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Globalization, Markets and Resource Management: An Empirical Case Study on Sustainability

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Abstract

The concept of sustainability has gained an enormous attention and concern all over the world, particularly in the wake of economic reforms and market economy. It has become the current topic of debate in academia, policy making and practitioners. Sustainability, at bottom refers to resource sustainability, and that too exhaustible natural resources. Accordingly, the present paper focuses on natural resources management with special reference to depletable and non-regenerative resources. Energy and coal being what they are to the Indian economy, assume greater significance in resource management. Hence, coal mining industry is taken as an empirical case study of sustainability of resource-base in the context of faster rates of development. The analysis and inferences can be extended to the whole of the extractive sector, may be with some modifications. The policy of cross-subsidization seems to be one of the best policy instruments to achieve a sustainable mining sector in pace with the sustainable development. It is noticed that globalization can be made compatible with ever depleting resource base through exploration. The relative roles and contributions of exploration, extraction and conservation to the sustainable resource base need to change during different phases of development. Marketing may be insidious to resource base but not the market. On the whole, the paper tries to make the lofty ideal of sustainability into a reality.

Key words : *Cross-subsidization; growth-decline paradox; sources of growth; technology-absorption; Resource-management; exhaustible resources; resource-illusion; sustainability; exploration and market-size.*

Introduction

In the wake of economic reforms, the global demands for energy in different forms registered phenomenal strides in recent years. There is a well established relationship between economic development (GDP) and energy. Energy demand /growth is both a cause and consequence of development. During the initial stages of development, it will be its cause or its contributory factor. Later, it becomes the consequence because people will be demanding energy in an increasing measure to live more comfortably from their rising incomes. Needless to

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say that energy is a vital input in all the human activities across all the sectors of the economy. Its consumption is considered as a determinant of economic well-being of people besides the rate of growth. More importantly, it is the energy fuels that convert and transform the rest of the resource-endowments into consumable, useable and marketable products. In the long run, the resource-base of a country determines its trajectory of growth. Hence, the fundamentals of an economic system are mostly defined by the extent of energy resources-endowments and partly by other resources. That is what energy is.

Through free trade, globalization arguably enhances, if not maximizes, social welfare by achieving faster rates of development. Arguments can be found in literature on either side (see Reference No.1 in the list of references).

The objective of this paper is two fold. The primary objective is to bring out the inevitable impacts of growing globalization / corporatization on the sustainability of resource-base to cope with. This is carried out by developing a conceptual framework. The secondary objective is to critically evaluate and assess the sustainability of the known resource-base to cope with the rising trends in globalization and development through an empirical case study on a vital depleting resource, viz., coal. Accordingly, the paper is divided into two parts. Part-I deals with the designing of a conceptual framework and analysis, and part-II presents the analysis of an empirical case study to validate part-I to the extent possible.

PART-I

1) Energy and other Natural Resources: the Fountainhead of all development

The nature provides us with infinitely large number of resources for human use and consumption by which the human lives become more comfortable and worth living. Nature's endowments are meant for use in rightful ways for rightful purposes and not for preservation forever. If so, why then there is a growing concern on conservation of natural resources particularly the exhaustibles. The main reason lies in the quantities (–how much use/ consume and by how many and how long). The extent of resource-base and its quality will be the major determinant. It is true that the nature has given enough to satisfy our needs but not greeds. In the ultimate analysis, the problem turns out to be the ever growing and widening mismatch between the rate of consumption of natural resources and the nature's capacity (its rate) to replenish / renew the ever depleting stocks. Since the gap is widening larger and larger, the great movement for conservation has become more important than all others now before the people. Therefore, the knowledge about the endowed resource-base (its potential, quality, distribution etc) should guide the design of many key public policies including corporate (See, R. B. Toombs and P.W. Andrews, 1976)

Natural Resources: A comment

All natural resources, whether or not visible, have intrinsic utility to humans. Human civilization has been evolved and shaped by them and their use. Knowledge discovers their uses. They have many and varied uses. There is nothing like a useless thing. It may appear to be so because we are not capable of using. They are highly heterogeneous w.r.t. their quality and quantity across the regions either within the country or across countries. There is thus a wide geographical dispersion in nature's endowments. It is not uniformly bountiful nor uniformly niggardly. Consequently, this gives rise to specialization in production and trade. There is however a subtle invisible **compensating-variation** which, by and large, levels off all the regions. Thus proves, nature is the best leveler. It is very complex to understand. Earth took several millions of years to get the resources formed and to make our lives comfortable. There is an intricate linkage among humans, animals and nature to forge an interwoven web with a delicate balance.

2) The classification of natural resources:

There are many classificatory systems. In the present context, the natural resources are classified between mineral and non-mineral resources based on their scarcity, renewability, formation, utility etc. Another classification is between **"exhaustible & non-replenishable" and "non-exhaustible & replenishable/renewable"**. The former consists of mainly minerals and the later comprises air, water, land, fertility, forestry, fishery, landscapes etc. In this case, it can be surmised as:

“If the rate of exploitation and consumption of renewables exceeds the rate of their replenishment or regeneration, then they tend to be as grave as the non-renewables”.

What all that is happening in the case of forestry, fisheries, top soils, etc and even water in some places, will substantiate the case in point. This aside, those happenings will also give credence in favor of the above proposition. Nevertheless, the problem of their copious supplies/availabilities can be resolved by scientific planning and utilization in such a way that the rate of their consumption and replenishment matches. It may specially be noted that the rate of reckless exploitation and utilization of renewables itself debilitates the nature’s capacity to regenerate. In a sense, the very non-use over longer periods enhances the nature’s capacity to regenerate the depleted stocks of renewables.

The earlier proposition can be diagrammed as below:

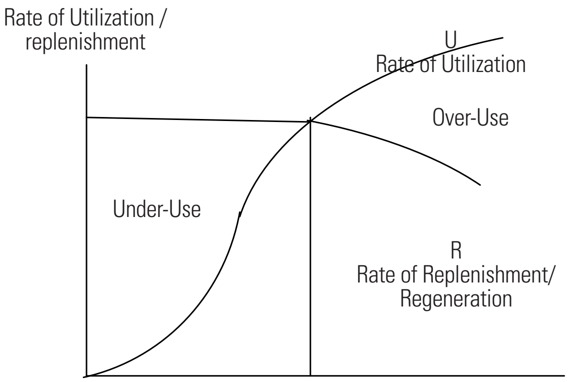

Diagram 1 The patterns of consumption and replenishment of Renewables.

The diagram is self-explanatory. The U-curve will arguably cut the R-curve at a point where the R-curve starts showing the signs of decline. This to say that the Nature’s capacity to replenish is not able to cope with the rates of consumption. However, both are matchable so as to avoid the shortages in the supplies of renewable resources. In some cases, the over-use reduces the nature’s capacity to regenerate. It is to be noted that the intersection of the two curves (U & R) indicates the equilibrium point. Left of this point, suggest that there is under-use and right of this point, suggests the over-use of renewables. Both are relative to the nature’s capacity to reproduce. The equilibrium point suggests that there is an optimum level of both consumption and replenishment. This can be achieved by scientific planning. Deviation from the equilibrium point can be corrected by appropriate remedial measures.

3) The case of Non-renewable Resources (minerals)[1]

The case of minerals is totally different. They just cannot be replenished/reproduced as in the other case. Earth takes several millions of years to get minerals formed. Hence, a ton extracted is a ton depleted without any replenishment. **Extraction means depletion** in this sector. Since the minerals are embedded below the earth’s crust at depths, they are not visible. They need to be searched, identified and assessed. This operation is called **exploration**. It replenishes the depleted stocks till all the mineral-bearing (likely, probable & suspected) areas are fully explored. When once all the areas are completely explored, the exploration cannot find or bring any new deposits. In the end, the mineral-base becomes finite/fixed in quantity and fully known. Hence, the mineral resource-base is considered as the nature’s reserve-fund, which is known, finite and fixed (see, David B. Brooks, 1976)[2]. This is available for extraction and utilization by the industrial sector as raw materials. Since it is finite, the continuous extraction/depletion leads to a total extinction of the mining sector in the longrun, which is called the **doomsday.** One thing is clear, Doomsday is imminent and certain if the extraction goes on constantly. Higher rates mean sooner and vice versa. The consequence of doomsday is everybody’s knowledge. But the contentious issue is “when” and “how long is the longrun”. In this context, another important point to be noted is that the **exploration cannot create resources** but can only postpone the occurrence of doomsday if there are unexplored virgin areas. Of course, the intensity of exploration operations provides more detailed information about the mineral resource-base on the basis of which a sustainable extraction–planning can be worked out. ***(For a detailed explanation on exploration, see N.Naganna, 2000.)***

1. *There are two types of minerals viz., above and below ground.*
2. *He defined natural resources as those things which actually or potentially create new wealth; and exist independently of man’s efforts but potentially, useful to him*

In comparison with the earlier case on renewable resources, the case of nonrenewable exhaustible mineral resources over time can be presented in a free hand curve as below.

Rate of Extraction/Depletion/Resource-base

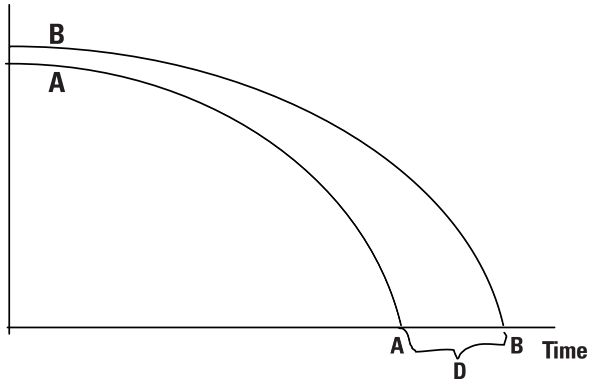

Diagram 2 The constantly declining Mineral resource-base over time due to extraction.

The two curves in the diagram-2 denote two different scenarios (viz, without exploration, Curve A and with exploration curve B) assuming that there is a finite and known mineral resource-base catering to the needs of growing industrialization and development.

The curve–A indicates that there is a continuous decline in the quantity of endowed resource-base due to constant extraction. It also signifies the fact that there will be a doomsday one day or the other. This assumes that there is no exploration activity in the economic system or exploration-contribution has reached its capacity–limits in a totally explored area. On the other hand, the curve-B delineates the same pattern of declining resource-base but it makes two additional observations. Firstly, the rate of extraction will be higher due to the exploration-contribution to the depleting stocks. What follows from the above analysis is the most challenging issue to resolve.

How to make globalization and faster rates of development compatible with environmental and resource sustainability. Achieving this compatibility is the most challenging task now before the planners and policy makers (R. U. Ayres, August, 1996).

Further, it can be hunched that the rates of extraction may reach their peak levels during the periods when the exploration-discoveries of new deposits are maximum. There may also be liberal extraction by avoiding the workings in "difficult mining conditions". In other words, the mining enterprises will be induced to resort to selective/slaughter mining practices while keeping the issue of conservation/sustainability at bay. Secondly, it postpones the resort occurrence of doomsday to a later date. The point-D indicates **the span of extension of doomsday due to exploration-discoveries**. Since exploration is a gamble, it is difficult to specify the width of time-span. However, the doomsday is definite and certain because the resource base is finite and exhaustible. The diagram-2 seems to be general, rudimentary, notional and perceptual. Nevertheless, it stands to reason and logic because even the most intensive exploration cannot make the resource-base infinite and everlasting. In the ultimate analysis, this **gives rise to the limits to growth** (meadows et.al, 1972).

Distinguishing features of minerals: In contrast with the renewables, the non-renewables (particularly minerals) are characterized by few distinctive features. They are mainly: exhaustible/depletable; nonreplenishable/nonrenewable or non-regenerative; scarce with scarcity value; highly heterogeneous in quality, utility and mineability; vital inputs for industry or the base for industry; location-specific; determinant of human progress; endowed in uninhabited areas/forests, chemical compounds; their extraction entails shifting activity; high levels of risk & uncertainty; hazardous; hidden in depths from surface; subsoil; and so on. These are some of the major distinguishing features of minerals in general and they have very significant implications in their: economics; politics; policy; sociology and environment. They are not found uniformly in all the minerals. Each one will have its own dominant features. Thus, they make each mineral unique leading to a multidimensional design for policy-making *(N.Naganna, 2001)*. Further, there is a wide and uneven geographical distribution of minerals within a country and across the countries. This necessitated specialization in production and foreign trade.

4) Classification of minerals: There are an infinitely large number of various types of minerals above and below the earth's crust. Minerals are said to be the mainspring of material civilization. They are the backbone of the industrial economy. The extent of their endowment is the defining feature of a country's strength and economic power. They are said to be the root cause for all military invasions. Being what they are, it is better to understand them through a variety of classifications. Minerals are classified in different ways depending upon the purpose and the chosen trait. There are several classificatory systems. They are broadly:

a) **Energy and non-energy minerals** depending upon their combustibility.

b) **Minor and major minerals,** depending on their value and price; and abundance. The former consists of sand, stones and building materials, slabs and slates etc.

c) **Metallic and non-metallic** minerals depending on the metallic content of the ores. The former contains iron ore, manganese etc.,

d) **Ferrous and non-ferrous** metallic minerals based on the ferrous content in the ores. The later comprises lead, copper, zinc, nickel, tin etc.

e) **Strategic and non-strategic** minerals based on their strategic importance for a country. The former consists of gold, silver, nuclear minerals, even oil etc.

f) **Stratified and vein type** of minerals depending on the nature of their geological formation. The former contains coal, ochre's, limestone etc and the later, mica, barytes, asbestos, gold etc.

g) **Above and below soil** (sub soil) minerals depending upon their visibility and formation by depth.

The economic parameters (eg: unit costs, productivity, capital & labor inputs etc) and the economics of extraction; the mining methods; policy frameworks; nature of environmental impacts; the issues of sustainability and conservation; trade policies, royalties & taxation; etc vary from one type of minerals to the other. Even the meanings of output vary among them.

Each one is unique. The way in which differential rent arises also vary. These divergences suggest that there cannot be a uniform policy nor can there be a single theory and practice for the entire mining sector. This aside, the mining sector has a few more special features that distinguish it from manufacturing and agriculture sectors. They are: derived demand; the syndrome of depletion or the depleting asset; shifting activity; locational and occupational hazards; prone to higher levels of risk & uncertainty; severe environmental hazards since mining is the destructive use of land; safety; no alternative uses for costly equipments & machinery; and so on. That being the case, **the mining sector becomes unique by itself.**

On the whole, the extractive sector being what it is, requires a distinct body of knowledge or theories to deal with the problems of policy, planning and practice in tune with the needs of development and resource sustainability (Robert M. Solow, 1974).

5) Globalization and Development: A Critical Appraisal

In the ultimate analysis, development implies exploitation and utilization of natural resources (both renewable and nonrenewable) or altering and using the resources to satisfy human needs and wants. **More development means more exploitation**. It is simply the **commoditification of natural resources** through S&T. In simple terms, it means: extract more, produce more, distribute more and consume more in such a way that a larger number of people are facilitated and enabled to consume more than before and to make them better off. In other words, development ultimately means making human lives or the lifestyles more and more energy and material-intensive leading to more resource extraction and hence more depletion. On the face of it, this seems to be unstainable over very long periods. Thus, it implies an Extraction-Production-Consumption (E-P-C) stream, which is essentially resource-centric. Of course, it also involves sub-streams like processing, beneficiation, smelting, conversion etc both at the mine sites and factory sites. Further, consumption means generation of wastes or residues because we don't consume anything but only use the service element contained in the products. Consumption, infact, is a misnomer. Similar is the case with other sub-streams. Thus, all the associated development-processes, at the end, generate wastes/ residues *(see Allen V. Knesse (1972)*.

That apart, in mining sector, extraction means depletion. That is, a Ton extracted means a Ton depleted from the finite known resource-base. Hence, it follows that **growth contains decay** or, **in growth lies decay**. This is the inherent feature of the mining sector. Since economic development is considered as the E-P-C stream, its growth must also logically contain decay; or, **in development lies its own decay**. So to say, economic development is inherently prone to decay. This is its innate quality. Development comes from natural resource utilization in many different ways. Higher rates of one means the higher rates for the other resulting in higher rates of depletion. This is the reason why, the issue of sustainability came up for serious debates globally, particularly in resource management. The concept of sustainability in the context of development involves **two dimensions,** viz.,

(a) **Resource-sustainability** since development means processing, conversion and transforming all kinds of resources into usable products for exchange in the markets, and

(b) **Environmental-sustainability** (since development means generation of wastes/residues) to receive, absorb and assimilate all type of wastes/residues generated by the E-P-C stream.

In the debates on sustainable development, a distinction has to be made between resource and envital sustainability, although resources are an integral part of environment[3]. Because, they represent two altogether different phenomena. Both need to be examined, evaluated and assessed separately.

After having seen what development is all about, is essentially a physical phenomena and hence, it has to be guided by and adhered to the physical laws and not economic/financial principles. If the physical laws impose constraints/limits on the physical phenomena, then development must have constraints/limits. In other words, if the resource-base is finite and limited, then development must also be finite and limited. It cannot be endless in a spiraling way. Before extreme depletion sets in, indicating resource scarcities, is onething. Thereafter, it is another. This distinction has vital implications in policy and planning (R. U. Ayres, July 1996).

In the same vein, it may be noted that development entails extraction & utilization of minerals through S&T as also entices consumption through marketing tools and techniques. So to say, development means mining. It is the source of all developments (S Sederi and S Johns, 1980). In this context, the best suited definition of mining is that "it is the destructive use of land". By logically stretching, it implies that the development itself is the destructive use of land and other precious environmental resources[4]. Thus, development means destruction, may be, to borrow Schumpeters's phraseology, the constructive-destruction. Because development raises consumption levels of many more people and enlarges the consumption-baskets to make us feel better off than before. However, the issue is not on the positives of development. The problem and the global concern lies in the unbridled, reckless, conspicuous and wasteful and careless exploitation and utilization of the finite resource-base. This is, in fact, insidious to resource-base and environment, at large. Besides, it also makes sustainability increasingly critical.

Development Vs Land:

It is rightly observed that the land, air and water are found to be the life support systems for the humans and other organisms. All the three have become victims under the veil of development. Among the three, land lays the basic foundation for all the rest. If land is managed and conserved properly with ample vegetative cover (i.e., forestry etc), then the others (air, water, climate etc) will fall in line. Land, being the primary source of everything like environmental quality, food, fuels fodder etc., is being used indiscriminately and recklessly. Because, industrialization and energy generation/fuels (coal, hydel, oil, wind, solar, biofuels etc) are mainly land consuming or land–intensive. Like mining, both can be seen as the **destructive use of land**. Land is wrongly perceived as a raw material to be consumed/used. India paid a heavy price for this misconception. In the ultimate analysis,

3. The "environment" is an all-inclusive term encompassing everything external to all the living organisms including humans.

4. When once the environmental resources are destroyed by developmental activities, it is very difficult to bring them back to their original form. That is why, prevention is always better than cure. Because, the costs of treating the aftermath is more expensive than the prevention-costs.

the issue turns out to be **land vs energy & industry**. The choice or the trade-off between the two needs to be understood in the context of:

a) Low land-man ratios due to population explosion.

b) Raising levels of land erosion, depletion of top soil fertility, desertification, etc resulting in constant decline in land productivity.

c) Raising demands for food-security.

d) Problems of deforestation from industry & energy and thereby, making land increasingly fragile.

e) Several competing uses/demands on land such as roads, railways, urbanization, housing, canals and many others. In a sense, all human activities are rooted in land.

f) Wrongfully being treated land as a speculative asset.

g) Land is scarce and limited in supply. At present, all lands are occupied in someway or the other. No vacant land is available for any purpose.

Land being the fountainhead of all human activities needs to be used judiciously, with utmost caution in achieving sustainable development. Keeping in view of the primary importance of land in human civilization, the following proposition can be tendered.

Proposition 3:

Land- use planning & management has to be a precondition or a perquisite for industrialization and energy management. Both should be considered, coordinated and planned together in a holistic manner and definitely, not in isolation as is the case now.

After economic reforms/globalization, the impacts on land became not only larger but different. It has become the first victim of development through globalization.

Economic Development: A Rudimentary Resource-Centric Analysis

Development is both the objective of, as also a constraint on the rising trends in globalization. It is a constraint because the present rates and patterns of development are not sustainable in the long run due to faster rates of resource depletion. Resource-crunch is already being felt in many of the industrialized countries making them to search for better sources in unexplored and untapped areas in Africa and other continents. Besides this, it is also realized that industrialization (i.e., development) is fraught with several other problems in environmental degradation, pollution, land availability and so on. Without foreseeing these problems, the theories and practices of economic development are based on some untenable assumption that the resources are **given** (while infact they are **taken**), implying that the resources are plentifully and perennially available just of asking. In fact, the reality has proved to be different. The other assumptions either implicitly or explicitly made in development approaches are:

i) Uninterrupted copious supplies/availabilities of raw materials over time (i.e., non-depletion) with stable costs/prices.

ii) No decline in quality/grades of ores/minerals.

iii) Resources are given while they are actually taken. Resource-base is infinite and unlimited with a stable population.

iv) Resources are available just for asking (i.e., no scarcity value).

v) Transport costs of raw materials remain stable over time implying that mining is NOT a shifting activity.

vi) Nature is uniformly bountiful and not niggardly.

vii) Environment is considered to be a bottless-sink to receive the wastes/residues.

viii) Development is viewed more as economic phenomena than a physical phenomena.

It may be true that these assumptions might have been valid and reasonably realistic during the early stages of industrialization development. More particularly when:

a) The resources were available plentifully in relation to population size and their consumption patterns/levels.

b) Environmental problems were not seen as serious/threatening and

c) The depletion rates were not noticeable and neglible, if at all. The present situation turns out to be almost the opposite tending to make those assumptions unrealistic and are not tenable any more. In fact, they belie the very concept of sustainable development. They can at best serve building economic history.

If those assumptions are negated then the issue of sustainability in development comes to the forefront of analysis. And now, the resource-base enters explicitly in the developmental planning and processes. In this context, the concept of development needs to be viewed as a pure physical phenomena and not economic as was distortingly considered so far. If so, the pattern and the rate of development will be limited by the extent of the known resource-base. There cannot be exponential growth endlessly. In this context, globalization and free trade are tending to make the globe as a single unified entity with a free flow of resources and technology besides goods and services.

6) Globalization, Development and the Resource-Base

Globalization and coporatization are found to be the two sides of the same coin. The later became a dominant economic institution in recent times because of the former. In practice, they are considered as synonyms. In the wake of economic /market reforms globally, the trends in corporatization registered amazing growth (see N. Naganna & Savitha Rani R, 2007). In the process, the corporates took precedence over state in terms of investments, R&D, resources, technology and soon. They gained monopoly power over production, distribution and markets (Paul Shrivastava, 1995). They gained economic power on the basis of their strength in R&D, technology and resource-base (see N. Naganna & Savitha Rani R, 2007, op.cit). Under any socio-economic arrangement, the knowledge and resource-control will be the two primary sources of economic power. Corporates could acquire both. This the history unfolds (see, Joel Bakan, 2004, Mike Moore, 2009).

In the 1990's, economic/market reforms swept the world(Covadonga. M, 2009). The underlying force to undertake economic reforms and the resulting corporatization, is the principle of comparative cost advantage which entails free trade. All this, is to achieve faster rates of growth and development than before to solve the continuing basic socio-economic problems which the earlier economic system and arrangement presumably failed to achieve. The hallmark of the globally accepted system is the market economy in place of state-run-economy, scaffolded by competition, free trade and private enterprise. Among them competition is the most striking feature.

Trade, arguably achieves faster rates of development. It promotes development. Following the principle of comparative cost advantage, all the production facilities will be located at the least cost points. Specialization also follows the same pattern. Consequently, the costs of products go down and the prices will be lower. Everything will be operated at its best. Continuous advancements in S&T resulting in continuous improvements in "innovation & efficiency" contributed a great deal towards this trend. In this way, development is made hopefully an endless/ limitless process along with constant market expansions. In effect, this scheme of macroeconomic arrangements would enable to create a larger volume of consumption with a bigger consumption basket for a larger number of people and thereby maximize the global welfare. This is how free trade leads to faster rates of growth. It should be noted that trade takes place through the exchange of goods & services and not through currencies. What we see is a modified and improved version of barter system. For instance, if country-A wants to sell something to country–B it has to buy something from Country–B. Otherwise, trade cannot take place. However, the whole model of development is based on, perhaps an unrealistic, assumption that the resource-base is infinite and non-depletable. This then would give rise to the question whether or not this model would ensure sustainability or the sustainable development. The paper addresses this question.

In a broad sense, trade creates utilities by bringing the hitherto unknown products to markets. It creates saleability and utility in products. Production does not have any meaning without trade. Corporates with their multiple roles, are its engine. Trade makes people think that development is their imperative need through marketing strategies (see N. Naganna & Pankajakshi R., 2009). It transforms the mindsets of people to desire more for more and more products, both new and old. Its objective is to promote consumption on an increasing scale. However, trade as such does not consume resources but induces and encourages the economy to consume more resources for production and trade. This makes a dent on resource-base in different ways. It promotes, induces and encourages resource-exploitation in an increasing measure. This leads to continuous depletion of resources. In the ultimate analysis, both resource and environmental sustainability become increasingly critical or may be hastening the process to face doomsday earlier than expected. In the same vein, it is to be noted that transport is its complementary which is both energy and resource intensive. Trade entails transport. Thus, trade, transport, marketing and development are all inseparably interwoven. If left unchecked and unregulated, they do more harm than good to social well-being.

The fundamentals of the trade-centric model of development focuses mainly on the production–consumption stream on the scale that supports the continually expanding markets. This implies that the consumption or for that matter consumerism on a scale that is seen today, is the fundamental base of the market economy. It thrives on consumerism. The very base itself seems to be on flimsy and shaky grounds because of the inevitable faster rates of depletion (See part-B of this paper) and the impending dangers of environmental degradation. **It is antithetical to conservation**. This is why the issue of sustainability is brought to the forefront of academic debates, particularly, when globalization propels large-scale growth impulses into the whole economy through trade. This model will jeopardize both resource and environmental/sustainability beyond remediable limits. Therefore, both trade and development need to be made compatible with sustainable resource base. Otherwise, they take place for their own peril.

The following informed hunch can be made from the above analysis.

"Competitive market economic system, being the driving force for faster rates of development, has an inherent tendency to make sustainability incompatible"

7) Trade, Resource-Categorization and Development

The three are interconnected. Sustainability is their unifying theme. Trade and development have different degrees of impact on resource-base and its sustainability in ways that give different signals and research–leads for remedial policy measures (Jose Antonio et.al, 2009). The composition and the extent of resource base defines the long term growth path of the trade and development. At the outset, it may be noted that whether the resource-base is abundantly adequate or scarce is relative to several factors such as: (a) Population size, its profile and aspiration levels; (b) The level and rate of development & its current and expected trends; (c) The level of poverty, unemployment etc and other social problems; (d) The composition of commodity trade; (e) The size of geographical area; (f) The magnitude of the known resource base and its detailed composition; (g) The suspected extent of mineral-bearing areas; and the intensity and the extent of exploration conducted. These are some of the most important factors identified to evaluate and assess the level of sustainability in consonance with the present and future trade & development. In another sense, they can also be considered as the determinants of resource sustainability and rate of depletion. In earlier times, say during the initial periods of industrialization, those factors were not that pronounced and significant as to take note of them. Hence, sustainability was never the issue. Now, the resource scarcities/inadequacies are being noticeably felt. In effect, sustainability became the core concern of many economic policies. It is of course country, resource and time-specific. Therefore, the analysis becomes more complex making the validity of generalizations restrictive or narrow.

Trade has different implications and imperatives with respect to resource categorization as described earlier. Needless to say that development cannot take place without trade. Both are mutually reinforcing as also reciprocally related. In this context, trade as an engine of growth refers to both internal and external. It may be understood in its context and situation (see, Christian Kirchner, et.al, 1979).

On the basis of analysis contained in this paper, the following observations can be made. They may deceptively seem to be mere hunches or ungrounded impressions. Nevertheless, they give some long-term indications of things to come on the resource front, which may serve as leads to formulate long-term policy measures on resource sustainability. They also give some alternatives to choose from.

(1) If a country's trade and development are derived from and depend on its source of an abundant-resource, then there will not be felt any resource crunch in future irrespective of whether that resource is renewable or nonrenewable. In such a case, the resource sustainability would encourage the longrun trajectory of growth in trade and development, particularly, if the resource is under-exploited. However, precautionary measures need to be concurrently in place to overcome the adverse effects of resource-curse (see Richard M Auty, 1993)

    If the resource in question loses its abundance-status, then the issue of sustainability comes to the fore for consideration.

(2) If a country's dependence on and the source of development and trade lie in renewable resource-base, then the resource sustainability will be quite comfortable so long as its rate of regeneration is more than or equal to its rate of exploitation. If the rate of regeneration lags behind the rate of exploitation, then sustainability gradually tends to become grave. This will be the most preferred path of development.

(3) If the source of trade and development lies predominantly in nonrenewables, then sustainability will become increasingly grave either after the depletion of superior/ better quality and economically more viable base or after a near perfect substitute is developed or both. Such a pattern will be shaky and unsustainable. It calls for diversification of economic activities.

(4) Depending solely on one resource as a single source for trade and development while ignoring the rest will be perilous in the long run as also self-defeating.

(5) If there is a major technological development, which deletes the use of a particular nonrenewable resource in the production processes, then it will tend to become a neutral stuff particularly if alternative uses are not developed.

(6) If a country's trade and development, particularly foreign trade, comes mainly from renewable resources by saving and preserving its known nonrenewables, it will be more beneficial and advantageous in the long run. It acts like insurance for posterity. The opposite is correspondingly disadvantageous.

(7) It will be more beneficial if there is a judicious combination of both renewables and nonrenewables in such a way that it will ensure sustainability and balanced growth. This can guide and direct the long run growth path.

In this way, one can construct some more variants of the combinations for trade and development. In a sense, they will also act as guidelines /pointers for foreign policy (trade) as also a source of international trade conflicts and frictions. Different countries follow different combinations depending on their relative resource endowments, the rates of depletion, potential resource base and the demands of development. The S&T always attempts to develop the inter-resource and intra-resource substitutions depending on the demands of relative rates of depletion, relative scarcities and the needs of development. Each country can learn lessons from the experiences of others in resources management and the practices of conservation/sustainability.

8) Globalization and Markets

For all practical purposes, globalization can be considered as corporatization. The later being the instrument of the former, the former takes place only through the later (see, N.Naganna and Savitha Rani, 2007). They are thus two sides of the same coin, or so to say, synonyms. They need to co-exist together. Economic reforms in India and elsewhere were introduced mainly to facilitate globalization through corporatization. The accompanied package testifies this. Globalization thrives on or through marketing as also creating markets or expanding the market-size. And, this will have a major impact on the structure of mining industry and its sustainable resource base. This is the debatable issue. In any case, the result is the rising levels of consumption which comes only through raising the levels of E-P-C streams. That being the case, globalization then becomes resource-centric. In this context, it is necessary to make a **distinction between marketing and market**. Both signify two different kinds of phenomena. Marketing creates market. The capacity to buy (economic factors) and willingness to buy (psychological factors) together define a market (or its size). Through various psychological factors, marketing creates market and its expansion. If it crosses its limits, it leads to unbridled consumers making homes cluttered with unnecessary products which in turn, results in making sustainability more critical. The adverse impacts of excessive marketing resulting in consumerism, on the finite resource-base is examined (in Naganna and Pankajakshi, 2009). Consumerism is viewed as buying more than what is normally required to lead a normal life. "Buying & discarding" without using has become a mania in some sections. **'Buying and wasting' without using fully,** became a symbol of exhibitionism. This became a disastrous social feature. Behind buying lies the precious exhaustible resources. Sustainability needs urgent realization[5].

Globalization, with a presumably laudable objective of raising global welfare, creates market (Alan V. Deardorff & Robert M. Stern, 2009). By implication, this goes to conform the **Say's law of markets** which states that *supply creates its own demand*. There is thus, at the end, a situation of resource-supplies and resource-demands to satisfy the over-all markets. Price, together with exploration operates as an equilibrating force in the resource-markets. For instance when price goes up, the mining enterprises will increase the level and rate of exploration to discover new deposits for exploitation as also enhance the R&D/S&T efforts to make use of inferior or low grade minerals which otherwise would have been left unmined. In this way, they enlarge the resource-base to cope with the expanding markets. Scarcity also does the same thing. Enlarged market-size, in effect, creates scarcity and the rest follows. Rising prices reflect the expanding market. Thus, price (or the market-size) operates as an equilibrating mechanism in the resource-markets. In reality, we can find two kinds of markets in an economy. They are:

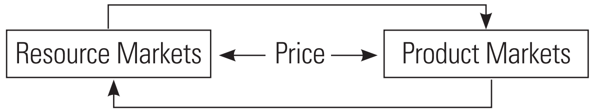

Exhibit 1 A Resource-Centric Model of an Economic System

Resource-markets are derived from the known finite resource-base. They are the fountain-head for all product-markets. They cannot exist in isolation. One exists for the other. They are thus two integrated and inseparable parts of an economic system. In fact, both together give rise to the emergence of an exchange economy with an E-P-C stream. In one sense, globalization means the levels of both. However, which one preceeds and which one follows is a matter of egg-hen controversy. The two markets together define the boundaries or the contours of an economic system to operate. Crossing the boundaries would strike an alarming-bell (if one can hear). The contours, though appear to be more notional than real, do exist at least conceptually, to determine the capacity of a nation to consume.[6]

The pricing mechanism operates as a bride between the two markets in such a way that the resource shortages/ bottlenecks are avoided to make the production process copious.

The above model is too simplistic and incomplete. It ignores the vital element like S&T/knowledge and technology/engineering (Naganna & Savitha Rani, 2008). The extended model is given below:

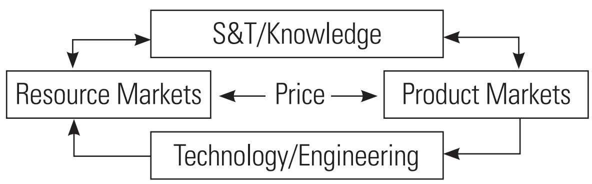

Exhibit 2 The Extended Model of an Economic System

5. *Some sections are over-paid or over-gotten while others under-paid. The over-paid are creating the demonstration/imitation-effect which is leading to over-consumption or stretching the capacity to consume of a nation beyond its sustainable limits (see, N.Naganna and Pankajakshi, 2009).*

6. *These concepts are by no means elusive. Empirical evidence, either direct or indirect, can be generated to quantify and measure. Thereby, the sustainability levels can be worked out.*

Technology and price together will bring compatibility between the resource and product markets to avoid the supply-bottlenecks. The above model **defines the fundamentals of an economic system at any level of abstraction.**

Having realized the greatest role and significance of S&T/ knowledge in the competitive markets, the corporate invest heavily on R&D to make themselves increasingly powerful (see, Naganna & Savitha Rani R, 2007). In turn, this enables them to get access over the resources and their uses through technology and innovation. Thus, their competitive strength over knowledge and resources make the corporate to emerge as the supreme economic institution in the global economy. In the process, they could acquire **power and control over the very fundamentals of the global economic system.**

9) The Depletion Effect and its Implications:

It is the most important concept in resource management. It is central to its analysis. The core concern lies in the ways to cope with its rate (depletion), to maintain the current levels of production and consumption in a sustainable manner. This is the great art and science of resource management. Had there been no depletion and the resource base infinitely inexhaustible, the growth would have been unquestionably endless; and the question of resource management would have just vanished. The depletion effect is the inevitable consequences of developmental processes because development is resource-based which is inherently prone to depletion. Then, the issue is as to how to make development compatible with depletion. In this paper, the thrust is laid more on nonrenewable minerals.

The depletion effect has far reaching consequences on the economics of extraction. It is considered as the indispensable outcome of extraction which make the additional ton to come from longer hauling distances both within and outside a mine as also shifting to far off places to extract from the virgin areas and resorting to lower grades and thereby causing the **longrun real costs** of extraction to raise (Rex Bossonad Benson Varon, 1977). Thus, it refers more to long run. It also makes the costs of raw materials raise. Its broad implications can be summarized below:

(i) The resource base or the workable deposits for extraction will be shifted to far off places from consuming /using centers. At times, the push will be even to the inaccessible areas. All these will result in ever increasing transport costs.

(ii) Shifting to the inferior grades of lesser quality and thus processing/smelting costs to higher levels constantly. Also, causing to go for minerals deposits with difficult working conditions or with harder and thicker over burden.

(iii) In the case of operating mines, depletion constantly push the working-faces to far off places from the mine-mouth and there by raising the hauling and roofing costs resulting in higher overall extraction costs.

(iv) Working mines become less and less productive or more fragile due to increasing hauling and roofing costs due to depletion. They have to go either deeper or less fertile areas with difficult working conditions.

(v) In the case of open-cast or surface mining, depletion pushes the workings to go to deposits with harder and thicker overburden; Also, cause relocation of transport and other infrastructure facilities.

(vi) Creating a situation of raising scarcity values and raising costs; and subsequently injecting material substitution into the production system, the effects of which are difficult to know.

(vii) Availability of raw materials tends to become increasingly critical in future besides quality problems.

(viii) The net effect will be the overall decline of economic efficiency in future; besides posterity getting adversely affected. The S&T may mitigate this problem to a large measure but not totally.

(ix) **Intergenerational equity issues**

The broad implications of depletion are particularly severe in the longrun. The net effect will be raising longrun costs of raw materials supplies. And, the rest follows. How long is the longrun, is a matter of opinion and judgment. However, the adverse effects of depletion on E-P-C stream is definite and certain. This is how, it operates. However, there could be some aberrations due to S&T developments and surprising finds from exploration.

10) Exploration & Depletion Effect

Given the resource base and the rate of developments, the adverse impacts of depletion effect can be overcome by exploration and thus the issue of sustainability in development /globalization can be resolved. Without exploration, the mining sector will cease to exist after some time. It is essentially complementary to extraction and thus saves it from extinction. **Extraction starts with it and comes back to it, for survival.**

Since extraction means depletion, growth in mining enterprises is fraught with decline. It has to achieve growth while at the same time constantly coping with depletion through exploration and thereafter, developing new mines/fields. Therefore, growth and exploration need to go together to replenish the exhausted stocks. Otherwise, exit. This is the broad implication of **extraction-depletion syndrome**. The way out from this inherent **growth-decline paradox** is through exploration and development of new mines to achieve sustainable growth of mining sector. Achieving growth and sustaining the growth are two different phenomena. The former is achievable through the application of more capital and labor while the latter by exploration. The growth-management needs to take this aspect fully into account.

Exploration is a scientific and technological activity geared towards searching and finding new mineral bearing areas and mineable deposits embedded at different depths from the earth's crust in both the virgin and known operating areas on the basis of clues, surface data and the outcrops/exposures. Indications and surface data give only the likelihood of presence/absence of a mineral. From this information, a decision will be taken on exploration which explores to find minerals. They are non-common stuff in appearance, shape, weight, colour etc. On the other hand, the S&T assign utility and saleability to a resource. In other words, it converts the neutral stuff into a resource for use through various laboratory investigations and tests. In essence, exploration is the discovery of mineral deposits and hence, can also be viewed as the creation of wealth. In effect, it can also be considered as the creation of profitable investment opportunities in the mining sector. **It is the main spring of all development** and material civilization, at large. It is so vital that it needs to be undertaken disregarding its economics (F. J. Anderson).

The outcome of exploration is information/knowledge regarding a mineral about its quality, quantity and mineability to serve the industry. In this case, both successes and failures are equally important. It is a pure gamble (see R G Burn; also, Brian W M. 1987). Mineability and utility of minerals resources vary with the technological developments. In that sense, the supposedly useless and non-mineable stuff of today may become useful and extractable tomorrow due to technological developments. (See Naganna, 2001). Therefore, resource base is relative to technology. Incidentally, this may give comfort to the advocates of aggressive globalization.

On the whole, exploration together with S&T give rise to the whole gamut of interrelated industrial activities. More importantly, **exploration ensures material security to the industrial economy**, which otherwise will have to face the impending dangers of collapse due to material scarcities. Because, it brings hitherto unknown deposits for exploitation and thus ensures copious flow of raw material supplies. But, there is an inescapable limitation to this trend. It cannot continue indefinitely because a day will be reached when the entire globe will be totally explored giving no scope for any more new additions to deposits. This means that the total knowledge /information about resource base in detail by country/region and by quantity/quality etc., will be made known fully well. In other words, the quantity of new founds by exploration (or the exploration contribution) will tend to reach zero limits when the globe is fully explored. For instance, the Indian geologists report that the iron ore prospects are fully explored in India and further exploration may not add anything more. Thus, exploration gives a detailed map of resource base across all countries and geographical regions. That being the case, it gives not only the material-security but also gives a detailed baseline data on the basis of which several public policies can be formulated such as: limits to growth; an empirical assessment of sustainability; the growth rates; supply–side issues and substitute development; inter resource substitutions; conservation plans, scientific resource management etc. It gives a road map and empirical database for sustainable development. All this apart, a resource-centric approach can be formulated to make globalization compatible with sustainable resource base. Otherwise, globalization remains to be an empty slogan.

Keeping the above arguments in view, the following propositions can be made.

"If there are limits to exploration, there must also arguably be limits to growth based industrialization and corporatization. By stretching logically, this then would impose limits on globalization".

One need not show very great concern on these limits in the short/medium term since they are all long term in nature though inevitable. But, we are all dead in the long run, as Keynes said. However, these limits can be postponed to fairly longer periods through exploration. In other words **exploration makes globalization compatible with ever depleting resource base**. The main purpose of exploration is to discover new workable deposits in virgin areas. Thus, it creates supply or the copious flow of raw materials while the S&T assigns utility and saleability to resources; and technology creates the actual utilization of resources through manufacturing. Marketing creates demand and markets for the products. In this scheme, **exploration lays the foundation for sustainable development**. In this context, it is considered in a very broad sense. It is an integral part of S&T, which achieves sustainability in more than one way. It is considered in a very broad sense besides the search for mineral deposits. It can be shown below:

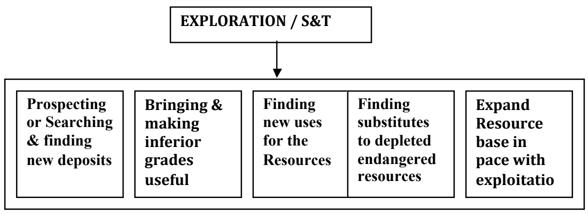

Exhibit 3 Exploration Continuum

This is how exploration enables the economic system to get access to uninterrupted resource-supplies to maintain and sustain the current levels of production and consumption for longer periods. Thus, exploration and S&T together make globalization compatible with depletion. This then would ensure sustainable development. In follows is the identification of its basic components.

The pillars of sustainable development can briefly be presented in a chart below.

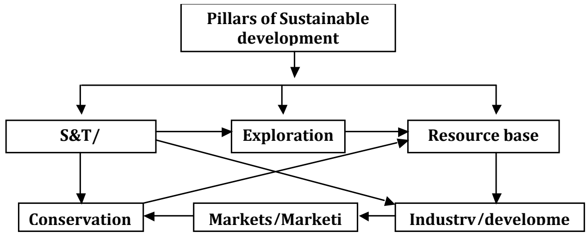

Exhibit 4 Pillars of Sustainable development

The above chart is self-explanatory. It summarizes the broad elements in achieving sustainable development/ globalization (Thomas N Gladwin et.al, 1995). It may specially be noted that the "S&T/Knowledge" is kept at the start because it is the resource of the resource. It creates the resources and the rest. This chart is slightly, modified and expanded to give more clarity on the issue in question. This expanded chart is given below.

RESOURCE BASE

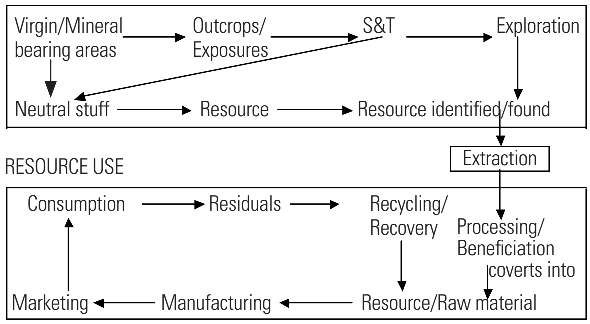

Exhibit 5 Exploration & Resource supply chain

In the same vein, those two charts have been expanded further to bring some more elements to understand more about the increasing trends in globalization and its wider impacts on the environmental and resource sustainability. The distinguishing feature in this chart is that environment is placed at the center. Because, everything has to come from the environment and also goes back to it though in a different form (i.e., residues / wastes etc). It is central to sustainable economic development. Since it is not a bottomless sink, development cannot afford to be reckless and indiscriminate. If it is streched too far, then the very purpose of development becomes questionable. This is displayed in the expanded chart below. All these charts are inter connected because they are all the extensions of the basic issue of sustainability.

It enters either implicitly or explicitly in all of them. It is the unifying theme. Hence, all these charts are to be read together to get fuller meaning and understanding (Harold Hotelling, 1931).

Environment is central to all the developmental activities (Judy Brown & Micheal F, 2006). It is the core of the EPC stream. Development orginates from environment and goes back to it, though in a different form, i.e., wastes and residues. Because, development means consumption which in turn means generation of wastes residues. Accordingly, by placing environment at the centre, an extended chart is fabricated. It is given below.

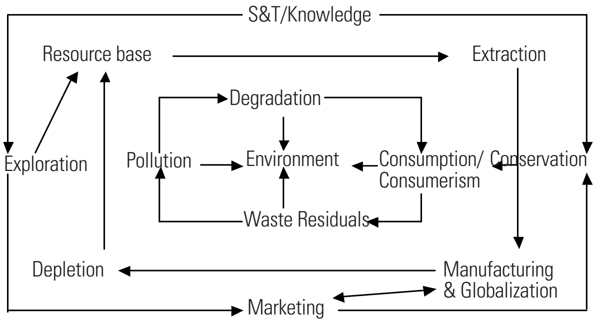

Exhibit 6 Dimensions of Sustainability by placing Environment at the centre

One of the major impacts of globalization will be on the extraction sector resulting in faster rates of depletion than before and thus making the issue of sustainability more critical. To keep pace with the increasing demands of industry, significant shifts were made in mining policy allowing both private sector and foreign enterprise participation in exploration, development and exploitation of mineral resources. All lead to faster rates of extraction than before. In effect, continuous over-exploitation for long periods without any substantial exploration efforts result in total depletion of scarce mineral resources and thereby, depriving the future generations with adequate mineral deposits to maintain their production and consumption levels. It is argued that the issues of sustainability can be made compatible with globalization through undertaking exploration ventures and conservation programs on a continuing sizeable scale. There is no other way.

Exploration and Conservation

"If depletion is a corollary to extraction, then exploration is complementary". One makes survival critical while the other comes to the rescue to save from exit. Exploration constantly replenishes the depleted stocks to see the extraction continues over very long periods. Otherwise, doomsday will be reached. Thus, exploration essentially achieves sustainability or the sustainable development by:

- Replacing or replenishing the depleted resource stocks.
- By maintaining the resource base intact.
- By preserving the future living standards without impeding the ability of future generations to meet their own needs.
- By providing an unchanging or non-declining resource base for the future.
- By ensuring resources availability over longer periods.

Thus, it leaves to the future generations an inheritance of wealth no less than we inherited. **Development is thus made compatible with sustainability**. Hence, it follows that the sustainable development can be achieved through exploration coupled with the conservational practices at all levels/fronts. Conservation also enhances the lifespan of resource base though from a different route. Both have the same goal of achieving sustainability.

11) Conservation/Sustainability

In fact, both are the two sides of the same coin because it is only through conservation that sustainability of the development can be achieved. It is difficult to distinguish between the two since they have almost the same goals and the processes to achieve. However, conservation is a wider concept to cover sustainability. Both are central to natural resources management. Further, the resource-base and conservation are integral parts of sustainable development because development means resource extraction and utilization. It is not only difficult to define the meaning and scope of sustainable development but defies measurement by any single index. It is easier to identify policies that would contribute to achieving sustainable development than to define the term itself[7]. (For various views

7. See the India's Seventh Five year document (chapter on Environment). Later on, The Eighth plan document broadened the base of economic planning by suggesting to include the efficient use of resources and long-term sustainability. In fact, these guidelines should be more imperative than indicative. It has become a guiding principle in all the developmental programs.

on sustainable development and sustainability, see Naganna 2001 and 2000 respectively). Sustainability as defined by various scholars is difficult to attain because it is not possible to leave the resource base for posterity in the form we inherited. Further, rationality demands that we should take first the best that is known and leave the rest to the future. If so, future will be deprived of the best, which impairs their productive efficiency.

Way back in 1908, the natural resources policy is defined as: **"the use of foresight and restraint in the exploitation of the physical sources of wealth as necessary for the perpetuity of civilization, and the welfare of present and future generations". And, the conservation as: "the preservation of the unimpaired efficiency of the resources of the earth" (Charles S Pearson, 2000, p: 471).**

This explains the gist of the rational resources management. This implies sustainable development requires an active role for government in efficient and prudent management of natural resources. In this context, A.C. Pigou wrote in 1932 that: "It is the clear duty of government which is the trustee for unborn generations as well as for its present citizens , to watch over, and if need be, by legislative enactment, to defend the exhaustible resources of this country from rash and reckless spoilation" (Requoted from Charles S Pearson, 2000, op.cit). This implies the need for state intervention in all the matters relating to natural resources management, particularly the exhaustibles. This directs the government to follow the principles of sustainable development in the exploitation of resources and their use in a manner which is sustainable.

Sustainability essentially refers to: (a) the carrying capacity of the resource base and (b) the waste absorption-capacity of the environment, to maintain current and the future levels of E-P-C streams. In other words, the posterity should not become worse off because of our reckless and rash over-use of resources and the environment. Thus, it converges with conservation since the posterity is meaningfully meshed up with both. Both vehemently advocate the **maximization of the lifespan** of the resource deposits by **minimizing all kinds of conceivable wastages** in the E-P-C streams to effectuate resource-savings for the future. This is the crux of sustainability/ conservation or the sustainable development.

In this context, a number of definitions or perspectives on sustainbilility are presented in David Pearce, et.al, 1989, pp 173-185. In these perspectives the major **noticeable deficiency** is that they do not provide space for exploration and conservation and their beneficial impacts on the resource-base and its longevity. An attempt is made in this paper to overcome that deficiency in rational resources management and there by, to make the increasing rates of extraction/ depletion compatible with sustainable development.

History unfolds the fact that the conservation was strongly advocated way back in the first decade of the last century itself in the U.S.A. (the land of plenty blessed by the bounty of nature). It was rightly observed then (charles R Van Hise, 1910, pp: vi) that

"…. may serve a useful purpose in forwarding the **great movement for conservation which is more important than all other movements now before the people"**. He defines conservation as: "The natural resources limited in quantity should be conserved. By their conservation is meant that they should remain as nearly undiminished as possible in order that this heritage of natural wealth may pass in full measure to succeeding generations" (1910). This is indeed a laudable idea to emulate. It is a utopian state. Conservation does not, however, preach abstinence from consumption/production. It only advocates the parsimonious and prudent use of resources or the wise or efficient use of resources. It is a frontal attack on all kinds of wasteful and reckless extraction and use of resources; and mainly the conspicuous consumption or the ostentaneous consumerism. In effect, it advocates resource-savings for future generations to enable them to meet their needs without dampening their resource productivity.

The principle of conservation, though started as a moral principle, underwent gradual transformations over time in terms of its meaning, scope, content, importance and relevance; and ultimately culminating into the principle of sustainability or the sustainable development. After making a quick scanning of literature (see Naganna, 2000, op.cit), its transformational path has been identified and delineated as:

[Conservation] → [**Moral principle** to eliminate all wasteful and ostentaneous consumption] → [**Academic principle** to construct models] → [**Constraint on growth** to highlight the finiteness of resource base] → [**Substitute to production** to eliminate wastes in E-P-C leading to resource-savings → [**Cost-saving device** to reduce energy and material intensities in products] → ending in the [**Sustainability/sustainable development** a guiding principle to orient and direct all economic policies]. Thus, the principle of conservation gradually transformed over time into a guiding principle in all the developmental projects under one rubric, called the **sustainable development**. This transformation was greatly influenced by the then existing values, tastes & preferences, needs and social priorities during the corresponding period of transformation. They can't be ignored.

However laudable conservation is, is a difficult task to achieve. It can only be achieved by both S&T as well as by bringing the attitudinal changes in the E-P-C streams. A three-pronged approach is suggested below:

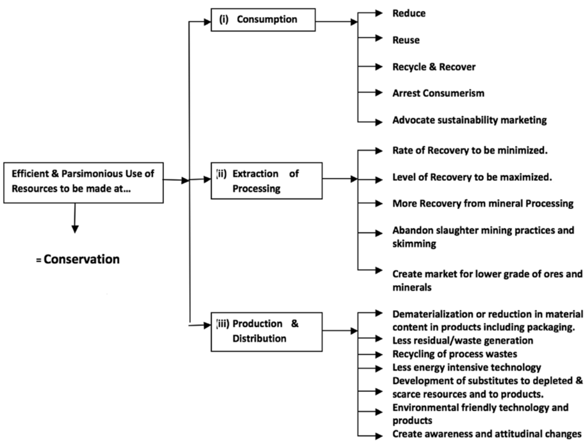

Exhibit 7 A three-level Approach to achieve Conservation

In the ultimate analysis, conservation through this three-pronged approach with a judicious mesh of measures enhances the life span/longevity of the resource base by efficient exploitation and use; and thus maximizes the resource-availabilities to the succeeding generations. And also, mitigate all kinds of suspected impairments to maintain their living standards. This is how, resource base can be made compatible with sustainable development. There is no other way. But…. they need to be implemented uniformly across all the operating units.

Otherwise:

"Non-compliance will create bitter distortions in unit costs among the enterprises and consequently, their competition position gets differentially affected in a foul manner".

In a competitive market economy, a uniform compliance is a pre-requisite for successful implement of any policy. Otherwise, it will do more harm than good.

In all the above three approaches, the S&T reflecting in continuous innovations, plays an indispensable role. This is perhaps the reason why Ram Nidumolu et.al, argued in a recent issue of **Harvard Business Review,** sep 2009, that the **innovation needs to be the key driver for sustainability.** They also rightly highlighted the fact that **there is no alternative to sustainable development.** But there is a rider to their statements. In this context, a distinction needs to be made between: **(a) process innovation and (b) product innovation.** Both signify two different types of phenomena. It is true that the former only promotes sustainability by reducing energy and material intensities and thereby, resource-savings; but the later spreads consumerism to defeat the very essence of sustainability. Hence, process-innovation is to be promoted and encouraged through incentives and subsidies.

In the same vein, one more distinction can be made. In fact, the modern marketing practices, in one sense, are more insidious and even hazardous to both environment and resource base than the industry itself. It is encouraging the unbridled industrialization. It is the major culprit for the wide spread wasteful and unsustainable consumption (see Naganna and Pankajakshi, 2009). That being the case, it needs to be replaced by the newly emerging marketing concept called **Sustainbility marketing** which aims to promote sustainable consumption and consumer behavior (see, Frank-Martin Belz and Kenpeattie, 2009).

12) Mineral Markets Expansion and Conservation /Sustainability: A Paradox:

Higher rates of development induced by globalization/ corporatization increase the extent of markets for minerals along with the concurrent rise in depletion rates. This aside, the expanding mineral markets will have impacts on the resource base in a different way[8]. Our **lurking hunch/surmise** based on our field visits not only to several coal belts but also to other mineral belts in the country from time to time during the past few decades, is that the expanding markets for minerals promote and foster conservation/ sustainability of mineral resources through increased mine-size, mechanization programs, better (scientific) mining methods, more exploration efforts and so on (see part-II of this paper). Expanding markets may even bring the lower grades into productive uses which otherwise would have been discarded and uncared (or wasted). Further, this situation also encourages the beneficiation and blending of different grades where ever possible, resulting in the parsimonious use of resources (i.e., conservation). In the same vein, it can also be inferred that the minerals market expansion creates the awareness for the need to conserve due to the fears of increasing scarcities and rising prices. So to say, the market expansion and rising levels of awareness for conservation go together. The oil crisis of 1970's and its aftermath would substantiate the case in point. Thus, market expansion would ensure product wise-use of resources (or conservation). On the other hand, the **contraction of markets** or the lower levels of demand **do the opposite** and even promote the slaughter mining, skimming etc.

Thus, the extent of market has a definite bearing on conservation from the point of view of **level of recovery.** Experience shows that larger markets promote and foster conservation[9].

A paradox/Conflict: A conflicting situation arises in the context of marketing and conservation. Expanding markets may foster conservation through increasing the "levels of recovery" including the extraction of lower grades but conflicts with the rates of recovery (or the sustainability). Because, higher rates of annual recovery means the higher rates of depletion and thus, making sustainability more critical. This conflicting situation among the expanding markets, conservation and sustainability needs to be resolved through compromises. There is no other way, other than working out some agreeable compromises/tradeoffs. Consequently, the issue gets drifted from resources management to the domain of public policy. The following proposition follows from the above analysis.

➛ **If the extent of market is low relative to the resource-base, then the extractive sector in general is prone to resort to the slaughter mining practices, skimming the deposits, rat–hole mining and of sort; or in other words, the resource damages/wastages will be more and unheeded as well. And, vice versa.**

From this proposition, we can also derive that the principle of conservation becomes more relevant and necessary when mineral markets get expanded. It does not catch the attention of policy markers if the resources are found to be plentiful and abundant in relation to the needs/requirements. But the situation is different now due to population explosion, higher rates of growth etc. Accordingly, this places the issue of sustainability/ sustainable development at the core of policy making. In this context, it has been observed that: "It is easier to agree on policies that would contribute to sustainable development than to define the term itself. Examples of unsustainable development or the least inefficient or

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8. Expanding markets obviously imply higher prices across the board. Both together induce the firms to invest more on S&T and innovation in exploration, finding uses for inferior grades, going to inaccessible areas, reducing mining wastages and so on. Thus, the resource base constantly gets enlarged in pace with the speed of development. But ultimately, it is finite/fixed in quantity to defy the arguments favoring limitless and unbridled growth.

9. However, this is not to be mistaken that we are advocating to leave the issue of conservation to market forces. Policy intervention is necessary to achieve conservation.

wasteful practices are numerous". (Charles S. Pearson, 2000, p149).

In conclusion, it can be said that sustainable development does not plead for a reduction in the E-P-C streams. But focuses mainly on the mechanisms to maintain the current rates of the E-P-C streams over longer periods while at the same time keeping the resource base intact by continuous exploration, conservation and the development of substitutes etc to replenish the used up or depleted stocks and thus enabling the economy to overcome the impending ordeals of the doomsday. The whole market mechanism in relation to resource base as outlined above, operate between the two extreme bounds viz., **an upper bound,** beyond which no exploration or any S&T development can push the resource base; and **a lower bound** signifying hitherto unknown and unexplored areas perhaps with large resource potential. Both are quantifiable and measurable. Keeping these bounds in view, a policy framework for resources management and sustainable development can be worked out (R. U. Ayres, July 1996).

PART II

13) Empirical Analysis with a Case Study

The present empirical analysis on a case study deals essentially with non-renewable resource management to make it compatible with sustainable development over long periods. Sustainability is essentially a long term concept. The most striking feature is that **growth contains decay or in growth lies decay** in the mining sector. Hence, sustainability assumes a special significance. Sustainable resource-base / resource availabilities in pace with the rising trends in growth is the crux of the issue on hand. In essence, it implies the making of inherently depletable resource compatible with sustainable development/sustainability. More realistically, it is the other way round necessitating the sustainable development to be made compatible with the known resource base. **Making resource base compatible with sustainable development is different from making sustainable development compatible with resource base.** This distinction (i.e., market vs market-base) is crucial because both represent two diagonally opposite phenomena. One signifies the primacy of markets over the resources while the other assigns primacy of resources over markets. In other words, one represents a case of "matching supply (resource base) with demand (market)" and the other "matching the demand (market) with supply (resource base)". This has many great implications in sustainable resource management to satisfy the ever increasing requirements of development. Resources being what they are (see part-I), it is necessary in the interest of sustainability to advocate the replacement of the present practices of **"matching supply with demand" by "matching demand with supply"**. It is hoped that this will ensure resource-security for the future. However, this involves a major paradigm shift in consumption-oriented development models through corporatization/globalization. This will also entail a radical thinking in resources management. It also calls for a drastic change in strategic thinking on national policies for development. In this framework, both exploration and conservation assume a greater role and significance. Both can overcome the impending ordeals of fast rising depleting rates.

In this paper, the methodological approach is based on the grounded-theory framework in which, the research does not start with a hypothesis or with any preconceived notions about the phenomenon to be inquired, but ends up with some. It starts with a clean slate. It is a form of inductive logic through which some theoretical assertions are derived from empirical observations (Roy Suddaby, 2006; Karl E. Weick, 1989 & 1995).

Exploration creates and expands continuously the supply-base (Resource base) while markets create demand (i.e., resource use) in the E-P-C stream. S&T and rising globalization/corporatization trends over time and at faster rates are threatening the looming onset of the dangers of doomsday. Besides, the other socioeconomic developments are also giving rise to the differential rates of growth in exploration and markets. So to say, markets are growing much faster than exploration. This has become a matter of grave concern. However, there can be, or rather it needs, an equilibrium point between the two which is facilitated by conservation. This can be diagrammatically shown as below.

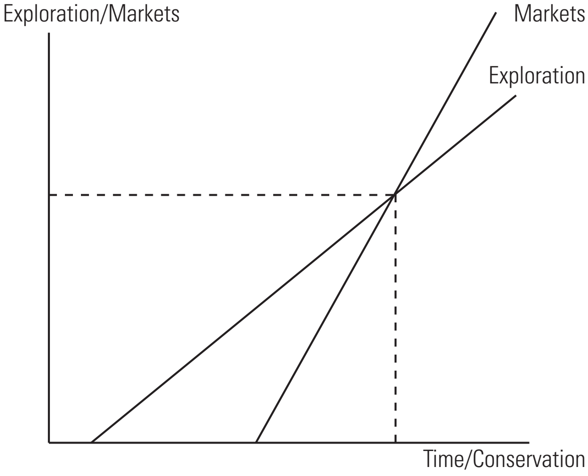


Exhibit 8 Equilibrium Between Exploration and Market–Expansions

In what follows is a brief explanation of the **underlying arguments on the above Exhibit:**

Conservation acts as an equilibrating force to match or bring a balance between, markets (i.e., demand or the resource use) and exploration (i.e, resource supply or the resource base). That is why it is rightly called, a century back, as a great movement. In this context, it may be recalled the earlier distinction between the **level of recovery** (i.e, conservation) and the **rate of recovery** (i.e., market) from a given known mineable deposit. The extent of market refers to the rate of recovery (i.e., annual rate of mineral rasings) while conservation is concerned with the level of recovery (i.e., the maximum amount of mineral that can be extracted from a given known deposit over its life span at a particular price level, with a given technology and mining method.) It is more relevant to conservation because this would ensure minimum "loss/damage". Thus, the level of recovery is relative to price, market size and technology. In this sense, that part of conservation which deals with mining–aspects will also become relative to mineral prices and technology with a positive correlation (Harold Hotelling, 1931).

Both level of recovery and rate of recovery operate in opposite directions. The former enchances the sustainability-levels while the other leads to the faster rates of depletion. If the level of recovery is higher than the rate of recovery, then the total depletion will comfortably be postponed indefinitely and the lifespan of the deposit gets enhanced and vice versa. Thus, the sustainable development is ensured without the fears of doomsday in the near future. This is the most ideal state. Further, the extent of mineral markets **acts in two ways**. Firstly, the expanding markets followed by obvious rising prices, will tend to increase the level of recovery by (a) converting hitherto uneconomic deposits (for any reasons) into economically mineable ones and (b) inducing technological improvements through R&D investments. This is the positive side. Secondly, when total resource base reaches its finite-limits (i.e., with no further new additions through exploration), it does more harm than good by making rates of depletion awefully faster. Hence, the extent of market will be beneficial to sustainability within **some range** referring low and high respectively to "before" and "after" situations of the resource base reaching its finite limits. This is all about the extent of market and its relation to conservation.

"Extract the last tonne" from a mine, can figuratively be taken as the guiding principle in all matters relating to the exploitation of mineral resources. **This the conservation advocates**. On the other hand, conservation is totally and eternally beneficial in more than one way. It refers, in this context, restrictively, to the level of recovery by adopting better methods of extraction, reducing mining wastages, extracting high-cost less fertile deposits through **cross-subsidization,** going to hitherto discarded inaccessible deposits and so on. Thus, it contributes directly to sustainability by enhancing the resource base. Hence it is said that they are two sides of the same coin. In effect, it also acts through other ways(see part-I) as an equilibrating force to bring a judicious balance between the markets and sustainability.

A word of clarification on exploration. It operates and contributes to the stock of resources in a range of two extremes from zero to the unknown but finite quantity of a mineral deposit embedded below the earth's crust. It progresses gradually by stages (see Naganna, 2000; op.cit) from zero to the maximum possible mineable deposit which is unknown but finite. At this final point which will be reached one day, its contribution tends to become zero. That being the case, the exploration curve can be drawn in many ways depending on its assumed place between the two extremes.

Keeping the above framework in view, an empirical case study has been carried out to give the empirical base to the contents in part-I (see also, Appendix 1). Many of the concepts are operationally quantifiable and measurable and they get empirically validated either explicitly or implicitly. Accordingly, the case study focuses on: (a) Output trends/depletion rates; (b)Exploration trends and the corresponding new additions; (c) Mine size; (d) Shifts in mining methods; and (e) Cross subsidization trends to achieve conservation/sustainability. In the process, environmental impacts particularly the land damages are also considered very briefly.

14) Role of Coal and Energy

India's energy policy is essentially based on its relative fuel resources endowment. Since the country is richly endowed with coal resources, the coal continues to be the primary source of energy. About 70% of electricity even now come from coal. It has is its everlasting primacy. Official documents reveal this. Role of coal and energy in economic development needs no explanation. Among other things, they transform and convert the rest of the resources into various usable products. This is their role. They are the strategic assets which define the level, rate and structure of development. This explains the relevance and significance of our case study.

15) The Empirical Case study

An empirical assessment of sustainability/ conservational practices both directly (intended) and indirectly (unintended) as practiced by the mining industry is carried out. For this purpose **a case study method** is chosen (Robert K.Yin, 1994, Kathleen M. Eisenhardt 1989; Rikard Larrson 1993; Michael Gibbert, et.al 2008; Robert K Yin 1981). The case in question refers to the coal mining industry in the state of Andrapradesh (AP), India. The source of data is the **longitudinal field investigations** (Garret M Fitzmaurice, et.al, 2004). Due to the repeated visits since 1967 with long intervals, we could get a long time series data on important parameters, particularly the output data for more than a century since the very start of coal mining operations in AP. To get fuller meaning, these data have been complemented by the ideas gained in seminars, debates and the lengthy discussions with several mining officials and experts not in only India but in some foreign countries like the US, UK, Thailand etc.

A quick scanning reveals that the whole literature on minerals economics is replete with models, mostly mathematical and econometric, focusing mainly on the optimal exploitation or the optimal rates of recovery and the longrun resource depletion and thereby, giving a variety of doomsday messages and red signals on the sprouting awesome scarcities and the endangered future availabilities of resources[10]. And, most of the studies are theoretical in nature with little or no empirical analysis particularly at the industry level. This is where the present case study makes a **detour** into the critical issue of increasing the levels of recovery instead of rate (optimum or otherwise) of recovery from the existing known mineral deposits. Because, the core of conservation/sustainability is the level of recovery while the rate of recovery enters only when we discuss the intergenerational equity over the resource accessibility or the longterm availability of resource supplies to sustain the current levels of development and consumption. How long is the long run, is in fact a matter of social choice/judgment. Whether or not the mathematical modeling can solve this question is again a matter of opinion and analysis.

The central concern of this case study is to examine and analyze the practices of conservation in the industry, both intended and unintended, within a theoretical

10. An exhaustive survey is given in Frederick M Peterson &Anthony C Fisher ," The exploitation of extractive resources A survey, "The Economic Journal, 87 Dec 1977 pp:681-721. Also a similar survey in Anthony C Fisher & Frederick M Peterson," The Environment in Economics: A survey", Journal of Economic Literature,14 March 1976, pp:1-33. The whole literature largely centres around scarcities, optimal rates of extraction, preservation of environment etc, through mostly mathematical modeling at the cost of ignoring what is being perceived and practiced at the industry level. In the context of over reliance on mathematical modelling, see the classic paper and the subsequent debate in David Novick." Mathematics: logic, quantity and method", The Review of Economics and Statistics, November 1954, pp:357- 386.

framework. The lessons from this analysis can be of use in making a policy-design and formulation for the entire mining sector. Since such policies are derived from empirical analysis, their implementation will be more effective and fruitful. There are not many empirical studies of this nature.

16) Coal resources in Andhra Pradesh: A Historical review

Andhra Pradesh is amply endowed with coal resources (with about 10 billion tones accounting for about 10% of all India coal reserves) spreading over four districts, viz, Adilabad, Karimnagar, Warangal and Khammam districts. The status of endowed reserves gets constantly changed or improved through exploration operations not only in AP but in other Indian states also. Below this state, there are no other coal fields except lignite deposits in Tamilnadu. Thus, it has locational advantage. The Singareni Collieries Company Ltd (SCCL) is the lessee of all the coalfields in the state. It is charged with the responsibility of playing a vital role in the exploitation, development and exploration of the coal deposits endowed in the state. SCCL is the oldest public sector coal company in India with the share capital being owned both by the state (51%) and the central (49%) governments. SCCL is one of the most progressive companies constantly looking for modernization and growth.

Historical evidence/records from the **State Archives** of AP show that the exploration (drilling) operations were taken up in october1872 by an order from the HH, the Nizam Government to ascertain as accurately as possible the extent of coal resources in the Singareni coalfields of the Telangana region[11]. In November 1872, the prospecting operations were commenced. In 1875, a report (Henan's Report, 1875) was submitted which estimated the total coal resources embedded in the Singareni Coalfields (AP) will be of the order of 46.5 million[12] tons of which 19.5 million tons of coal was considered to be of first class quality and decidedly equal to, if not better than any coal as yet discovered in India.

On 7th January 1886, the government of Hyderabad granted a mining concession to Mr. John Stewart and William Clarence Watson of London. A limited company called The Hyderabad (Deccan) company Ltd. was duly registered and incorporated under companies Act of 1883 on the 29th July 1886. **The company started raising coal from the Singareni coal fields on the 7th August 1886**. Thus, the coal mining industry in AP was started in the year 1886 with **an annual output of about ten thousand tons**. Thereafter, the output has grown into astronomical figures despite the year to year mild fluctuations. In the year 1888, a couple of years after the start, the output was a meagre 13 thousand tons and **it reached to a little over one lakh tons mark by the year 1890**. From this humble beginning, the SCCL at present is raising about 40 million tons of coal annually by operating 69 coal mines (including 11 open cast mines) with an employment of about 100,000 workers. And, it is aspiring to reach a 50 million mark by a few years from now.

The important noteworthy events in the long history of over a century of mining operations in AP is given below:

- Discovery of : 1870
- Confirmation of coal deposits : 1872
- Hyderabad(Deccan) company Ltd. : 1886
- Commencement of mining operations : 1886
- Starting of SCCL : 1921
- SCCL became public sector undertaking : 1961
- Commencement of open cast mining : 1979
- Mechanized long wall face : 1983
- Commissioning of drag line : 1986

The major sources or the drivers of the phenomenal growth of coal industry in AP are:

- Technological change / mechanization programs.
- Shifting in mining systems/methods
- Geographical diversification through opening new coal fields.
- Increased mine size and
- Continuous explorations from 1973 onwards.

11. *The author visited and spent a couple of weeks in1967 in these Archives to dig the historical evidence on AP coalfields.*
12. *The latest reserves position is estimated to be of the order of about 11 billion tones. Note the contribution made by the intensive exploration operations undertaken subsequently.*

As a matter of fact, technological change is the primary factor while the rest are all supportive and facilitative. Of course, the comfortable resource-base is the basic foundation.

Not only growth but sustainable growth over a fairly long period could be achieved through a combinations of those factors **without facing the ordeals of depletion**. Since there are no other coal fields in the whole of Southern India, the AP coal fields have to meet their ever increasing demands for coal. Since coal transport is energy intensive as also high cost one, the southern states have to increasingly depend upon AP coal fields due to their proximity to various consuming centers in the south. This is the reason why the SCCL registered faster rates of growth than the Coal India Ltd (CIL). Consequent upon the higher and faster comparative growth rates in the SCCL, its relative position in the All India coal output has gone up significantly. SCCL was contributing about 5% to the All India coal output in 1964-65 (see Naganna, 1974) which increased to about 7% by the year 1974-75 and thereafter to about 10% in 1985-86. Subsequently its relative position in the All India coal sector continued to remain at about 10%. In one sense this implies that the SCCL could achieve not only growth but the sustainable growth. This is the striking feature. **The underlying factors of this success story are mainly:** (a) The comfortable resource base

(b) the continuing exploration operations to replace the ever depleting stocks and to some degree (c) the conservational practice through cross subsidization. An attempt is made here to investigate these factors in as detailed a manner as possible.

Coal Resource–Base of the SCCL: Sustainability?

The issue then becomes one of whether or not the AP coal fields have adequate resource base to maintain and sustain the phenomenal growth in output as observed above. Among other things, this implies primarily **the issue of sustainability or the carrying- capacity of the resource base** to achieve, maintain and sustain the immensely impressive growth rates.

The company's published documents show that the coal bearing area of the SCCL extends over a stretch of nearly 450 kms in the Godavari valley with an airial extent of about 15,000 sq.kms. This coal bearing area contains the coal reserves as on 2001 March.

a) Indicated reserves	: 1112 mil tones
b) Inferred reserves	: 3543 mil tones
c) Proved reserves	: 6201 mil tones
Total coal reserves	**: 10,856 mil tones**

These reserves might go up still further since there is a large chunk of unexplored area. It appears that the sustainability level is quite comfortable to meet the ever growing requirements of coal to achieve the goal of sustainable development. In India, coal assumed a special significance after oil price hikes. More importantly, it needs to be specially noted that what all proved cannot be extracted due to mining losses and several unexpected geological risks and uncertainties in the process. **In effect, the proved-reserves seem to be a myth while production is a reality**. The extent of exploitation from a given deposit depends on several complex factors which are not known and which cannot be planned to control. The role of "unknown unknowns" is very critical in matters relating to exploitation . In this context it is worth noting an observation from M.W.Watkins (1944) who says :

"Even after the discovery of a 'vein', a 'pool' or a 'seam', its extent and richness can only be determined by actual extractive operations. And these estimates remain nothing more than estimates until these operations are completed and the deposit exhausted".

This classic statement summarizes the whole matters of risks and uncertainties relating to the reserves/ deposits and the extent of their recovery level. The extent and richness of the embedded deposits are so to say, inherently unknowable and hence, unestimatable. The very concept of a reserve then is really deceptive and elusive. It is therefore true that all the "deposit" cannot be extracted. The level of recovery from a given deposit depends on mainly "luck" factors. On general grounds, it can be said that only about a half (or 50 to 60) of the deposit can be exploited after giving adequate allowance for mining losses , geomining uncertainties, surface land protection and so on. **The level of recovery from a given deposit, however,**

varies also by the type of mining system adopted (see Chart no.II). The lowest can be seen in "Bord & pillar" method while the highest in the opencast mining. The choice of mining systems has the significant implications in achieving the goal of sustainability/ conservation or maximizing the level of recovery.

17) Empirical Assessment of Resource-base:

The brand empirical assessment of resource base is presented in Table-1. In this exhibit, the concept of **geological reserves** is used which is slightly different from the concepts of "resources" and "reserves". The discrepancy in data, however, is not factual but conceptual.

and the journey is ridden with several uncertainties at each stage [for details see Naganna, 2000 and 2001 op.cit].In Table-1 above, the known coal deposits are classified under two broad categories viz, reserves under working mines and reserves under virgin areas; and again under this bifurcation, a few categories are also be made. They are mostly self explanatory. This classificatory system is industry-specific. It is to be noted that there are losses [called mining losses or geological impediments] in between the two categories. **Thus, the extractable reserves is the net of the losses among which some are avoidable and some unavoidable**. Consequently, the extractable reserves in the AP coal fields get drastically reduced,

Areas	Working Mines					Virgin Areas				
	Proved geological reserves	Consumed geological reserves	Available geological reserves	Available mineable reserves	Available extractable reserves	Projectised			Un projectised	
						Geological reserves	Mineable reserves	Extractable reserves	Extractable reserves	Total Available Extractable reserves (6+9+10)
1	2	3	4	5	6	7	8	9	10	11
KGY	844	88.143	284.575	194.234	150.154			0.000	191	341
YLD	429	47.217	121.881	75.492	51.770	50.978	25.970	25.970	101	179
MN	777	59.094	146.866	118.644	104.636	313.57	179.573	106.830	175	386
RG-1	384	102.350	285.738	178.206	120.707			0.000		121
RG-	1162	49.706	246.978	158.725	104.221	128.350	68.990	50.000	265	419
RG-	129	12.458	117.022	84.982	84.962			0.000		85
RG-	119	38.917	79.892	47.035	47.035			0.000		47
DHP	645		33.875	26.170	12.972				150	163
BPA	707	84.193	216.725	145.946	84.29	106.313	54.720	33.869	170	288
MM	242	67.198	116.744	90.579	55.827					56
RKP	418	45.774	82.806	65.685	41.123				95	136
SRP	1239	5.458	104.188	296.927	162.692	37.230	30.560	14.700	301	478
Aband oned mines		243.5	243.500							
TOTAL	**7095**	**844.728**	**2380.790**	**1482.625**	**1020.409**	**636.499**	**359.993**	**231.369**	**1448**	**2700**

Table 1 The status of coal reserves (million tonnes) in AP fields as on 31-3-2001.
Source: *Field Investigations. This status will not change in the shortrun.*

Table-1 reveals that the AP coal fields have an altogether a comfortable resource base at 7095 mil tones of proved geological reserves while the geological resources are estimated, as seen earlier to be 10,856 mil tones. It implies that there is a long journey before a resource gets converted into the status of an extractable reserve,

after providing allowance for mining losses, to only 2700 mil. tonnes from a high of 7095 mil. tonnes of proved geological reserves which may be termed as **resource-illusion**. Thus, the extractable reserves forms only 38 % of the total proved geological reserves, and most part of the remaining reserves except the consumed reserves is lost/wasted in the process. Some of these mining losses become extractable at higher unit costs and better technology. **The concern of sustainability/conservation is with these mining the losses and the practice of conservation is to increase the extractable percentage [38% in this case study] to the maximum possible extent.**

The extractable reserves indicate that they are immediately available for working economically and technologically. Such reserves are estimated to be 2700 m.t [or 38% of geological reserves] which may not even lost for a century at current rate of extraction. Needless to say that the future is much longer than a century and the resources are finite. Therefore this calls for immediate conservational measures designed not for abstinence but to increase the level of recovery from the known deposits. In the same vein, the intensity of exploration needs to go up such that the geological reserves [or geological resources] get assigned higher probabilities of getting extractable. Thus, both exploration and conservation together would ensure compatibility of ever depleting resource base with sustainable extraction/development.

On the whole, the detailed empirical evidence given in Table-1 confirm the fact that the extent and richness of deposits can only be ascertained after the actual extractive operations completed. This is all due to the resource illusion. Therefore, the concept of resource base is highly misleading and deceptive too because it raises falls hopes resulting in reckless, unbridled and unaffordable consumption levels/patterns besides giving raise to several complexities in planning and policy making. Accordingly, it is to be specially noted that the resource analysis/estimates need to be used with utmost caution .However complex it could be, resource analysis needs to guide the path of sustainable development (i.e., E-P-C streams). In this content, it is to be noted that: **"Better methods for estimating the magnitude of potential mineral resources needed to provide the knowledge that should guide the design of many key public policies"** [V.E.Mckelvey, 1972].

18) Mining systems: Implications, Impacts & Conflicts

The primary concern in this section is to show the conflicts between conservation and environment. One choice will affect the other. If conservation is advocated for any reason, then the environment get adversely affected; and vicecersa.[In this case, environment is restricted to mean land and forestry only]. It appears that the conservation can only be achieved at the cost of sacrificing environment. Thus the problem becomes more complicated if both are considered together. The solution however, involves a value-judgment or a social choice reflecting its priorities, preferences, values and needs. Therefore, the choice becomes one of prioritizing among conservation, environment and depletion.

The extent of achieving conservation and the extent of environmental damages due to coal mining vary from one method to the other. Each method has different degrees of impact. The extent of severity and diffusion also differ. For a brief description of different mining systems, see Naganna, 1980.There are broadly three widely used mining methods available to the industry for coal extraction, viz.,

- **Bord and pillar method**
- **Long wall methods** [Advance and Retreat], and
- **Opencast mining method**

The properties of each the mining system and their respective extent of impacts on land resources [forestry] are given in chart-EII. The chart–EI presents the environmental impacts of expanding use of coal. The chart E-III delineates the conflicts arising out of choices on mining methods. These charts are prepared in the interest of brevity and not to suppress analysis. Each choice reflects not only the corporate values but of the social values (or preferences) at large, since the coal industry is under public ownership. The issues that are either implicitly or explicitly involved in these choices contain public interest to a large measure. In what follows is a brief account of the identification and assessment of the conflicts arising out of the choices on extraction methods, environment, depletion and conservation.

a) Bord and pillar method: This popular and widely used method is characterized by : low mine capacities, low mine size, long gestation periods, low subsidence rates, low level of recovery etc. More importantly, it is characterized by very low extraction intensities which acts as an impediment to growth. Consequently, it fails to cope up with the newly emerging coal markets and fast increasing coal demands. This method with stowing has the least damages to surface land resources, forestry etc. Thus, we can have coal without disturbing environment, particularly land and forestry etc. But, conservation is least in this method since the levels of recovery are lowest. Therefore, the choice turns out to be: which resource, either land or coal, we intend to conserve. There is also problems of stowing costs, coal prices and market size.

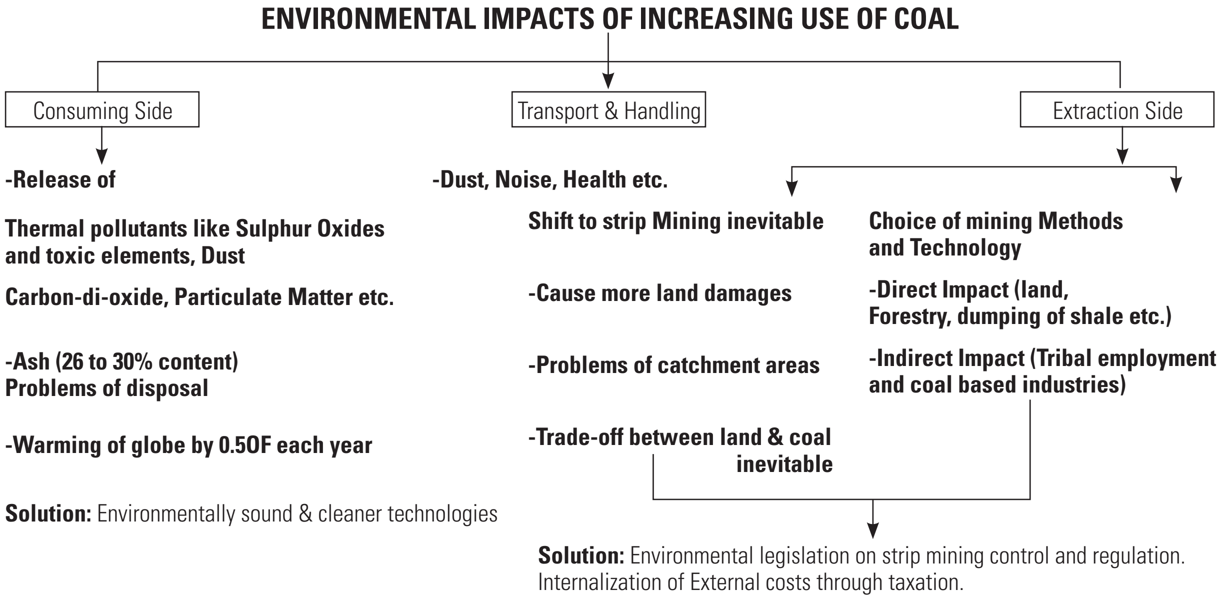
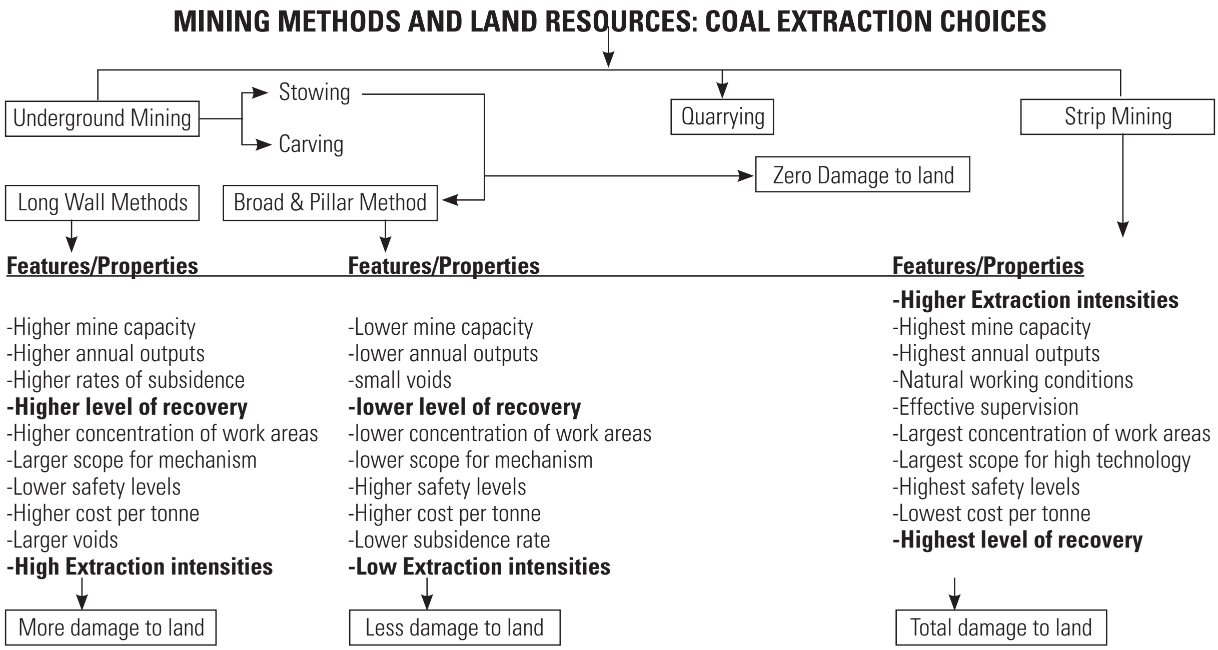


Chart-E1 ENVIRONMENTAL IMPACTS OF INCREASING USE OF COAL

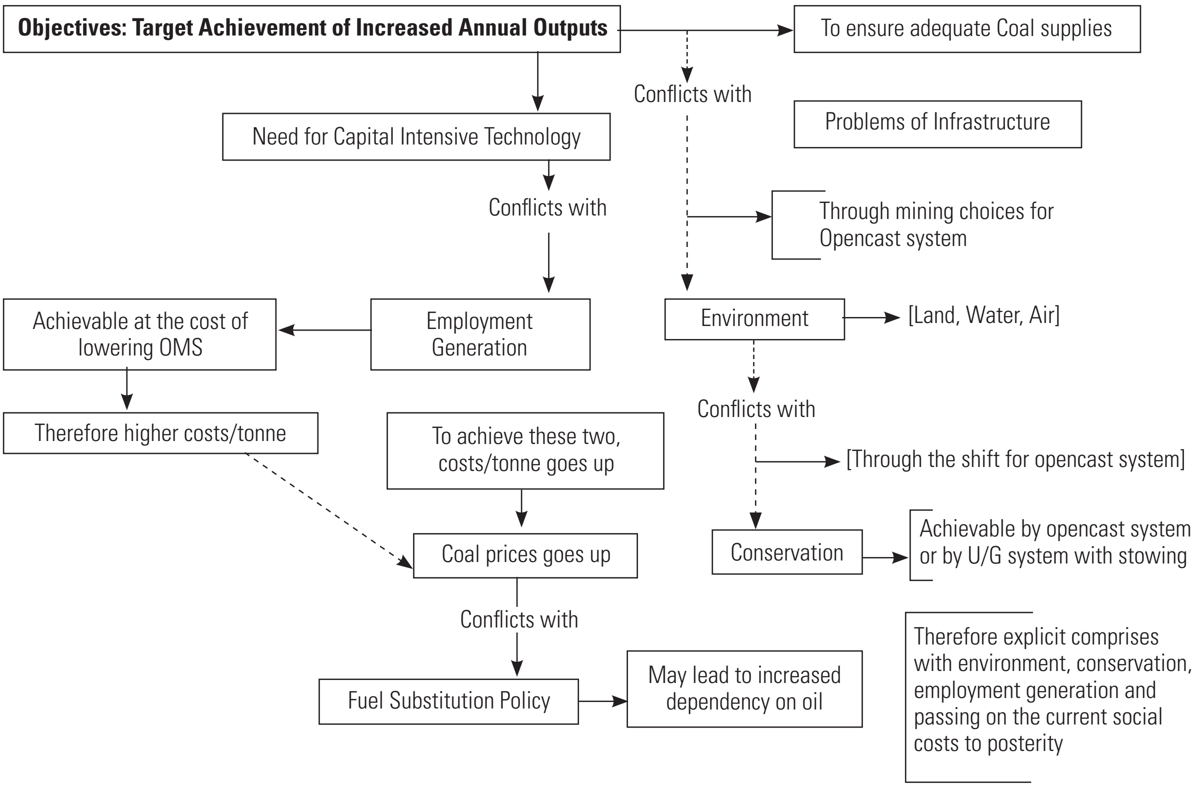


Source: Naganna & Savitha Rani, Oct 2005.

Notes: In comparison, the mining methods are different from the production methods in manufacturing. In extractive sector, they refer to the ways and patterns in which the coal is dislodged from the solid seam. In mining, there is no question of transforming the raw-material inputs in different proportions to make products through technology.

Chart-EII MINING METHODS AND LAND RESOURCES: COAL EXTRACTION CHOICES

CONFLICTS IN OBJECTIVES/GOALS OF THE COAL INDUSTRY



Solution: A Programming Approach to coal expansion and environmental resources to get rational compromises and trade-offs.

Chart-E III CONFLICTS IN OBJECTIVES/GOALS OF THE COAL INDUSTRY

b) **Long wall methods:** The properties of this method are : higher mine–capacities, higher rate of subsidence, higher levels of recovery, etc. This is better suited for larger markets since the extraction-intensities are high. In this case, one can have higher conservation level but land gets damaged due to higher rates of subsidence. Of course, it depends on local mine conditions. Therefore, the emerging choice is better: higher conservation and lower land damages.

c) **Opencast mining:** From the view point of conservation, the opencast mining has been advocated. In fact, this is the best method for conservation because the level of recovery is the highest. In addition, the mine-capacities are also the largest and the cost of extraction the least. When the coal markets get expanded, there is no other alternative but to go for this system because the extraction-intensity is the highest. But, the major problem is that the land and other forest resources get almost totally damaged in this system and the whole surface vicinity gets disturbed due to mining operations[13]. This is mainly land-intensive. Therefore, the choice will be one of between land protection and total conservation of coal. Both cannot be achieved together. As a result, there is a mounting public opinion in the west against this mining method. Even in our country, it started building up. Therefore in this system one can save one resource only at the cost of the other (land v/s coal). This is the problem in resource management. **The benefits arising out of the opencast mining may not outweigh its severe social costs. But**

13. More importantly, this method requires large tracts of land for its mining and other operations. Hence, this involves the involuntary displacement of large number of families and their rehabilitation and resettlement. This is the most acute problem giving raise to other problems of land acquisition. See, Roli Asthana, 1996.See also, M.Sen, 1995 and Michael M Cernea, 2000.

ensures conservation. The choice then is between land and coal.

It may be noted that a shift in mining methods accompanied by technological changes to achieve faster rates of growth as has happened in the case of SCCL, create many and varied kinds of structural changes in the organization and management styles. Besides, it also creates inter-departmental conflicts and inter-personal conflicts due to changes in the skill composition and requirements, age-distribution, competence demands etc. Thus, growth is fraught with many organizational conflicts and problems. Nevertheless, it is still wanted because it offers more opportunities than problems.

Other conflicting situations: To a larger extent, environmental (land) problems can be mitigated through both stowing and land reclamation programs in some combination depending upon the local conditions. But, this leads to another problem that the costs of coals extraction go up considerably and tends to conflict with the accepted policy on the inter fuel substitution. This many even lead to more dependence on oil which is not a desirable thing. This is another conflict. Further, the objective of supplying low cost power for developmental purposes will also get into conflict. Thus, the problem of conservation becomes much more complicated if viewed from different angles. Since there are a number of conflicts arising out of choices on conservation and environment, some meaningful and agreed-upon compromises or trade offs are to be worked out through a detailed analysis. Consequently, **the conservation analysis will be more effective, more meaningful and more solution-oriented if it is viewed within a paradigm of conflict and compromise rather than of rational choice**.

The coal mining cannot be undertaken without damaging land in some way or the other, and hence the issue of land management assumes a greater importance. Since land is the primary, perennial and inexhaustible source of food, fodder, fiber and fuels for human existence, it should not be destroyed for the sake of one time benefit (i.e.,coal). By stretching the role of land to its logical limits, the following surmise can be put forth for further policy analysis.

"If a coal-based energy policy is not rightly complemented by a correspondingly appropriate land-use policy, then it will be counter-productive in the longrun and the development generated by such a policy cannot be sustainable for long".

- There is an inevitable trade off between land and coal which can be resolved by relative resource endowments.

19) Output Composition by Mining Methods and Technology:

The ever expanding coal markets, the increased mine size, the mechanization and the shifts in the mining systems are all reflected in the changing output composition of the industry over time. All these structural and radical changes took place mainly to meet the ever increasing coal demands from various consuming sectors like power generation, industry etc. The output composition for the period 1973-74 to 2007-08 is given in Table-2.

Year	Underground				Open Cast	Total (UG+OC)	T	O	PLMB
	Head Section	Machine Mining	Long-Wall	Total (UG)					
1973-74	49.41	3.71		53.12		53.12	7.0	-	
1974-75	58.06	3.73		61.79		61.79	6.0	-	
1975-76	68.73	4.85		73.58		73.58	6.6	-	
1976-77	78.45	4.53		82.98		82.98	5.5	-	
1977-78	84.31	4.81		89.12		89.12	5.4	-	
1978-79	85.93	4.15		90.08		90.08	4.6	-	0.01
1979-80	87.54	4.45		91.99	2.04	94.03	4.8	2.2	0.49
1980-81	91.76	4.32		96.08	4.89	100.97	4.5	4.8	2.93
1981-82	102.70	6.59		109.29	11.74	121.03	6.0	9.7	4.23
1982-83	99.82	5.65		105.47	17.98	123.45	5.4	14.6	2.27
1983-84	100.89	7.01	1.33	109.23	17.64	126.87	7.6	13.9	3.42
1984-85	95.07	7.96	2.47	105.50	17.78	123.28	9.9	14.4	3.17
1985-86	118.76	7.85	5.75	132.36	24.19	156.55	10.3	15.5	1.20
1986-87	121.29	4.58	6.18	132.05	33.75	165.80	8.2	20.4	3.09
1987-88	113.12	6.41	6.12	125.65	38.36	164.01	10.0	23.4	0.60
1988-89	127.28	7.24	4.62	139.14	46.91	186.05	8.5	25.2	2.48
1989-90	107.61	8.07	4.64	120.32	57.73	178.05	10.6	32.4	2.50
1990-91	97.48	7.40	6.33	111.21	65.88	177.09	12.3	37.2	1.40
1991-92	103.10	8.10	12.2	123.49	82.34	205.83	16.4	40.0	0.75
1992-93	110.73	11.12	13.23	135.08	90.04	225.12	18.0	40.0	3.30
1993-94	123.19	12.26	16.11	151.56	100.53	252.09	18.7	39.9	2.12
1994-95	112.73	14.40	10.44	137.57	118.93	256.50	18.1	46.4	1.73
1995-96	97.36	14.09	20.19	131.64	136.06	267.70	26.0	50.8	0.80
1996-97	99.89	14.51	22.93	137.33	150.01	287.34	27.3	52.2	3.40
1997-98	103.05	13.96	19.20	136.21	153.20	289.41	24.3	52.2	4.66
1998-99									
104.95	8.17	16.42	129.54	143.72	273.26	19.0	52.6	3.05	
1999-2000	104.43	7.69	15.79	127.91	167.65	295.56	18.4	56.7	2.63
2000-01	114.56	9.65	13.66	137.87	164.87	302.74	16.9	54.5	3.90
2001-02	112.93	13.27	11.27	137.47	170.64	308.11	17.9	55.4	2.91
2002-03	102.58	15.40	10.10	128.08	204.28	332.36	19.9	61.5	0.25
2003-04	100.90	21.07	11.17	133.14	205.40	338.54	24.2	60.7	-
2004-05	89.11	29.47	11.16	129.74	223.29	353.03	31.3	63.2	0.30
2005-06	70.86	47.71	8.54	127.11	234.27	361.38	44.2	64.8	-
2006-07	55.74	53.13	9.89	118.76	258.31	377.07	53.1	68.5	8.10
2007-08	48.26	66.88	11.31	126.45	279.59	406.04	61.8	68.9	-

Source: Field Investigations
1 lakh = 1,00,000

T = % of longwall & machine mining output in total underground output
O = % of opencast in total output
PLMB = Production loss due to Machine-breakdowns (lakh tonnes)

Table 2 Out composition by Technology and Mining Methods (1973-74 to 2007-08) *(in lakh tonnes)*

Output trends and its composition by technology and mining methods are presented in Table-2 for the period covering 35 years from 1973-74 to 2007-08. A number of startling observations /inferences are clearly discernible from this long time series data. During this period several structural changes took place in the economy;- the major one being the economic reforms. All these changes are reflected fairly adequately in coal output trends and its composition. Table 2 can be understood and interpreted better in combination with chart-II. The later explains the former. Coal has no direct demand but a derived one. The industry has responded fully well to the ever rising coal demands. This is reflected in the growth trends. The coal industry registered a remarkable output growth from a meager 53.12 lakh tones in 1973-74 to a high of 406.04 lakhs by 2007-08, showing an **amazing rise of 7.64 times**. The issue then is to identify the underlying forces that facilitated this phenomenal growth. The year 1985-86 is chosen as the baseline for analysis since the structural changes that took place in the industry reached their respective stabilized states by then. The **identified source** or the driving forces of growth are:

(a) The first and the foremost important driving force was the introduction of **opencast mining system** (see chart II) in the year 1979-80. This was introduced because the conventional Board and Pillar method could not cope with the fast rising demands. It has reached its stabilized state of production by the year 1985-86 during which it was contributing only 24.2 lakh tones or 15.5% to the total output (see Table-2). Then, it made tremendous strides to contribute as high as 279.6 lakh tones or 68.9% to the total output by 2007-2008. This dramatic rise is by 11.56 times in 2007-08 over the base year 1985-86. This is **the major source of growth**.

(b) Next in the order is **a shift in underground mining method** to the longwall method. It was felt earlier that the long-wall methods were not fit to India's thick seams. Now, the later technological developments made them fit. Hence, they were introduced in the SCCL in 1983-84. In the year, 1985-86, the long wall method was contributing only 5.75 lakh tones (3.67%) to the total output of 156.55 lakh tones (see Table-2). By the year 2007-08, its contribution has become doubled at 11.31 lakh tones but its % contribution to total output declined substantially from 3.76% in 1985-86 to 2.78% by 2007-08. This % decline is mainly due to the relative predominance of opencast mining.

(c) Another equally important force in the growth dynamics is the **technological change** reflected in the extent of machine-mining (or the extent of mechanization). The machine-mining was contributing 7.85 lakh tones (or 5.0%) to the total output of 156.55 lakh tones in 1985-86. This increased substantially to 66.88 lakh tones or a rise of 8.52 times by 2007-08 over 1985-86 (See Table 2). Its % contribution in 2007-08 has gone up to high of 16.47% to the total output of 406.04 lakh tones. Thus, the technology/mechanization played as a high role as the opencast mining in achieving the high growth rates.

In the same vein, Table-2 reveals that the percentage contribution of both long wall and machine-mining together has increased very significantly to a high of 61.8% in 2007-08 over the base year 1985-86. This is indeed a remarkable change.

Correspondingly, the output from non-mechanized (or the hand sections) has dipped drastically from 118.76 lakh tones in 1985-86 to a mere 48.26 lakh tones in 2007-08 (See Table-2). This decline is 2.46 times[14]. Looking at the % contribution, the hand sections were contributing as high as 75.86% to the total output in 1985-86 which declined drastically to a mere 11.9% in 2007-08. This is the most striking change exhibiting that the coal industry has become highly technological/ mechanized to achieve growth and to satisfy the markets. But, this directly conflicts with the social objective of creating employment generation (see Chart–3). It is a matter of public/social choice.

(d) Capacity to absorb new technology:

Most of the UG mining machinery both in LW and B&P methods are NOT designed and manufactured indigenously but imported from the west. Some part of the OC mining machinery is also imported.

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14. In fact, hand-sections are not totally primitive. They use a minimum of mechanization like drilling, mechanical hauling but loading is manual. Roofing is also manual. Hence, they are relatively designated as the hand-sections.

In this context, the **"production loss due to machine breakdowns"** can be taken as a proxy to indicate the levels of technology absorption-capacity of the mining industry. It is to be taken as **the higher the production loss due to machine-breakdowns lower will be the level of technology absorption-capacity and vice versa.** From this view point, the empirical evidence (last column of Table-2) clearly indicate that it is really negligible, and in some years, it is even zero. From this evidence, it can be inferred that the Indian mining engineers are good technology absorbers but not innovators. It also shows that the coal mining industry (SCCL) has very high levels of capacity to absorb any new technology (World Bank, 2008; see also, Robin Williams & David Edge, 1996; Mariacristina et.al., 2005; D. Comin and B. Hobijn, 2004).

In summary, the four major sources of the growth of coal mining industry are identified empirically as:

a) Opencast mining;
b) Shift in mining systems;
c) Technological change/mechanization (for a historical comparison, see N.Naganna, 1980 op.cit). These three together propelled growth to astonishing levels supported by technology and,
d) High capacity to absorb technology.

When growth takes place due to impacts of the driving forces, the mining organization undergoes, in consonance with them, several structural changes to absorb and assimilate growth. It undergoes cyclical changes keeping in pace with the growth path (Henry Mintzberg and Frances Westley, 1992).

20) Meaning and Scope of Technology in Coal Mining:

Generally, technology refers to the ways in which the inputs are **transformed** into outputs. But, in mining sector, there are neither inputs nor their transformation. It is only extraction either manually or mechanically; either using explosives for blasting or without it. The mechanical extraction also differs by the degree of technological intensities. Hence, **technology in coal mining refers to the ways in which the coal is dislodged from the solid seam.** Since there are several ways of dislodging, each way represents a type of technology.

Each way requires a particular structure of sub-systems such as loading, hauling/conveying, roofing, dewatering, lighting and ventilation, working faults and so on; as also a particular mining system and mine-layout. Each type of technology requires a good-fit among all the inter-related subsystems. Accordingly, the **technological change** is considered as the change that impacts the actual mining processes/operations of dislodging the coal from the solid seams as also impacts correspondingly the subsystems like loading, hauling, roofing etc. In a sense, it can be considered as the change that impacts the actual **ways of using the** factors-inputs. Thus, technological change brings out a total change in the organizational structure within a mine and the inter-linkages of various mining processes. Since each type of technology requires a unique combination of the subsystems, an optimal capital-balance to achieve viable rates of capacity (machine) utilization is necessary (Micheal L. Tushman & Philip Anderson, 1986).

It may specially be noted that each mining method (see, chart-II) requires a unique and non-transferable technology. For instance, the technology used in opencast cannot be applied in underground methods. Similarly, the longwall technology cannot be used in Bord & pillar method. Thus, each mining method is technology-specific. Technological change brings many structural changes interms of organization, skill composition, training needs, HRM practices etc.

The technological change that has been observed in the SCCL is mainly through technology-transfer and absorption.

In coal mining industry, the vital role of technology is to act as an equilibrating force between supply of and demand for coal. In the process, it bridges the widening gap between them.

21) Number of Mines and Mine Size

Both together facilitate and support the growth process in the industry as explained earlier. In one sense, **they act as a precondition for growth**. Both reflect two different kinds of phenomena. The number of mines reflect the **extent of geographical diversification** or **divisionalization**. This is one of the major sources of growth. The nature and scope of mining necessitates this trend. While the mine-size indicates the level and

capacity to absorb higher levels of technology. Both together provide impetus to growth. In extractive sector, growth requires both. Otherwise growth will be impeded.

Number of Mines: the number of mines with a breakup of underground (UG) and Opencast (OC), is presented in the **Table-3** for the period from 1973-74 to 2007-08. The number of mines were comparatively few at 21 producing only 30.6 lakh tones in the year 1964-65(see Naganna,1974). They increased to 26 by 1973-74 and further to 50 by 1979-80. They reached a maximum of 68 by 1990-91. There after their number remained stable with mild fluctuations. The opening of new mines and closing of old ones after total depletion of the embedded resource is a common phenomenon in this sector. At times, amalgamation of contiguous mines also takes place. The present position is 69 out of which 15 are opencast mines and the remaining 54 are underground mines (see Appendix 2). In 1973-74, there were only five divisions which increased to eleven by 2007-08. Each division consists of a few number of mines; spreading over hundreds of miles apart. Each one is considered as a separate **profit centre** headed by a divisional manager.

Year	UG	OC	Total
1973-74	26	-	26
1974-75	26	-	26
1975-76	32	-	32
1976-77	44	-	44
1977-78	47	-	47
1978-79	49	-	49
1979-80	48	2	50
1980-81	49	2	51
1981-82	49	2	51
1982-83	51	2	53
1983-84	55	2	57
1984-85	56	2	58
1985-86	58	4	62
1986-87	57	5	62
1987-88	61	5	66
1988-89	61	5	66
1989-90	61	7	68
1990-91	61	7	68
1991-92	61	8	69
1992-93	59	8	67
1993-94	59	9	68
1994-95	60	10	70
1995-96	59	11	70
1996-97	60	11	71
1997-98	60	11	71
1998-99	58	11	69
1999-2000	57	11	68
2000-01	56	13	70
01-02	57	13	70
02-03	55	12	67
03-04	54	12	66
04-05	54	11	65
05-06	57	12	69
06-07	57	13	70
07-08	54	15	69

Table 3 Number of coal mines: Underground (UG) and Opencast (OC) in the SCCL (1973-74 to 2007-08)

Source: Field investigations

22) Mine-Size

Mine-size is a great concept in resource management with several implications besides the well-known scale effects. It plays a dual role both as a facilitator and absorber of technology. The mine-size (in lakh tonnes) with a break up on underground and opencast, and all-mines is presented in Table-4 for the period between 1979-80 and 2007-08. The index numbers have also been computed for them to see their broad trend. Mine size is derived from the number of mines. Both the number of mines (reflecting geographical diversification) and mine size (reflecting extraction intensities) have the common goal of achieving faster rate of growth necessitated by market expansion. But their mode of operations is different. One achieves growth by **extensive-mode** and the other by **intensive-mode**. These modes have significant economic and environmental implications. Both are interrelated and necessary in **growth management**. The choices in this regard depend on the nature and extent of resource endowment, the intended level of technology/mining methods and the environmental concerns.

	Mine size (in lakh tonnes)			Index:1985 - 86=100		
	Underground	Open cast	All mines	Underground	Open cast	All mines
1979-80	1.92	1.02	1.88	-	-	-
1980-81	1.96	2.45	1.98	-	-	-
1981-82	2.23	5.87	2.37	-	-	-
1982-83	2.07	8.99	2.33	-	-	-
1983-84	1.99	8.82	2.23	-	-	-
1984-85	1.88	8.89	2.13	-	-	-
1985-86	2.28	6.05	2.53	=100	=100	=100
1986-87	2.32	6.75	2.67	100.8	111.6	105.5
1987-88	2.06	7.67	2.49	90.4	126.8	98.4
1988-89	2.28	9.38	2.82	100.0	155.0	111.5
1989-90	1.97	8.25	2.62	86.4	136.4	103.4
1990-91	1.82	9.41	2.60	79.8	155.5	102.8
1991-92	2.02	10.29	2.98	88.6	170.1	117.8
1992-93	2.29	11.26	3.36	100.4	186.1	132.8
1993-94	2.57	11.17	3.71	112.2	184.6	146.6
1994-95	2.29	11.89	3.66	100.4	196.5	144.7
1995-96	2.23	12.37	3.82	97.8	204.5	151.0
1996-97	2.29	13.64	4.05	100.4	225.5	160.1
1997-98	2.27	13.93	4.08	99.6	230.2	161.3
1998-99	2.23	13.07	3.96	97.8	216.0	156.5
1999-00	2.24	15.24	4.35	98.2	251.9	171.9
2000-01	2.46	12.68	4.32	107.9	209.6	170.8
2001-02	2.41	13.13	4.40	105.7	215.4	173.9
2002-03	2.33	17.02	4.96	102.2	281.3	196.0
2003-04	2.47	17.12	5.13	108.3	283.0	202.8
2004-05	2.40	20.30	5.43	105.3	335.5	214.6
2005-06	2.23	19.52	5.24	97.8	322.6	207.1
2006-07	2.08	19.87	5.39	91.2	328.4	213.0
2007-08	2.34	18.64	5.88	102.6	308.1	232.4

TABLE 4 MINE SIZE: 1979-80 to 2007-08

Source: *Field Investigation. Mine size = Total output / Number of mines.*

The average mine-size at all-industry level has **more than doubled during this period** (Table-4) between 1979-80 and 2007-08. This is a remarkable change that took place in the industry. As against this, the average mine-size in the underground mines remained more or less stable and stagnant. In fact, it declined in some years (Table-4) over the base-year.

On the other hand, there is a three-fold rise in the average mine-size of the opencast mining system, with its index reaching a high of 308.1 in 2007-08 (Table-4). This rise is also continuous without any decline over the base-year. This is the most striking observation. It is clear that the very fundamentals of the operations of this industry. The observed growth can mainly be attributed to this system without which, the industry would not have been able to meet the fast rising coal demands.

There is thus a substantial growth in the average mine-size. Mines have become bigger. This could take place because of: (a) shift in mining system to opencast and longwall; (b) Mechanization programs/technology; and (c)facilitated by expanding coal markets. Mine-size has several implications particularly in nonrenewable resource management because it is in effect concerned though implicitly with the level of recovery. This is explained below.

It is widely known that the mining sector is generally **subject to the law of increasing costs** or a positive relationship between mine-size and unit costs. **The logical outcome** of such a relation is the smallness in the size of operations or the prevalence of rat-hole type of mines under competitive conditions with private ownership. Keeping this, relation in view, the **size distribution** of coal mines in the Indian coal mining industry was characterized by an overwhelmingly large number of small-sized mines before nationalization (in 1972). The fact that the Government of India appointed the Amalgamation Committee (1956) to amalgamate all the contiguous mines into techno-economically viable units, **confirm this**. They brought out the demerits of such small units. Among other things, **these small mines go against the principle of conservation** because: (1) they do not adopt any scientific methods of mining; no scope; (2) No scope for technology/ mechanization; (3) Resort to slaughter mining practices; and (4) **Low levels of recovery**.

The rat-hole mines, as they are called in mining circles, are extremely detrimental to the practices of conservation. They inflict disasters on resources because they pick-up the best selectively near the pit-mouth and leave the rest which cannot be easily exploited later. This kind of skimming the deposit involves loss/wastage of resources. Hence, the level of recovery is very low that they really become a menace to scientific resource management[15]. The menace of small-sized (rat-hole) mines was tackled by nationalization of coal industry in India. As a matter of fact, one of the two objectives of nationalization is to achieve conservation through scientific mining methods.

The opposite seems to be true in the case of large-mines (see, Chart-II). From the above discussions, it follows that the large markets accompanied by increased mine-size will be beneficial to conservation since the mining losses/damages will be much less.

Our analysis as contained in this paper gives rise to the proposition as under:

> **"Marketing is insidious to resource base but markets NOT"**
> Since marketing creates market, it may be modified as:
> **"Over-Marketing promoting consumerism is insidious to resource base but markets NOT".**

In case, larger market leads to faster rates of depletion, then they need to be controlled and regulated by conservation (in a broader sense) measures. This is how, they can be made compatible with the finite-base. However, this leads to an egalitarian consumption instead of present concentric one. Here, there is a social choice (C. K. Prahalad, 2010).

15. A field visit to the old abandoned decoaled areas in Bengal/Bihar coal fields would give ample credence to this observation.

23) Increased Mine-size and Conservation[16]

As observed earlier, small mines impede conservation which the larger mines promote through raising the levels of recovery. It may also be recalled that the small mines is the logical outcome of the laws of increasing costs under competitive conditions with private ownership (See Naganna, 1974, 1984, 1981, and 1994). As against this, the increased mine size or the emergence of large mines occurs mainly for two reasons, viz:

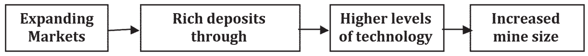
(a.) due to enlarged markets generally accompanied by price rise; and (b) public ownership ignoring the forces of competition. This is what has happened in the case of tremendously increasing mine size in the industry under investigation (See Table: 4). It is both the cause and consequence of output growth (see also Appendix 2). Mine size has several implications in reference to conservation particularly by raising the levels of recovery through raising technology intensities with a shift in mining systems (See Chart II). In what follows is a brief explanation of those implications:

1. Increased mine size will enable a mine to enhance its absorption-capacity for higher levels of technology. It also facilitates a shift in mining systems from a low-capacity one to higher ones (e.g. B&P to LW to OC). Thus it has the **enabling-effect**. On the other hand, small mines do not have the absorption capacity because the machine-utilization rates will be low. Hence, **size is a determinant of a particular level** of technology or mechanization. More importantly, technology will determine the production-capacity of a mine given a deposit size and its fertility features. This is shown below:

A Sequence (1) of events:

There is yet one more historical fact. Coal demand increased enormously due to undertaking of several massive industrialization programs through five year plans in India. To cope with this high velocity rise in coal demands, the coal industry undertook three important measures, viz, (a) Shift in mining systems to LW and OC, (b) mechanization/technological change, and (c) exploration programs to bring in more (fertile) deposits for exploitation. Without these measures, the coal markets would have been left unsatisfied. Thus, the **market-size determines the level of technology and mine size**. This can be summarized as:

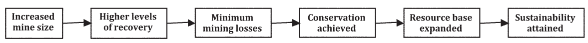
A Sequence (2) of events



24) Mine size, Level of Recovery and Conservation

The above sequence of events accompanied normally by higher prices will lead to an increase in the level of recovery from a mine. If so, the mining losses/ resource losses will be reduced to a minimum. This means that more coal can be extracted from a given deposit under a mine without leaving much as mining losses. This means conservation. There is yet one more dimension. If the above sequence occurs, then the mining industry will tend to reach the uneconomic and inaccessible resource areas for exploitation. Thus, the sequence converts the inaccessibility into accessibility; and the uneconomic into economic (viability). For instance, a mine can now go one or two more seams below the currently working seams which otherwise would have been left unmined. This works into two ways: (a) Minimizing the mining/resource losses, and (b) Resource-base is also expanded by going to once-thought uneconomic seams under the current workings and by going to inaccessible coal bearing areas or inferior grades. Thus, both together contribute in a significant measure to sustainability. The above sequence(2) or the chain of events can further be expanded to:

A Sequence (3) of events



A Corollary to mine size: As the mine size increases, the **extraction-intensity** also increases

16. *underlying all the explanations and analyses that follow, is the two charts, II and III presented earlier.*
Meaning and scope of technology is explained earlier. For all practical purposes, technology and mechanization are used inter changeably or as synonyms.

correspondingly. It is the determinant of mine size and hence the source of growth. It can also be considered as the **concentration-intensity**. It is partly related to rate of recovery, but mainly to level of recovery. And, it curbs the slaughter mining practices and thus, promotes conservation. It is considered as the quantity of coal that can be extracted from a **unit (area)** of coal-bearing area in a working-mine during a specified period of time with a given technology, factor-inputs and mining system. It is somewhat similar to that of intensive-cultivation in agriculture. It is to be noted that the unit (area) is called the **working-face** in mining parlance. It is the real unit of operation where the factor-inputs are used. There can be more number of such working faces in a mine. Availability of working faces in a mine is a critical factor. (This is the difference between a mine and a manufacturing firm). As a matter of fact, production/ mine capacity is a function of the number of working faces (See, chapter II & V of Naganna, 1974). A mine is only an administrative unit of collection of such faces. In this sense, the extraction-intensity is nothing but **size within the size**. Thus, both the mine size and working face size are the indices of extraction or concentration intensity indices. It varies from technology and mining systems. The extraction-intensity is the lowest in B&P and the highest in OC (see Chart 2). Similarly, its number within a mine is the highest in B&P and the lowest in OC. The LW method lies in between the two. The higher extraction-intensity level works in two ways: (a.) Reduces the unit cost through scale-effects, and (b.) Increases the level of recovery. In practice, (b) is the derivative of (a). The analysis reveals that is has a great significance and influence on various economic and extraction parameters. Hence, it assumes a greater role and significance in **extraction management**. For instance, high intensity means that the more coal can be extracted from a given area in a mine while leaving much less behind. Thus, in turn, means levels of recovery is high and the rest follows.

All the factors that contribute to conservation/ sustainability either explicitly or implicitly can be summarized in a chart form below.

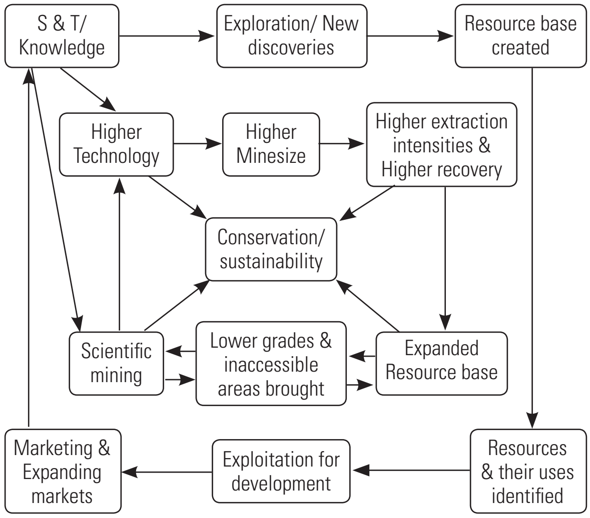


Chart IV Linkages among the contributory factors to conservation/sustainability: A Conceptual framework.

Source: Author

Notes on chart: Crisscross linkages are avoided for the sake of clarity and simplicity. There are in fact multilateral and reciprocal interactions among the identified factors. Besides, some of them operate jointly with others. This is how, sustainability in development can be achieved otherwise, the concept becomes elusive.

The above framework will be of use in the formulation of extraction strategies.

It may specially be noted that the **"S & T, Knowledge/ information"** is placed at the top in the chart-IV. It is **the resource of the resource** which never depletes by its use in any manner. The more we use, the more useful it becomes. And, it grows by its use defying the law of diminishing returns.(Naganna & Savitha, 2008). An inert and supposedly useless neutral stuff becomes a useful and saleable resource only through knowledge. Neutral stuff is the material that does not have either utility or saleability. In this context, the primary functions of "S & T, Knowledge" are : (a) Develop exploration technology; (b) Use it to discover resources above and below the earth's result; (c) Develop technology to use resources for development and thereby, assign "utility & Saleability" to resources which, otherwise would have remained as neutral-stuff; (d) Process-innovation to achieve wise and parsimonious use of resources in manufacturing and product-innovation to expand the market but not consumerism; and (e) Develop technology to extract resources with minimum or no mining-losses. From this account, it can be said that the resources are not, but they are made to become through S&T and Knowledge. Conservation/sustainability can only be achieved through S&T/knowledge. Hence, knowledge is power. Incidentally, it may also be noted that **power over resources give power over people[17].**

In conclusion, it can be stated that: **Conservation is a multidimensional concept giving rise to and advocating for a multipronged approach to achieve sustainability or the sustainable development.**

- It is a way of life.

Both process and product innovations need to be combined judiciously in such a way that it ensures compatibility between sustainability and resource-base. Innovation is the only way by which the sustainability or sustainable development can be achieved. **There is no other way**.

25) OUTPUT GROWTH OR DEPLETION GROWTH?

To reiterate the fact that it is the increased mine-size followed by and resulting from a shift in the mining systems and improvements in technology/mechanization coupled with a comfortable resource-base that contributed to the unprecedented growth in the output.

Production/output in mining sector, in general, has a different meaning. The mining sector does not produce any output but only takes out from the earth's crust. A mine does not produce but extracts. Hence, the term production/output is not applicable in mining sector, in the normal sense. From this, two things follow: (a) a ton extracted is a tonne depleted; and (b) extraction means depletion. Because, the embedded resource in a mine is a fixed quantity. From this, it follows that growth contains decay or in growth lies decay. This is the root cause for the emergence of the issue of sustainability in recent years as also forms the basic tenet or a premise for resource management. It is only through exploration that growth can overcome decay.

The trends in the growth of coal output for a long time period of 120 years from 1889 to 2009 are summarized and presented in Table-5. The data covers from the very start of coal mining in AP by the SCCL. It is evident from this Table that the rate at which extraction is taking place or the rate at which depletion is threatening. For instance, the sum of the last 20 years (i.e., 1989 to 2008) output is more than the double (precisely 2.13 times) of the cumulated sum of the past 100 years. There is no decline in any of the decades. Hence, our concern on depletion and its after effects.

Years (Decades)	Total Output (in '000 tonnes)	% change over previous decade	Cumulative output (in '000 tonnes)
1889 - 1898	2167	-	2167
1899 - 1908	4310	99	6474
1909 - 1918	5568	29	12042
1919 - 1928	6428	15	18470
1929 - 1938	7227	12	25697
1939 - 1948	10671	48	36368
1949 - 1958	14764	39	51132
1959 - 1968	30901	109	82033
1969 - 1978	57406	86	139439
1979 - 1988	126608	121	266047
1989 - 1998	232519	84	498566
1999 - 2008	334809	44	833375

Table 5 Trends in the growth of coal output (Decade-wise)

Source: Field Investigations

Incidentally, these last 20 years (i.e., 1989-2008) coincides with the post-economic reforms era in India (see also, Table-6). In short the economic reforms accompanied by globalization/corporatization leading to higher levels of consumption ultimately pushes the

17. *The modern corporates, for instance, derive their power through the control over resources and knowledge through their huge R & D investments (see Naganna & Savitha Rani, 2007,pp: 181-226).*

EPC streams to increasingly higher levels. They are imposing heavy pressures on coal extraction. This is clearly discernible in the data contained in Tables 6 and 7. The evidences show that the coal output is increasing at much faster rates in recent years (i.e., 1989-2008) than ever before. This exhibits the alarming rate of depletion resulting in higher rates of diminution in the lifespan deposits. This aside, it has severe environmental impacts on land and forestry which are due to both economic reasons (coal mining) and sociological factors (detribalization and township formations etc), (see Naganna, 1984). This, in turn, makes the problem of sustainability increasingly critical. Consequently, the solution lies in undertaking the conservation measures which imply: a) Higher levels of recovery and (b) Reducing mining losses.

The oil price hikes during 1971-72 brought revolutionary changes in the global landscape of energy management. All countries started looking at and evaluating and assessing critically their respective fuels resource endowments to rearrange their energy plans so as to reduce their excessive dependence on oil (Carrou L. Wilson, 1980). Before the oil prices hykes, the relative position of coal in the world energy generation declined because oil replaced coal. Oil has some advantages over coal like the ease in use, easy to transport, higher heat value etc. After the oil price hikes, the coal started regaining its relative position significantly. On the basis of evaluating the relative fuel resources endowment globally, the coal was assigned to play a triple role, viz., as a direct fuel, as a substitute fuel and as a transitory fuel. Following the global trends, India also assigned a more dramatic role to its coal. The coal company of our case study (i.e., the SCCL) has realized the impending dangers of higher rates of depletion (see, Table-5) as also the importance and necessity of exploration for two reasons: (a) its own long-term survival without facing the threat of exit; and (b) to cope with and enable itself to meet the ever growing coal requirements in India's energy futures. Thus, **exploration is mainly geared to counter depletion**. Accordingly, the company started an exclusive department for exploration in the wake of unprecedented demands for coal. This was in 1973-74. The data for our case study are obtained for 35 years from 1973-74 to 2007-08.

The data on exploration with a break up on: (a) total meteraged drilled; and (b) corresponding coal reserves proved, along with annual output for the period from 1973-74 to 2007-08 are presented in Table-6. The amount of "drilling-meters used to prove one million tonne of reserves" is also computed for each year. Incidentally, it may be noted that exploration is prone to a very high level of risk. It is a pure gamble. The relative growth trends mustered by these four parameters would explain the case in point. **The Table-6 and the relative growth trends revealed by it, give the evidence-base or the empirical-base to construct a wholesome approach to resource management**. This is nothing but a grounded theory approach which is more meaningful than the deductive approach as seen in current literature.

It is evident from Table-6 that the "total meterage drilled" per annum registered a staggering rise from a low of 27.9 thousand meters in 1973-74 to a high of about a lakh meters by the year 2007-08 (a rise of about three and a half times). This obviously indicates the **intensity of the need felt by** the company to undertake the exploration operations in many of the surrounding virgin areas to replenish the stocks and to fight against depletion. In contrast with this trend, **the amount of "total reserves proved" exhibits an opposite trend**. It is evident from Table-6 that it declined significantly from 263 million tonnes in 1973-74 to 187 million tonnes during 2007-08 for a meterage of 27.9 thousands and a lakh respectively. Surprisingly this decline took place despite the fact that there was almost **a four-fold rise in exploration-intensity. This is the most revealing observation.** In other words, the exploration is consuming more meterage now (2008) than in the past (1974). For instance in 1973-74, it took just 106.1 mtrs to prove one million tonnes of coal reserves. Now in 2007-08, it is taking as much as 516.2 mtrs to prove a million tonne deposit. This is an amazing rise of 4.86 times. If the same trend continues a day will be reached soon when no amount of drilling can add any new reserves. This is to say that, when all the suspected mineral-bearing areas are fully explored, the exploration cannot add any new additions to the stock. This is the crux of the sustainability-issue. Table-6 makes our arguments highly tenable beyond any reasonable doubt. Besides, it also confirms the shape of the Exploration-curve. It needs to be specially noted that what all proved by exploration cannot be mined out due to mining losses and several other geo-mining uncertainties in the process. **In effect, proved-reserves seem to be a myth while production is a reality**.

To make the comparative analysis complete, the output trends are superimposed on exploration-trends to display the impending problems of depletion. While retaining its simplicity, the Table-6 reveals the coal outputs increased many fold (7.64 times) during this period while the exploration-addition is lagging behind. It increased from a low of 5.3 million tonnes in 1973-74 to a high of 40.6 m.tonnes by 2007-08. Unlike the exploration trend, there is a substantial continuous year-to-year rise in outputs. This is the most striking observation loaded with significant implications. Exploration reaching surely one day a near zero contribution, the ever rising output trends indicate the alarming levels of depletion leading to growing materials scarcities (Coal). This the paper cautions. Because, exploration cannot create resources but can only identify and discover them from the earth's crust. It cannot totally mitigate the occurrence of doomsday (i.e., total depletion) but can delay its occurrence.

The Determinants of Sustainability

Year	Total Meterage Drilled (Meters) (1)	Reserves proved (million tones) (2)	Output (Lakh tones) (3)	Mtrs used to prove one million tones (1)/(2) = 4
1973-74	27904	263	53.12	106.1
74-75	35284	157	61.79	224.7
75-76	37566	243	73.58	154.6
76-77	38767	289	82.98	134.1
77-78	30471	75	89.12	406.3
78-79	31848	126	90.08	252.7
79-80	29940	68	94.03	440.3
80-81	29819	116	100.97	257.1
81-82	37477	284	121.03	132.0
82-83	47752	779	123.45	61.3
83-84	39228	408	126.87	96.1
84-85	48087	151	123.28	318.5
85-86	71173	204	156.55	348.9
86-87	75485	219	165.80	344.7
87-88	79463	518	164.01	153.4
88-89	93291	416	186.05	224.3
89-90	87300	520	178.05	167.9
90-91	100895	432	177.09	233.6
91-92	91344	337	205.83	277.1
92-93	105884	144	225.12	735.3
93-94	107812	129	252.09	835.8
94-95	98729	162	256.50	609.4
95-96	93369	209	267.70	446.7
96-97	76314	297	287.34	257.0
97-98	86823	200	289.41	434.1
98-99	86575	251	273.26	345.0
99-2000	80895	158	295.56	512.0
2000-01	73528	225	302.74	326.8
01-02	82526	215	308.11	384.0
02-03	74783	147	332.36	508.7
03-04	78744	141	338.54	558.5
04-05	75970	216	353.03	351.7
05-06	85714	130	361.38	659.3
06-07	105681	393	377.07	269.0
07-08	96534	187	406.04	516.2
% change in 07-08	346.0	-29.0	764.4	486.5

Table 6 Exploration: Total meterage drilled, Reserves proved and output raisings (1973-74 to 2007-08) and the mtrs used per a million tone to prove.

Source: N. Naganna & Savitha Rani, Feb 2006. Field data.

Further, the structure of the growth trajectory in the four major parameters presented in Table-6 took a definite turn after the introduction of economic reforms in 1990 in India. **The big four are the determinants of sustainability**. Keeping this in view, the whole period between 1973-74 and 2007-08 is divided into Pre and post-economic reforms to delineate their broad impacts on the outputs and exploration. Accordingly, the data in

Table-6 are re-casted in Table 7 below.

Five-Year Average:

Five Year Periods	Meterage Drilled per year (Meters)	Reserves proved per year (million tones)	Output (Lakh tones)	Mtrs used to prove one million tones
Pre-Economic Reforms Period				
1973-74 to 77-78	33998	205	72.12	205.2
	(-)	(-)	(-)	(-)
1978-79 to 82-83	35367	275	105.91	188.7
	(4.3)	(34.1)	(46.90)	(-8.0)
1983-84 to 87-88	62687	300	147.30	252.3
	(77.2)	(9.1)	(39.1)	(33.7)
Post-Economic Reforms Period				
1988-89 to 92-93	95743	370	194.43	327.6
	(52.7)	(23.3)	(32.0)	(30.0)
1993-94 to 97-98	92609	199	270.61	516.6
	(-3.3)	(-46.2)	(39.2)	(57.7)
1998-99 to 2002-03	79661	199	302.41	415.3
	(-14.0)	(0.0)	(11.75)	(-19.6)
2003-04 to 07-08	88523	213	367.21	471.0
	(11.1)	(7.0)	(21.4)	(13.4)

Table 7 Five year averages of Meterage drilled, Reserves proved and output.

(Figures in brackets show the percentage variation over the previous period(s). Computed from Table 6)

Since Table-7 summarizes the data in Table-6, the observations made there in holds good in this case also. In addition, the impacts of economic reforms are more clearly discernible (see Table 7) particularly on: (a) exploration, the urge to find new deposits to cope up with the expanding coal demands and to replenish the fast depleting stocks, and (b) the output levels. Understandably, their impact is not much on the extent of "Reserves Proved". **Hence exploration is not keeping pace with depletion**. This is what was expected. To reiterate, the empirical evidence however inadequate it appears to be, strengthens the proposition put forth in the paper(for more empirical base, see Appendix 1).

The fact that exploration will certainly reach its limits in future implying that there will be no more virgin areas, indicates that the limits to exploration give rise to limits to growth (Meadows et.al, 1972). By inference, this means that the impending material scarcities in the near future are more definite than prophesied.

The same analysis of this single mineral case study can be extended to all the minerals across the countries to evaluate the sustainability levels for the country and projected rates of global economic development. We guess more or less the same findings will emerge. For instance, the experts in the Geological Survey of India (GSI) reported that the likely Iron ore bearing areas in the country are almost fully explored. Iron-ore presents a different story. It's extraction is considered as a commodity for exports. It's exploitation has a dual purpose (one for the steel production and the other for exports). Hence its depletion rates seem to be higher than otherwise. Similar is the case with most of the metallic minerals. So also the oil reserves. By implication, this suggests that the additional exploration efforts will not fetch any new fresh deposits for exploitation. It means that exploration has reached nearly its limits. In the case of coal, it may reach soon, say in a decade. This being the case, the rising outputs will push the Doomsday sooner to occur. In the wake of exploration reaching its limits sooner, the issue of sustainability assumes more critical dimensions. When once exploration reaches its limits, the sustainability of resource availability has to come from: (A) Recycle and recover, and (B) Stringent Conservation measures to reduce material–intensities and enhancing product durabilities etc. Both together may differ the occurrence of Doomsday considerably or till viable alternatives are found.

In the case of renewable and replenishable resources, the rate of depletion depends on the rate of regeneration. If the later cannot cope with the rate of their exploitation, then the awe-full depletion is definite. In other words renewables behave the same way as that of non-renewables. The difference between the two vanishes. If the rate of their replenishment and the rate of their exploitation are made to match, then there may not be any problem of depletion in their availability (eg., forestry, fisheries, underground water etc).

Reserve-output Ratios by States in India: There are in all nine coal endowed states in India with different endowment levels. Some are richly endowed. Reserve output ratios are computed by states and presented in Table-8. They indicate the lifespan of the reserves at 1997-98 levels of production. Now, the production levels have gone up after 1998. So also, the reserves. Therefore, the ratios are merely indicative and suggestive. As said earlier, all the reserves cannot be extracted totally and hence , they appear to be **misleading**. They are relative to rates of extraction, price, markets and technology. Thus, the concept of a reserve and its extractability is relative to many factors. However, the life span of coal reserves in India and in Andhrapradesh is comfortable with the current rates of exploitation. One can expect that they may last for about 150 to 200 years. If the current rates of extraction go up higher and higher, their longevity will tend to become critical. Before reaching this critical level, it is better to adopt the conservational measures so as to avoid the criticalities later.

On the whole, the following proposition regarding the misleading concept of reserves can be derived from our analysis.

> **"Apart from the inherent mining losses and other geomining uncertainties, the extent of mineability from a known reserve is relative to technology, mining systems, markets and the prices, which, in turn will determine the lifespan of a reserve."**

Narrowing down to the more important ones, it can be said that the **price** and **technology** are the major decision-variables in resource management.

Sl. No.	States (1)	Output (mil. tonnes) (2)	Total Reserves (m. tonnes) (3)	Ratio (4) = (3)/(2)
1	Andhrapradesh	28.94 (9.74)	10856 (5.5)	375.1
2	Assam	0.68 (0.23)	865 (0.4)	1253.6
3	Jammu and Kashmir	0.1	--	--
4	Bihar	81.27 (27.35)	64601 (32.8)	665.6
5	Madhyapradesh	84.75 (28.52)	41343 (21.0)	487.8
6	Maharashtra	26.17 (8.80)	6276 (3.2)	240.0
7	Orissa	42.16 (14.18)	46527 (23.6)	1103.6
8	Uttarpradesh*	15.78 (5.32)	--	--
9	West Bengal	17.40 (5.86)	26442 (13.4)	1519.7
10	All-India	297.16 (100.00)	196911 (100.00)	662.6

Table 8 Coal Reserve-output Ratios in Different States (1997-98)

Source: Field investigation. The ratios are misleading due to resource-illusions (see, Appendix 1)

***UP** is added to Bihar before its bifurcation. Figures in brackets show percentages.*

Total Reserves = Indicated + Inferred + Proved

Notes: The above Table gives an indirect way of measuring sustainability though it may be suggestive/ indicative. Though the data pertains to an earlier year, it gives broad dimensions and relative position which may not change in the shortrun.

26) Longrun Trends and Sustainability *(A Simple Diagrammatic presentation)*

On the basis of our experiences in mining sector in general coupled with the empirical evidence in this paper, three free-hand curves have been drawn on the vital parameter, viz., exploration, exploitation and conservation. They are the dominant and defining features of sustainability. It gives some sort of visibility and clarity to the analysis as also some guidelines for minerals policy. This will be the culminating point in which all the observations converge to give a holistic view.

By definition, the sustainability or the sustainable development refers to the longrun trends in resource availability or the supply-side of the development strategies. Although, forecasting in these matters is a difficult and complex exercise, it needs to be taken up to get some surmises or even advance information on basis of which, policy modifications and future investment decisions can be made. The issue then is one of generating surmises or conjectures about the future patterns of sustainable development in an exploration-exploitation-conservation framework, which underlies behind the sustainability. This would give a whole some approach. The conjectures thus generated will have immense use in making long range planning and in evolving a policy design for the mining sector. It gives, among other things, the preparedness to the economic system. Keeping aside the controversial unborn posterity and their needs, technology etc; the essence of the operational meaning of sustainability (or conservation) implies the arrangement of natural resources supplies/availabilities (both non renewables and renewable) over very long periods without curtailing the current levels of production and consumption.

Focusing on non renewables, the longrun trends in exploration, exploitation and conservation underlying the principle of sustainability can be conceptualised diagrammatically as below.

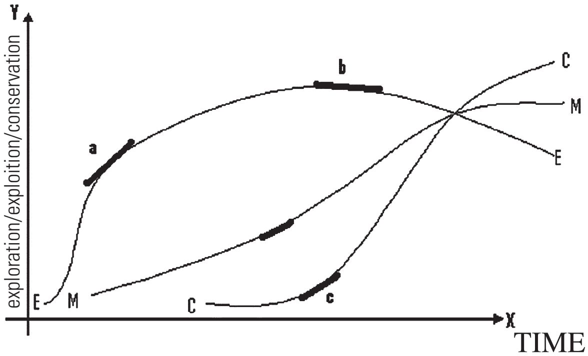


Diagram 3 Longrun Trends in Resource-base and sustainability (A simple Diagrammatic Presentation)

This is only an attempt to conceptualize the longrun trends in resource base with reference to sustainability. EE curve represents exploration, MM curve exploitation and CC curve refers to conservation. The extent of activities and the contributions of exploration, exploitation and conservation are represented on the Y-axis. Time periods are shown on X-axis. In this context, it may be noted that conservation is considered in broad terms so as to include all the attacks on avoidable wastes of all kinds on all fronts, reduction in material-intensities in product, more recoveries from the resources and the mines, shift in more efficient mining methods etc., such that the life span of deposits(or resources availabilities) increased. Similarly, exploration includes the discoveries of the new deposits, virgin areas, expanded resource-base, new uses for less fertile or inferior deposits etc., signifying the supply-side of the economic system. Exploitation obviously refers to the extraction of minerals to support the production-consumption streams. It may be noted that both exploration and conservation together add to the resource availability/resource base as also contribute to their longevity or the sustainability. Both are driven by science and technology. And, both are continuing processes indefinitely.

Sustainability does not have any noticeable starting or ending points. The first tonne that was extracted was depleted and the rest is all nascent. In time it is indefinite. However, for the sake of simplicity and understanding, it has been divided into three broad phases notionally to delineate the behavioral patterns of the three parameters. It is just a simplification.

Phase-I: It is characterized by a large potential of suspected mineral-bearing areas on the basis of the surface data, untapped virgin areas, large tracts of unexplored areas in the existing mining-belts etc,. All these areas indicate an immense resource potential to be explored and exploited. This being the case, the rate of contribution to the resource stock by exploration will be very high while its cost will be very low. Hence, the slope of EE curve will be very high during this period. As against this situation, the rate of growth of exploitation, being market-dependent, can take place with ease and without any caution or concern on any other issue. Because, the resource base is fertile and plentiful. Its rise (MM curve) could be at high or low rate depending on the market demands. In contrast, the CC-curve will be at its lowest level or it may even non-existent because the resource-base is very comfortable. Since the bounty of nature will be at its peak, the issue of conservation does not arise noticeably. Resources will be available just for asking. This induces the mining enterprises to resort to the slaughter mining practices or skimming of the deposits as was the case in the past. This will be due to the extent of mineral markets being very low in relation to the plentiful resource base. Resource-wastages or the mining losses may be significant but they do not come to the cognitive levels.

Phase II: This is the period during which the concerns on sustainability or conservation will start sprouting gradually. It will be in a nascent stage. The dominant features of this period are: (a) the rate of contribution by new discoveries of deposits either in the known areas or in the unknown virgin areas through exploration will be slowed down. Thus the rate of growth in the expansion of resource base will start slackening. Hence, the slope of the EE curve will be less than in the earlier period. Another note worthy feature is that the rate of contribution by exploration will reach its peak or the asymptotic limits towards the end of this period. This gives a wakeup call both to governments and corporates. This will be its upper boundary beyond which it cannot maintain the same level of adding fresh deposits to replenish the ever depleting stocks. This has some significant implications such as; (i) Many of the suspected and more promising mineral bearing areas might have been totally explored. Not many new virgin areas with high potential and prospects will be available; (ii) at this peak point, most of the endowed resource-base is made known by its quantity, quality and mineability. Hence, the earlier rates of expansion is not possible now. (iii) refer to all the minerals forming the aggregate of the resource base for EPC streams (iv) by implication, it means that sustainable development needs to take this upper bound explicitly to work out its strategies, limits, rate and structure.

From this analysis, an important proposition can made out as below:

"Limits to exploration give rise to limits to growth comprising the EPC streams and thereby, to globalization".

In contrast with the behavior of EE curve, the MM curve registers higher rates of growth with higher slope. This occurs for two reasons: (a) The rate of development will be higher in the economy trigged by promising plentiful resource base; and (b) Expanding mineral markets, will push the MM curve to higher rates which will induce the mining enterprises to shift to better mining methods with higher levels of technology and recovery. In effect, the slaughter mining practices will be reduced resulting in lesser resource damages or mining losses. The above pattern of behavior of EE and MM curve, will give signals on the brewing problems of depletion. Then, conservation starts gaining ground. Accordingly, the policy of cross-subsidization may start getting initiated in the mining enterprises towards the end of the second phase. This may gradually become a necessity during the middle and particularly during the later part of the third phase.

The CC curve, though continues to lie below the other two, starts mustering higher rates of growth. Because, the mining enterprises, the government and the resource analysts will start realizing the importance of sustainability. This is a major change that takes place towards the end of phase II. All those involved in policy making, will initiate thinking in terms of sustainable development and management and not merely the development per se.

Phase III: This is the most crucial period in the growth path of resource development and management. This calls for stringent policy measures and investments on all fronts and across the whole spectrum of EPC streams to overcome the likely and possible material shortages to maintain the current levels of production and consumption. The longterm survival of the present levels and rates of growth in the EPC streams is becoming increasingly critical due to faster rates of depletion. This made the issue of sustainability as central to resource management as also its core concern. Accordingly, significant turning points take place during this period. There are two such striking points: (a) CC curve overtake the other two to reach above them; and (b) EE curve starts declining. The implications have far reaching consequences such as:

(i). After reaching its peak rate of contribution at the end of phase-II, the EE curve exhibits decline. The peak may create illusions and false hopes of copious flow of minerals indefinitely leading to unsustainable and distorted EPC streams. Further, the rate of decline will be faster and ultimately, it reaches its zero limits during this period. These two observations will have great implications in resource management. It shows that all the suspected mineral bearing areas are fully explored giving all the geo-mining information about the reserves in terms of quantity, quality and extractability etc. This means that the whole endowed resource-base in a region/country is fully known in all its geomining details. In India, 'The geologist' reported that all the iron ore areas are almost totally explored and hence, exploration is not bringing any new additions/discoveries. By implication, this means that sustainable development need to be planned within this limit. It also means that exploration will not be able to add any new deposits from any area to the stocks. Given this information, one can workout the strategies for extraction, conservation and sustainable development. Further, the public and corporate policies can be formulated on the basis of the finite known resources base.

(ii). This period needs an utmost care and caution in extraction strategies making right choices on mining methods, technology; and rates and level of recovery. It demands that the reckless exploitation through slaughter mining practices normally noticed during period-I should be condemned and banned by stringent legislation and public may oversee their implementation. The rates of recovery need to be just in tune with the maintenance of current levels of production and consumption. The later should not be pushed beyond the sustainable limits because the concerns on doomsday will begin to crop up. Accordingly, the unbridled consumption and the fast spreading consumerism need to be checked, controlled and regulated to push the brewing doomsday to farther away.

The policy makers should be aware of the fact that the MM curve lies above the EE curve indicating that the rate of extraction (or depletion) is not getting replenished by exploration any more. This necessitates that the conservation needs to come to the fore and should be made central to or the core of all the policy making processes at all levels.

(iii) Arguably, the CC curve denoting conservation takes precedence over the other two. In this context, is considered in its broad sense encompassing the whole spectrum of EPC streams as explained in phase-I, beside the narrowly focused "levels of recovery". The EE curve is declining while the MM curve may not because the mining sector has to maintain the current levels of extraction to sustain the present level of EPC streams. The widening gap between the two suggests that the policy implications of this period are very significant and far-reaching. When all the areas are fully explored, the resource base becomes static with no likely foreseeable reserves getting added to enhance its longevity with current rates of extraction remaining constant. (EE curves declines). This being the case, the forces of sustainability will have to come from a different source (i.e., conservation and science and technology). Unlike the other two, the CC curve continues to rise indefinitely though with different intensities. It is to be noted that there exists **"a time span"** during which **a transition to the primacy of conservation over exploration takes place** (including the development of substitutes). This means that **the resource base will be maintained more by science and technology (S&T) rather than new discoveries**. This can also be seen as a paradigm shift from exploration to conservation in resource management.

When the EE curve starts declining, there will be an increasing role to S&T. The developments in technology may bring the hitherto technologically inaccessible and uneconomic deposits into commercially viable category, implying thereby that the resource base is expanded. Similarly, the depletion and its consequent scarcity resulting in higher mineral prices may add significantly to the process of converting hitherto uneconomic deposits into profitable ones. This trend will also lead to the **developments of substitutes to overcome scarcities (i.e., S&T route)**. The extent of market-expansions may also cause similar positive effects on the resource-base. All these techno economic changes will have implications on sustainability. Thus, it is a dynamic concept as it varies with resource appraisal.

The rates of exploitation (MM curve) will have to lie in between conservation and exploration. In effect, this is to be considered as **a necessary condition for sustainability while the sufficient condition** being the adequate public investment on conservation and exploration.

Regarding the depth-wise extraction (see, Appendix) under different phases, it can be broadly inferred that:

(a) The seams embedded in the shallow or smaller depths (say, less than 300 mts) will be extracted during the first phase; (b) the seams embedded in medium depths (say, 300 to 600 mts) will be extracted during the second phase; and (c) the seams embedded in deeper or larger depths (above 600 mts) will be extracted during the third phase. It may be noted that depth is one of the determinants of unit costs. Hence, the above movements in terms of depths take place mainly to: (i) market expansion; (ii) price rise and (iii) technology developments. They are the major decision variables in this regard. These three factors together will determine the extent of extraction by depths. Needless to explain that they have significant implications on sustainability.

Concluding remarks: It is to be noted that the shapes of the curves and their slopes, the inflexion and intersection points etc, in the diagram depend upon several factors like the extent of potential resource-base and the mineral-bearing areas, exploration intensities, the rate of development, investment patterns, population size, status of environment and so on. The above diagram serves as a tool to analyze and understand, the broad implications for long range policy and planning with an objective of achieving sustainability or the sustainable development along with a sustainable mining sector. A set of different long rang scenarios can also be worked out on the relative positions of exploration, exploitation and conservation depending on the social needs. A set of three propositions can be derived from the above diagram on resource management (see Appendix 1).

Proposition-A: Sustainable development or sustainability entails that the rate of exploitation will have to lie always somewhere in between the rate of exploration and the level of conservation. This is a necessary condition. As a corollary, it can also be surmised that the doomsday and its consequential zero-growth (may even declining growth) can be by-passed by this approach.

Proposition-B: For any reason, if the rate of extraction is pushed above exploration and conservation, then the doomsday is imminent and that too, much sooner than expected.

Proposition-C: If the rate of extraction lies below the rates of exploration and conservation, then it can be inferred that there is under-exploitation and utilization of the endowed known resource-base implying thereby an immense potential for sustainable growth.

In conclusion, it can be said that **the issue of sustainability of higher rates of development through globalization / corporatization can be made compatible with non-declining resource-base through conservation and exploration.**

27) Cross- Subsidization for Conservation:

In this context, conservation is restricted mainly to mean the levels of recovery from a given known deposits to ensure, figuratively to extract the last tonne from a working mine. Its main concern is to counter the adverse effects of fast rising depletion rates (see, Table-5) arising out of globalization. This does not however mean that its other concerns in the overall EPC stream are less important. This is only a demonstration exercise with a real life case study to operationalise its meaning and intent.

The mining enterprises are seen, by the very nature of mining operations, to operate more than one mine to meet the market demands. Whether they are under public ownership or private ownership, are multi-unit (or multi-mine) enterprises in practice. This is inherent in mining sector. Similarly, each mine operates multiple working faces. The major reasons are due to an inverted U-shaped age-size relation, depletion, design of mining systems, high demand conditions etc. The mineral resource endowment is not uniform in quality, quantity, mineability, geomining conditions, depths, seam thickness and so on. This being the case, some mines are geologically favorable (more fertile) while some unfavorable (less fertile). Some sections within the same mine may be more fertile than others. Similar is the case with multiple seams. Accordingly, the mines operate under widely varying geo-mining (cost) conditions. This is the reason why the mines resort to the notorious practice of slaughter mining. (This is the most damaging practice.) This gives rise to the fact that their cost structures vary widely with the same technology, size and mining systems. More importantly, the divergent geo-mining conditions give rise to the phenomenon of **"equal amounts of factor-inputs producing unequal results in terms of outputs/revenues"**. This is called the **"differential rent"** (Ricardian) which is also called as the **"unearned income"**. This is mainly contributed by the indestructible powers of the natural factors (i.e. the geomining mining conditions).

The unearned-income or the differential rent can be appropriated by the policy instrument of cross-subsidization to subsidize the less fertile (or the geological unfavorable) mines whose unit costs may be higher than the market price (then, they may have to exit). Thus the loss making mines (or less fertile) are enabled to continue to operate by which the mining losses or the resource damages due to their exit can be saved. The purpose of cross-subsidization will be twofold: a) to eliminate resource damages and closures (of mines and working faces) and b) to meet the market demands. Since the loss making (or the geologically unfavorable) sections within a mine due to longer hauling distances etc. are also subsidized by the profit making ones, the levels of recovery go up. In simple terms, cross-subsidization is a policy by which financial losses of a unit are subsidized by the financial gains earned in the other units. The financial losses are subsidized from the gains accrued elsewhere. In non-financial terms, it involves subsidizing the geological unfavorables with the geological favorables.

Cross-subsidization is thus inherent in the coal mining industry as it maintains a large number of mines operating under extremely divergent conditions of costs, natural and working conditions, age, size, history, resource-base with multiple seams and their thickness, depth etc. it becomes an imperative policy particularly to achieve its primary objective of conservation of coal resources. In a sense, both are inseparable. **Together, they give a wholesome approach to sustainable mining sector** as also the sustainable resource management.

Cross-subsidization is a method by which the **avoidance-costs** of depletion, resource damages, enhancing the level of recovery etc, can be **internalized** by the mining enterprises. It is a way of **internationalization of depletion-costs**. Stowing is a good example to demonstrate that the levels of recovery (i.e. conservation) can be increased by subsidizing. So to say, the costs of sustainability/ conservation can be internalized. It is a kind of **built-in mechanism** to achieve conservation and to tackle the problem of niggardliness of nature within its bountifulness. Niggardliness is seen in the guise of geo-unfavourables within favourables. It becomes, in effect, a **self-financing system** because the unearned incomes or the rental elements can be diverted towards this noble cause; or plough back into the system to finance the conservation practices. It needs to be the corporate policy to internalize the external depletion-costs. If the social objective (or the corporate social responsibility) is to achieve sustainability or a sustainable mining sector ridden with the depletion-syndrome, then the cross-subsidization needs to be the **defining core** of corporate strategy. Unlike other policies (see Chart-III) it is **conflict free** and hence it should be explicitly integrated with the overall corporate strategy. Therefore, a better resource management model would be the one that considers together the differential-rent, cross-subsidization and conservation. This would then ensure a solution on the annual rate of production with higher levels of recovery while simultaneously considering costs of extraction explicitly. This model may be complemented by the lifecycle costing model (See, Naganna, 1974, 1982, 1984). Both together would give a fairly comprehensive theoretical framework to the practice of conservation as also provide with an in-built mechanism for self-financing.

An Empirical Assessment

The data for the empirical analysis and assessment of cross subsidization found and practiced in the coal industry characterized by the depleting syndrome, are collected through field investigations on the same industry (i.e., SCCL in AP) at different periods. The first was in 1967, the second in 1979 and the third was in 1999[18]. Hence, this can be considered as a

18. *The data for the last few years (i.e., 2000 to 2008) are given by a Ph.D scholar (Mrs. Savitha . R. R) from her thesis work. This data have been collected through a field survey during2009.*

longitudinal study because the same industry (i.e. the SCCL in AP) has been consistently inquired into. Several visits were made with some intervals, into the UG and OC mines to observe the changes taking place in them. From the vintage point of our growth of knowledge and information gathered about the industry overtime, a more meaningful and realistic framework seems to have emerged. We could get enormous help and co-operation from the senior executives/ managers of the company. This enabled us to have lengthy discussions and exchange of ideas/ notes with them. This is to say that the observation/ inferences made here, get ample credence. Hence it is not the data that speak but people behind.

The empirical evidence with a few relevant break-ups for the years 1964-65, 1974-75, 1988-89, 2000-01 and 2008-09 are displayed respectively in Tables 9, 10 and 11. At the outset, it may be noted that the industry is not facing any market prices but administered prices fixed by the Indian government. This price is reference point for assessing cross-subsidization. The mines that operate above this price level (due to unfavorable geo-mining conditions) obviously incur losses which have been cross-subsidized by the profit making mines (or the more fertile ones or geologically favorables). The loss making ones are not closed to save resource damages/ mining losses. Thus, cross-subsidization acts as a built-in mechanism to achieve conservation/sustainability[19]. The growth strategies and the consequent structural changes in the company are fairly clearly reflected in rising trends of the extent of cross-subsidization.

As a matter of fact, there was little or no cross-subsidization before the year 1964-65. It started taking place only during and after 1964-65 on an increasing scale. This is mainly because of the ever expanding coal markets/demands. When the market size is low, the mining enterprises generally extract the **easy coals** from more fertile deposits with more favorable geomining conditions and that too, from the top seams (a form of slaughter mining). This the history confirms. The **difficult coals** from the less fertile deposits/ mines with difficult and unfavorable working conditions are left unmined.

When the extent of markets get enlarged, the mining enterprises will have to go for “difficult coals” to satisfy the market demands. By implication, this means that both “easy coals” and “difficult coals” need to co-exist in the market place. Easy coals alone cannot satisfy the coal demands. More importantly, the supplying-capacity of the fertile deposits (easy coals) is not adequate enough to satisfy the expanding markets. Hence, the less-fertile deposits (difficult coal) need to be placed in the extraction stream. This is imperative (or imperated by market-size). This then leads to cost-differentials and thereby, cross subsidization. This is what has exactly happened in the industry under study. In simple terms, the difficult coals are cross subsidized by the easy coals to ensure the copious flows of resource supplies. From this analysis, an important proposition can be derived as below:

19. *Before nationalization of coal industry in 1972, it was under private ownership with competitive markets. In those days, there was the National Coal Board which was giving subsidies to mines with geologically unfavorable conditions like bad roof, over watering, side falls, etc, and to arrest the slaughter-mining practices. It implies that the cross-subsidization policy has to be followed even under market conditions with private ownership but* ***with the state intervention.***

A Demonstration Exercise on Cross-Subsidization

Mines	1964-65						Mines (Rs.)	1974-75					
	Outpur (lakh T)	Direct Costs (Rs.)	OH (Rs.)	TAC (Rs.)	Price (Rs.)	P/L (Rs.)		Output (lakh T)	Direct Costs (Rs.)	OH (Rs.)	TAC (Rs.)	Price (Rs./T)	P/L (Rs./T)
M1	1.99	–	–	35.10	30.30	-4.80	A	3.81	54.24	25.93	80.17	64.88	-15.29
M2	1.28	–	–	33.32	"	-3.02	B	3.38	51.65	27.16	78.81	64.88	-13.93
M3	1.07	–	–	31.50	"	-1.20	C	2.68	50.37	24.04	74.41	64.88	-7.20
M4	1.33	–	–	30.33	"	No-rent mine 0	D	2.31	49.64	14.59	64.23	63.72	+0.51
M5	2.52	–	–	29.65	"	+0.65	E	2.14	48.76	13.37	62.13	63.72	+1.59
M6	1.91	–	–	29.45	"	+0.85	F	2.45	46.63	13.69	60.32	63.72	+3.40
M7	2.85	–	–	29.35	"	+0.95	G	2.26	45.65	13.79	59.44	63.72	+4.28
M8	2.49	–	–	27.91	"	+2.39	H	2.10	38.29	13.73	52.02	63.72	+11.70
M9	4.78	–	–	27.78	"	+2.52	I	2.60	42.55	11.67	54.22	63.72	+9.50
M10	2.17	–	–	26.41	"	+3.89	J	2.95	40.48	11.21	51.69	63.72	+12.03
M11	1.20	–	–	25.20	"	+5.10	K	3.07	41.74	12.08	53.82	63.72	+9.90
M12	1.51	–	–	25.08	"	+5.22	L	2.13	50.30	11.91	62.21	63.72	+1.51
M13	1.00	–	–	25.04	"	+5.26	M	1.19	53.30	11.49	64.79	63.72	-1.07
M14	1.93	–	–	24.74	"	+5.56	N	2.02	38.58	11.83	50.41	63.72	+13.31
M15	1.31	–	–	24.00	"	+6.30	O	1.53	33.85	10.41	44.26	63.72	+19.46
M16	0.81	–	–	23.85	"	+6.45	P	3.40	38.53	12.38	50.91	66.17	+15.26
M17	0.46	–	–	23.61	"	+6.69	Q	1.87	44.79	12.06	56.85	66.17	+9.32
M18	0.74	–	–	23.60	"	+6.70	R	1.76	43.09	12.07	55.16	66.17	+11.01
M19	4.59	–	–	23.32	"	+6.98	S	3.22	41.78	13.19	54.97	66.17	+11.20
M20	0.35	–	–	21.09	"	+9.21	T	2.69	39.08	12.16	51.24	66.17	+14.93
M21	0.20	–	–	19.19	"	+10.39	U	3.54	40.45	12.62	53.07	66.17	+13.10
M22	–	–	–	–	–	–	V	1.01	38.91	13.04	51.95	66.17	+14.22

* During the year 1964-65 and before, there was no grading of coals by quality to fix the administered prices by grades. This was introduced later. Hence, there is a uniform price of coals across all the mines during 1974-75.

Lakh = 1,00,000 T = Tonne. P/L = Profit or Loss per tonne Price = Sales realization per tonne
TAC = Total Average Costs (in Rs.) OH = Over Head costs per tonne (in Rs.)

Table 9 Per tonne costs (in Rs) of Coal-raisings and Price (in Rs) for the years 1964 – 65 and 1974 - 75

A Demonstration Exercise on Cross-Subsidization

Mines	Output (lak T)	Direct Costs (Rs.)	OH (Rs.)	TAC (Rs.)	Price (Rs.)	P/L (Rs.)
a(ug)	3.02	281.47	113.32	394.79	217.45	-177.34
b(ug)	3.98	207.62	140.51	348.13	217.45	-130.68
c(ug)	1.10	305.98	133.60	439.58	217.45	-222.13
d(ug)	5.15	167.57	59.40	226.97	212.35	-14.62
e(ug)	4.13	190.48	69.37	259.85	212.35	-47.50
f(ug)	2.65	147.85	54.65	202.50	212.35	+9.85
g(oc)	7.02	54.82	70.92	125.74	212.35	+86.61
h(oc)	2.00	79.98	84.77	164.75	212.35	+47.60
i(ug)	1.91	211.57	80.37	291.94	302.08	+10.14
j(ug)	1.88	209.59	62.33	271.92	302.08	+30.16
k(oc)	8.78	86.55	72.75	159.30	302.08	+142.78
l(oc)	7.54	98.00	84.21	182.21	302.08	+119.87
m(ug)	1.22	376.01	117.46	493.47	305.60	-187.87
n(oc)	2.42	135.53	165.18	300.71	305.60	+4.89
o(ug)	1.12	338.01	79.03	417.02	274.14	-142.90
p(ug)	2.25	202.76	80.28	283.04	295.72	+12.68
q(ug)	2.69	207.94	80.38	288.32	295.72	+7.40
r(ug)	4.49	196.99	80.33	277.32	295.72	+18.40
s(ug)	4.76	195.45	84.88	280.33	301.17	+21.00
t(ug)	4.85	195.97	76.45	272.42	301.17	+28.75
u(ug)	2.25	171.68	72.29	243.97	301.17	+57.20
V(ug)	2.94	197.49	75.12	272.61	301.17	+28.56

Oc = Open Cast mines **Ug = Underground mines** **T = Tonne**

P/L = Profit or Loss per tone (in Rs./T)
Price = Sales realization per tonne (in Rs./T)
TAC = Total Average Costs (in Rs./T)
OH = Over Head costs per tonne (in Rs./T)

Table 10 Per Tonne Costs (in Rs) of Coal-raisings and Price (in Rs) : 1988 - 89

Demonstration Exercise on Cross-Subsidization:

Mines	2000 - 01					Mines	2007 - 08				
	Output (lakh T)	Direct Costs (Rs.)	TAC (Rs.)	Price (Rs.)	P/L (Rs.)		Output (lakh T)	Direct Costs (Rs.)	TAC	Price (Rs.)	P/L (Rs.)
OC-1	33.79	263.03	375.84	1021.57	+645.72	OC-1	12.86	421.80	517.44	1253.81	+736.37
OC-2	12.20	316.07	445.23	1020.72	+575.49	OC-2	2.51	462.41	537.07	1254.62	+717.55
OC-3	26.57	317.91	450.68	922.38	+471.70	OC-3	40.06	202.42	336.61	995.74	+659.13
OC-4	7.27	397.15	488.40	922.36	+433.96	OC-4	8.10	515.11	767.10	1297.21	+530.11
OC-5	2.36	523.15	633.94	1021.49	+387.55	OC-5	30.16	648.78	786.72	1253.86	+467.14
OC-6	30.41	417.96	594.00	922.69	+328.69	OC-6	17.52	155.37	314.91	760.34	+445.43
OC-7	6.34	242.77	391.93	664.89	+272.96	OC-7	25.02	632.14	813.44	1214.79	+401.35
OC-8	2.49	267.61	416.31	664.41	+248.10	OC-8	26.28	695.10	935.37	1345.64	+410.00
OC-9	12.09	477.22	1012.20	1137.49	+125.29	OC-9	23.45	794.08	899.96	1254.04	+354.08
OC-10	16.01	323.07	562.18	686.17	+123.99	OC-10	19.17	479.22	598.31	785.74	+187.43
OC-11	8.27	397.61	568.54	664.59	+96.05	OC-11	7.77	575.30	776.21	970.07	+193.86
UG-1	3.79	786.26	1065.94	1000.63	-65.31	UG-1	8.68	720.83	920.41	1128.85	+208.44
UG-2	2.87	785.46	1089.75	1000.27	-89.48	UG-2	4.92	953.54	1233.56	995.45	-238.11
UG-3	4.13	747.63	1113.90	982.69	-131.21	UG-3	2.88	1009.37	1256.79	996.50	-260.49
UG-4	1.86	875.99	1189.98	921.76	-268.22	UG-4	4.54	1136.27	1482.71	1214.42	-268.29
UG-5	4.92	913.75	1270.42	981.20	-289.22	UG-5	5.51	1171.13	1566.83	1297.33	-269.50
UG-6	1.59	1200.18	1324.87	1021.52	-303.35	UG-6	4.08	1226.18	1579.80	1295.13	-284.67
UG-7	3.74	895.83	1337.24	922.07	-415.17	UG-7	1.27	1397.70	1781.04	1297.76	-483.28
UG-8	4.35	838.48	1361.28	923.19	-438.09	UG-8	1.63	1059.87	1272.89	788.28	-484.61
UG-9	1.21	1019.99	1440.14	1000.47	-439.67	UG-9	2.31	1219.16	1671.13	1127.43	-543.70
UG-10	2.35	1283.73	1433.82	664.97	-768.85	UG-10	1.01	1650.16	1922.12	1219.39	-702.73
UG-11	0.84	1249.74	1747.46	951.73	-795.73	UG-11	2.25	1311.88	1744.95	970.83	-774.12

TAC = Total Average Costs (Rs) per tonne
P/L = Profit or Loss (Rs) per tone
T = Tonne
OC = OpenCast mines
UG = Underground mines
Price = Average sales realization per tonne
Lakh = 1, 00,000

Table 11 Per Tonne Costs (in Rs) of Coal raisings after Dichotomizing the mines between OC & UG. (2000-01 & 2007-08)

“The extent of markets will have a definite bearing on the extent of Cross-subsidization.”

Both are interrelated. Higher the market-size, higher will be the level of cross subsidization. This is perhaps inherent in the extractive sector. Nature is highly heterogeneous. This proposition gets validated with the empirical base given in Tables 9, 10 and 11, as also supported by the registered growth. Thus, market-size assumes a greater role in resource management. The above analysis reassures the fact that the market is good but not marketing.

The data on the extent of cross subsidization for five years are presented in Tables 9, 10 and 11. In the year 1964-65, there were only 21 mines. For the sake of simplicity and clarity; and without putting objectivity at risk, only 22 mines were taken though there were more in the industry (See Tables 4&5). Accordingly, the empirical assessments on cross subsidization refer to the 22 mines; and they have been presented in Tables 9,10 and 11. The empirical evidence as contained in these Tables is summarized below.

Years (1)	Number of Mines Cross Subsidized (2)	Total Output of 22 mines (lakh tones) (3)	Total Output of cross subsidized mines (lakh tones) (4)	% to Total output of 22 mines (5) = (4)/(3)
1964-65	3	36.49	4.34	11.9
1974-75	4	54.11	11.06	20.4
1988-89	7	78.15	19.72	25.2
2000-01	10	189.45	31.65	16.7
2007-08	11	251.98	30.40	12.1

Table 12 A Brief summary of the trends in the extent of Cross Subsidization (from Tables 9, 10 & 11)

Source: Computed from Tables 9,10 and 11.

It is clearly evident that the extent of cross-subsidization followed by the company is on the rise due to expanding markets (or rising outputs). **This validates the earlier proposition**. We were told by the mining officials that it was not there before 1964. If at all, it was very insignificant in one or two mines. Even in 1964-65, the extent of Cross Subsidization was much less with three mines only. The number of cross-subsidized mines increased substantially to about ten. The total cross-subsidized output and its percentage to total output also follow the same pattern of rise over the years. By implication, the analysis indicates the mechanism by which the **resource-supplies** through the dynamics of resource-base, get adjusted with the **resource-demands**. In a sense, cross-subsidization acts as an **equilibrating force** in resource-markets. This is the essence of resource management (Noelia R. C. and J. P. Chousa, 2006).

On general grounds, one may understandably suspect that there needs to be some **limits on Cross-Subsidization** from the point of view of the financial health of the industry. On the basis of our experiences in the extractive sector in general, it may be suggested intuitively that the limits could be notionally around 10 to 15% of the total industry output. This would ensure conservation and a sustainable mining sector. Another determinant could be the overall profitability levels of the industry.

It may be noted that the % of cross subsidized-output to total output declined in 2000-01 and 2007-08. This could be due to technological improvement in UG mines because one loss-making mine in 2000-01 turned into profit-making in 2007-08. Further, this could also reflect improved financial management practices in the industry.

On the whole, it has been identified that the cross-subsidization policy assumes a **dual-role** in resource management, viz.,

a) in achieving conservation and sustainability and
b) acting as an equilibrating force to match the supply of and demand for resources.

There is one more **Startling Observation**. The recent evidence for the years 2000-01 and 2007-08 reveal that almost all the loss-making UG mines are getting Cross Subsidized by the profit making OC mines (See, chart-3). Since there is a conspicuous absence of undertaking any reclamation programs of the damaged decoaled areas, deforestation etc., as also the exclusion of socio environmental costs of displacements reveal that the present levels of untenable consumption patterns are

Cross-Subsidized by the unborn posterity. The present is subsidized by the future. Because, the coals are under-priced at present due to the exclusion of social-costs in pricing. This is true across all the minerals.

As revealed by our empirico-conceptual analysis that there are wide variations in quality, geo-mining conditions and technology/markets in mineral resources and the mines, the logic demands that the cross-subsidization needs to be an integral part of extraction strategy to achieve conservation and sustainability. **Hence, it becomes a logical necessity and an empirical demand to achieve a sustainable mining sector to support sustainable development**.

Conclusion

An attempt is made to establish an intelligible dialogue between mining engineering and management to achieve a sustainable resource management in pace with the sustainable globalization-driven development.

Mining sector in general and coal mining in particular define the fundamentals of an economic system. They form the basic foundation for the market-driven industrial economy. In effect, the natural resources management particularly relating to the non-regenerative and exhaustible resources, gain greater significance and relevance. Since growth contains decay in extraction sector, the paradox of growth-decline syndrome comes to the fore. This is resolved through managing appropriate changes in the relative roles and contributions of extractive-exploration-conservation operations in line with the sustainable growth. The economic system needs to safeguard itself against the resource-illusions which normally lead to over exploitation and over-use of resource. It has been observed after identifying the sources/driving forces of growth (viz., resource-base, technology and its absorption capacity, shifts in mining methods, mine-size, and market-size) that exploration and conservation act as equilibrating forces to make globalization (i.e., demand) with sustainability (i.e., supply). **Sustainability, at bottom, refers to resource-sustainability**. It is advocated that sustainable resource management in pace with development is achievable through policy of **cross-subsidization** at the enterprise level. This frame work, developed on the basis of grounded theory approach, can be applied to all the minerals to contrive a macro level natural resource management model. Managerial and organizational responses will automatically follow suit by learning through experience.

Market-size and marketing are observed to have opposite effects on resource base. Every other thing remaining the same, increasing market-size helps expand the resource-base. Globalization, if finds new markets to expand market-size, will arguably be beneficial to resource base. This leads to a rise in aggregate consumption making sustainability critical. Hence, globalization needs to be complemented by conservation measures and to make it a way of life. This is all to advocate the need to follow the principle of wise and parsimonious use of exhaustible resources in production and marketing strategies. But, not abstinence. In this regard, cross-subsidization is found to be a logical necessity and an empirical demand but yet needs to be made an empirical reality. Sustainability or sustainable development will be a myth without a rational and consistent resource management model. This the paper attempts.

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Appendix-I

A Note on the Dynamics of Resource-base

The appendix gives more empirical base particularly to the relative roles of extraction, exploration and conservation during three phases as explained in the text. The concept of the known resource base of a mineral is considered as the summation of a mineral-deposit/reserve in likely and probable mineral-bearing belts of a region like a district, state or a country. If it is summated over all the minerals, then it will be the total minerals resource base of a region. The known total resource base forms the basic strength and source for the development and maintenance of the EPC stream. The quantitative estimation of the resource base is crucial in knowing the extent of sustainability of the EPC stream. This knowledge will be necessary in designing appropriate policy measures at all levels.

Resources are geological mineral occurrences found on the basis of peripheral or much-less-intensive explanation mostly by surface data and partly by drilling. Hence, they do not give a true indication of endowed potential of exploitable and mineable reserves for economic use. On the other hand, reserves are the subset of resources that are economically recoverable using available technology of extraction and utilization. Therefore, it is the technology and the extent of knowledge and information that converts the resources into recoverable reserves.

The concept of resource base seems to be very nebulous because its components (i.e., inferred, indicated and proved) do not reveal clearly what they are supposed to. As a result, it creates several illusions to the resource planners and policy makers leading to false perceptions of reality regarding the exact resource position. The whole problem lies in the fact that the concept of resource base is fraught with many components which are themselves relative to and subject to many complex factors like technology, markets, price and mining methods besides geo-mining factors. Hence, today's resource position is different from tomorrows even without exploration. It is so uncertain and unknowable that its exact position will be known and realized only after it is fully extracted. In effect, resource planning and management is carried out under extremely risky, uncertain and unknowable conditions.

Keeping this in background, a quick scanning and a rapid appraisal and analysis of resource base have been undertaken both at the all-India and the SCCL of AP levels. This refers only to coal reserves/resource base.

A1): **Estimates of State-wise Resource base of coals in India (2004):**

The resource base is given by the Indian official documents in terms of three categories in a probability framework, viz.,

- Inferred,
- Indicated, and
- Proved reserves

They are arranged in an ascending order of probability level of their extractability/mineability. Or, they can simply be said as "proved" and "probable" reserves based on the degree of certainty of their availability for extraction. The availability of adequate and reliable information is the basis for this categorization. Hence, it is the exploration that decides the level of recoverability of a reserve/resource in terms of technology, market conditions and price. Generally, all the inferred reserves are based on extensive or peripheral exploration from virgin areas while the indicated ones refer partly to virgin areas and mainly to the already explored areas. In this case, the exploration will be of medium intensity. On the other hand, all the proved reserves refer to intensive exploration on the already known explored areas. This is the general pattern. The degree of intensity of exploration converts low category into a higher one. The state-wise distribution of reserves in this format, though implicitly, presented in Table-A1.

Distribution of Coal Reserves in India					
State	**Inferred**	**Indicated**	**Proved**	**Total**	**% to Total**
Andhra Pradesh	2514 (15.0)	6092 (36.5)	8091 (48.5)	16697 (100.0)	6.8
Arun Pradesh	19 (21.1)	40 (44.4)	31 (34.5)	90 (100.0)	-
Assam	34 (10.0)	27 (7.9)	279 (82.1)	340 (100.0)	0.1
Bihar	160 (100.0)	-	-	160 (100.0)	0.1
Chattisgarh	4355 (11.0)	26419 (66.8)	8771 (22.2)	39545 (100.0)	16.1
Jharhand	6348 (8.8)	30107 (41.9)	35409 (49.3)	71864 (100.0)	29.2
M.P.	2914 (15.6)	8233 (44.1)	7513 (40.3)	18660 (100.0)	7.6
Maharashtra	1605 (19.1)	2156 (25.6)	4653 (55.3)	8414 (100.0)	3.4
Meghalaya	301 (65.6)	41 (8.9)	117 (25.5)	459 (100.0)	0.2
Nagaland	15 (75.0)	1 (5.0)	4 (20.0)	20 (100.0)	-
Orissa	15135 (24.8)	31239 (51.2)	14614 (24.0)	60988 (100.0)	24.8
U.P.	0	296 (27.9)	766 (72.1)	1062 (100.0)	0.4
W.B.	4488 (16.4)	11523 (42.1)	11383 (41.5)	27394 (100.0)	11.2
Total	37888 (15.4)	116174 (47.3)	91631 (37.3)	245693 (100.0)	100.0

Table A1 State-wise Distribution of Coal reserves in India, 2004. (million Tonnes)

It is evident from the above Table that the country is richly and immensely endowed with 245.6 billion tonnes of total coal reserves in which the inferred, indicated and proved reserves account for 15.4%, 47.3% and

37.3% respectively. The AP/SCCL is endowed with 16.7 billion tonnes (or 6.8%). The three major coal endowed states (viz., Chattisgarh, Jharkhand and Orissa) together account as high as 70% of the country's total reserves. The other important coal bearing states are: West Bengal (11.2%), MP (7.6%) and AP (6.8%). These three together contribute 25% to the country's total reserves. These six states together constitute as high as 95% of the total reserves. There is thus a wide geographical dispersal of coal reserves which are obviously far away from the major consuming centres.

This involves unduly high transport costs of coal. So to say, the Nature's niggardliness can be seen in its bountifulness; or niggardliness can be seen in the guise of bountifulness.

Implicit in Table-A1 is the most revealing observation. The old coal producing states (such as AP, Jharkhand (i.e., Bihar), UP, West Bengal, Chattisgarh)* are found to have lesser percentage of inferred reserves in their respective total reserves (see, Table-A1). Correspondingly, their percentage of proved reserves is found to be high. On the other hand, the new entrants like Orissa, Maharashtra etc., exhibit surprisingly an opposite composition of their respective reserves. There is a great implication in this broad pattern. By implication, this reveals that exploration by extensive-method in virgin areas (old coal producing states) is clearly **reaching its limits**. This is to say that virgin areas for exploration are exhausted. In other words, the new finds/additions to the stocks have to come only from the already explored (old) areas through intensive-exploration. This also means that all the likely, probable and suspected coal bearing areas are explored. All this confirms the fact that exploration has certain and definite limits beyond which it cannot contribute any more new deposits. By implication, this observation gives an empirical credence to the changing relative roles of exploration, extraction and conservation during the three phases, as explained in the text.

A2) The Dynamics of Resource-base

The concept of resource-base is not static but a dynamic one. It improves progressively from almost a zero-quantity to an unknown but finite quantity which will be reached after a period of time when all the suspected and probable mineral-bearing areas will be totally explored both intensively and extensively. In a sense, it is dubious and misleading because it indicates a huge unrealizable quantity which cannot be totally extracted to the last embedded tonne for various reasons of notorious geological risks and uncertainties. Hence, it gives false hopes and unrealistic strengths leading to resource-illusions and thereby, resulting in over-extraction through wasteful methods. The empirical base is implicit in Table-A2.

State	Inferred	Indicated	Proved	Total	% change over previous year
1-1-1999	41219 (19.7)	88427 (42.3)	79106 (37.9)	208752 (100.0)	-
1-1-2000	39697 (18.8)	89501 (42.3)	82396 (38.9)	211594 (100.0)	1.4
1-1-2001	39250 (18.3)	90242 (42.2)	84414 (39.5)	213906 (100.0)	1.1
1-1-2001*	38023 (17.2)	98546 (44.6)	84414 (38.2)	220983 (100.0)	3.3
1-1-2002	37417 (16.0)	109377 (46.7)	87320 (37.3)	234114 (100.0)	5.9
1-1-2003	38050 (15.8)	112613 (46.8)	90085 (37.4)	240748 (100.0)	2.8
1-1-2004	37888 (15.4)	116174 (47.3)	91631 (37.3)	245693 (100.0)	2.1
% of change in 2000 over 1999	-8.0	31.4	15.8	17.7	-

*Revised. Figures in backets show percentages to total

Table A2 Estimates of Coal Reserves in India: 1999 to 2004 (million Tonnes)

*Source: (for Table A1 & A2); Vikas Singhal, "**Indian Industry: 2006**; Indian Economic Data Research Centre, New Delhi; 2006, pp 156-169.*

**Chattisgarh and Jharkhand are the newly framed states carved out of the old coal-producing states like Bihar, U.P etc. Hence, they are considered as the old coal-producing states. For details on the classification of reserves, see Naganna, 2001.*

Though the Table refers to a small period, reveals implicitly some observations of far reaching significance.

They are: (a) The rate of additions to the depleting stocks is lagging much behind the output/depletion growth-rate. Since there are limits to exploration, there will be a widening gap over time. (b) The total reserves increased substantially by 17.7% in 2004 over 1999. It can be observed (Table-A2) that the two main sources of growth lie both in **indicated** (31.4%) and **proved** (15.8%) reserves. On the other hand, the extent of **'inferred'** reserves declined significantly by 8.0% during this period. In the same vein, the relative share of inferred reserves in the total declined sharply from about 20.0% to about 15.0% during this period. By implication, all these trends suggest that the additions to resource-stocks came through intensive exploration rather than by exclusive method. In turn, this indicates that there are no virgin areas available for exploration. In other words, the additions came from the known and already explored areas. On the whole, the evidence reveals the fact that: (a) **exploration has limits**; (b) all the suspected and probable mineral-bearing areas will be totally explored gradually over a period of time. That being the case, the new additional deposits will have to come from intensive but not extensive exploration. The later gives the broad contours of embedded resource over large areas. (c) The shifts in reserves from one category to the other are mainly guided by and adhere to the movements in **prices, markets and technology**. These are the primary driving forces to dynamise the resource-base; and (d) The pattern as observed in Table-A2, arguably brings the changes in the relative roles of exploration, extraction and conservation as delineated earlier under three phases. On the whole, the analysis as contained in Tables-AI through A4 give empirical justification to those three phases (see, text of the paper). **And so is the movement from a simple notion to empirical reality**.

A3) Depth-wise Distribution of Proved-reserves in SCCL:

Coming back to the empirical analysis of our case study (i.e., the SCCL), it is to be noted that the **proved reserves** need to be arranged, for all practical purposes, by depth to facilitate decision-making on extraction front. This has more practical value. The proved reserves are the ones that are readily available for extraction planning. The other two will not be of much use in this regard. The depth (i.e., the vertical depth refers to the distance between the embedded seam below ground and the surface) is one of the major decision-variables in matters relating to extraction strategies and the choice of mining methods. It influences the unit costs and so, the price. Coal quality is also influenced by it. It also exerts influence on the extent of mineability of a deposit. The depth-wise distribution of proved reserves of the SCCL for the year 2009 is displayed in Table-A3.

Sl. No.	Depth (mtrs)	Proved Reserves (m.t.) (2009)	Proved Reserves (m.t.) (2000)
1.	0-300	5986.70 (63.8)	3609.0 (58.2)
2.	300-600	3387.49 (36.1)	1796.0 (28.9)
3.	>600	10.14 (0.1)	796.0 (12.9)
Total		9384.33 (100.0)	6201.0 (100.0)

Table A3 Depth-wise Distribution of PROVED Reserves in SCCL/AP Coal Fields (as on 31-3-2009)

Source: SCCL Website for 2009, Field survey for 2000 Figures in brackets show percentages.

It is evident from the above table that the SCCL is fortunate enough to have its proved embedded reserves at lesser depths of less than 300 mtrs. This enabled and facilitated it to shift to more productive and the least cost mining method (i.e., opencast) and to make it as the dominant feature. Regarding the depth-wise distribution of proved reserves, it can be seen in Table A3 that a major share (58% in 2000 and 64% in 2009) lies in the depth of less than 300 mtrs. Another 36% lies in the range of 300 to mtrs depth. Both together account for 99.9% (2009).

It may be noted that the shift in extraction to higher depths will be determined mostly by: (a) **price;** (b) **market size** and (c) **technology**. These three together will define the fundamentals of the mining enterprise and its extraction strategies. As a matter of fact, the higher prices resulting from market expansion will enable the industry to go to larger depths (implying different cost levels) simultaneously or sequentially keeping in view the stability of longrun real costs. This is in fact a contentious issue because the concerns of posterity enters explicitly and so is the concerns of sustainability.

For instance, if the industry decides to extract only top seams of lesser depths leaving the deeper bottom seams to posterity, then the posterity will get adversely affected due to obvious higher real costs of extraction. It is a very complex issue.

The most significant feature of the mining sector in general is that all the minerals whether they are above or below ground, vary widely by quality which is normally designated by grade. Coal is no exception. The depth-wise and grade-wise distribution of proved geological reserves of the SCCL (2009) is given in Table-A4.

Depth-Class (mtrs)	GRADE							TOTAL	% TOTAL
	A	B	C	D	E	F	G		
0-300	46.21 (0.77)	223.63 (3.74)	1216.82 (20.33)	1263.79 (21.11)	1215.42 (20.30)	1522.46 (25.43)	498.37 (8.32)	5986.70 (100.00)	63.79
300-600	27.18 (0.80)	177.70 (5.25)	687.90 (20.31)	1044.33 (30.83)	812.26 (23.97)	583.26 (17.22)	54.86 (1.62)	3387.49 (100.00)	36.10
>600	2.64 (26.04)	3.60 (35.50)	1.35 (13.31)	0.90 (8.87)	1.56 (15.38)	0.09 (0.89)	-	10.14	0.11
Total	76.04 (0.81)	404.92 (4.32)	1906.07 (20.31)	2309.02 (24.61)	2029.24 (21.62)	2105.82 (22.44)	553.23 (5.89)	9384.33 (100.00)	100.00

Table-A4 Depth-wise and Grade-wise Distribution of proved Geological Reserves of the SCCL as on 31-3-2009. (Million tonnes)

Source: SCCL Website. Figures in brackets show the percentages.

The above Table-A4 reveals that 50% of the proved geological reserves lie in the grades of A through D. Another 50% in E through G grades. Only 0.81% are of A grade followed by 4.32% B grade and another 20.30% C grade. Together, they account for only 25.4% of the total reserves. On the whole, it is evident that the quality of the SCCL coals are not of superior quality but just an average. This affects the profitability of the enterprise. Because, the per tonne price depends on quality but not on unit costs. This then, in effect would mean that the equal amount of labor and capital, everything else remaining the same, produce unequal amounts of results in terms of output and revenues. There arises thus an unearned income or economic surplus due to natural factors. This unearned income is called the **differential rent** which can be appropriated for cross-subsidization.

A4) The Myth of Reserves: A Critical Appraisal

Conceptually, there is a wide difference between the geological resources and geological reserves. There are many kinds of definitions and nomenclatures in the process of a resource getting converted into an extractable reserve. So also confusion (see, Discussion paper: Extractive Activities, 2010; see also Naganna, 2001). There is no uniformity in this regard. The geological resources generally refer to all the occurances over large areas whose information is known through outcrops, surface data and peripheral exploration. In this case, information is too inadequate to make any dependable assessment. When an intensive exploration is conducted, they tend to become a mineable reserve. It is the quantity and quality of information that distinguish the two. The single most important parameter is the degree of recoverability in terms of technology and economics. This means that a geological resource tends to become a reserve if it can be technologically and commercially extractable. In essence, its conversion is contingent upon commercially viable recoverability. This is the underlying reason for the myth of resource base. What all that is known to be a resource/reserve cannot be extracted due to several geomining risks and uncertainties which are generally ignored in rosy resource estimates. They are misleading.

Keeping the above conceptual analysis inview, a critical appraisal of resource base in the SCCL of AP is carried out below. It is displayed below in Table-A5 in which the **myth of resource base** is clearly reflected. It gives an empirical base to the statements made earlier on the resource base.

(million tonnes)

Geological Reserves		WORKING MINES			VIRGIN			Un projectied Extractable Reserves	Total Available Extractable REserves (7+8+9)
		Available Reserves			Projected Reserves				
Proved	Consumed	Geological	Mineable	Extractable	Geological	Mineable	Extractable		
1	2	3	4	5	6	7	8	9	10
9,155	754	2,974	1,451	779	2,040	1,402	1,208	1,287	3,274

Table-A5 Presenting a Critical Appraisal of Reserves/Resource base of SCCL/AP (as on 31-3-2008)

Source: SCCL Website. Figures refer to the total of the SCCL.

The SCCL categorizes the reserves into: geological, mineable and extractable, on the basis of recoverability in terms of technology and economics. The three major determinants of reserves ultimately getting converted into extractability are: **price, market size and technology**. If these factors go up, then geological reserves tend to become mineable and then to extractable. Thus, the resource base is dynamic and relative to price and market size. They are the significant decision-variables in resource management.

(a) **Working Mines:** Out of a total geological reserves of 2974 m.t. placed under working mines, it is estimated that only 1451 m.t. (or 48.8%) are mineable while extractable reserves are estimated to be only 779 m.t. (or 26%). Another noticeable feature is that only half (or exactly 53%) of the mineable reserves are extractable (Table-A5).

(b) **Projected Reserves:** They refer to those known reserves for which the mining projects have been prepared for extraction. There are a total geological reserves of 2040 m.t. under this category, out of which 1402 m.t. (or 68.7%) are estimated to be mineable and only 1208 m.t. (or 86%) are extractable out of 1402 m.t. of mineable reserves. In comparison with the earlier one, it is implied that the resource base is over estimated in this case. This implies that the reserve position normally overestimated before the actual start of mining operations due perhaps to lack of adequate information on geomining conditions.

(c) **Total Extractable Reserves:** The myth of resource base is more revealing in this case. For instance, it is only 3274 m.t. (or only 35.74%) that are extractable from an astonishing total proved reserves of 9155 m.t.

The distinction between mineability and extractability is crucial in resource assessment. The difference lies in the fact that the geomining conditions and their associated risks and uncertainties are considered to a lesser extent in the former while they have been taken into account to a greater extent in the later. This may be due to lack of sufficient data. Even then, there could be some unknown unknowns. This is the reason why it is said that the exact reserve position will be known only after the extraction is completed. Until then, they remain as estimates.

Thus, the extent of extractable resource base is relative to price, market size and technology. Implicit in this exercise on resource analysis and assessment, are the following:

(i) If price goes up, a large uneconomic resource potential tends to become economically extractable by making gradual shifts in reserve categories to make them extractable.

(ii) From the analysis, it follows that the longrun real costs of coal will increase and hence, the future price of coal will be much higher.

(iii) Resource planning and management will be much more complex than the planners think. The problem is as to which type of reserves to take as the baseline data; and so is the case with policy making. On the whole, the analysis reveals that all the extractable reserves are not really extractable irrespective of price/cost due to the ingrained geomining risks and uncertainties. In effect, this gives rise to resource-illusions and false perceptions of realities impeding the practice of parsiomonious, wise and rational use of exhaustible and non-regenerative resources.

Appendix – II

Year	No. of mines	Total Output (m.t.)	Mine-size (million tonnes)
1950-51	893	32.30	0.03617
1960-61	848	55.23	0.06513
1970-71	779	72.95	0.09365
1975-76	619	99.63	0.16095
1980-81	460	113.91	0.24763
1985-86	491	154.20	0.31405
1990-91	521	211.73	0.40639
1991-92	524	229.28	0.43756
1992-93	539	238.26	0.44204
1993-94	558	246.04	0.44093
1994-95	559	253.80	0.45408
1995-96	561	270.13	0.48152
1996-97	574	285.66	0.49767
1997-98	571	295.93	0.51827
1998-99	562	292.27	0.52005
1999-2000	606	299.97	0.49500
2000-01	591	309.63	0.52391
2001-02	564	327.79	0.58119
2002-03	564	341.27	0.60509
2003-04	564	361.25	0.64051
2004-05	564	382.61	0.67839

Table-A6: No. of mines, Total coal output (MT) and Mine-size in India

(Exclusive of Lignite) (1950-51 to 2004-05)

Source: *As in Table-A1 and A2*

When the market size was small in the past, there was a large number of small sized mines, generally resorting to unscientific slaughter mining practices and there by inflicting heavy damages on the non-regenerative resource base. This was the reason why the government appointed the Amalgamation committee to merge all the contiguous mines to make them optimum units.