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Valuation of Subsoil Minerals: Application of SEEA for Bangladesh

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Net present value
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Abstract

The quality of the Gross Domestic Product in developing countries is as important as its size given environmental degradation due to the aggressive extraction of subsoil minerals from the geo-sphere to accommodate production processes as well as emissions into the bio-sphere. Green national accounting is one way to come up with more durable environmental policymaking, which does not compromise ongoing economic expansion in developing and emerging economies. The present paper is an attempt to conduct a valuation of the three most important exhaustible natural resources, *viz*., natural gas, coal and hard rock, via the System of Environmental-Economic Accounting, which has not yet been carried out in Bangladesh. The study applies the net present value method for natural resources for this purpose. We prepare physical and monetary balance sheets for each of the three resources for the most recent accounting years. We test the sensitivity of the opening balance by using different discount rates for the selected minerals. The results reveal that the stock value of coal is about eight times higher than that of natural gas even though the latter is regarded as the most important subsoil mineral among the top three resources in Bangladesh. The findings of this study will be of use to policy makers to work on a more environmentally sensitive national accounting system.

Keywords

Subsoil resources, SEEA, Net present value, Resource rent, Physical balance, Monetary balance.

Valuation of Subsoil Minerals: Application of SEEA for Bangladesh

1. Introduction

The conventional System of National Accounts (SNA) is frequently criticized for the inability of the Gross Domestic Product (GDP) to be a satisfactory measure of welfare derived from the utility of the standard value of output (Howarth and Farber, 2002). Its inadequacy is further compounded in the case of developing countries where the quality of the GDP is equally important due to the aggressive rate of extraction of subsoil mineral resources like natural gas and coal from the geo-sphere to accommodate production processes. However, national accounting measures of many developing countries tend to exclude the “environment”, which makes it impossible to comprehend as well as to adequately quantify the impact of rapid natural resource depletion on the environment and the economy. Hence, devising more durable environmental policymaking which does not compromise ongoing economic expansion in developing and emerging economies is of paramount importance. Green national accounting, for this reason, has attracted significant attention in the literature, particularly over the last three decades, and in the last twenty years, there has been considerable debate over the method to be used in green national accounting (Dasgupta, 2013). In recent years, “green” measures of income and other related indices have begun to play an important role in providing comprehensive economic information systems. Such recognition of the importance of green national accounting is consistent with the standard view of national accounting systems, such as SNA (Heal and Kriström, 2005).

Understanding the welfare of national income was the initial point of departure for green accounting while also serving as one of the foundations of green accounting and durable environmental regulations. In his seminal contribution, which is today regarded as the theoretical foundation for greening the net national product, Weitzman (1976) showed the significance of analyzing the dynamic welfare of comprehensive national accounting aggregates as well as the uses to which they can be put in order to determine differences in the welfare of populations for the purpose of assessing whether development is sustainable. It, in turn, led to subsequent contributions on welfare and sustainability accounting, *viz*. Hartwick (1990) and Mäler (1991), to explicitly include natural resources and the environment in national accounting. They proposed corrections to national accounting to include the degradation of the wealth of natural resources and the value of the environment.

Harnessing natural resources, especially extractive ones (*viz*. natural gas, oil and soil minerals such as coal and hard rock), is important for sustainable development. But setting the extraction rate of natural resources in a sustainable and integrated manner is also essential for sustainable development. Sustainable development is conceived as a development trajectory which does not maximize the well-being of today’s generations at the expense of the well-being of generations to come (Lawn, 2003). Hence, understanding the stock value of exhaustible natural resources is crucial to reversing their rapid depletion.

Being one of the most densely populated countries of the world, Bangladesh has been prevented, due to economic imperatives, from adopting a growth and development path that takes into account the adverse impacts of mineral depletion and environmental degradation. Currently, an initiative is underway however to estimate the value of the natural resource stock in the country through which the optimal rate of extraction could be arrived at that is commensurate with the stipulated path of national economic growth and development.[1] At present, the contribution of natural resources such as minerals, water, fishery and forestry are calculated for financial years using the value addition method of national income accounting following the SNA 2008 (United Nations *et al*., 2008). It is important, therefore, to conduct a comprehensive accounting of national wealth, which would serve as the basis of natural resource planning for the country.

Given this backdrop, the present study applies the System of Environmental-Economic Accounting (SEEA) to undertake a valuation of the three most important sub-soil minerals, *viz*., natural gas, coal, and hard rock, in Bangladesh, which has not been undertaken before.[2] The three subsoil minerals constitute a case study to test the usefulness of SEEA to Bangladesh. The study has two objectives: firstly, to demonstrate how to calculate 'green national accounting' for Bangladesh; secondly, to contribute to the literature on green national accounting. With these objectives in mind, we have organized the rest of the paper as follows: Section 2 presents a brief account of the major subsoil minerals of the country. Section 3 gives the methodology for conducting the valuation of natural gas, coal and hard rock using the SEEA framework. Section 4 provides the results and analysis of empirical findings. Section 5 raises some critical issues in SEEA related to the valuation of sub-soil minerals and their implications for national accounting. Section 6 offers concluding remarks carrying policy implications.

2. Subsoil Minerals of Bangladesh

The country's major mineral resources are natural gas, coal, peat, hard rock and gravel. Of these, natural gas is the major mineral and energy resource of the country. It is used mostly in producing electricity and fertilizer and supplying fuel for motor vehicles and energy and inputs for households and industries (Figure 1). According to a July 2015 estimate, the proven gas reserve of Bangladesh was 14.05 trillion cubic feet (TCF) (Petrobangla, July 2015). The state-run Oil, Gas and Mineral Resources Corporation (Petrobangla) supplied about 2.44 billion cubic feet (BCF) of gas per day or about 0.89 TCF in 2014-15. Even though the demand for natural gas has been expanding rapidly in manufacturing, power generation, transport and households, no significant discoveries in natural gas has been made in recent years. In fact, Sangu, a prominent offshore gas field, was shut down permanently in October 2013 due to the rapid decline in reserves beyond a critical level, which has raised debates on the over-extraction that led to the alleged 'premature death' of a dependable source of natural gas serving the commercial capital of the country. Hence, the rapid depletion in gas reserves is likely to have a detrimental impact on the entire economy in the foreseeable future.

In addition to gas, coal is an important energy input and domestically extracted coal is in use in many areas. The estimated reserve of coal is 1.66 billion tons in four coal mines of which extraction is taking place in the Barapukuria coal mine in the Dinajpur district, which is the second biggest reserve of the country (at 300 million tons). In the last fiscal year (2014-15), domestic sales of coal generated Tk.8.5 billion whilst sale of the main energy input, natural gas, generated Tk.74.95 billion. The sales revenue from hard rock was Tk.0.78 billion (Petrobangla, July 2015).

[1] Bangladesh Bureau of Statistics (BBS) has developed Bangladesh Framework for Development of Environment Statistics 2017 in which component deals with "Environmental Resources and Their Use". It is in the process of undertaking valuation of natural resource stock of the country.

[2] The first comprehensive operational framework of environmental accounting, called the System for Integrated Environmental and Economic Accounting (SIEEA), was proposed by the United Nations Statistical Division (1993), but as the outline of a satellite account to the SNA for environmental goods and natural resources. Subsequently, the SEEA Central Framework (2014), which set out in detail the accounting structure that has been adopted as an international standard by the United Nations Statistical Commission (UNSC). It is also regarded as the first international statistical standard for environmental-economic accounting, which contains a multipurpose conceptual framework for comprehending the interactions between the economy and the environment, and for recounting stocks and changes in stocks of environmental assets.

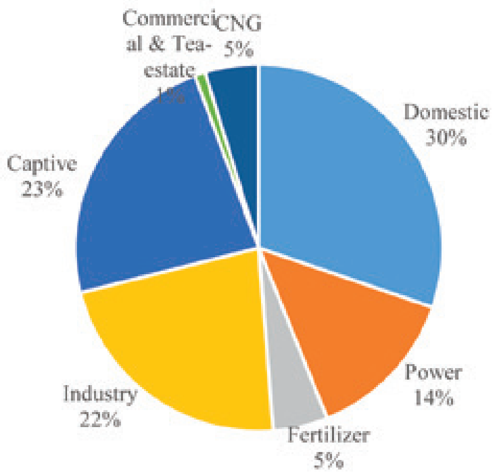

Figure 1: Use of natural gas by sector (2014-15)

Source: Petrobangla MES Report, July 2015

A large reserve of hard rock is located at Maddhapara in Dinajpur district. Hard rock deposits have also been recorded at Ranipukur and Pirganj in the Rangpur district and in Bogra, Joypurhat-Jamalganj, and Kansat in the Rajshahi district (Rahman, 1997). In addition to these, surface deposits of construction materials such as boulders, gravel, etc., have been found in the Tetulia-Panchagarh and Dinajpur districts as well as in Kaptai-Alikadam-Ukhia-Teknaf-St. Martin's Island in the Chittagong and Cox's Bazar districts, in addition to a few other places in the Sylhet division.[3]

There has been considerable debate in the public sphere for some time on the method of extraction of coal due to its adverse impacts on the environment and livelihoods as well as the role played by International Oil Companies (IOCs) in the energy sector. IOCs have been found to play quite aggressive roles in extracting natural gas as is evident from the increase in their share of total gas production which has gone up to 56 percent in 2014-15 from 52 percent in 2010-11. Since the country is critically dependent on minerals like natural gas and coal for nearly all sectors of the economy including manufacturing and services, it is important to arrive at a proper valuation of these resources which would generate useful information for determining an optimal extraction policy by the government.

3. Methodology and Data

3.1 Accounting method

The SEEA Experimental Ecosystem Accounting (2013) provides the following: a common set of terms, concepts, accounting principles and classifications; an integrated accounting structure of ecosystem services and conditions in both physical and monetary terms; and the recognition of spatial areas as forming the basic focus for measuring various ecosystem and asset accounting including carbon.[4] Physical flow accounts provide systematic physical descriptions of physical flow including the extraction of natural resources, their use and transformation within the economy, and the return to the environment. Conversely, monetary accounts identify environment-related transactions in the existing SNA flow accounts to make them more explicit for analysis. Another account called the "asset account" takes into account the stocks and changes in stocks (flows) of gas, hard rock and coal resources

[3] The hard rocks of Bangladesh are classified as (i) Maddhyapara subsurface hard rock, (ii) Bholaganj-Jaflong hard rock concretions, (iii) Tetulia-Patgram-Panchagarh hard rock concretions, and (iv) Chittagong-Chittagong Hill Tracts sedimentary concretions.

[4] However, Dasgupta *et al*. (2013) claim that the classification scheme described in the SEEA suffers from serious shortcomings. They suggest a number of measures for making the SEEA more conveniently serve the purposes of economic evaluation of environmental accounts. The SEEA also does not attempt to measure welfare; rather it works out the output in environmental accounts.

in physical and monetary terms. Wealth accounts and depletion are also calculated in this account. Finally, the SEEA Central Framework (United Nations *et al.*, 2014a) provides a combined module to form a full sequence of national accounts. It also integrates the physical and monetary accounts to obtain the relevant aggregates. The SEEA Experimental Ecosystem Accounting provides accounting for ecosystem stocks, the capacity of ecosystems to provide services, degradation in natural resource stocks and, finally, carbon and biodiversity accounts (United Nations *et al.*, 2014b).

Following the SEEA Central Framework (2014), physical and monetary balance sheets can be prepared separately for natural gas, hard rock and coal. The physical balance sheets consist of several items. Each accounting year starts with an opening stock which is equal to the closing stock of the previous year. During the year, the opening stock is altered by three annual flows: (a) reappraisal of existing reserves, (b) new discoveries, and (c) extractions. The combination of these items results in a physical balance sheet for natural gas, coal and hard rock.

For preparing the monetary balance sheets for gas, coal and hard rock reserves, an appropriate valuation method is followed and assumptions are made on future physical extractions, the resource rent and the discount rate. The value of an asset in the national accounts should reflect the value of the asset were it to be traded in an open market. Nordhaus (2000) has discussed different methods of mineral valuation, such as the current rent method, which describes variants of the Net Present Value (NPV) method such as the two types of current rent method based on the Hotelling valuation principle.[5] The study in question also calculates the value of minerals by using these methods to provide a comparative picture of valuation for USA. It uses two different discount rates for assessing the sensitivity of findings. Cairns and Davis (1998) have provided an algebraic representation of NPV, which is an improvement over Nordhaus (2000), as it takes the Risk-Adjusted Discount Rate (RADR) instead of the simple discounting used in the NPV method, thus implying that higher discount rates could result in lower asset values and vice versa. Veldhuizen *et al.* (2009) have laid out a detailed framework of valuation of oil and gas reserves in the Netherlands within an SEEA-consistent framework. It uses the NPV method for the valuation of these mineral resources for 1990-2005, which is based on scenarios of physical extraction and expected resource rent. The SEEA Central Framework (2014) also suggests the use of NPV for the valuation of subsoil minerals. However, the methodology of valuation in SEEA (2014) is different from that of Veldhuizen *et al.* (2009).

In Bangladesh, the marketing of natural gas is a state monopoly while the extraction coal domestically is undertaken by the Barapukuria Coal Mine Company, which is also state-owned. Bangladesh also imports large volumes of coal from India, at what can be considered a market price. However, since the observed market values for transactions in oil and gas reserves are not widely available, we use the NPV method to give a monetary value to the physical stocks of reserves. This method is recommended in the Handbook on Measuring Capital (OECD) and in the SEEA Central Framework (2014).

3.2 Value of stock at period *t*

Following the SEEA Central Framework (2014), the method of valuation of subsoil minerals can be described as follows. Assuming all yearly income from the extraction of reserves is received at the end of the year, the NPV of future income from the reserves at the beginning of year t can be written as:

$$V_t = \sum_{t=1}^{Nt} \frac{RR_{t+\tau}}{(1+r_t)^{\tau}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where r_t is a nominal discount rate valid at time t; RR_t is the resource rent at t, $\tau = 1, 2, \ldots, N_t$; and V_t is the value of the stock at the end of period t. Thus, $RR_{t+\tau}$ is the nominal value of expected future resource rents while the projected time profile of the resource rent $\{RR_{t+1}, RR_{t+2}, \ldots\}$ may be non-constant.[6]

[5] Hotelling, H. (1931), ‘The Economics of Exhaustible Resources’, Journal of Political Economy 39(2):137-175.

[6] This is a three-year moving average to estimate the expected unit resource rent.

The resource rent (RR_t) is the net income from extraction defined as the total revenue from sales less all costs incurred in the extraction process including the user cost of produced capital.[7] RR is composed of two components: (i) quantity of the resource extracted (S_t) and (ii) price per unit of the resource extracted (PS_t). The second component is equivalent to the unit resource rent, i.e., the rent per extracted unit of resource. Here, RR_t has been assumed to be observable from the rent payments that extraction enterprises pay to the owner of a natural resource. In the present analysis, the owner of the resource is the Government of Bangladesh.

Here, V_t is composed of a price (P_t) and a quantity of (a single resource) (X_t) components. In the present case, if V_t is the value of natural gas, P_t equals the price per cubic feet of natural gas at the end of period t, and X_t is the number of cubic feet of gas at the end of period t, we therefore have

$$V_t = P_t X_t \quad \text{..} \quad (2)$$

To obtain an estimate of the price P_t and subsequently of V_t, we use the NPV condition from equation (1) together with the definition of the resource rent $RR_t = P_{St} S_t$:

$$V_t = P_t X_t = \sum_{t=1}^{Nt} \frac{P_{s,t+\tau} S_{t+\tau}}{(1+r_t)^{\tau}} \quad \text{..} \quad (3)$$

The SEEA Central Framework suggests making two alternative assumptions on the future rate of extraction of non-renewable natural resources and the expected price change of P_{St}. One would be that the most recent quantity of extraction would prevail in future extractions so that $S_{t+\tau} = S_t$ $(\tau = 1,2,3,\ldots,N_t)$. To avoid the effect of unusually large or small extractions in a particular year, the rate of extraction can be excluded and a moving average taken from the rate of extraction of the most recent three years by assuming that such unusual rates of extraction are unlikely to occur again in future. Another assumption would be a constant rate of extraction, so that $S_{t+\tau}/X_{t+\tau}$ is constant for $\tau = 1,2,3,\ldots,N_t$. However, in this study, we decided to adopt the first assumption to accommodate the usual changes in extraction over time.

3.3 Depletion, discoveries and losses

In the *ex* post sense, the difference between X_t and X_{t-1} can be decomposed into three components: depletion (or extraction), discoveries and other additions, and catastrophic losses and other reductions. However, *ex ante*, discoveries and catastrophic losses are unknown at the end of the preceding period t-1. Hence, depletion is defined as $S_t = X'_{t-1} - X'_t$ where S_t is the extraction during period t, and X'_t is the quantity of subsoil minerals at the end of t given the information available at the end of t-1. Discoveries constitute an unexpected addition to the resources while catastrophic losses indicate their unexpected and significant reductions during the accounting period. Their combined effect can be measured as $X_t - X'_t$ or the difference between actual and expected quantities at the end of the period.

In order to disentangle the discoveries and catastrophic losses, let I_t and L_t be the physical amount of discoveries and catastrophic losses, respectively, such that $X_t - X'_t = I_t - L_t$. Thus, the total physical changes in the resources between the beginning and the end of the accounting period are:

$$(X_t - X_{t-1}) = (X_t - X'_{t-1}) \equiv \Delta X_t = (X_t - X'_t + X'_t - X'_{t-1}) = I_t - L_t - S_t$$

The change of value of a resource between t and t-1 given the available information in both the periods can now be decomposed as

$$(V_t - V_{t-1}) = (V_t - V'_{t-1}) = (P_t X_t - P_{t-1} X_{t-1}) = \underbrace{P_{t-1} \Delta X_t}_{\substack{\textit{Quantity} \\ \textit{Effect}}} + \underbrace{X_t \Delta P_t}_{\substack{\textit{Revaluation} \\ \textit{Effect}}}$$

[7] It is also equivalent to the total value of the natural resource input into the production process in an accounting period.

Alternatively, the two effects can be expressed as follows:

$$(V_t - V_{t-1}) = \underbrace{0.5\,(P_{t-1} + P_t)I_t}_{\textit{Discoveries}} - \underbrace{0.5\,(P_{t-1} + P_t)L_t}_{\textit{Catastrophic Losses}} - \underbrace{0.5\,(P_{t-1} + P_t)S_t}_{\textit{Depletion}} + \underbrace{0.5\,(X_{t-1} + X_t) \triangle P_t}_{\textit{Revaluation}}$$

The valuation of depletion with the average price of the period is consistent with the SNA for valuation of consumption of fixed capital. Also, discoveries and catastrophic losses are valued with mid-period prices to remain consistent with the valuation of depletion. The depletion-adjusted resource rent can be written as

$$RR'_t = r_t V'_{t-1} - 0.5\,(X'_{t-1} + X'_t) \triangle P'_t + 0.5\,(P'_{t-1} + P'_t)(S_t - G_t)$$

3.4 Data sources

The study is mainly based on data available at Petrobangla and the Ministry of Power, Energy and Mineral Resources of the Government of Bangladesh. In Bangladesh, the tariff (user price) of minerals is determined by the Bangladesh Energy Regulatory Commission (BERC) while the last tariff revision had been done in September 2011 though only for Compressed Natural Gas (CNG). Thus, there has been no change in the price [?] of gas and related petroleum (generated as by-products) for the accounting period of monetary balance.[8] The data of price and user cost of capital have been taken from Petrobangla MES and annual reports.

We calculated the rate of extraction from a three-year moving average rather than a constant rate of extraction in physical terms taking into account the non-food inflation[9] for incorporating the price level fluctuations. We adjusted the resource rent for price level fluctuation while also addressing the unusual large number or small number possibility in resource rent.

As mentioned above, the valuation of reserve and flow has been carried out through the creation of physical and monetary balance sheets. We derive the data for compiling the physical balance sheets for natural gas, hard rock and coal from what is available at Petrobangla and from various reports of the Bangladesh Bureau of Statistics including the database of the Statistical Yearbook (2011 to 2015). The volumes in the physical balance sheets have been presented in terms of ‘cubic meters’ and ‘tonnes’, respectively. The physical balance sheets consist of three elements, namely, the physical opening stocks, the different sources of annual alteration to physical stocks, and the resulting closing stocks of physical reserves.

[8] The method described above can be used when prices and resource rents do not experience substantial fluctuations. Since we found heavy fluctuation in unit resource rent with negative resource rent in the last (2013-14) fiscal year, we follow:

$$NPV_t = RR_t \sum_{t=0}^{Nt} \frac{(1+\rho)^\tau}{(1+r)^\tau} = RR_t\,\Omega$$

Where

$$\Omega = \sum_{t=0}^{Nt} \frac{(1+\rho)^\tau}{(1+r)^\tau}$$

and P = rate of inflation of non-food items.

[9] Bangladesh Bank (2016), *Economic Trends: January 2016*, Bangladesh Bank, Dhaka.

4. Results and Analysis

4.1 Physical balance

The gas reserve in Bangladesh, given in Petrobangla's reserve data, the Annual Reports and the monthly MES reports, is usually reported on the 2P basis, i.e., proven and probable reserve. While roughly half of the reserve of natural gas is proven, the estimated probable reserve is also regarded as quite reliable in the literature. However, as per Petrobangla's official data, the reserve of natural gas has experienced a significant upward movement in 2011 due to reappraisal (see Table 1).

Table 1: Natural gas reserve

Year	Gas Initial In Place (GIIP)	Recoverable (proven + probable) in Billion Cubic Feet	Net Remaining Reserve (proven + probable, 2P)
30 June 2010	28856.70	20605.10	12506.68
31 Dec 2011	37618.00	26842.39	16739.44
31 Dec 2012	37920.20	27038.49	16123.18
30 June 2014	37910.20	27072.13	14936.90

Source: Petrobangla MES Reports and Annual Reports (various issues)

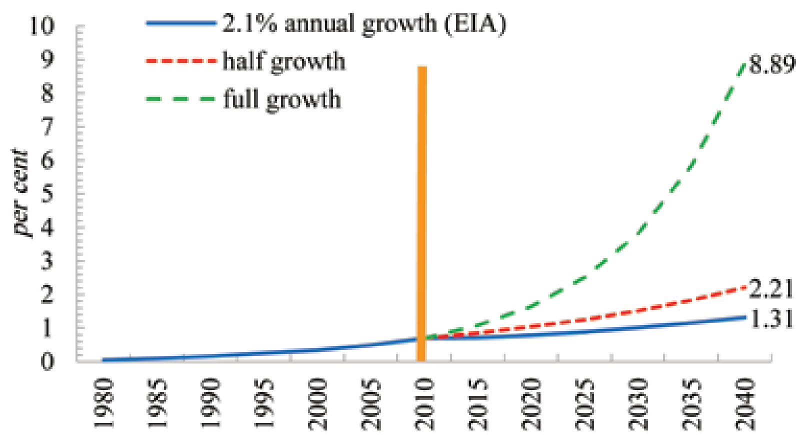

Figure 2: Demand for natural gas in Bangladesh

Key: Half-growth = half of the growth rate of the last 10 years; Full-growth = growth rate of the last 10 years

Source: Calculation based on EIA (2013)

Rapid depletion of stocks due to the high and rising domestic demand is evident from the latest figure for the net remaining reserve. From the 709 Billion Cubic Feet (BFC) for the fiscal (accounting) year 2010-11, annual consumption has reached 820 BCF for the fiscal year 2013-14 (Figure 3). It reveals that at the rate of consumption for the last fiscal year available, the net remaining reserve would meet the requirement of the country for nearly 18 years. However, as consumption is bound grow due to increased domestic demand, there is bound to be a more rapid depletion of gas than before. In addition, many fields are bound to be declared marginal and/or abandoned even though gas would be statistically available.

The physical balance sheet for natural gas has been prepared following the SEEA Central Framework (2014), which is reported in Table 2. It reveals that a significant positive gross reappraisal of 5.57 TCF took place in the fiscal year 2010-11, which was followed by a small discovery in the next few years although, simultaneously, there were continuous other readjustments every year.

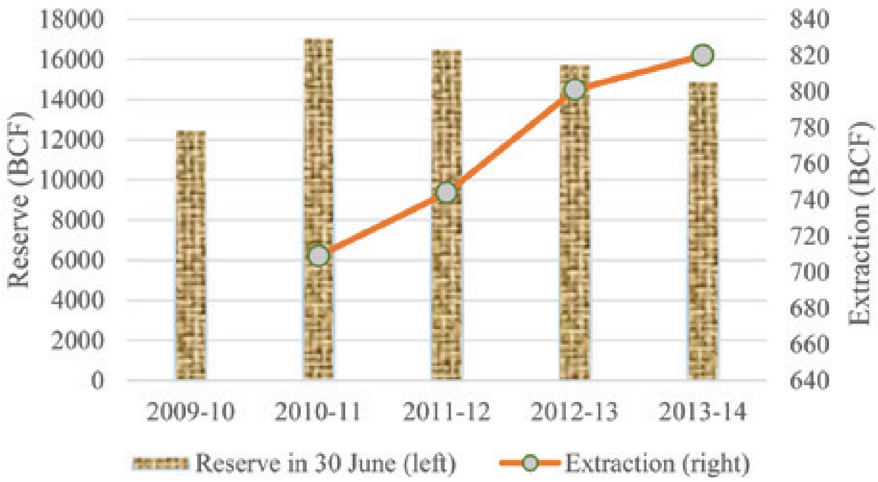

Figure 3: Net remaining reserve and extraction of natural gas (BCF)

Source: Calculation based on Petrobangla data

Table 2: Physical balance of subsoil minerals

Sl.	Stock	Natural Gas (Billion Cubic Feet)				Coal (Million Ton)				Hard Rock (Million Ton)			
		2010-11	2011-12	2012-13	2013-14	2010-11	2011-12	2012-13	2013-14	2010-11	2011-12	2012-13	2013-14
1	**Opening stock**	**12,507**	**17,101**	**16,524**	**15,791**	**3,295**	**3,294**	**3,293**	**3,292**	**114.44**	**114.16**	**113.80**	**113.47**
2	**Additions to stock**												
	Discoveries		35	161	34								
	Upward reappraisals	6274	213										
	Reclassifications												
	Total additions to stock	**6,274**	**248**	**161**	**34**								
3	**Reductions in stock**												
	Extractions	709	744	801	820	0.7	0.85	0.89	0.94	0.278	0.360	0.333	0.206
	Catastrophic losses												
	Downward reappraisals												
	Reclassifications	971	82	93	67								
	Total reductions in stock	**1,680**	**826**	**894**	**887**	**0.7**	**0.85**	**0.89**	**0.94**	**0.278**	**0.360**	**0.333**	**0.206**
4	*Revaluations*												
5	**Closing stock**	**17,101**	**16,524**	**15,791**	**14,937**	**3,294**	**3,293**	**3,292**	**3,291**	**0.278**	**0.360**	**0.333**	**0.206**

Source: Calculation based on Petrobangla data

The reserve of coal shows a slowly declining trend, which is due to small annual extractions from one coal field, Barapukuria, which is the second largest coal mine from which the state-owned company is extracting coal. However, the demand for coal is substantial although domestic consumption has been at the same level for quite some time due to imports of coal from India. Thus, from the 0.73 million ton of 2009-10, annual extraction has risen to 0.94 million ton in 2013-14, which implies that the remaining reserve can meet the coal demand in Bangladesh for many years to come. But the extractable stock would also depend on the extraction method used in the biggest coal mine at Phulbari, which is yet to be determined.

Unlike natural gas, the physical balance of coal is composed of the opening stock and the amount of extraction. In the accounting years, there has been no discovery or reappraisal reported in the Petrobangla reports. However, with regard to the monetary balance, there have been big revaluations during the fiscal year 2011-12 which has been repeated in subsequent years. Therefore, the value of stock experienced a rapid rise in 2012-13 while the stock value continued to demonstrate an upward trend in the following year due to further upward revaluations.

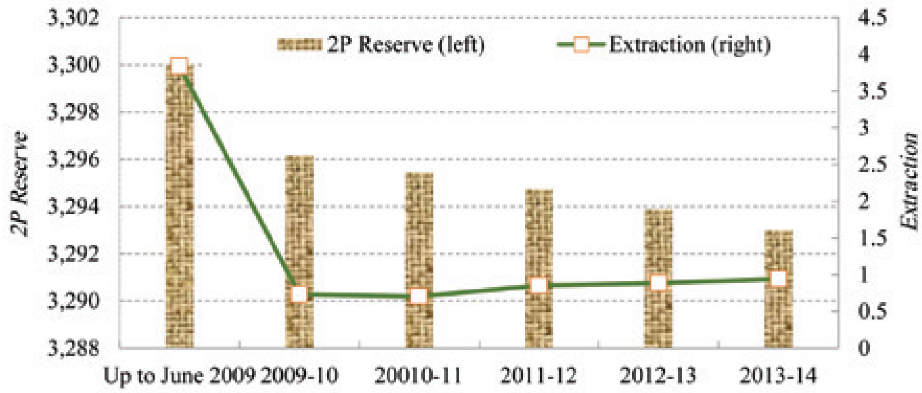

Figure 4: Reserve and extraction of coal (Million M Ton)

Source: Calculation based on Petrobangla data

Hard rock is the third most important mineral resource of Bangladesh. It is an important raw material for construction of housing apartments, commercial buildings, roads & highways, bridges, dams, river dykes and embankments as well as for purposes of flood control, railway ballast and sleepers, and for decoration pieces, tiles, etc. But the reserve of hard rock has undergone a steady decline though its annual extraction reveals considerable fluctuations in comparison with natural gas and coal over the last couple of years. This may be due to the unpredictable patterns of domestic demand emanating from the rate of substitution between domestic and imported hard rock and the varying growth rates of physical infrastructure, communication and construction sectors.

Like coal, the physical balance of hard rock is composed of the opening stock and the amount of extraction. But no new discoveries have been reported in the Petrobangla reports for the accounting years under consideration. Indeed, the last reappraisal was conducted in 2007-08. However, in the monetary balance, there were downward revaluations for the fiscal year 2011-12 though it showed a significant reversal in the following years. Therefore, the value of the closing stock experienced a plunge in 2011-12 although it has seen an increase thereafter.

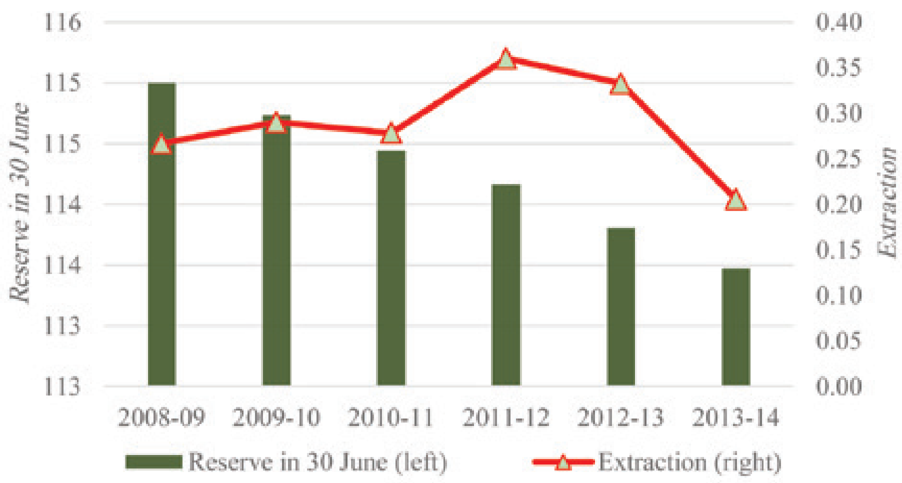

Figure 5: Reserve and extraction of hard rock (Million Ton)

Source: Calculation based on Petrobangla data

4.2 Monetary Balance

Following the SEEA Central Framework (United Nations *et al*., 2014), we conducted the valuation of the subsoil minerals using the residual valuation and appropriation methods. In the residual valuation method, estimates of the value of minerals are obtained based on the following steps. *Firstly*, we obtained estimates of the Gross Operating Surplus (GOS)[10] , specific subsidies and taxes on extraction, and the user cost of produced assets for the extractive activity, from relevant sources. Relevant activity-specific information and assumptions regarding the rate of discount of natural gas and related petroleum were derived from the national accounts data of the Bangladesh Bureau of Statistics (BBS) and Petrobangla. *Secondly*, we estimated the resource rent as GOS less specific subsidies plus specific taxes less user cost of produced assets. *Thirdly*, we estimated the asset life based on physical assessment of the stock and projected rates of extraction and growth. *Finally*, we projected the estimate of resource rent over the life of the asset, taking into account any expected changes in the extraction pattern.

In the appropriation method, we estimated the resource rent using the actual payments made to owners of subsoil minerals. In Bangladesh, the government is the legal owner of these resources. As legal owner, a government can collect the entire resource rent derived from the extraction of the resources that it owns. This amount would, in principle, be equal to the GOS less the user costs of the produced assets of the extractor as defined. The collection of the resource rent is generally undertaken by governments through mechanisms such as fees, taxes and royalties.

While the preparation of the physical balance sheet is quite straightforward, elements of the monetary balance sheet requires inclusion under the NPV method. The first is to get the data on resource rent, which is the net income from the extraction of natural gas and coal, defined as total revenue from sales less all costs incurred in the extraction process including the user cost of produced capital. The data on both the revenue and costs are available in the MES reports, from which the resource rents have been calculated for each of the natural gas, coal and hard rock fields.

Table 3: Resource rent of minerals (million USD)

Resource	Sl.	Gas/Coal Fields	2009-10	2010-11	2011-12	2012-13	2013-14
Natural Gas	1.	Titas	159.31	140.06	101.60	97.96	111.47
	2.	Bakhrabad	35.29	1.90	6.40	8.08	11.94
	3.	Karnafuli	0.00	62.86	45.99	52.11	43.38
	4.	Jalalabad	4.08	5.96	6.33	8.25	8.70
	5.	GTCL	23.79	23.14	21.23	41.12	45.20
	6.	BGFCL	11.24	13.39	8.59	14.98	14.09
	7.	SGFL	29.76	41.22	41.36	69.58	55.67
	8.	PGCL	2.00	2.33	1.88	2.41	4.41
	9.	BAPEX	3.18	3.82	-1.63	6.92	6.98
	10.	RPGCL	7.77	6.35	6.93	5.70	8.10
		Natural Gas	**276.42**	**301.05**	**238.68**	**307.11**	**309.94**
Coal	1.	Barapukuria	5.42	4.19	-12.15	26.16	42.02
Hard Rock		Total	3.63	0.09	0.37	2.09	-3.80

Source: Calculation based on Petrobangla data

Based on the SEEA Central Framework (2014), we assume that the future resource rent is a function of that of the most recent years. Thus, expected resource rents were derived from the moving average of stocks of the last three years. However, the resource rents of the hard rock projection for the base year 2013-14 were affected by negative values. To control the unusual number for resource rents, we excluded the resource rent for 2013-14 in calculating the moving average as per the Central Framework. In addition, the extractions of stocks were also projected based on the last three consecutive years' moving average.

[10] This is the portion of income derived from production by incorporated enterprises that is earned by the capital factor.

The next step is to set the discount rates for each of the resources. A higher discount rate indicates a lower time preference or less priority to future consumption. In the SEEA, a discount rate is perceived as a rate of interest which is used to adjust the value of a stream of future flows of revenue or income so that the value of future flows can be compared with that of the current flows. Generally, social discount rates are lower than market-based discount rates while the lower rates will place a higher relative importance on the income earned by future generations (SEEA, 2014). Dasgupta (2008) expresses the social discount rate as the society's deliberation over a "consumption swap" between today and tomorrow. According to Ahmed (2000), from an empirical perspective, the discount rate for Bangladesh is 15 percent. In comparison, the social discount rates are 3 and 10 percent for the US (Nordhaus, 2000), and 4 percent for the Netherlands for oil and gas (Veldhuizen *et al.*, 2009). Based on various studies, Rubio (2005) suggests 3, 6 and 15 percent social discount rates in valuing minerals.

The SEEA Central Framework (2014) suggests using the social discount rate for the valuation of non-renewable resources as it reflects the time and risk preferences of the entire society. In Bangladesh, the government owns the sub-soil minerals which are under consideration in the present study and is expected to make decisions about extraction on behalf of the society. However, we use different discount rates to analyze the sensitivity of the results. Furthermore, we make two assumptions in preparing the monetary balance sheet: one, that proven and probable reserves are always extracted first and, two, that the social discount rate is a minimum 3.5 percent.

The monetary balance shows that there is a jump in the value of the natural gas reserve in 2012-13, which was due to new discoveries and reappraisal. However, the monetary value of the opening stock of the current fiscal year is different from the closing stock of the last fiscal year because of changes in the annual average exchange rate although it remains the same in the local currency unit. On the other hand, the stock value is highly sensitive to the discount rate, which indicates a higher preference for present consumption that will, in turn, significantly reduce the present and future value of the stock.

Table 4: Monetary balance (million USD)

Sl.		Natural Gas			Coal			Hard Rock		
		2011-12	2012-13	2013-14	2011-12	2012-13	2013-14	2011-12	2012-13	2013-14
1.	**Opening stock**	5,884	8,692	9,478	53,111	72,812	75,391	202.86	131.82	204.48
2.	**Additions to stock**									
	Discoveries	26	132	29						
	Upward reappraisals	158								
	Reclassifications									
	Total additions to stock									
3.	**Reductions in stock**									
	Extractions (gas, coal and hard rock)	550	658	715	12	26	42	0.37	2.09	1.29
	Extractions (others*)	0	0	0						
	Catastrophic losses									
	Downward reappraisals									
	Reclassifications									
	Total reductions in stock	550	658	715	12	26	42	0.37	2.09	1.29
4.	**Revaluations**	2,737	1,308	1,089	16,045	2,574	5,396	-77.31	74.67	166.54
5.	**Closing stock**	8,254	9,474	9,882	69,144	75,359	80,744	125.18	204.40	369.73

* In the case of natural gas, other extractions from the same field include other petroleum products such as petroleum, condensate, etc.

Calculation was done at the 3.5 percent discount rate.

Source: Calculation based on Petrobangla data

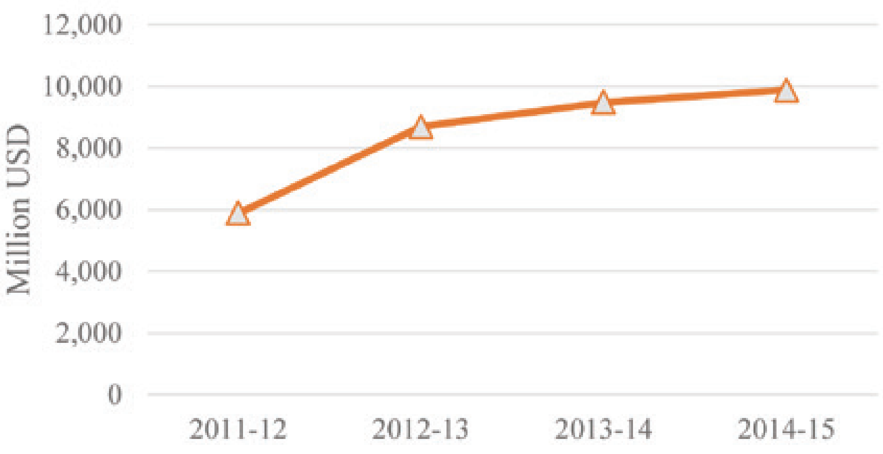

Figure 6: Opening stock of natural gas including other petroleum products, 3.5 percent discount rate (million USD)

Source: Calculation based on Petrobangla data

Contrary to the monetary balance of natural gas, the reserve value of coal varies significantly due to changes in the discount rate. At the 3.5 percent discount rate, the stock value of coal rises as high as USD 81 billion in 2013-14 while it comes down to only USD 22 billion (or just one-fourth) in the same year at the 10 percent discount rate. At the 15 percent discount rate, it goes down even further to USD 9 billion. On the other hand, the stock value of natural gas comes down to two-thirds of its previous value due to changes in the discount rate from 3.5 to 10 percent. It shows that the time preference is highly sensitive to the reserve value of coal compared to that of natural gas.

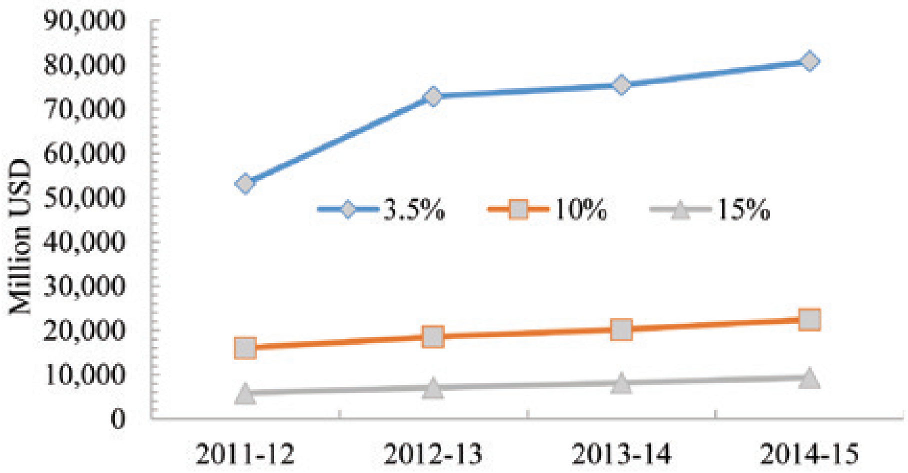

Figure 7: Opening stock of coal (million USD) at different discount rates

Source: Calculation based on Petrobangla data

Due to the fluctuating pattern of extraction and varying resource rent, the opening balance of hard rock shows a parabolic shape in the medium term at the 3.5 percent discount rate. However, the shape begins to flatten out and increase smoothly at the 10 and 15 percent discount rates at which the stock values become quite negligible, i.e., less than one-third and one-sixth, respectively. While the opening stock value is USD 370 in 2014-15 at the 3.5 percent discount rate, it goes down to a meagre USD 49 million at the 15 percent discount rate.

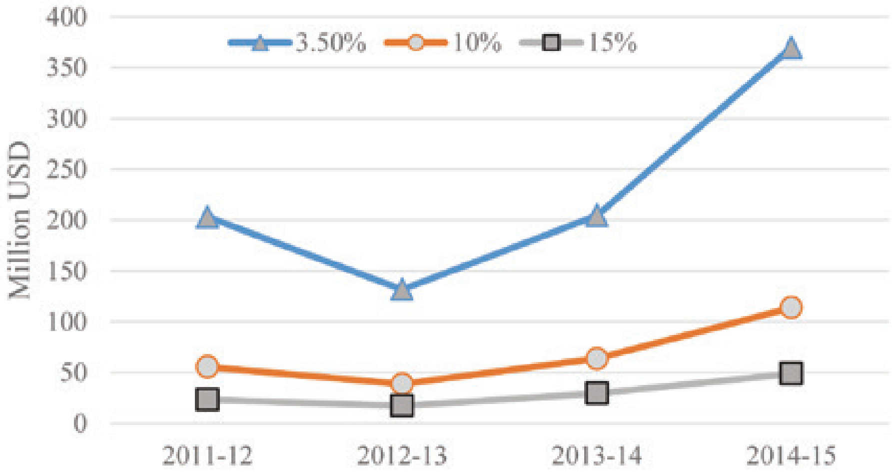

Figure 8: Opening stock of hard rock (million USD) at different discount rates

Source: Calculation based on Petrobangla data

In sum, the results reveal that the stock value of coal is about eight times higher than that of natural gas even though the latter is regarded as the most important subsoil mineral in Bangladesh among the top three resources. This implies that coal can add significant value to the GDP of Bangladesh for many years to come. However, measures must be taken to generate power and energy from this mineral through environment-friendly technologies such as clean coal to minimize carbon emission and heating.

5. Issues for National Accounting

The valuation of selected sub-soil minerals offers some powerful insights to conventional national income accounting. The resources are extracted or depleted to earn income during the period of their respective stocks and revaluated to determine the increasing or decreasing value of the stock. Theoretically, changes in the value of the stock through depletion and revaluation at the beginning and end of the period capture the flow or income. There might be unexpected events like catastrophic losses, which may lead to a depletion of the physical stock without earning an income, which are also deducted from the physical and monetary balance sheets. Conversely, traditional SNA only considers the income or return of resources in a particular year. Thus, the income (flow) can be calculated from the stock in two different periods, which would be different in SEEA compared to the traditional SNA. Even though the SEEA Central Framework (United Nations *et al.*, 2014) does not indicate how national income can be worked out from the value of stock, in case of SEEA the GDP coming from a resource can be expressed as the difference between the value of opening and closing stock. The value of opening stock is basically the value of closing stock of the last accounting year, which is added by new discoveries, upward reappraisals and reclassifications, and flow of the resource to an economy after extraction to provide the value of the closing stock. Moreover, revaluation due to price change also makes out the value of closing stock of the next accounting year. New discoveries in a specific accounting year is not extracted immediately. Rather, they are extracted and reappraised over future years that added gradually in imminent flows.

Table 5: Contribution to GDP at current prices (Million US$)

Sector (National Accounts)	2011-12		2012-13	
	SNA	SEEA	SNA	SEEA
Natural gas & crude petroleum	1,303	3,287	1,466	1,966
Other mining & quarrying	1,134	15,980	1,480	2,677

SNA = Based on UN System of National Accounts followed by BBS (Statistical Yearbook 2013)

Thus, the GDP coming from the subsoil minerals can be expressed as the sum of extraction and revaluations due to price change in an accounting year that give the difference between the value of opening and closing stocks. The analysis reveals that the share of GDP from subsoil minerals turns out to be much higher than that of traditional SNA.

The second critical issue overlooked in the calculation of the value of subsoil minerals in SEEA due to simplification is related to the investment spending on resources for development and protection from catastrophic losses. As mentioned in Section 3, all expenditures including the user cost of capital and cost of extraction to make the resources available for consumption are included in the net income from extraction. Thus, costs of investment and protection of resources are not included explicitly in the valuation although it would be included in investment spending at the government- and IOC-operated mines. The unit resource rent would have been lower if such costs were explicitly factored in.

The third issue is related to the services of resources, which have not been transmitted into valuation principles. The three ecosystem services in question are provisioning, regulating and cultural services (SEEA Experimental Ecosystem Accounting, 2014). The extraction of a resource causes income flow (provisioning) but consumption of the resource also leads to carbon emission (regulating) and the eviction of people living in mine areas either for development of the mines or at the time of explosions (cultural). But the issue of provisional services is not directly included in the Central Framework in the context of resource valuation though it is covered in the Environmentally Extended Social Accounting Matrix in the satellite account. However, the private and public costs of eviction and resettlement have not been properly covered in the SEEA.

6. Conclusions and Policy Implications

The present paper is an attempt to conduct green accounting of three critical natural resources for Bangladesh. In order to do so, it adopts the SEEA framework which outlines the method of preparing physical and monetary balance sheets. We prepared physical and monetary balance sheets for natural gas, coal and hard rock. We found that, among the three resources, the stock value is the highest for coal, followed by natural gas and hard rock. However, issues like the method of calculating GDP from the valuation of resources, costs of investment for the protection and development of mines, and accounting of all services should be covered in future studies in order to address the existing gaps in the SEEA.

We make two other observations in this regard. Among other aspects needing attention, one of the most important is the availability of subsoil minerals, which is facing rapid depletion and may result in eventual disappearance in a decade or so. Therefore, setting a low social discount rate is imperative to understand the importance of giving priority to preserving exhaustible natural resources for future generations. The second aspect is related to the greater value of future consumption. In the context of government monopoly, the Energy Regulatory Commission (ERC) of Bangladesh decides on the energy tariff, including that for natural gas, but the gas tariff has not experienced a significant increase over the last half a decade due to political reasons. Indeed, the real price of natural gas has gone down. Thus, greater emphasis on non-renewable natural resources in future consumption would contribute a higher added value to the national income, which calls for policy attention to reform the national accounting to better reflect the future value of these resources.

The SEEA is difficult to operationalize in a developing country such as Bangladesh where the national statistical agency is not yet ready for environmental accounting in all sectors of the economy. Hence, such accounting in a critical sub-sector or product that has profound implications on other sectors of the economy might be a place to start. Sub-soil minerals like natural gas and coal are widely used as energy sources in Bangladesh since it is crucially dependent on them for economic activities. Moreover, attempts to attain higher growth is expected to result in greater energy use, which are bound to have significant though expected consequences: rapid depletion of the stock or reserve due to over-extraction. Achievement of optimal rates of extraction thus require the lowering of social discount rates, which would ensure greater consumption opportunities for future generations as well as sustainable development.

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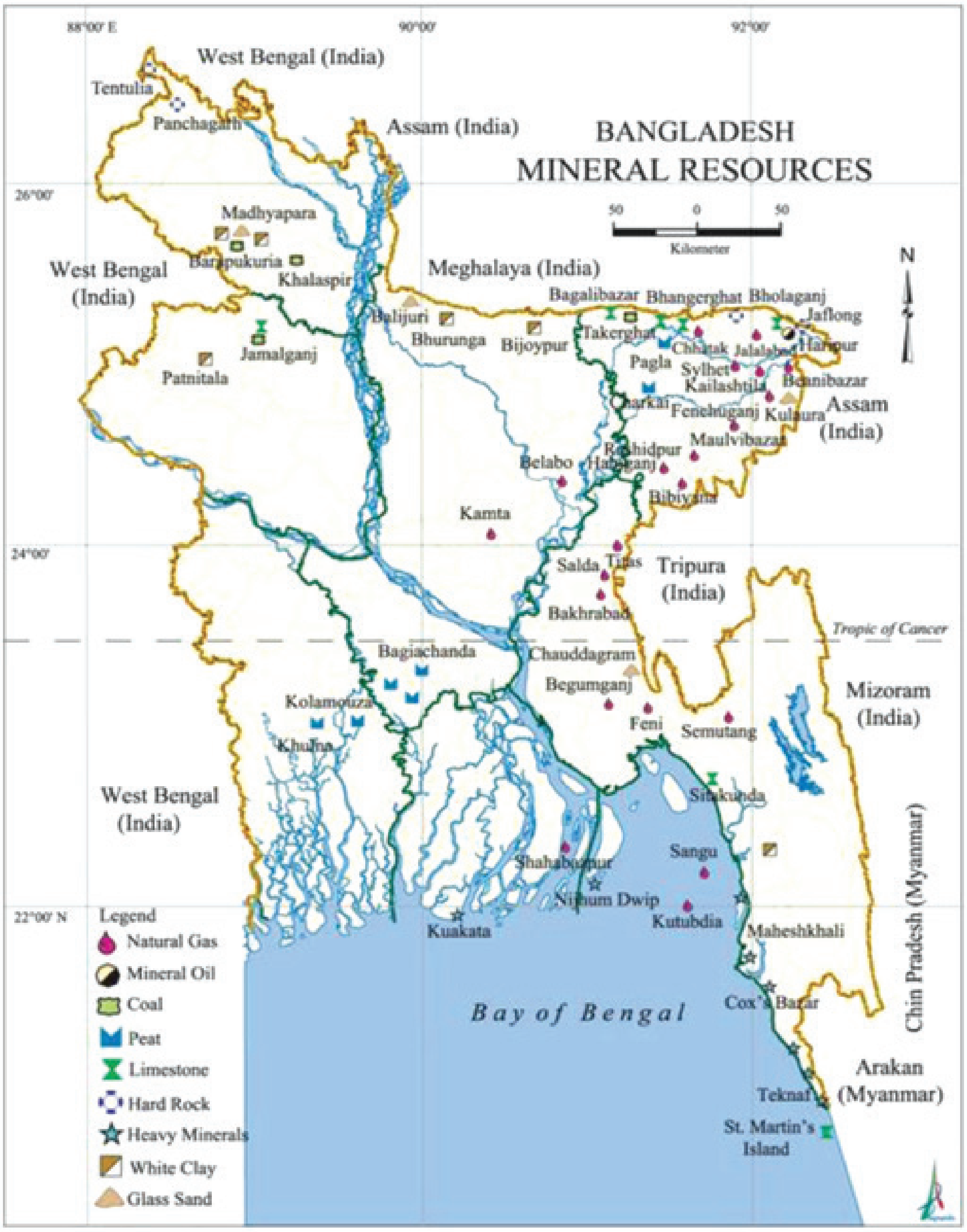
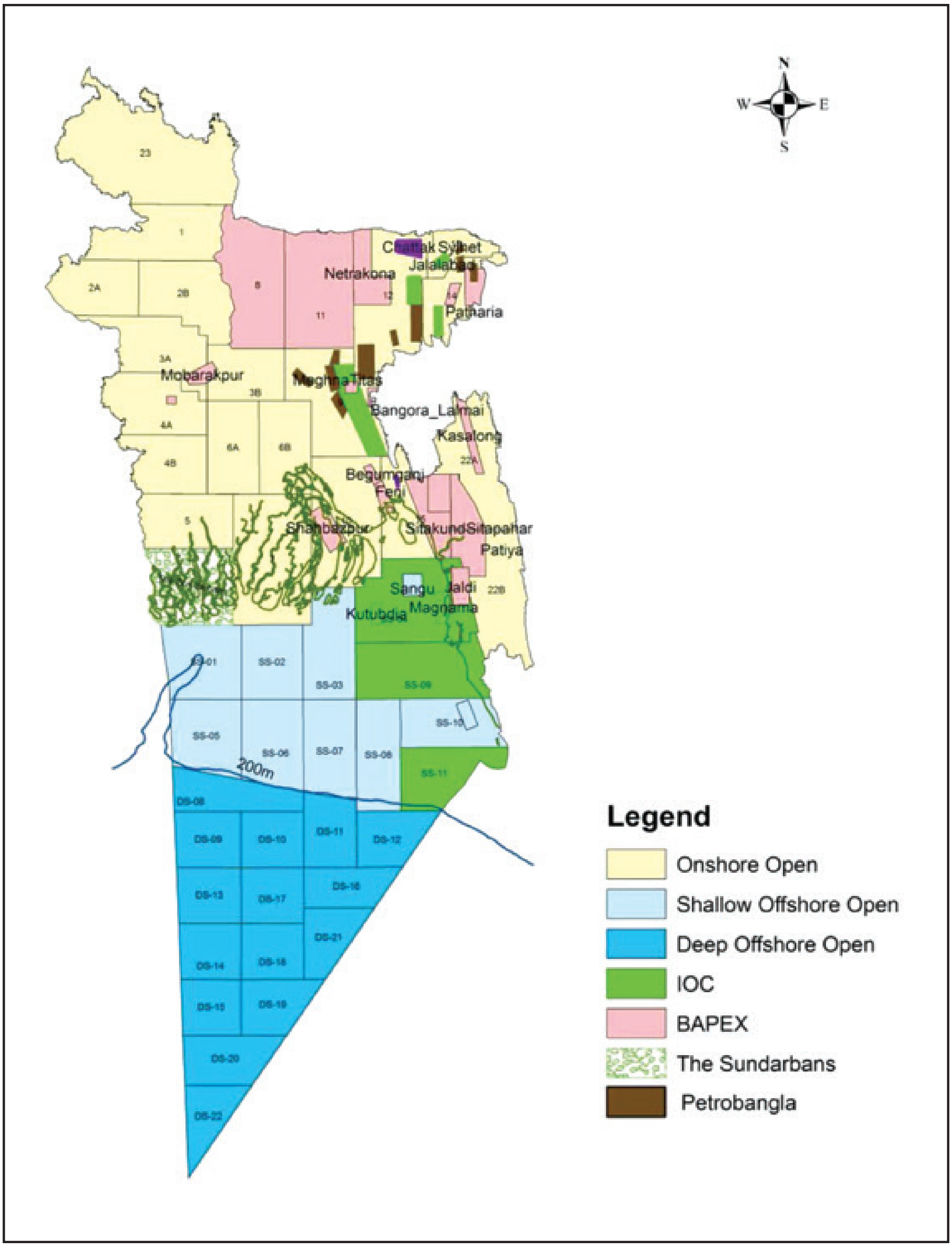
Appendix

Map 1: Mineral resources in Bangladesh



Source: Banglapedia

Map 2: Natural gas blocks in Bangladesh



Source: Petrobangla Annual Report 2014

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