colony is required to be collected either in centralized sewage network or separately. A sewage treatment plant to treat the sewage biologically is to be provided and wherever a collective effort is not possible, individual septic tanks are to be provided. The treated water can be used for watering the plantations.
4. The effluent generated from the workshop containing oil and grease is to be treated by installation of oil and grease removal traps.
5. To prevent water pollution by oil, grease, and sewage waste leak proof containers are used for storage and transportation of oil/ grease.
6. In a quarry suitable garland canals are required to be provided to deal with rainwater and other surface runoff.
7. Adoption of closed water circuit in coal handling plants, etc is suggested not only to cut down industrial effluent but also to conserve water. The garland canals would have to be connected to the main drainage system of the area.
8. Rainwater harvesting is to be undertaken for water conservation and used for mining operations.
9. Water quality is required to be monitored regularly.

Measures for control of noise pollution

To control noise pollution the following measures are to be undertaken.

1. Suitable blasting techniques are required to be evolved after field trials to keep ground vibration to minimum. Noise generating machinery including transportation vehicles is required to be properly maintained.
2. Noise producing sources are to be oriented with due regard to wind rose diagrams.
3. Air silencers are to be provided to modulate the noise generated by the machines.
4. Speed limit is imposed on HEMM near residential areas.
5. Operators of high noise generating equipment like drills are provided with earmuffs and acoustically designed insulated cabins. The exposure time of workers to the higher noise level is to be minimised.
6. Absorbent material on the surface is to be used for reducing reflected noise. Dampening of vibration by using vibration - absorbing materials like wood is required. Noise absorbing pads in foundations of vibrating machines and cushioned bearings are to be used to av oid metal-to-metal contact.
7. Thick quality noise insulators are to be used for noise and vibration free operation of mobile plants.
8. Thick foliage around the strategic areas in the mine i.e. road, around CHP, are to be provided to protect the surroundings adequately from the noise. Ventilating fans are run at full efficiency and dampers are to be provided in the form of well spread out leafy trees, tall and short in alternate row.

Disaster management

Control measures are also required to be undertaken to prevent accidents and occupational hazards to workers. Accidents can be caused from mine gas leakage, underground mine fires and spontaneous combustion of coal. Precautionary measures during blasting, drilling and other mining activities constitute part of disaster management. The following measures are generally adopted to avoid mine gases:

1. The quantity of inflammable gas given out in each ventilation district is determined at least once in every month and borehole samples once in a quarter. The quantity of air sent to each district is to be maintained such as to keep percentage of inflammable gas in the district return airway below 0.75% and 1.25% in any place in the mine.
2. Flameproof apparatus is required to be installed in each working face whether in a development or depillaring area and in every discontinued gallery as also in other places where the percentage of CH_4 exceeds 0.2%. The state of air quality in underground operations is to be continually tested by flame safety lamps.

4. A suitable mechanical ventilator would be required to be installed on the surface.

Underground mine fires are a major source of occupational hazard in mines. To prevent underground mine fires, safety measures as given below are to be adopted.

1. The workers are to be checked for any inflammable things like matchbox, lighter, any contraband before going to underground.
2. Burning of fire inside or within 15m of an incline/ pit is not to be allowed. Storage of inflammable products like oil, grease, timber is to be restricted. All woodcuttings, oily and greasy cotton waste are to be removed out of the mine.
3. Electric equipments are to be installed with utmost care and maintained with regular checking. Approved safety lamps are required to be used. Machinery is to be properly assembled so that during use they do not give off sparks or generate heat.
4. In order to reduce the chance of spontaneous combustion in coal stacks they are stacked in thin layers and frequent sprinkling of water is required to be restored to.

Several other steps are required to ensure the safety of workers. Blasting is to be done at a fixed time as far as possible for safety and sufficient warning is given for people to move to a safer place. Attention is also to be paid to construction for stability against vibration control. HEMM deployed are to be equipped with suitable inbuilt safety devices like audio-visual alarm, fire extinguishers. Dumping of overburden in OB dumps is to be undertaken with care. The project should be fenced and efficient communication system, scheduled maintenance, trained personnel should be employed to minimise accidents and other hazards. Finally, all mining operations are required to be suitably supervised.

Post EMP approval

On the basis of an elaborate exercise (involving a scrutiny of EIA documents, site visits wherever necessary, consultation with experts on specific issues, interaction with the affected people and environmental groups directly and other consultative processes with the public), the Environmental Appraisal committee on mining projects makes recommendations for approval or rejection of any project. The recommendations are then processed in the MoEF for approval or rejection.

Once the project has been approved and has been operational, each mining company usually sets up a department at the project level to take up the responsibility of environmental management as required for planning and implementation of the projects. The purpose of the monitoring is:

- To ensure that no impacts are in excess of standards
- To check the predictions made in EIA
- To facilitate identification of any unidentified impacts and make provisions for their mitigation.

A monitoring and feedback mechanism is required to be effectively implement and monitor the environmental management plan. It is mandatory to monitor and report the ambient quality of the environment along with other indicators as quarterly environmental statements[1] to the state pollution control boards in India. This is meant to ensure proper implementation of mitigation measures proposed and also to effect mid course corrections, if required. Suitably qualified personnel are required to carry out monitoring on a regular basis using standard methods for various environmental attributes.

Mine closure

The mine closure plan as proposed in the EMPs is required to be implemented in two stages: 1) Progressive mine closure plan and 2) final mine closure plan This is in accordance with the recent amendments in the MCDR 1988 (Mineral Conservation and Development Ru les), which provide for statutory guidelines for mine closure planning[2]. With growing environmental concerns it essential that the management of land post mining be planned right from the design of the mine. New legislation such as this provide statutory obligations on the part of the mine operators to carry out protective, reclamation and rehabilitation measures progressively as well as permanent measures so that mined-out sites do not pose danger to the surrounding environment and may not disturb the aesthetic beauty of the area. These statutory provisions if implemented can be powerful tools for effective reclamation and rehabilitation of closed mines.

In conclusion, it may be said that clearly there is an elaborate legislative framework and guidelines to ensure that the socio-economic and environmental impacts of mining are minimized. However, these are only as effective as the efficacy of their

[1] As we have discussed ea rlier and analysed the environmental statements in the appendix. A perusal of the air quality and water standards as reported by sample mines in both West Bengal and Madhya Pradesh showed no exceedance from the norm.

[2] Central Government vide G.S.R. 329(E) dated 10.04.2003 and G.S.R.330 (E) dated 10.04.2003 have amended the Mineral Concession Rules, 1960 and Mineral Conservation and Development Rules, 1988 respectively and introduced the statutory provisions for preparations and implementation of 'Progressive Mine Closure Plan' and 'Final Mine Closure Plan'.

implementation and monitoring. In fact, if mining has to match international environmental standards, the benchmark should go beyond adhering to ambient norms towards attaining ISO: 14000 standards for each project.

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Annexure 1: CPCB environmental standards for coal mines

Air Quality Standards

The SPM (Suspended Particulate Matter), RPM (Respirable Particulate Matter), SO_2 (Sulphur dioxide) and NO_X (Oxides of Nitrogen) concentrations at downwind direction at considering predominant wind direction at 500 m from the following dust generating sources shall not exceed the standards given at Tables I, II and III.

Table I

Category	*Pollutant*	*Time weighted Avg.*	*Concentration in Ambient Air*	*Method of Measurement*
I New Coal Mines (Coal Mines coming up after Dec. 1998	Suspended Particulates Matter (SPM)	Annual Average*	360 m g/m^3	- High Volume Sampling (Average flow rate not less than 1.1 m^3/minute)
		24 hours**	500 m g/m^3	
	Respirable Particulate Matter (size less than 10mm) (RPM)	Annual Average*	180 m g/m^3	Respirable Particulate Matter Samples
		24 hours**	250 m g/m^3	
	Sulphur Dioxide (SO_2)	Annual Average*	80 m g/m^3	1. Improved west and Gaeke method
		24 hours**	120 m g/m^3	2. Ultraviolet fluorescene
	Oxide of Nitrogen as NO_2	Annual Average*	80 m g/m^3	1. Jacob & Hochheiser Modified (Na-Aresnic) Method
		24 hours**	120 m g/m^3	2. Gas phase Chemilumine-scence

Table II

Category	*Pollutant*	*Time wighted Avg.*	*Concentration in Ambient Air*	*Method of Measurement*
II Existing coal fields/mines given below: Karanpura, Ramgarh, Giridih, Rajhara, Wardha, Nagpur, Silewara, Pench, Patharkhera, Umrer, Korba, Chirimiri, Cenral India Coalfields including Bisrampur, Singrauli, Ib valley, Talcher, Godavari valley.	Suspended Particulates Matter (SPM)	Annual Average*	430m g/m^3	- High Volume Sampling (Average flow rate not less than 1.1 m^3/minute)
		24 hours**	600 m g/m^3	
	Respirable Particulate Matter (size less than 10mm) (RPM)	Annual Average*	215 m g/m^3	Respirable Particulate Matter Samples
		24 hours**	300 m g/m^3	
	Sulphur Dioxide (SO_2)	Annual Average*	80 m g/m^3	1. Improved west and Gaeke method
		24 hours**	120 m g/m^3	2. Ultraviolet fluorescene
	Oxide of Nitrogen as NO_2	Annual Average*	80 m g/m^3	1. Jacob & Hochheiser Modified (Na-Aresnic) Method
		24 hours**	120 m g/m^3	2. Gas phase Chemilumine-scence

Table III

Category	*Pollutant*	*Time wighted Avg.*	*Concentration in Ambient Air*	*Method of Measurement*
III Old coal fields/mines given below:	Suspended Particulates Matter (SPM)	Annual Average*	300m g/m^3	- High Volume Sampling (Average flow rate not less than 1.1 m^3/minute)
		24 hours**	700 m g/m^3	
	Respirable Particulate Matter (size less than 10 mm) (RPM)	Annual Average*	250 m g/m^3	Respirable Particulate Matter Samples
		24 hours**	300 m g/m^3	
Jharia, Raniganj, Bokaro	Sulphur Dioxide (SO_2)	Annual Average*	80 m g/m^3	1. Improved west and Gaeke method
		24 hours**	120 m g/m^3	2. Ultraviolet fluorescene
	Oxide of Nitrogen as NO_2	Annual Average*	80 m g/m^3	1. Jacob & Hochheise r Modified (Na-Aresnic) Method
		24 hours**	120 m g/m^3	2. Gas phase Chemilumine-scence

Note:

* Annual Arithmetic mean for the measurements taken in a Year, following the guidelines for frequency of sampling laid down in clause 5.1.1.

** 24 hourly / 8 hourly values should met 98% of the time in a Year. However 2% of the time it may exceed but not on two consecutive days.

The ambient air quality standards shall apply to the nearest residential / commercial places (existing / likely) on the leeward direction on the mining and allied activities.

Unauthorised construction will not be taken as a reference of nearest residential / commercial place for monitoring.

Frequency of Sampling

Air quality monitoring at a frequency of two days in a month at the nearest residential / commercial place and at the points given in Para 5.1 may be carried out.

As a result of monthly monitoring, if it is found that the value of the pollutant is less than 50% of the prescribed standards, for three consecutive months, t hen the sampling frequency may be shifted to two days in a quarter (3 months).

In case, the value exceeds the prescribed standard, the Air Quality sampling should be done twice a week. If the results of four consecutive weeks indicate that the concentra tion of pollutants is within the prescribed standards, then monthly monitoring may be reverted to.

Effluent Standards

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The standards for effluent discharge into sewer/stream/land, are given below:

Effluent	*Standards for discharge*
PH	5.5 to 9.0
Total Suspended Solids	100 mg/l -
Land for irrigation	200 mg/l
Oil & Grease	10 mg/l
Mercury (Hg)	Absent
Nitrate Nitrogen	10 mg/l

Noise level standards

The proposed standards are as given below:

Time	*Noise level Leq dB(A)*
6.00 AM – 9.00 PM	75
9.00 PM – 6.00 AM	70

Occupational exposure limit of noise prescribed by the Director General, Mines & safety (DGMS) shall be compiled with.

SOURCE http://www.cpcb.nic.in/jun2000env.htm (accessed on May 6, 2005)

CHAPTER 7 Environmental costs of coal mining

Introduction

Mining activity impacts air, water, soil and other resources. These impacts in turn can adversely affect human and ecological health. The magnitude and significance of environmental degradation depends on the method of mining, scale and concentration of mining activity, geological and geomorphologic setting and the abatement and mitigation activity undertaken during the mining process. It is therefore required to estimate these environmental costs in order to arrive at the actual economic cost of producing coal. In this study we estimate the environmental cost of mining activity by using the control cost method of valuation. The chapter also examines the components and determinants of this cost.

Despite the coal industry being confronted with potentially serious environmental impacts, there are several data gaps and practical difficulties in assessing the scale of these impacts. The absence of data on the crucial link between mining and its contribution to pollution in the region is the first constraint in this study. Mining companies in India are not required to measure the pollution load discharged during operation[1]. Instead, they have to adhere to the ambient environmental standards imposed by the pollution control board. The monitoring stations within the mines record the ambient quality of air, quality of water discharged from the mine and noise levels at different sites in the mine. The environmental statements submitted by coal mining companies in the study states have shown that the recorded data on various pollution parameters largely conform to the norms.

Although there could be externalities imposed outside the mine area, where transportation of coal and other mining operations could adversely impact the air quality through fugitive dust emissions, this study is limited to the mine area. Source apportionment of environmental impacts outside the mine due to activities within the mine would require models based on data on emissions. Emissions are difficult to monitor since mining produces fugitive emissions rather than

[1] If pollution loads are available for mining companies, like for instance the thermal power generation industry, various methods could be employed to calculate the shadow price of pollutants. One such method the distance function approach was explored earlier in the study. For unavailability of data, this method cannot be currently used for estimating the shadow price of pollutants from coalmines. But the Annexure1 discusses the application of this method in the future, if data on pollution loads are available.

stack emissions. The problem of source apportionment also raises difficulties for valuation using ambient standards.

In our study therefore we assume that if the air, water and noise quality within the mine adheres to the norms set up by the SPCBs, the environmental costs of the mine are completely internalised. Further, it is assumed that the environmental standards are being met if the environmental management plan is being implemented. Since the environmental statements of the sample mines have reported conforming to the ambient standards stipulated by the State pollution control boards, we use the data on the environmental costs of abatement and mitigation as proposed in the EMPs to estimate the control costs. It must be noted that EMPs are only estimated expenditures towards environmental protection by the companies and may differ from the actual expenditure as occurred in the books of accounts. Similarly reported environmental quality data may mask true environmental state throughout the area of mining operations (See Box 1). In such cases, there will be externalities in terms of health and other costs. This study, thus provides a very conservative assessment of environmental costs.

Box 1 Exceedance in ambient concentration: the Korba coalfield study

The Korba coalfields are the largest producing area of South Eastern Coalfield Limited (SECL). Coal is supplied to power stations and other sectors in the region.
In 2000, a study was undertaken by TERI to assess the status of ambient indoor and workplace air quality in the Korba coalfield and identify the probable sources of pollutants to facilitate effective control measures. The report based on the results obtained from the primary monitoring, laboratory analysis and assessment showed that there were monitoring stations that exceeded the ambient norms as prescribed by the CPCB. The level of exceedance varied across the monitoring season, pollutant and the monitoring stations. Some of the sources of heavy metals observed were identified as corrosion of metallic parts, tyre wear and combustion of coal in the region.

These control costs could also be seen as defensive expenditures as defined in the SEEA. It is those expenditures that are assumed to maintain the services of the natural environment and can be interpreted as the minimum cost required to retain the environmental quality. These environmental protection expenditures are incurred for activities which reduce or eliminate pressures on the environment and which aim at making more efficient use of natural resources (UN, EC, IMF, OECD, WB 2003[2]). These

[2] UN, EC, IMF, OECD, WB. 2003, Integrated environmental and economic accounting 2003, (Final draft circulated for information prior to official editing), United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, World Bank. 572 pp.

expenditures are then to be adjusted from the GDP measures to arrive at a "greener GDP" as suggested in SEEA.

Methodology for the derivation of environmental costs

Sample selection

The reported control costs for the coal industry are largely incurred for mitigation and abatement activities such as reclamation of damaged land in the mine area or anti-pollution measures for air and water. The objective is to estimate an average for the industry by type and technology of mining, based on the EMP data from a representative sample of the mines. EMPs give detailed information about the environmental impacts, control measures and the cost of such measures for each project or mines.

The first step was to select a sample of mines from West Bengal and Madhya Pradesh, representative of the varying capacity of production and type of mining[3]. See Annexure 2 for a list of mines classified according to the type of mining and capacity of production in MP and WB. The respective mining companies were requested to provide EMPs and data on environmental costs incurred for the sample mines[4]. EMPs were also collected from other sources including the Ministry of Environment and Forests, private consulting agencies and the regional CMPDIL offices in the states. In the absence of information for all the sample mines, the study made use of EMPs of 21 open cast and 6 underground mines that could be gathered (for the two study as well as the neighbouring states of Jharkhand, Maharashtra, Uttar Pradesh and Chattisgarh) and other environmental data collated from various sources - this sample does not coincide with the original sample designed for the study. Table 1 list the type and number of mines from various states used for the analysis. From Madhya Pradesh we cou ld get EMPs for 6 underground and 11 open cast mines (36:64 ratio of underground and open cast mine). For West Bengal, we could get the EMP for only one open cast mine. It was pointed out by the Ministry of Environment and Forests[5], that there has been no new underground mine commissioned or expansion undertaken since 1995 in the state. In the case of open cast mining too, there have been a few expansion projects but no new mines commissioned.

[3] In West Bengal the share of production of underground to opencast mines is about 45:55 in 2000-01 and in Madhya Pradesh it is 30:70.
[4] See Annexure 3 for the questionnaire sent out to companies on environmental costs incurred by the companies.
[5] EIA department in MoEF, New Delhi.

Table 1 Number and type of mines for which EMPs (environmental management plans) were available

State	*No. of Opencast mines*	*Technology*	*No. of Underground mines*	*Technology*	*Total*
Chattisgarh	3	Shovel Dumper	0		3
Jharkhand	1	Shovel Dumper	0		1
Madhya Pradesh	11	(4) Dragline & Shovel Dumper, (7) SD	6	(5) Bord and Pillar, (1) Longwall	17
Maharashtra	5	Shovel Dumper	0		5
West Bengal	1	Shovel Dumper	0		1
Total OC	21	Total UG	6	Total	27

Components of environmental costs

In this study environmental costs are defined as expenditures that arise from either compulsory or voluntary activities to achieve environmental objectives. The costs under the EMPs are usually measured under the two major heads of capital and revenue costs. The EMPs provide details of the capital cost. The components of capital costs were studied and annualised as discussed later[6].

Revenue costs are incurred towards the maintenance of environmental protection equipment, wages and salaries for manpower involved in environmental protection activities and other operational expenses[7]. These are generally reported as a lump sum or per tonne estimate in the EMPs.

Annualized capital costs were added to revenue costs in order to arrive at total annual environmental costs. This cost was estimated at the mine level and an average for the industry and each type of mining was worked out.

Analysis of capital costs

The EMPs give capital costs usually under the following heads:

1. Land reclamation
2. Environmental control measures in mine and industrial area
3. Green belt or afforestation
4. Pollution monitoring and other expenses
5. Rehabilitation package

[6] The annualisation of the capital costs depends on the life of the equipment, which was based on discussion with experts and the CSO norms. Annualized cost was estimated using the formula $A = Cr / [1 - (1+r)^{-y}]$, where, C is the capital cost, r is the interest rate and y is the life of the equipment.

[7] Some of the EMPs in the sample did not contain revenue costs

Rehabilitation expenses and expenditure on community health and development are strictly not part of environmental costs of mining, as these are not incurred to mitigate or abate any environmental impact. Accordingly, this component has been excluded from the analysis.

In order to annualize capital expenditures, it is necessary to use appropriate estimates of the life of capital equipment or the duration over which the benefits of such expenditure will extend. The study uses 9 years as the life for most equipment, based on expert opinion and CMPDIL norms for most mining equipment[8].

The other determinant of annualised costs is the rate of discounting. The rate of discount will be determined by the current cost of capital. The interest on capital is the opportunity cost of capital, i.e., the interest that would have been received on the capital amount, if they had not been invested for environmental protection measures. The rate of discounting for the study is assumed to be 6%. A sensitivity analysis at lower and higher rates of discount (3% and 9%) was also undertaken.

The following section discusses the components of capital costs and how these were treated in the analysis.

1. Technical reclamation: As discussed in the previous chapter, the measures for land reclamation include technical reclamation, particularly for open cast mines. The life of equipment used for technical reclamation is taken as 9 years. The study assumes that the initial expenditure on technical reclamation is incurred during the first year of beginning mining operations.
2. Biological reclamation: Only 6 EMPs in the sample studied reported capital allocation for biological reclamation. Usually the mining companies contract out the activities towards biological reclamation to the state forest departments and therefore the related expenses appear as recurring costs. Where relevant, biological reclamation is assumed to begin in the 6th year of the mine operations.
3. Compensatory afforestation: If forestland is acquired for mining, it is statutory for mining companies to pay the Forest department of the state to compensate for the loss of forests. In addition to the cost of compensatory afforestation per hectare of land acquired, some state governments have also come up with other norms such as the recently devised "net present value" of forest services. These costs are incurred before the beginning of mining operations.

[8] CSO norm for mining machinery is 10 years

4. Pollution control
   Dust suppression: Air pollution control measures are adopted within the mine area and the workshop to control the ambient air quality and adhere to the stipulations by the state pollution control boards. Control measures are required to be undertaken at the various stages of mining like drilling, blasting, loading and transport. It is assumed that the life of equipment (e.g. like mobile sprinklers, extractors) used for control of air pollution is 9 years and that the costs are incurred in the first year of operations.
   Water pollution and noise abatement: The capital cost of equipment used towards water and noise pollution in the EMPs is annualised assuming life of equipment as 16 years. The expenses are assumed to be incurred in the first year of mining operations.
5. Pollution monitoring equipment: Environmental monitoring equipment for measuring the ambient air, water and noise quality is a statutory requirement for mining companies. The capital cost of such monitoring equipment is assumed to be incurred in the first year of the project. The life of such equipment varies with the number of samples required and the period of monitoring. For our study the life of equipment is assumed to be 4 years based on suggestions from sector experts.
6. EMP preparation: Preparation of EMPs for new projects or project expansions is mandatory for coal companies. The cost of undertaking this and other scientific studies is assumed to be incurred before the start of the project and to be incurred only once through the life of the project (assumed to be 16 years on average).
7. Miscellaneous: Miscellaneous capital expenditure such as consent fees and other expenses incurred towards environmental protection in the projects is assumed to be incurred during the first year of the mining operations. The life of such equipment is assumed to be 9 years.

It is important to note that some of these components of environmental protection expenditures may also aid the production process itself. For instance, the dust suppression equipment lowers the concentration of dust in the mining area (and is taken as part of the environmental protection expenditure in the study) but is also a requirement for the mining activity itself since the presence dust impairs visibility and hinders mining.

SEEA classifies expenditures where the main objective is protecting the environment as the “pure purpose criterion” and those where a portion of the cost of a technology contributes towards the environmental improvement as “extra-cost criterion”. The SEEA suggests that only the extra expenditure could be included in the latter case. But SEEA recognizes that these are working definitions and it may not be possible to identify the 'environmental share' when classifying expenditures, so the pure purpose criterion could be used. The study follows the pure purpose guideline and includes any expenditure that is primarily towards environmental protection as an EPE.

Therefore, as the SEEA suggests, the interpretation of the estimates have to consider that the dual effect may not be captured in EPE accounts. The increases or decreases in EPE cannot be interpreted unambiguously as showing whether the economy is becoming more sustainable or less so. (SEEA 2003)

Additionally using EMPs that are documents prepared before the commissioning of a project may not accurately depict the magnitude of the actual environmental expenditure during the course of operation. Besides, if revised cost estimates (RCE)[9] are used for estimating the EPE of older mines, these may not report the capital components towards environmental protection that already exist. Using such data may undermine the capital estimates of environmental protection expenditure in the mines of older vintage.

It should also be understood that the analysis of the EMPs which give an estimate of the environmental protection expenditure has been seen as laying too much attention on the expenditure side. According to SEEA the possibilities for revenue and cost savings through implementation of process-integrated environmental measures have not received so much focus. As companies adopt process-integrated pollution prevention instead of pollution abatement approaches, the conventional environmental protection expenditure accounts are less useful in analysing the economic impact of environmental regulation or likely response to changes in regulation. (SEEA 2003)

Estimates of environmental costs- analysis and results

The environmental costs were calculated for 27 sample mines in the study including 19 in the study states. The sample consisted of 6 underground mines and 21 opencast mines. Since recurring costs were not reported for 6 mines, the results are based on reported costs for 21 sample mines[10]. The overall average environmental cost per tonne of coal

[9] In expansion projects, revised cost estimates (RCE) are prepared for sanctioning of new investment. This report will also contain the proposed environmental protection expenditures in the light of the expansion.

[10] Later in the chapter regression analysis has been used to arrive at an estimator of recurring costs for mines based on their capacity and environmental capital costs incurred.

produced in these 21 sample mines amounts to Rs. 10.17 per tonne (Table 2). The average environmental cost per tonne of coal produced from opencast mines is estimated at Rs. 11.12 and that of underground mines at a lower Rs. 6.12.

Table 2 Estimated environment cost of coal mining (Rs/tonne)

Type of mine	*Capital cost*	*Recurring cost*	*Total environmental cost*
Opencast	3.90	7.22	11.12
Underground	2.80	3.32	6.12
Overall	3.69	6.47	10.17

An earlier TERI study[11] had arrived at costs in the same range for another sample of mines. Although the methodology used for the two studies are similar, this study did not consider rehabilitation and resettlement expenses as part of environmental cost of companies. Moreover the other study used norms for several cost components, when the costs were unavailable, but this study is entirely based on the EMP estimates of environmental protection expenditure.

Table 3 below gives the cost details at the mine-level for the study sample.

[11] TERI, 1994. Study of Environmental Issues in Coal Mining and Associated costs, BICP report.

Table 3 Mine wise environmental cost estimates

Mine	*State*	*Type of mine*	*Capacity (million tonne per year)*	*Environmental cost per tonne (Rs.)*		
				Capital cost	*Recurring cost*	*Total cost*
Mine 1	Chattisgarh	OC	5.25	4.35	5.51	9.86
Mine 2	Chattisgarh	OC	5	2.99	3.86	6.85
Mine 3	Madhya Pradesh	OC	1.25	3.45	11.79	15.24
Mine 4	Madhya Pradesh	OC	10.00	4.62	4.48	9.10
Mine 5	Madhya Pradesh	OC	0.18	12.11	1.14	13.25
Mine 6	Madhya Pradesh	OC	1.00	2.43	1.40	3.83
Mine 7	Madhya Pradesh	OC	4.50	9.57	8.80	18.37
Mine 8	Madhya Pradesh	OC	1.15	1.12	18.12	19.24
Mine 9	Madhya Pradesh	OC	10.00	6.79	4.40	11.19
Mine 10	Madhya Pradesh	OC	10.00	3.83	14.54	18.37
Mine 11	Madhya Pradesh	OC	0.33	2.46	6.88	9.34
Mine 12	Madhya Pradesh	OC	4	6.84	3.69	10.52
Mine 13	Madhya Pradesh	OC	0.585	1.54	6.02	7.56
Mine 14	Maharashtra	OC	0.18	5.91	3.00	8.91
Mine 15	Maharashtra	OC	0.30	0.99	3.00	3.99
Mine 16	Maharashtra	OC	0.6	2.13	3.00	5.13
Mine 17	Maharashtra	OC	0.65	0.94	10.28	11.22
Mine 18	Madhya Pradesh	UG	0.36	1.11	9.06	10.17
Mine 19	Madhya Pradesh	UG	0.48	2.07	0.80	2.87
Mine 20	Madhya Pradesh	UG	0.82	0.43	0.41	0.84
Mine 21	Maharashtra	UG	0.5	9.47	3.00	12.47

The largest value of environmental cost in mine 8 is largely due to the high recurring environmental costs as reported in the EMP, Rs. 18.12 per tonne amounting to about 94% of the total environmental cost. The smallest value is reported fr om an underground mine (mine20), in Madhya Pradesh, and is due to the low capital requirement in the mine.

Analysing the components of environmental cost

An analysis of the cost estimates shows that average recurring costs account for 46 -48% of the total costs, with the share being slightly higher in the case of opencast mining. The high share of recurring costs is due to the fact that allocation towards salaries, wages and other administrative expenses could contribute to significant share of annual environmental protection expenditures. Additionally most expenditure towards biological reclamation and other contractual expenditure would occur as recurring costs.

The components of costs when analysed as percentage of total annualised costs show that technical reclamation and dust suppression accounted for significant portion of the capital costs of opencast mines and underground mines (Table 4).

Table 4 Components of environmental cost

Cost component	*Opencast*	*Underground*
Capital costs	*As percentage of capital costs*	*As percentage of capital costs*
Technical reclamation	44.63	59.64
Biological reclamation	3.23	0
Compensatory afforestation	9.86	0
Dust suppression	21.18	19.04
Pollution control (mine area + industrial area)	5.06	7.78
Pollution monitoring facilities	6.49	5.04
EMP preparation and planning	5.86	7.94
Miscellaneous	3.69	0.57
Capital costs	100	100
As percentage of total environmental cost		
Annualized capital cost	41.44	54.17
Recurring cost	48.56	45.83
Total annualized cost	100	100

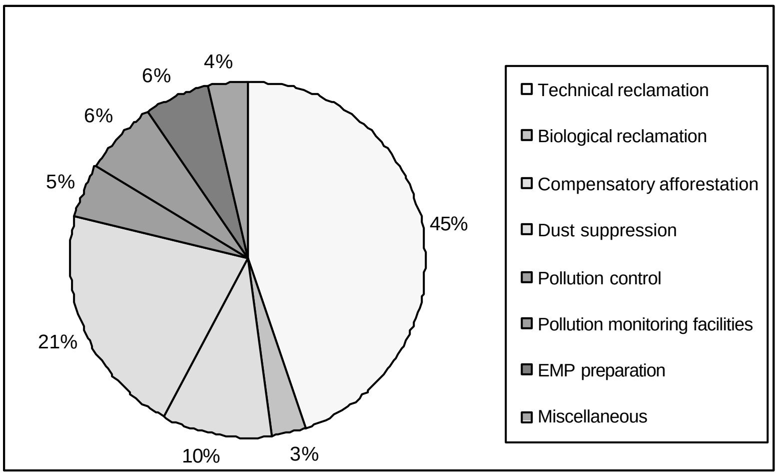

Figure **1** Components of capital cost in sample opencast mines

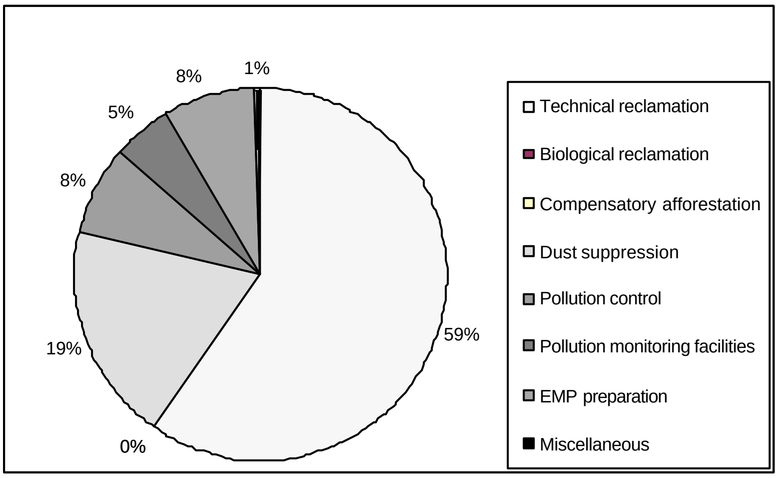

Figure **2** Components of capital cost in sample underground mines

Having studied the components of cost, the following section examines the various determinants of environmental costs.

Estimators of environmental costs

It will be useful to look how the production parameters like type of mining, method of mining and other geological factors influence the cost of production.

Analysis across mines reveals that there is a large variation in the environmental cost estimates, with standard deviation from the mean being 6.68 (Table 5). This variation can be explained by various factors including mine capacity, type of mine and geological factors like stripping ratio for opencast mines. Analysing the opencast mines and underground mines separately gives similar levels of standard deviation from the mean.

Table 5 Descriptive analysis of the costs of mining: by type

Descriptive	*Underground (Rs.)*	*Opencast (Rs.)*	*Overall (Rs.)*
Mean	6.12	11.12	10.17
Standard Error	2.53	1.64	1.46
Median	6.42	9.34	9.34
Standard Deviation	5.05	6.78	6.68
Range	10.10	27.07	29.68
Minimum	0.77	3.38	0.77
Maximum	10.86	30.45	30.45
Count	4.00	17.00	21.00

This variation is also reflected in scatter plots of costs against scale of production. The scatter for underground and overall may not be meaningful because of lack of requisite data and pooling of data respectively. The scatter plot for opencast mine shows some positive relationship between mine capacity and environmental cost per tonne (Figure 3). However, fitting an OLS line for the scatter below results in a low correlation (R square of the plot is 0.53) between production capacity and environmental cost per ton ne.

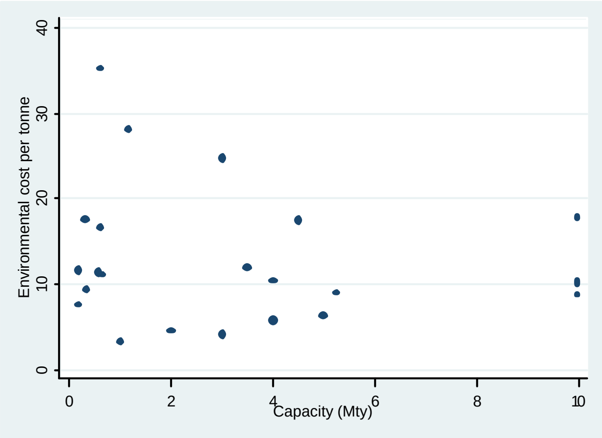

Figure **3** Environmental costs and mine capacity - opencast mines

Nevertheless, the study attempted to come up with estimators to assess environmental costs as a function of mine capacity. The analysis was undertaken separately for capit al and recurring costs. For instance, annualised capital costs for the sample mines (in lakh) were regressed on mine capacity (in million tonnes per year), using dummy variables for type of mine (1 for open cast and 0 for underground mines) and the state dummy (1 for Madhya Pradesh and 0 for other states in the sample). The correlation coefficient shows a moderate level of relationship between mine capacity and environmental costs.

For opencast mines in Madhya Pradesh, the estimator of annualized capital costs is as follows:

Annualised costs (in lakh) = 87.20 + 110.73 X Capacity (in MTY) + E

In other words, on an average an opencast mine in Madhya Pradesh with the mine capacity of 1 Mty would have an annualised capital cost of 197.93 lakh for environmental protection expenditure.

Likewise, the estimators for annualised and recurring costs for mine in Madhya Pradesh and outside the state are summarized in Table 6 below. The estimators have been derived from the OLS regression results, which are summarised in Table 7 and Table 8.

Table 6 Estimators for annualised and recurring costs in and outside Madhya Pradesh

	Estimators
Mines in Madhya Pradesh	
Annualised environmental cost	
Open cast mines	Annualised costs (in lakh) = 87.20 + 110.73 X Capacity (in MTY) + E
Underground mines	Annualised costs (in lakh) = -40.86 + 110.73 X Capacity (in MTY) + E
Recurring costs	
Open cast mines	Recurring costs (in lakh) = 19.4 + 72.12 X Capacity (in MTY) + E
Underground mines	Recurring costs (in lakh) = - 10.6 + 72.12 X Capacity (in MTY) + E
Mines outside Madhya Pradesh	
Annualised environmental cost	
Open cast mines	Annualised costs (in lakh) = -51.89 + 110.73 X Capacity (in MTY) + E
Underground mines	Annualised costs (in lakh) = -179.97 + 110.73 X Capacity (in MTY) + E
Recurring costs	
Open cast mines	Recurring costs (in lakh) = - 39.10 + 72.12 X Capacity (in MTY) + E
Underground mines	Recurring costs (in lakh) = -69.10 + 72.12 X Capacity (in MTY) + E

Table 7 Regressing total environmental costs against mine capacity

Regression Statistics		*Coefficients*	
Multiple R	0.899524	Intercept	-179.968
R Square	0.809144	Million tonne per year (capacity)	110.7265
Adjusted R Square	0.78425	Type of mine	128.0696
Standard Error	194.282	State	139.1072
Observations			27

Table 8 Regressing recurring costs against mine capacity

Regression Statistics		*Coefficients*	
Multiple R	0.80006443	Intercept	-69.103336
R Square	0.64010309	Million tonne per year (capacity)	72.1167899
Adjusted R Square	0.57659188	State	58.4936933
Standard Error	212.731439	Type of mine	30.0059695
Observations			21

Sensitivity analysis: capital expenditure and rate of discount

As provision of reclamation equipment is one of the most critical issues associated with environmental management in coal mining operations, particularly opencast mines, two more scenarios are analysed assuming that the capital provision for land reclamation by increasing HEMM is increased by 25% and 50%.

Table 9 Environmental cost per tonne (with 25% increase in Technical Reclamation)

Mean	10.60
Standard Error	1.51
Median	9.83
Standard Deviation	6.93
Sample Variance	48.00
Minimum	0.77
Maximum	31.75
Count	21

With an increase of 25% in the cost of technical reclamation the overall average environmental cost increases to Rs. 10.60 per tonne. For the sample opencast mines the cost is Rs. 11.56 and for the sample underground mines it is Rs. 6.50 per tonne of the coal produced.

Table 10 Environmental cost per tonne (with 50% increase in Technical Reclamation)

Mean	11.04
Standard Error	1.57
Median	10.08
Standard Deviation	7.20
Sample Variance	51.81
Minimum	0.77
Maximum	33.05
Count	21

With an increase of 50% in the cost of technical reclamation the overall average environmental cost increases to Rs. 11.04 per tonne. For the sample opencast mines the cost rises to Rs. 12.01 per tonne and for the sample underground mines it becomes Rs. 6.89 per tonne of the coal produced respectively[12].

Similarly, the sensitivity of the environmental costs per tonne to discount rate is analysed. We have assumed a rate of discount of 6% for the analysis in the study. Tables 11 and 12 show the cost implications of changing the rate to 9% and 3% respectively.

[12] See Annexure 4 for the descriptive tables

Table 11 Environmental costs at 9% discount rate

Type of mine	*Capital cost per tonne (Rs.)*	*Recurring cost per tonne (Rs.)*	*Environmental cost per tonne (Rs.)*
Opencast	8.44	5.84	14.28
Underground	4.70	2.21	6.91
Overall	7.61	5.04	12.64

Table 12 Environmental costs at 3% discount rate

Type of mine	*Capital cost per tonne (Rs.)*	*Recurring cost per tonne (Rs.)*	*Environmental cost per tonne (Rs.)*
Opencast	3.97	6.47	10.43
Underground	3.01	3.32	6.33
Overall	3.79	5.87	9.65

With an increase in discount rate to 9%, we find that the environmental cost per tonne for opencast mines increases to Rs. 14.28 per tonne and to Rs. 6.91 per tonne in underground mines. There is an increase in environmental cost per tonne by increasing the discount rate from 6% to 9 %, from Rs. 10.17 per tonne to Rs. 12.64 per tonne. Similarly, applying a 3% discount rate as an annualising factor decreases the environmental cost per tonne from Rs. 10.17 per tonne to Rs. 9.65 per tonne.

Adjusting the mining sector SDP

Although environmental protection activities are already incorporated in the income accounts and as such no adjustment is required, there is an inherent asymmetry in the treatment of this expenditure depending on who incurs it. While environmental protection by government adds to the measure of economic activity, that undertaken by private industry does not.

A method suggested by SEEA to address the asymmetry between government and private environmental protection expenditure is the “gross gross” approach. GDP will have to be increased by the amount of environmental protection expenditure by the industry, similar to treatment of government expenditure towards environmental protection. To arrive at “green GDP”, both the government expenditure and industry expenditure on environmental protection activities have to be reduced.

In our study, we have used the estimators from the sample mines to estimate the total environment protection expenditure for the Madhya Pradesh coal mining industry. The estimation could not be done for West Bengal because of absence of data for adequate number of mines in the state.

Based on the production capacity of the mines we estimated the total environmental protection expenditure by the coal mining industry in Madhya Pradesh to amount to Rs. 7255 lakh, which is 3.5% of the value added by mining in the year 2001-02. According to the adjustments suggested by SEEA, the sector's SDP will have to be increased by this amount to attain symmetry with the treatment of government expenditures towards the environment. Both the government and the industry expenditure towards environmental protection activity will then have to be reduced to arrive at an environmentally adjusted SDP. Since the industry expenditures already appear in the economic accounts, there will be no net effect of such an environmental adjustment on the "green SDP" for the sector.

In the context of the aggregate economy, this could be a simplification, as this does not exclude the addition to GDP by the sectors producing the equipment, which is purchased by the mining industry for environmental protection, e.g. water sprinklers. While adjustments for defensive expenditures may be made at the macro-economic level, this will not capture the inter-linkages across the economy. According to SEEA, the suggestion to remove identifiable elements of defensive expenditure from the expenditure side of the accounts is not tenable within a coherent accounting system unless corresponding adjustments are made in related sectors.

The SEEA also suggests that environmental protection expenditure accounts be prepared for each industry, in order to understand the extent and type of such expenditure. We have suggested a framework for classifying and reporting environmental protection expenditures in the coal mining companies, as in Annexure 5.

Conclusion

The chapter discussed various estimates for average environmental costs in opencast and underground mining for the selected mines in the study states. The average environmental cost per tonne for coal mining was estimated at Rs. 10.17 per tonne, with estimates for opencast mines higher at Rs. 11.12 per tonne compared to Rs. 6.12 per tonne for underground mines. An analysis of the costs shows that technical reclamation accounted for nearly 50% of the capital cost in opencast and for more than 50% in underground mines. Regression analysis was used to determine estimators of environmental costs based on mining capacity and the estimators for recurring costs per tonne on mining capacity. Sensitivity analysis concluded that increasing or decreasing the discount rate from 6% would only marginally affect the environmental cost per tonne. Finally, the study estimates the total environmental protection expenditure of coal industry in a study state based on production capacity of the mines. These costs are already reflected in the income accounts, thereby obviating the need for any adjustment to the state domestic product from mining; however, the figures can be useful in studying the extent of environmental protection costs in the sector.

Annexure 1: Distance function approach for arriving at environmental costs

Output distance function is one of the most attractive representations of the technology of a firm, which produces both desirable and non -desirable outputs. The conventional production is defined as the maximum output that can be produced from an exogenously given vector of inputs. In reality the production processes might be characterized by levels, which are less than that from the predictive levels given technology and inputs. So there is a gap between the actual generation and the maximum generation. Ou tput distance function therefore describes, how far, an output vector is from the representative output set, given the fixed input vector and is often represented as a function of inputs and outputs. One of the extended applications of the output distance function is the calculation of the shadow prices of the undesirable outputs.

Stochastic Frontier Estimation Method

The econometric formulation of the output distance function can be expressed as

Do = f(x, y) exp e .... (1)

where e is the random disturbance term and is assumed to be independently and identically distributed (iid) as N (0, s ^{2}). In econometric estimation, the basic problem with output distance function is the inability to observe the dependent variable. Further if the function is assumed to efficient (i.e. Do = 1), the left hand side of the equation is invariant, an intercept can not be estimated, and the ordinary least squares (OLS) parameter estimates will be biased. To solve this problem, we utilize the property that the output distance function is homogenous of degree +1 in outputs.

?Do(x, y) = Do(x, ?y)

Now suppose ? = 1/ym, then

1/ymDo(x, y) = Do(x, y/ym) ....(2)

From the econometric formulation of output distance function

Do(x, y) /ym = Do(x, y/ym)... (3)

Equation (3) can be converted into a stochastic frontier model for 'Do' by introducing the composed error term.

ln (1/ym) = Translog(x, y/ym)+u+v ....(4)

where v refers to random shocks and noise, u represents the production inefficiency. It is assumed that v is iid as N(0, s_v^2) , and u is assumed to be distributed independently of v and to satisfy u= 0. After having estimated (4), E[u/(v+u)] is calculated for each plant from which plant -specific measures are computed as

Do(x, y) = exp[-E{u/(v+u)}] ....(5)

Like that, the sub-vector output distance function can be estimated. To estimate the sub vector output distance function when the objective is to increase the good output only for the given level of conventional inputs and bad outputs, the distance function takes the form of conven tional production function in which bad outputs enters as inputs. When we are estimating the sub vector distance function in which the objective is to contract the bad outputs for the given level of good output and the conventional inputs, the distance function, as mentioned above, behave like an input distance function. The input distance function has also the property of homogeneity of degree one in inputs. By utilizing this property of homogeneity, we estimate this sub vector distance function that takes the form of stochastic cost function, which again can be estimated by the same procedure.

Annexure 2: List of mines for which environmental costs were requested from companies in the study states

EMP's of any of the following projects (new of expansion), if prepared over the last five years (2000-2005) were requested for. Since the list may not cover all the projects, any EMP prepared outside the list over the five years was also requested for.

Eastern Coalfields Limited

Open cast mines

1. One mine with production > 3 million tonnes per year.

Sonepur Bazari.

2. Four mines with production in the range of 0.2 to 1 million tonnes per year.

Any four mines from the following list:
Shankarpur, Damagoria, Khottadih OCP, Jambad, Chora, Parsea, Mohanpur, Gourangdhi, Bansra, West Kenda.

3. Three mines with production of 0.2 million tonnes per year or less.

Any three mines from the following list:
Toposi OC, Bonjemihari, Mahabir, Setaldasi, Egara, Ardhagram, Methani.

Underground mines

4. Three mines with production > O.3 million tonnes per year.

Any three mines from the following list:
Jhanjra 1&2 incline, MIC Jhanjra project, Khottadih colliery, Bankola, Nimcha.

5. Four mines with production in the range of 0.1 to 0.3 mt per year. Any four mines from the following list:

J K Nagar Colliery	Madhaipur Colliery	Madhab Pur Colliery
Bahula Colliery	Khandra Colliery	Mandarboni Colliery
S S Pur Colliery	Lower Kenda Colliery	Dubeswari Colliery
North Searsole Colliery	Moira Colliery	Kuardi Colliery
Bansra Colliery	Bejdih Colliery	Siduli Colliery
Parbelia Colliery	Pandaveswar Colliery	New Kenda Colliery
Dalurband Colliery	Patmohana Colliery	Sodepur Colliery
Khas Kajora Colliery	Sankarpur Colliery	Naba Kajora Colliery
Parasea Colliery	Jambad UG Colliery	Kanustoria Colliery
Satgram Project	Narsamuda Colliery	Chinakuri - III
Tilaboni Colliery	Kalidaspur Project	Amritnagar Colliery
Kumardihi-B Colliery	Belbaid Colliery	
3 & 4 Incline	Kumardihi-A Colliery	

6. Four mines with production in the range of 0.05 to 0.1 mt per year.
Any four mines from the following list

Haripur Colliery	Madhusudanpur 3 & 4 Pits	Central Kajora
Chora & & 9 Pits	Chapuikhas	Chinakuri - II
Chora 10 Pit	Lachipur Colliery	Mithapur
Dabor Colliery	Madhusudanpur 7 Pits	Methani
Dhemomain Incl	Parascol East	C L Jambad
Sripur Seam Incline	Amrasota Incl.	Madhujore
Nakrakonda Colliery	Ratibati Colliery	Chinakuri - I
Parascol West	Bhanora W B Colliery	South Samla
Dhemomain Pit	Monoharbahal	Parasea 6 & 7
Begunia	Satgram Incline	Kalipahari

7. Four mines with production of 0.05 mt per year or less. Any four mines from the following list

Sangramgarh Colliery	Kendra Colliery
Tirat Colliery	Jemehari Colliery
Chakballavpur Colliery	Puresearsole Colliery
Chora Block Incline Colliery	New Ghusick Colliery
Ningah Colliery	Victora (West)
Musulia Colliery	Khairabad Colliery
Gourandi-Begunia Colliery	Samla Colliery
Girimint/K D I Colliery	

Northern Coalfields Limited

Open cast mines
1. Two mines with production > 5 million tonnes per year.
Nigahi and Jayant.

2. Four mines with production in the range of 1 to 5 million tonnes per year.
Any four mines from the following list.

Gorbi-B	Amlohri
Kakri	Jhingurda
Khadia	

South Eastern Coalfields

Open cast mines
1. Two mines with production > 1 million tonnes per year.
Rajnagar and Dhanpuri.

2. Four mines with production within 1 million tonnes per year. Any four mines from the following list.

Harad Incline	Baiga
Sharda	Amlai
Kotma OC	Jamuna OC

Underground mines

1. Three mines with production > 0.4 million tonnes per year.
Rajendra, Behraband and Rajnagar RO.

2. Four mines with production in the range of 0.2 to 0.4 mt per year. Any four mines from the following list.

Jamuna 9 & 10	Pali
Nowrozabad (W)	South Jhimar
Jamuna RO (1 & 2, 11 & 12)	Bangwar
Vindhya	Kapildhara
Somna	Malga
West Jhagrakhand	Amlai
Pinoura	Bijuri

3. Four mines with production under 0.2 mt per year. Any four from the following list.

New Amlai	Umaria
Chachai	Bhadra
N Jhgarkhand	Navgaon
Seetaldhara	Birsinghpur
Rajnagar UG (Old)	Govinda
South Jhagrakhand	Kurja
Amadand	Piparia
Palkimara	Kotma West
Bartarai	Nowrozabad (E)
Meera	B – Seam
Subhas Incline	Dhanpuri

Western Coalfields Limited

Open cast mines

1. Three mines with production > 0.1 million tonnes per year.
Chhinda OC, New Sethia, Ghorawari patches.

2. Three mines with production within 0.1 million tonnes per year.

Kukumunda OC Mine	Ambara OC
Damua OC Mine	Mohan OC Mine
Shivpuri OC Mine-II	Haranbhata OC Mine
Pench East OC Mine	Rawanw ara OC

Underground mines

1.Three mines with production > O.4 million tonnes per year.
Satpura mine, Tawa mine and Shobhapur mine.

2.Four mines with production in the range of) 0.1 to 0.4 mt per year.
Any four from the following list.

Chhatarpur-I Mine	Vishnupuri-II UG Mine
Vishnupuri-I UG Mine	Chhatarpur-II Mine
Nehariya UG Mine	Ghorawari UG Mine
Thesgora Mine	Maori UG Mine
Gajendoh	Rawanwara Khas UG
Mathani UG Mine	Pathakhera Mine-II
Nandan-2 UG Mine	Sarni Mine
Ambara UG Mine	Pathakhera Mine-I
Nandan-1 UG Mine	

3.Four mines with production under 0.1 mt per year. Any four from the following list.

Chandametta Colliery	Mahadeopuri Incline
East Donger Chikhli Colliery	Mohan UG Mine
Sukri	Ganpati Incline
Bansi UG Mine	Damua UG Mine
Tandsi UG Mine	

Annexure 3: Questionnaire for collecting environmental costs incurred by companies

1. **Recurring environmental costs**

	Revenue expenditure		**Rs.**
1	Repairs and maintenance of haul roads		
2	Repair and maintenance of pollution control equipment (air, land)		
3	Repair and maintenance of effluent treatment plant		
4	Stores and consumable		
5	Miscellaneous expenditure		
6	Administrative charges		
7	Depreciation on machinery (Used for control measures)		
8	Salaries and wages		
9	**Manpower for environmental activities**	No. of persons	Average annual wages
	Land reclamation including technical & biological		
	Air, water and noise control management		
	Environmental monitoring		
	Community development		

2. **Environmental cost matrix**

Sl. No.	**Particulars**	**Equipment quantity**	**Expected life of equipment**	**Amount/unit**	**Total amount**
1	**Air pollution control cost**				
	Capital for anti-pollution measures in mine industrial area: Dust suppression and extraction equipment				
	Water sprinklers				
	Plantation/arboriculture in industrial area				
	Metalling/concreting of roads				
	Air quality monitory station				
2	**Water pollution and effluent control cost**				
	Settling tank and garland drain				
	Sedimentation pond for treatment of mine pumped out water				
	ETP for workshop effluent				
	Water quality monitoring station				
3	**Land/ Biodiversity and landscape reclamation**				
	HEMM for reclamation with Float engine				
	Biological reclamation and greening				
	Compensatory afforestation				

4	**Noise control**				
	Ear muffs for workers				
	Noise pressure meter				
5	**Other environmental control measures**				
	Please specify				

3. Payment to State Pollution Control Boards

1. Initial air, water consent fees
2. Annual air, water consent fees
3. Water consumption (KLD and KL per year) and water cess paid (both domestic and industrial).

Annexure 4: Descriptive statistics of sensitivity analysis by type of mining

Environmental cost per tonne (opencast, with 25% increase technical reclamation)	
Mean	11.56
Standard Error	1.72
Median	11.07
Standard Deviation	8.05
Sample Variance	64.82
Minimum	3.91
Maximum	36.52
Count	21

Environmental cost per tonne (underground, with 25% in technical reclamation)	
Mean	6.50
Standard Error	3.41
Median	2.87
Standard Deviation	7.63
Sample Variance	58.19
Minimum	0.77
Maximum	19.08
Count	4

Environmental cost per tonne (opencast, 50% in technical reclamation)	
Mean	12.01
Standard Error	1.83
Median	11.38
Standard Deviation	8.36
Sample Variance	69.90
Minimum	4.37
Count	21

Environmental cost per tonne (underground, with 50% in technical reclamation)	
Mean	6.89
Standard Error	3.71
Median	2.87
Standard Deviation	8.29
Sample Variance	68.80
Minimum	0.77
Maximum	20.63
Count	4

Annexure 5 : Framework for classifying environmental protection expenditure in the mining sector

CEPA	Environmental impact/pollutant	Expenditure category	Amount (In Rupees unit)
Protection of ambient air and climate	SPM, Sulphur dioxide and Nitrogen Oxides	**Capital expenditure** Drills with dust extractors (extra-cost) Surfacing all permanent roads, incl. Haul roads HEMM equipment with dust proof cabins Dust extraction/suppression system Provision of green belt/Arboriculture	
		Current expenditure Use of chemical additives for dust suppression Watering of overburden dump surfaces	
Waste water management	Suspended particulate matter, heavy metal content	**Capital expenditure** Water treatment plant Water quality monitoring station Sedimentation by slurry ponds, check dams and closed water circuit	
		Current expenditure Maintaining drains, nallah etc.,	
Waste management	Stacking of waste dumps	**Capital expenditure** Industrial effluent treatment Domestic effluent Other measures	
		Current expenditure	
Protection and remediation of soil, ground water and surface water	Overburden material, subsidence, external dumps, disruption in water regime, silting of water stream	**Capital expenditure** Settling tanks, Garland drains	
		Current expenditure	
Noise and vibration abatement Face dust masks and ear protectors	Ground vibration	**Capital expenditure** Noise absorbing equipment including padding/lining and operator cabin design Ear muffs for workers	
		Current expenditure Maintenance of all P & M and replacement of worn out parts	
Protection of biodiversity and landscape	Disturbance to flora, fauna and aquatic life	**Capital expenditure** Biological reclamation HEMM for reclamation with float engine Compensatory afforestation	
		Current expenditure	
Protection against radiation	Health impact to miner workers	**Capital expenditure**	
		Current expenditure	

Research and development		**Capital expenditure**	
		Current expenditure	
Other environmental protection activities		**Capital expenditure**	
		Current expenditure	
General environmental administration and management		**Capital expenditure** Base line data generation Community development	
		Current expenditure O&M cost for environmental monitoring	
Education, training and information		**Capital expenditure**	
		Current expenditure	
Activities leading to indivisible expenditure		**Capital expenditure** Rehabilitation package Shifting allowance Economic compensation to land losers Rehabilitation packages	
		Current expenditure	
Activities not elsewhere specified		**Capital expenditure**	
		Current expenditure	

CHAPTER 8 Summary and the way ahead

This project was commissioned by the Central Statistical Organization, Ministry of Statistics and Programme Implementation, Government of India, as part of a larger exercise to develop a framework for natural resource accounting in the country. The study focuses on the mining sector, looking at issues related to both the depletion of sub-soil assets as well as the environmental impacts associated with extraction of these resources. As suggested by CSO, the states of Madhya Pradesh and West Bengal were taken up for demonstrating the methodology.

In both states, coal dominates the mining sector. In 2002/03, coal accounted for about 85% and 98% of the total value of mineral production in MP and WB respectively. The states make up for about 7.5% and 11% of the total coal resources available in the country, respectively. Therefore, the study focused on the coal sector in both states.

This chapter summarises the main findings of this project and highlights the data problems that were faced in the analysis. The usefulness of a study such as this lies in its potential application in policy making. The chapter discusses some of the policy applications of such research. It concludes with ideas for future research in this area.

Summary

The study begins with a detailed survey of the current literature related to natural resource accounting in general; and the physical and economic estimation of depletion of non-renewable sub-soil assets and the environmental impacts of extractive industries in particular. A number of recent studies in this area are highlighted while emphasizing on the approaches outlined in the United National System of integrated Environmental and Economic Accounting (UNSEEA). The UNSEEA aims at bringing together international experience in the use of statistical accounts for studying the interaction between the economy and environment. Despite these initiatives, there are as yet no universally accepted frameworks/approaches to dealing with natural resources in the conventional income accounts. The design of methodologies is dependent on the resource being studied, crucially on data availability and the peculiarities of the sector in the country. These issues are illustrated in the following sections.

Before preparing physical and economic accounts for coal depletion and environmental impacts due coal mining, the report provides a general discussion of the coal industry in India. Geologically, Indian coal is of mostly sub-bituminous rank, followed by bituminous[1] and lignite (brown coal). Of this coal non-coking constitutes almost 90% of the production of total raw coal, the rest being coking coal. Post nationalisation of the coal mines in India in 1972/73, the coal industry turned into a virtual monopoly of Coal India Limited (CIL). The public sector CIL is the parent company holding seven coal producing subsidiaries concentrated in central and eastern India. Arising out of the monopoly structure of the industry are problems of production inefficiency in some mines and of pricing coal. With the beginning of economic reforms in the country and increasing competition from international traded better quality coal, there have been steps to improve the commercial and financial viability of the industry by inter alia lowering import tariffs, gradually deregulating pricing and distribution and opening up captive mining and coal-washing to private ownership.

Inefficiencies in production can have a direct bearing on the estimation of resource rent. This issue is dealt with in detail in the report and highlighted later in this chapter.

Chapter 4 discusses physical asset accounts for coal – separately for various grades of coking and non-coking coal as classified in India. These accounts make use of the following basic identity

Closing stock = opening stock + reserve accretion – production (depletion)

Continuous assessments have been adding to the coal availability in the states. Since the mineral classification system in the country does not distinguish between reserves and resources, "proved coal" resources in the states were used to prepare the accounts. The analysis found that overall, non-coking resources noted a net increase over the period 2000/01 - 2002/03, with the rise generally being higher for lower grades. In the case of coking coal, there was a marginal drop in available resources in both states.

The chapter discusses the United Nations Framework Classification (UNFC) for energy and mineral resources and compares it with the Indian system. The UNFC takes into account geological certainty, feasibility assessment, and economic viability in making the distinction between 'resources' and 'reserves'. Reserves are defined as the economically viable and technically feasible part of the 'resource'. The Indian system is based entirely on geological assessments and does not isolate reserves from resources. Such reporting has resulted in misplaced confidence in the long-term availability of coal in

[1] Bituminous coal is a soft coal containing a tar-like substance called *bitumen*. It is of better quality than lignite coal but of poorer quality than anthracite coal.

India. The study estimates that reserves constituted less than 20% of the reported proved resources of coal in both Madhya Pradesh and West Bengal in 2003. Physical accounts based on estimates of reserves suggest that the long-term availability of coal in the country is not as promising as suggested by accounts based on reported proved resources.

The next chapter estimates the resource rent of coal. Various scenarios were worked out based on the different data sources. In one of the scenarios (in which consumption of fixed capital was derived from the financial statements of mining companies), the resource rent for MP in constant 1993/94 prices was found to fall from Rs 35/ tonne in 1999-00 to Rs 22 in 2000-01 and then rise to Rs 48/tonne in 2001-02. This fluctuation could also be due to the formation of Chattisgarh in 2000.

In the case of WB, the striking finding is the existence of negative resource rents for coal for most years being studied. It is postulated that the negative resource rents are on account of the presence of several uneconomic underground mines in the state. Inefficiencies in production are apparent from the low levels of output per man shift and high CoE (compensation of employees) per tonne as compared to underground mines in other states.

In order to eliminate these biases, the input distance function approach was used to estimate the productive efficiencies of inputs used in individual mines with respect to a notional efficient frontier. The average efficiency for all underground mines was found to be 74%. Using the revised estimates of "efficient" CoE, the resource rent per tonne was estimated at Rs 204 and Rs 166 at current and constant prices respectively as compared to Rs –87 and Rs –8 under the original scenario in 2001/02.

With this level of CoE, the depletion premium or user cost component as a share of mining sector SDP in WB varied from to 0.1% (at 6% rate of discount) to 2% (3% rate of discount) in 2001/02. For Madhya Pradesh, the estimates of depletion as share of mining sector SDP for the same year varied from 2.5% (at 6% rate of discount) to 6% (at 3% rate of discount).

Chapter 6 outlines the environmental impacts due to mining in general and the particular impacts of opencast and underground coal mining in India. The chapter discusses the mitigation and abatement activities required to be undertaken by the mining industry in the country to address these environmental impacts.

Chapter 7 arrives at estimates of average environmental costs in opencast and underground mining for selected mines by using the control cost method of valuation. The study calculates that the average environmental cost per tonne for coal mining is Rs. 9.92, with estimates for opencast mines higher at Rs. 10.70 per tonne compared to Rs. 6.59 per tonne for underground mines. An analysis of the costs show s that technical reclamation accounts for nearly 50% of the capital cost, both in opencast and underground mines. Regression analysis is used to determine estimators of environmental costs based on mining capacity. As percentage of value added by the mining industry of Madhya Pradesh, environmental protection expenditure was estimated at 3.5% in 2001/02[2].

Data issues

The availability of data is perhaps the most important factor in determining the approach to any study and the robustness of its results. The problems of data could be many : data not being generated in the first place, inconsistency across sources and data not being shared.

Mine wise data on inputs and outputs for all mines in the two states, for instance, was not readily shared. As a resu lt the analysis on productive efficiency of mines could not be extended to all mines or more time periods.

Likewise, expenditure data from EMPs (environmental management plans) of mines could have been verified with actual recurring and capital environmental protection expenditure. The mining companies, however, did not share this information. This data would have been crucial in understanding the deviation of actual costs from those envisaged at the time of preparing the EMPs. There is a need for mining companies to appropriately classify and report their environmental protection expenditure. One such classification and reporting framework is suggested in this report.

In some cases, data from different sources did not match. For instance, IBM norms (as percentage of the value of output) for depreciation and the actual consumption of fixed capital (estimated from financial statements of mining companies) vary widely for the study states. Likewise norms and actual data on cost of inputs do not match. These norms need to be updated.

The environmental statements by the companies in the study states showed that they adhered to the ambient norms set by the state pollution control boards. However, many experts felt that in actuality there might be violation of norms, with actual ambient data not being reported. Some independent monitoring studies do point towards such violation. However, since the study did not carry out primary monitoring, it could not take up this issue of discrepancy between actual measurements and reported data.

Finally, some of the data required for such research is not being generated at all. The value of physical capital stock and depreciation by sector is not estimated at the state level. All

[2] A similar analysis could not be carried out for West Bengal due to the lack of data

India estimates are divided across states based on specific criteria for different sectors.

There are no estimates of pollutant loads from coal mining. Given the fugitive nature of emissions from the mining sector, information on loads is necessary to examine the extent of pollution due to mining and to apply techniques such as 'distance function' to estimate the shadow price of the pollutants.

These and other data gaps noted in the individual chapters need to be bridged if such resource accounting exercises are to be taken up on a systematic basis.

Policy applications

Perhaps the most important use of natural resource accounting initiatives is to mainstream natural resources in the conventional income and wealth estimates, forcing policy makers to take note of the "hidden cost" of economic growth. However, such an accounting exercise could also contribute to policies for natural resource management such as in the design of taxes and subsidies and in studying their efficacy.

In the context of this project, these accounts could indicate more than just the cost of depletion and environmental degradation due to mining. They could, for instance, provide pointers to the level of royalty that should be collected from the mining industry and the use it should be put to.

In the case of non-renewable assets, the weak sustainability paradigm suggests that a part of the rent received from these assets should be reinvested in alternative forms of capital (including human capital) so as to maintain the level of 'total' capital stock in the economy. This reinvestment of capital must take place in the region of extraction so that the ability of the local economy to generate the same level of income is maintained even after the resource has been exhausted.

This requires that the royalty is set at the correct level (reflecting the 'user cost' component of rent) and that it is channelled into a dedicated revenue fund used for investment in the region. Botswana, an economy highly dependent on mineral resources, has developed the Sustainable Budget Index (SBI) to indicate how much of the mineral revenues are used in capital expenditure. The government has adopted an informal fiscal guideline requiring that no revenues from mining should be used for other current expenditures.

Likewise, accounts on environmental costs can be useful in guiding policies for pollution abatement. This study examined the environmental protection expenditure of the mining companies and arrived at norms for calculating environmental costs in the study region. These norms serve not only as a measure of the costs that have to be incurred by the mining companies to mitigate and abate environmental impacts, but at an aggregate level, are indicative of the importance of the environmental protection sector in the economy.

The study proposed a framework for reporting environmental protection expenditures (EPE) that could assist policy makers in studying the response of the mining industry to environmental standards. Together with an understanding of ecological impacts of environmental regulation, such information can be useful in assessing the costs and benefits of environmental standards and in designing their appropriate levels.

Similarly, the tax component of the EPE accounts along with data on physical impacts, can be useful in assessing whether the tax regime provides appropriate incentives or disincentives or whether environmental regulations need revisions. (Lange, 2003)[3] notes that EPE accounts can provide the following information to policy makers:

- the cost of implementing environmental regulations over time by companies; and the assessment of costs of regulation in relation to their benefits.
- the effectiveness of environmental protection expenditures and eco-taxes in reducing pollution.
- the economic impact of environmental expenditures and taxes on prices, productivity and international competitiveness.

Future research

While there has been considerable work on natural resource accounting, its integration in conventional income accounts remains a contentious issue. This area requires the close involvement of national income accountants. That this project has been initiated by the CSO is, therefore, commendable.

Accounting for natural resources requires a clear understanding of the interlinkages between anthropogenic activities and the physical environment on the one hand and the impacts of environmental damage on the other. Scientifically generated information on these linkages can itself provide useful indicators independent of valuation initiatives.

In the mining industry, detailed time-series data on physical impacts like overburden generated, water use, forest land acquired etc., could be useful in policy formulation. Given that mining emissions are of a fugitive nature, the estimation of load becomes very difficult. Currently data is available only for ambient concentration of pollutants in the mining region. Since several coalmines coexist with thermal power plants and other industries which also contribute to worsening of the ambient air

[3] Lange, Glen-Marie, 2003. "Policy Applications of Environmental Accounting", Environmental Economics Series. World Bank.

quality, source apportionment studies are required to determine the contribution of mining to pollution loads.

Simultaneously, there is a need to estimate environmental costs of mining in terms of the damage they cause. An important aspect in this case would relate to the health impacts of mining. There have been reports of life expectancy being lower in mining regions, including those in the mining corridor. An understanding of the costs borne by the community in and around the mining regions could be useful not just in mitigating these costs but also in designing appropriate compensation mechanisms.

Along with research, it is also necessary for the country to move towards international best practices and conventions as in the case of minerals classification. This is also necessary for the country to strategize its energy plans in the future realistically. The Central Mine Planning and Design Institute Limited is currently working on adapting the United Nations Framework Classification (UNFC) for energy and mineral resources for a more realistic assessment of India's sub-soil resources. In 2000, the Ministry of Mines constituted a committee to formulate field guidelines for implementation of the UNFC in exploration and mineral resource estimation in India. These guidelines need to be formally incorporated in the mineral classification system of the country. Similarly, the country should gradually move towards ISO 9001 and ISO 14001 accreditation for its mines.

To conclude, accounting for natural resources is now accepted as being vital to derive indicators of the long-term health of the economy. This study focussed on the mining sector and attempted to suggest methodologies for estimation of mineral depletion and the environmental cost of mining; point out areas where the availability and quality of data can be strengthened; and identify areas for further research. It is hoped that this initiative will contribute to the efforts of the Central Statistical Organization towards developing a resource accounting system for India.