3 Review of existing literature on costs and benefits of environmental norms

Introduction

Definition of environment

All economic activities are dependent on the "environment", which is defined as the conditions, circumstances and influences under which an organization or system exists. It may be described by physical, chemical and biological features, both natural and man-made. The environment is commonly used to refer to the circumstances in which man lives. (Brackley, 1988)[a]

Thus, the surroundings in which an individual or organisation operates can be broadly described as the environment. Further, literature distinguishes three fundamental kinds of environmental services or functions, namely:

i) General life support ingredients in the environment, which are essential for health and human welfare. Some of these elements are subject to modifications due to economic activities (atmosphere, nature, etc) while others are 'finite' and subject to irreversible loss (biodiversity).

ii) Physical inputs like raw material and energy, which are used for production and consumption and are either renewable or finite in nature. Renewable resources can be sustained through proper treatment and maintenance or else is depleted as are the finite resources under excess use and insufficient maintenance.

iii) The accumulation of waste products of economic and social activities which are assimilated and absorbed through air, soil and water till a certain sustainable level. Beyond a particular level, the natural system is overwhelmed and saturated with waste.

Why environmental valuation?

[a] J. T. Winpenny, "Values for the Environment – A Guide to Economic Appraisal", Overseas Development Institute, London: HMSO. pp.1.

It can be therefore, concluded that renewable as well as non-renewable environmental resources, utilised for the support of economic and social activities, result in burdening and depleting of the natural system. “Sustainable development” and “environment economic” literature focuses on the need to preserve this environment. It highlights the necessity to value the environment and thus its usage, which was otherwise considered a free input by all activities, thereby resulting in discounting their impacts. It also led to subsequent unaccounted degradation of environmental resources. From this has evolved the concept of economic valuation of environment costs and benefits, which is then incorporated in the process of decision-making and planning, project evaluation and determination of project cost.

The valuation process

As already discussed, all economic activities, including electricity-generation, have certain environmental impacts, which generates associated costs. These costs can be categorized into two broad components, namely:

(i) cost arising due to the environmental damage caused by the impact of the activity; and

(ii)cost incurred to control this environmental impact.

To evaluate the former cost, certain steps need to be followed. Firstly the different environmental impacts of the activity need to be identified and then their respective impact pathways determined. Thereafter, the different valuation techniques provided in literature have to be suitably applied to determine the environmental cost. In case of the second cost, the evaluation is easier as most of the control measures have direct monetary value. Wherever such value is absent (e.g., deforestation), the value is calculated on the basis of certain suitable assumptions.

Even for the electricity sector, similar techniques are applied. The different stages in the generation and transmission process have an environmental impact along with impacts of certain backward linkages like the extraction effect in case of fossil fuels as well as transportation. The generation impacts are, however, at variance depending on the technology, fuel (oil, coal, gas and hydro) and location (pit-head *vis-à-vis* load centre) of power plants. It may not be possible to quantify all impacts, therefore some impacts are stated in qualitative terms. Annexure 3.1 lists the impacts of extraction, generation and transmission activities. In some cases, direct control measures are available *vis-à-vis* pre-defined environmental norms as provided in Annexure 3.2. The evaluation of impacts and of control measures provides the total environmental cost for the sector.

Many impacts have been theoretically or empirically quantified in monetary terms for different economic activities. It has been observed that many economic activities have similar impact pathways. Hence, the valuation of an environmental impact pathway for a particular economic activity can be applied to another economic activity with a similar impact pathway. Thus, in literature valuations of similar impacts are not necessarily done for all activities, as the same valuation technique can generally be used for similar impact pathways originating from different economic activities.

Chapter outline

This chapter reviews the available literature on environmental costs and benefits of the electricity sector and attempts to summarize the different concepts and valuation techniques available in relation to the economic valuation of such environmental cost and benefit assessment. It also tries to develop certain models and a framework for analysis of the environmental costs of any power project. Besides, it identifies issues and concerns specific to the Indian power sector on the same.

Environmental cost and benefit – literature review

Environment valuation techniques[a]

Economic valuation of environmental resources and the impact of activities on these resources is essential to make prudent and meaningful decisions on resource utilization and allocation. The total economic value (TEV) of the environmental assets can be disaggregated as follows (see Table 3.1)

TEV = Actual use value + Option value + Non-use value (Existence value)

Table 3.1 An economic taxonomy for environmental resource valuation

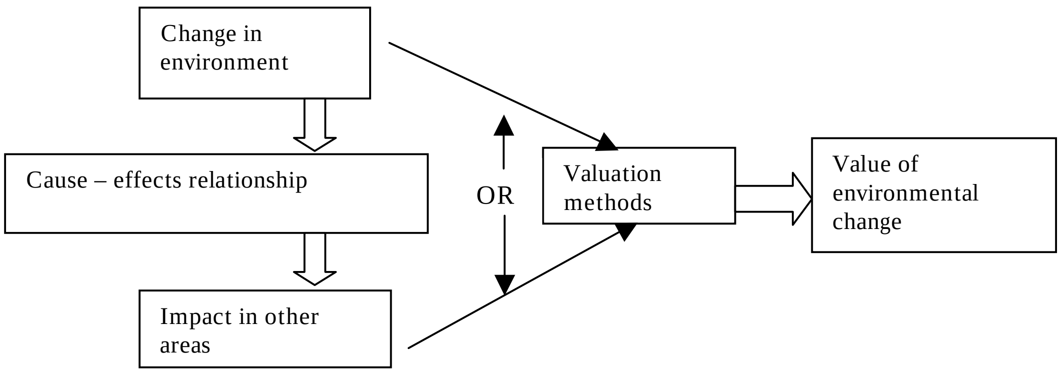
[a] Details on the valuation techniques are provided in Annexure 3.4 at the end of this chapter.

	Total economic value				
TEV =	Use value			Non-use value	
Types	Direct use value	Indirect use value	Option value	Bequest value	Existence value
Definition	Outputs directly consumable	Functional benefits	Future direct and indirect values	Use and non-use value of environmental legacy	Value from knowledge of continued existence
E.g.	Food Bio-mass Recreation Health	Flood control Storm protection Nutrient cycles	Bio-diversity Conserved habitats	Habitats Prevention of irreversible change	Habitats Species Genetics Eco-system

Source. Pearce *et al*. (1992)

There have been a variety of techniques and models developed for economic valuation of gains and losses associated with the change in quality or quantity of environmental assets described above. Figure 1 below, is a schematic representation of the valuation procedure.[a]

Figure 1: Steps in Valuation



The first step in the valuation technique, as already identified, requires establishment of a cause-effect relationship. This cause effect relationship of the environmental impact can be substantiated by the following methods:

i) Laboratory or field research (e.g., effect of marine pollution on fisheries through its effect on reef ecology); damage functions can be estimated

[a] United Nations, "Environment Accounting and Valuation", Volume 1, United Nations, New York, 1997, pp 30.

through controlled experiments (as mentioned above, the dose-response method, e.g., effect of air pollution on crop and corrosion);

ii) Controlled experiments in which the effect is deliberately induced (e.g., exposing animals to air pollution); making observations on receptors with and without the effect by using control groups as the norms.

iii) Statistical regression techniques that try to isolate the influence of a particular effect from that of a number of others.

On establishment of the cause-effect relationship, which is also known as the impact pathway, the different impacts are valued using certain valuation techniques, the details of which are provided in Annexure 3.4. Some of the commonly used techniques are:

- Dose response method: Human capital approach, where the probable loss of productive time and resources, in health care, is calculated.
- Replacement cost: This provides the cost to restore to original state, any product/material/building after it has been damaged by an environmental impact.
- Hedonic method: This determines the value of the environment by the premium an individual is willing to pay for certain environmental non-market goods.
- Travel cost method: Equates an individual's valuation of a particular amenity on the amount and time he/she is willing to spend on travelling to obtain the same.
- Contingent valuation method: This determines a respondent's willingness to pay (WTP) for an environmental amenity or the value of compensation he/she would desire, for a loss or degradation in the environment, through individual questioning.

However, the choice of any particular methodology in case of an environmental cost-benefit analysis is highly contingent on the availability of data, budget constraints and importantly the end use of the results.

Literature overview

The cost-benefit analysis of environment for the power sector specifically, focuses on the *impacts* of different electricity sector activities, along with the fuel cycles, on the environment (air, water, land, forest, bio-diversity etc.,). The control measure aspect of environmental cost is usually addressed in EIA reports generated during initiation of a new project.

The studies that address environmental impacts, generally define different impact pathways for different economic activities (refer Annexure 3.3), which are then valued using valuation techniques. International literature addresses the issue of environmental cost mostly at a macro-economic level. Most studies provide an impact valuation on the economy as a whole by generating stations at different locations. Some studies, on the other hand, look at the impact of only one particular pollutant (e.g., impact of emissions only) at a specific location. However, all studies are generally site– or location-specific and hence cannot be applied in generic terms.

Domestic literature on the subject is limited. One study (WB study 1998) focuses on the impact of electricity sector growth in two states and extrapolates the result on to the rest of India. Another study (Metaplanner Consultancy, 1989) carries out the costing of few representative projects costing with an emphasis on environmental costs. This study addresses the cost of adhering to the environmental norms/guidelines set by the different environmental agencies, while setting up a new power plant (coal, hydro, oil and gas). Other studies on environmental impacts are more general and survey impact valuation techniques or examine the valuation of a particular pathway.

All the studies reviewed in this section might not directly address the objective of this task, but they provide the necessary background and understanding to develop the framework and model required for analysis of the norms, which is the broader objective of the report.

International literature

The first multi-disciplinary bottom-up attempt at collating and analysing the scientific and economic literature applicable to all emissions from electric utilities was the Pace University led study, *The Environmental Cost of Electricity* (1990). There was another, less comprehensive study carried out in 1987 by ECO Northwest. Both identified the significance of the location in determining the magnitude of damage but failed to develop a methodology that would permit a consistent set of location-specific damages to be estimated. The studies also did not capture the fuel life-cycle impact. This life cycle concept was however, incorporated in a later study by Pearce et al. (1990), which in turn ignored the importance of siting criteria.

There have been further studies designed using sophisticated models for estimating air quality, epidemiological and economic impact of emissions not only from generation but also from all other stages of the fuel cycle and the electricity business including extraction, refining, transportation, construction of plants, transmission etc. But all these studies are integrated assessments rather than original research on valuation and assessment methods.

The following are some of the important highlights of the methodologies adopted by the different studies:

a) The studies are primarily based on the damage function approach with the focus on specific site locations.
b) The studies have averaged out the temporal measures and the health functions are linearised.
c) The studies address impact on the whole economy.
d) Mostly a marginal approach, that attempts to estimate incremental damages due to addition of a single power plant, is adopted.
e) Most studies appear to have a trade off between the precision of data and complexity of the analysis carried out.

Some of the important studies conducted by the following bodies are as follows:[a]

Regional Economic Research (1991): This study analyses the damage associated with airborne pollutants. A separate air quality modeling was done for the different air quality basins and also ozone modeling was carried out. The damages are calculated on a project- and site- specific basis. The analysis was limited to generation activities only, hence the full fuel cycle was not addressed at all.

National Economic Research Associates (1993): This study focussed on a specific location, Nevada. The air pollution pathways were calculated for the Las Vegas Valley and Southern Nevada for 1990. Further associated environmental costs were projected for the years 2000 and 2010.

Triangle Economic Research (1995): This study developed the damage per ton estimates for bringing on line, to the North Power System of Minnesota a combination of new coal plant and several natural gas combined- cycle plants in 2006. The study focussed on air emissions and their impact on health, visibility, materials and crops. It modeled the damages at the smallest spatial and temporal level compared to the other studies, using zip code level and estimating damages on an hourly basis. However, it focussed only on generation activities ignoring the associated linkages. The Monte Carlo simulation was used to express uncertainty.

[a] Alan J. Krupnick and Dallas Burtraw, “The Social Cost of Electricity: Do the Numbers Add Up?”, Discussion Paper 96-30, *Resources for the Future*, August 1996. pp 8-9.

Oak Ridge National Laboratories/ Resources for the Future (*Lee et al*. 1995): This study aimed to investigate and develop methods for estimating full fuel cycle external costs. All stages and all pollutants were considered initially, but many pathways had to be eliminated after complex screening procedures. The estimates of damages were developed for two reference environments and six generating technologies. The plants were not generic or representative. This study extensively focuses on estimation of non-environmental externalities. Monte Carlo simulation techniques were used to address uncertainty.

European Commission (1995): The study was designed to estimate the impact of the full fuel cycle in the European context. For most fuel cycles, two reference points and nine fuel cycles were studied. A limited effort was devoted to estimating the non-environmental externalities. Uncertainty was qualitatively discussed and not modeled.

Hagler Bailley and Tellus Institute (1995): The focus of the study was to develop a computer model capable of estimating damages to New York and surrounding states from new and repowered generation plants located anywhere in New York. The scope of the study was similar to the previous study by *Lee et al*., with the exception that less emphasis was placed on non-environmental externalities. Uncertainty was addressed through the simpler analogue of Monte Carlo.

The above studies all address developed nation scenarios. But a study conducted by Asian Development Bank extended the valuation of a power plant situated in New York State to the case of a coal-fired plant in the Philippines. A screening exercise was carried out at the outset to determine the potential impact of plant construction on air, land and water. The screening exercise eliminates them as land and most of the water impacts, as negligible or uncertain and sees those which can be mitigated easily. Thus, impact valuation is in terms of health impact of emission and the values adopted are from the Rowe *et. al* study (1994) as provided in the table below. The final calculation is based on the emission level from the Pagbilao plant in the Philippines and addresses three categories, namely, local (within 30 km), regional (within 80 km) and distant (less than 500 km downwind).

Table 3.2 Application of $ /tonne/person value to Pagbilao project site

Pollutant	Emission rate (tonnes/yr)	Local damage (Quezon province)	Regional damage	Distant damage	Total damage
PM10	1270	$508-$762	$1270-$3810	$381-$762	$2159-$5334
SO2	12700	$1016-$2032	$2540-$5080	$953-$1905	$4509-$9017
No_x	8450	$1014-$1352	$3380-$5070	$634-$1268	$5028-$7690
Total annual		$2538-$4146	$7190-$13960	$1968-$3935	$11696-$22041
Total lifetime					$350880-$661230

Source. *Economic Evaluation of Environmental Impacts – A workbook*, ADB, 1996.
Annual generation of 4600 Gwh
Total Lifetime value is undiscounted value over the project's 30 year life

Some of the thermal discharge mitigation costs are also taken into consideration. The other important impact considered is the impact on global climatic change and material damages. The total lifetime impact value arrived at is 652,410 to 1,312,140 thousand dollars annually.

The limitation of the above study lies in its adopting the emission-based unit value approach from New York State and, hence, may overstate or understate the actual damage cost. Moreover literature claims that impact of emissions on the population of a developed nation is very different from that on a developing country. Moreover, certain impacts are quite project- and region-specific, hence transferring the valuation of one project to another does not necessarily reflect the actual costs incurred. However, the above value can be used as a rough indication as to the extent of environmental cost of the project under consideration.

Homman and Brandon (1995): This study looks at the impact of different pollutants on the environment in the Indian context, but does not refer to any particular economic activity as the source. It classifies the environmental costs into two broad categories: (i) public health impact due to air and water pollution and (ii)the productivity impact due to soil degradation, deforestation etc.

The broad findings of the study of the main impacts can be summarized as follows, with the cost summary provided in Box 1.

Air pollution

Of the 23 cities with more than one million population in India, the ambient air pollution level exceeds the WHO standards in many of them. The rising trend in power consumption has been identified as one of the major components of worsening urban air pollution besides industrialization, increasing vehicles and refuse burning. The primary pollutants identified in terms of health impacts are SO_2, NO_x and lead. The dose-response function has been used to calculate the health impact. The estimate of the health impact has been stated to be on the conservative side. The methodology adopted, has been identified as the reason for this under-estimation. The dose-response function has been primarily evolved for developed nations and the poor standard of health infrastructure in developing countries like India, results in understating of all values required for estimation.

Water pollution

The study classifies the impact of water pollution into two categories, namely the impact on health and increased incremental cost of supply. However, the major polluting sources identified are domestic, industry and agriculture, of which domestic is considered to be most problematic. Moreover, amongst industrial sources, the electricity sector is not counted as a major concern.

BOX 1: **Summary of major environmental costs in India**

Problem	**Impacts on health and or production**	**Low estimate (Million US $)**	**High estimate (Million US $)**
Urban air pollution	Urban health impacts	517	2102
Water pollution (health impact)	Urban and rural health impacts	3076	8344
Water pollution (production impact)	Higher incremental costs for clean water supply	Not estimated	Not estimated
Industrial hazardous waste	Long term health impact e.g.,. cancer	Not estimated	Not estimated
Soil degradation	Loss of agricultural output	1516	2368
Rangeland degradation	Loss of live stock carrying capacity	238	417
Deforestation	Loss of sustainable timber supply	183	244
Coastal and marine resources	Unsustainable harvesting of marine resources	Not estimated	Not estimated
Loss of biodiversity	Loss of use, option and existing value	Not estimated	Not estimated
Tourism	Decline in tourism revenue	142	283
Total cost of degradation		5672	13758
Average cost		9715	

Source. The cost of Inaction, Carter Brandon & Kirsten Hommann, World Bank, 1995.

Land degradation

Land degradation caused by water and wind erosion, salinization, waterlogging, nutrient loss, and compaction or over-grazing is estimated to be extensive in the case of India. The primary costs associated with soil degradation are reduced yields (at constant level of output) and/or downgrading the use of that land to crops of lesser value. There are certain off-site costs involved, which arise due to siltation of reservoirs and changes in the hydrology of watersheds leading to increased flood frequency/severity or reduced water availability during dry seasons.

However, the Homman and Brandon study focuses only on the cost due to reduction in yields, which clearly reflects that the costs are understated. Cost calculation is based on estimation of the production foregone due to degradation of the soil. There is also an alternative valuation method where the cost involved to compensate soil degradation, through additional nutrient inputs, is estimated. However, as the survey indicates, Indian farmers do not invest in nutrient replacement strategies in the medium term, hence the application of the second alternative was restricted.

Deforestation

In India, though the quality of natural forest is on the decline, the total area under forest is increasing due to rapid forestation. This has led to increase in timber produce but a decline in natural forest resources like flora and fauna. Encroachment for agriculture production and population settlement has been identified as the main contributors to the above trend. But part of this encroachment is also directly associated with resettlement issues related to setting up power plants.

The user-cost methodology, which represents foregone future income from exploitation of a resource, is used for valuation of deforestation. The study, however, addresses only the cost incurred due to depletion of commercial timber and does not assign a value to the other economic losses.

Domestic literature

The World Bank study, (1998): This study identifies the polluter pays approach as the basic principle to mitigate any environmental impact of any economic activity. According to this study, there are two ways of implementing the above approach:

1. Through ensuring that any economic activity must comply with the environmental norms/guidelines set for that particular activity. And any case of non-compliance is severely penalised, either through closure of activity or high financial penalties.
2. The other alternative is the use of market-based instruments like tax.

This process of imposing a cost on the project or economic activity, is termed as internalization of the environmental cost, which is the focus of this study.

This study while addressing the environmental issues in the power sector in India, has attempted to implement the above approach to the extent possible by imposing discharge and quality standards on discharges in water and emissions to air, besides internalizing land and rehabilitation costs. The land use aspect is addressed through cost of acquisition and the rehabilitation cost is internalized through economic cost imposed by regulation. In the study, the above issues are discussed for two Indian states, Bihar and Andhra Pradesh under different scenarios, namely, business as usual (low hydro and high hydro scenario), economic reform and, inter-fuel substitution scenarios. The results obtained are then extrapolated on to the whole of India. The analysis of some of the data on the emissions (CO_2, SO_2, NO_X and TSP) for 1997 to 2015, show a steep rise over the years. According to the study, this rapid increase in emissions is not only due to the rise in electricity but also because of the increase in the carbon-intensive mix of generation.

The limitation of the approach applied in the study, is that the environmental cost, accounted in the economic cost, is not necessarily equivalent to the financial cost or the compensation value. Moreover, the study provides the cost to meet different environmental objectives but their comparative merits are not evaluated.

The study by Metaplanners and Management Consultants (1989) is a dated study, but could be considered as the most relevant in terms of providing a framework for determination of cost of compliance. According to the study, most economic activities recognise the importance of the environment, but very few attempt to account for the same for costing purposes. In India, as presented in the study, since the 1980s, different authorities in decision-making capacities, realising the seriousness of the rapid depletion and contamination of natural resources have accommodated the costing of environmental impacts in the decision-making process. Environmental costing has been made mandatory for any project evaluation. This study highlights the different Government procedures that look into environmental costing besides providing a few representative case studies.

The study highlights the different environmental focus of different legislation in India:

A. The National Water Policy (September 1987) has reiterated the urgency and importance of environmental and ecological aspects in water resource development by incorporating the following statements in the policy:

   4.4. There should be an integrated and multi-disciplinary approach to the planning, formulation, clearance and implementation of projects, including catchment treatment and management, environment and ecological aspects, the rehabilitation of affected people and command area development.

   4.6. The planning of projects in hilly areas should take into account the need to provide assured drinking water, possibilities of hydro power development and the proper approach to irrigation in such areas, in the context of physical features and constraints such as steep slopes, rapid run-off and the incidence of soil erosion. The economic evaluation of projects in such areas should take these factors into account.

B. The MoEF circulated consolidated guidelines on EIS preparation and submissions along with the proposal to divert forest areas for non-forest purposes under the Forest (Conservation) Act, 1980 through their letter no. 2-3/86 –FC dated July 31, 1986. The guidelines suggested (a) parameters for valuation of loss of forests, and (b) parameters for valuation of benefits. The assessment of following environmental losses and costs are specifically mentioned:

(i) Loss of values of timber, fuel wood and minor forest produce including loss of livelihood of those dependent on harvest of these commodities;

(ii) Loss of animal husbandry, including loss of fodder;

(iii) Cost of human resettlement;

(iv) Loss of public facilities;

(v) Environmental loss, soil erosion, effect on hydrological cycle, wildlife habitat, micro climate upsetting of ecological balance;

(vi) Oustee suffering;

(vii) Cost of supply of free fuel wood to workers with a view to prevent indiscriminate use of forests, etc.

C. The Planning Commission, the Central Water Commission and the Central Board for Prevention and Control of Water Pollution had also issued detailed guidelines on EIS preparation and submissions along with project reports and estimates. New power projects need to provide the same for approval purposes.

However, according to the study, one needs to also appreciate that there are many factors, which remain difficult or impossible to value. These include, human life, some aspects of human health and properties of the ecosystem, namely diversity of species. These assessments can be carried out to some extent for the economy as a whole, but estimation of the same for an individual project is difficult and hence has not been addressed in the study at all.

The study summarizes the average percentage of cost associated with environmental issues for different technologies as in Table 3.2 below. This value is arrived at on the basis of the cost assessments made by different power projects studied for this report.

Table 3.2 Increase (%) in cost of generation due to inclusion of environmental cost

Sl. No.	Electricity generation sources	% increase in cost
1	Hydro power backed by single purpose dam	20.81

2	**Hydro power backed by multi-purpose Dam**	**17.45**
3	**Coal based thermal power stations**	
	Located in forest land	**11.00**
	Located outside forest	**7.00**
4	**Combined cycle gas-based**	**5.00**

Source. *Study on Cost of Electricity Generation & Environmental Aspect*, Department of Non-Conventional Energy Sources, GOI, 1989

The study also provides representative project analysis for the Indian power sector. However, since for some of the technology, environmental assessment was not compulsory, the study fails to account for the same.

Valuation model/framework

On the basis of the above studies, valuation models and frameworks have been developed in this section. The Indian study provides a framework for analysing a specific project for the different technologies. While international literature provides a basis for developing a model for evaluating the environmental impact on the whole economy.

Environment valuation models

The objective, of the valuation exercises discussed above, is primarily to capture the environmental cost in the decision-making process of setting up plants, besides monitoring the operational norms of the existing plants. The studies have emphasised that to meet a particular electricity demand, the investment options evaluated on the basis of cost minimization, need to include environmental costs too. In this context, some of the energy system planning models, which address environmental issues, adopt four approaches[a]:

(a) Includes the costs of environmental protection as a part of the costs of energy supply and minimises the total cost.

(b) As in (a) above, but also includes certain environmental constraints in the minimization exercise.

(c) As in (a) above and then calculates the environmental impacts in a separate module, comparing the results by varying the restrictions imposed.

(d) Comparing the implications of alternative power-development strategies, without carrying out an optimization exercise.

The models could be considered tools to measure the total or the incremental environmental cost in the future under different scenarios.

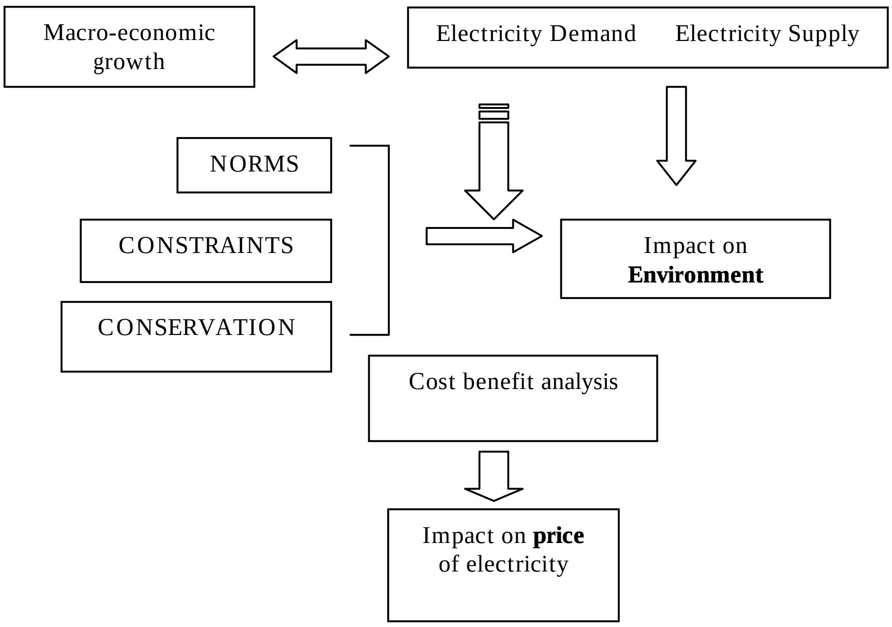
Model 1

One of the models that emerge from integrating the different models in literature is represented in Figure 2. The model provides different outputs depending on the scenarios developed by varying the basic assumptions namely, (i) macro growth rate, (ii) the resulting electricity demand, and (iii) norms, constraints and conservation strategies. A multi-criteria approach is applied, where environmental attributes are evaluated by calculating a weighted average of the actual values of the attributes. The controversial and crucial issue here, is the determination of

[a] Markandya Anil, *Environmental Costs and Power Systems Planning*, International Institute for Environment and Development, London Environmental Economics Centre, London, May 1990, pp.

weights. A number of suggestions for weight determination, such as the questionnaire approach, past trends etc., exist, but most of them suffer from a qualitative bias.

Figure 2: Electricity impact model

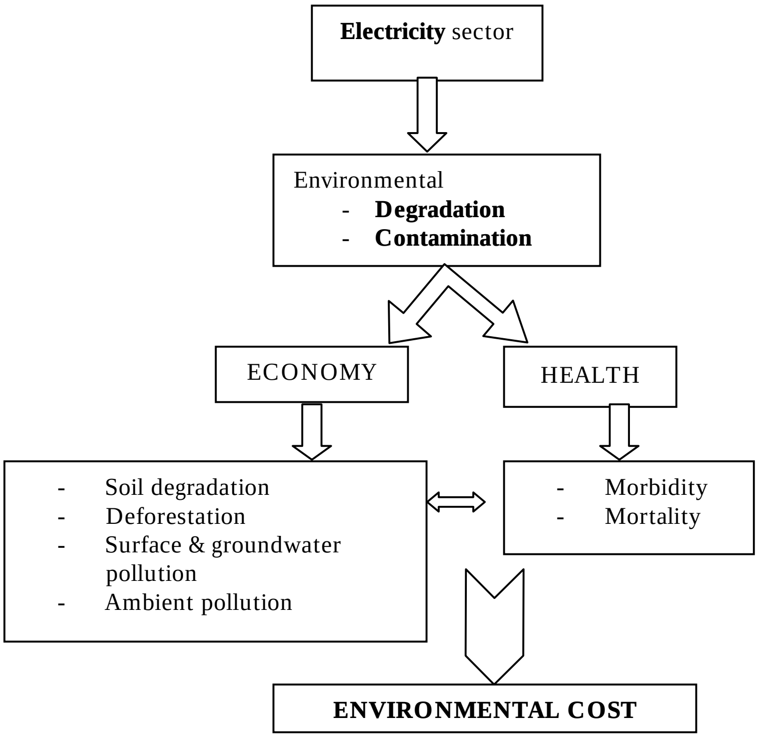


The above is a futuristic model, which could be used to provide an optimal direction on system planning to the economy, and the electricity sector specifically.

Model 2

The Brandon and Homman (1995) study discussed above, provides a framework for assessing the economy-wide cost of environmental degradation. This study, however, addresses all economic activities and is not specific to the power sector. The basic framework can be adapted for the electricity sector as depicted in Figure 3 below.

Figure 3: Model for assessing environmental degradation



Drawbacks of the models

In principle, one might state that the impact models are useful tools of analysis to show some of the environmental effects of a particular expansion plan, but the relevance of a generic model is still debatable. Moreover, most of the models consider the demand of electricity as given, focussing only on the supply side and ignoring the impact of price and other demand management instruments on the demand–supply balance. With reference to environmental issues, this might prove to be crucial, as energy conservation measures are generally benign with respect to the environment. According to the studies, the gains in this context can be substantial for developing countries where demand management can be achieved at low costs compared to the costs of increasing energy supply. Thus, specifically in the case of developing nations like India, conservation measures need to be adequately addressed.

Environment valuation frameworks

The two models discussed above provide an overall framework for addressing the issue of environmental cost assessment. However, in both the models the actual determination of the environmental cost requires a separate valuation framework, which will be addressed in this section.

In order to assess the environmental cost of an electricity project, the different impacts of the same needs to be determined. Annexure 3.2 (v) provides the environmental impacts as well as the control measures for the different electricity generation technology as well as coal mining activity. Annexure 3.3 further details the pathways of some of the impacts addressed in Annexure 3.1. The impacts are then to be valued with the help of the various valuation techniques (Annexure 3.4) to arrive at an environmental cost. Annexure 3.2(v) provides a table that indicates the applicability of the different techniques to assess the different environmental impacts identified for the projects in Annexure 3.2 (i-iv).

This section provides brief highlights and a description of the framework applicable for environmental analysis of different generation technologies. The same would be used for analysis of the norms in the subsequent chapter along with sensitivity analysis.

Hydro Projects

Hydro projects can be categorized into three broad categories with respect to location and type of plant, namely, (i) backed by reservoirs and located either at the toe of the dam or on the power channel taking off from the dam; (ii) run-of-the river plant with or without some pondage; and (iii) small head power houses on irrigation canals. However, of all the three types, projects backed by reservoirs cause maximum impact to the natural systems and environmental quality, primarily due to the need to erect a dam to impound the water. Some of the major impacts are enlisted in Table 3.3 below.

Table 3.3 Impact of hydro power projects

A	Catchment Area:	Effect on river regime upstream
		Soil erosion and degradation of land necessitating integrated soil and moisture conservation measures in the agricultural area, waste-lands, etc.
		Conservation and improvement of existing natural forests and plantations over new areas as an integrated package along with soil conservation
		Wild life protection
B	Reservoir	Mines and minerals – submergence
		Clearance of forest
		Fisheries and other aquatic habitats
		Wild life
		Flora & Fauna
		Cultural and archaeological places
		Draw-down slip
		Water quality
		Water weeds
		Resettlement of oustees
		Fore shore cultivation
		Health hazards
C	Dam	Induced seismicity
		Dam safety measures
		Operating arrangements – gated and ungated spillways
		Fish migration arrangements
		Flushing doses for maintenance of river regime
		Provision for releases to maintin the minimum and required supplies from the river
		Provision for releases required for pollution control

Source. *Study on Cost of Electricity Generation & Environmental Aspect*, Department of Non-Conventional Energy Sources, GOI, 1989

In the Indian context, there are very few defined control measures to arrest these impacts. Detailed norms or guidelines have only been defined for forest resources and certain parameters for handling displacement issues.

The MoEF circulated guidelines for submission of proposal for diversion of forest area to non-forest activity under the Forest (Conservation) Act, 1980 vide letter no. 2-3/86-FC dated July 31, 1986. There were suggestions for (a) parameters for evaluation of loss of forests; and (b) parameters for evaluation of benefit, notwithstanding loss of forest. The parameters thus defined are as follows:

1.	Loss of value of timber, fuelwood and minor forest produce on an annual basis, including loss of man	To be quantified and expressed in monetary terms

	hours per annum of people who derived livelihood and wages from the harvest of these commodities.	
2.	Loss of animal husbandry productivity including loss of fodder.	-do-
3.	Cost of human resettlement	-do-
4.	Loss of public facilities and administrative infrastructure	-do-
5.	Environmental losses: (Soil erosion, wildlife habitat, hydrological cycle, etc.)	Technical judgement is necessary to determine the monetary value, but, as a thumb rule the environmental loss of one hectare of fully stocked forest (density 1.0) would be taken as Rs.126.74 lakhs to accrue over 50 years, with the value decreasing proportionately with a decrease in density. Moreover, the value will also change with a change in the bank rate, the change being proportionate to the percentage increase in bank rate.

Besides, the following cost/loss needs to be considered too, according to the guidelines, in order to obtain a balanced value of the benefits derived from the project in terms of production, economy, employment, etc. The costs to be considered are as follows:

i) Cost of acquisition of facilities on forest and non-forest land, wherever feasible;

ii) Loss of agricultural and animal husbandry production due to diversion of forest land;

iii) Cost of rehabilitating the displaced community, which is different from the compensation package provided to them for displacement;

iv) Cost of supply of free fuelwood to workers residing in or near the forest area during the period of construction.

All the costs highlighted above are project-specific in nature and, hence, vary depending not only on the project size but also the location. Most of the above valuations are direct monetary valuations on the basis of the guidelines. However, to obtain the total economic value of the environmental cost, valuation of the impact pathway needs to be considered too.

Coal-based thermal projects

To develop a comprehensive environmental cost analysis for coal-based power projects, the spatially separate but backward linked activity of coal mining has to be taken into consideration too. To obtain a total cost, all activities, from mining coal through delivering the energy at load centres, are to be included. The four principle elements of this system are (i) coal mining, (ii) coal preparation, (iii) coal or energy transport and (iv) generation through coal combustion. The coal preparation activity usually takes place near or at the coal mine, but at times an additional step may be included at the power plant.

Since the energy to be met at the load centre is a pre-determined estimated quantum, the task thus is to minimize the environmental cost associated with coal mining, preparation, transport, combustion and electricity transmission. At the same time, the operations need to comply with the environmental guidelines/norms/standards specified for land, water and air by the environmental agencies.

The principal residuals generated in a coal-based power plant are:[a]

1. Acid mine drainage from underground mining;
2. Overburden from strip mining;
3. Suspended solids in the washed water of the coal preparation plant;
4. Particulate matter from the air-flow cleaners and thermal drier at coal preparation plant;
5. Particulate matter in power plant gaseous emissions;
6. Sulphur oxides in power plant gaseous emissions;
7. Oxides of nitrogen in power plant gaseous emissions;
8. Water borne heat from the power plant.

[a] Metaplanners and Management Consultants, *Study on Cost of Electricity Generation & Environmental Aspect*, Department of Non-Conventional Energy Sources, GOI, 1989, pp 23.

The coal handling and transportation aspects of coal-based power plants were ignored as their environmental impact was considered to be quite negligible. But with the increase in coal-based power generation, the proportionate impact would be on the rise. For a 100 MW thermal plant, approximately 5000 hectare of coal mining is required, 1200 hectare of structures and roads, 200 hectare for disposal of combustion wastes and additional lands for right of way of transmission lines are required. All this involves displacement of population, transfer of forest lands, public inconvenience and ecological disturbance.

Moreover, impacts due to coal transportation include air pollution resulting from coal dust and noise pollution near the tracks, besides increase in loads and traffic density. Another serious environmental problem is caused at the preparation of plants, with respect to coal-slurry pipelines. These require water at both the ends i.e., at the coal preparation end and slurry dewatering plants. At the dewatering facility, the effluent also contains coal leachates and the dewatering coal being of fine size, requires protection from rain, wind, oxidation and self-ignition to avoid further impacts. Table 3.4 below, delineates the impacts associated with different stages of the coal life cycle.

Table 3.4 Impacts on environment at different stages in coal life cycle

		Impacts Mediated Through		
Sl.No.	**Stages in coal life cycle**	**Land**	**Air**	**Water**
1.	**Extraction**	**Deforestation, disturbed land, soil erosion, reclamation.**	**Coal dust, occupational hazards**	**Chemical mine drainage, siltation**
2.	**Transport & Processing**	**Land requirements for roads and rails, creating water sources**	**Coal dust, noise, diesel exhaust, damage to public roads and accidents**	**Effluent of washeries**
3.	**Combustion**	**Combustion products fall-out including acid rain, reduction in plant productivity**	**Particulates (trace elements, radio nuclides, polycyclic organic matter) and gases (SO_2, NO_x, CO_2).**	**Thermal discharge, combustion products fall-out including acid rain, reduction in aquatic productivity**

4.	Transmission	Land-requirements reduction of tree cover	Corona discharge (generation of NO_x and O_3 – important in the generation of smog and reduction of visibility	-
5.	Ash disposal	Land required, Deforestation.	-	Possibility of leachates especially toxic trace and radio nuclides.

In case of coal-based plants, the environment agencies have more detailed norms and guidelines than for hydro projects. Even the coal mining has certain defined control measures. The stability and control measures are detailed in the following tables.

Table 3.5 Environment stability measures in coal mining and power houses

Measures on CHP	Dust suppression Dust extraction Liner
Dust suppression on roads	Metalled roads Metalled haul roads Sprinklers, etc.
Other social measures	Parks/abroriculture Environmental control measures in township Land reclamation Afforestation Rehabilitation of ousters
Control of water pollution	Pumping of ash slurry for ash slurry pump house in the plants to the ash disposal area located at low level with embankment constructed around Biological treatment of domestic effluents Treatment of trade effluents.

Table 3.6 Air pollution effects associated with coal use, and possible control measures

Effects	Control
Particulars (TSP) Act synergistically with other gasses,	Electrostatic precipitation etc.

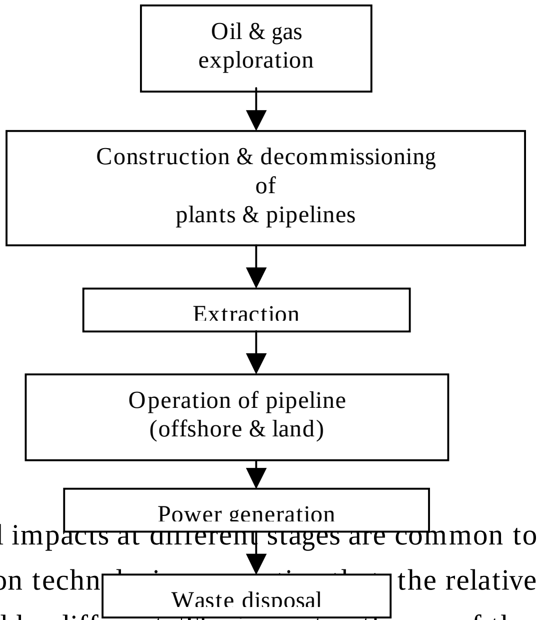
aggravate asthma, emphysema and cardiovascular diseases, cough, chest discomfort, reduce visibility, corrode steel	
Sulphur oxides (SOx) **Increased mortality & mobidity, bronchitis, emphysema, chronic plant injury, excessive leaf shedding, reduced productivity of plants and trees**	**Flue gas desulphurization systems; dilution by using tall stacks*; using low sulphur (washed) coal** ***The stack heights prescribed are:** **For 500 MW plant and more - 275 m** **For less than 500 MW - 220 m**
Nitrogen oxides (NOx) **Associated with emphysema, lung diseases, chronic nephritis, factor in causation of smog, yellow white clothes, fade synthetic fibres**	**By modification of combustion processes, a reduction of 35 – 40% in emissions achievable without loss of thermal efficiency**
Carbon monoxide (CO) **Impairment of mental functions, diminished visual perception, dexterity, learning ability, tolerance for exercise**	**Largely controlled by having efficient and complete combustion**
Hydrocarbons (HCs) **Shedding tears, coughing, sneezing, headaches, nervous weakness, bronchitis, chronic exposures may lead to cancer, acts synergistically with NO_x to form photochemical oxidants and smog**	**Same as for carbon monoxide.**
Carbon dioxide (CO_2) **Could have global effects through the greenhouse effect which could change local rainfall and temperature. The magnitude and timing are not known with certainty**	**Prohibitively expensive to control CO2 emissions, may require curtailment of fossil fuel combustion**
Trace elements **Metals are preferably concentrated in the smallest respirable particles, which are not removed by precipitators. Effects depend upon the metal**	**Use of coal low in trace elements**
Radio nuclides **(Radium Thorium Radon)** **Mutagenic, carcinogenic**	**Isolation of humans from fly-ash exposure.**
Polycyclic organic matter (POM) **Most important constitutent, Benzo (a) Pyrene, BaP, is highly carcinogenic**	**Same as for CO**
Coal dust **Pneumoconiosis (Black lung disease)**	**Improved ventilation, dust suppression by water sprinklers**
Noise **Hearing loss, psychological problems**	**Better equipment design, isolation of workers from noise, use of protective earmuffs**

Since the Government has made EIS mandatory, the project cost calculated for thermal project includes environmental related cost. The costs relate to the control measures installed to adhere to the respective environmental norms. However, it ignores the fuel cycle impacts.

Oil and gas-based plants

International literature on environmental impacts has addressed the oil and gas-based power plants, but in India, these plants have not received adequate emphasis. The fuel cycle for these plants is as depicted in Figure 4 below.

Figure 4: Oil & Gas fuel cycle



The environmental impacts at different stages are common to some of the above electricty generation techn[illegible] the relative importance of some of the stages would be different. The impact pathways of the different pollutants are presented in Annexure 3.3. And the primary and secondary atmospheric pollutants from the oil and gas cycle of power generation and their impacts are listed in the Table 3.7 below.

Table 3.7 Primary and secondary pollutants

Primary (emitted)	Secondary	Impacts
CO_2	**-**	**Global warming**
CH_4	**O_3**	**Photo-oxidants**
		Global warming
$N0_2$	**-**	**Global warming**
SO_2	**Sulphate aerosol**	**Acid deposition**
		SO_2 concentration – health, biodiveristy, crops etc.
NO	**NO_2**	**Acid deposition**
	Nitrate aerosol	**Photo –oxidant**

	O_3	**N fertilization** **NO_2 concentration** Global warming

Problem areas, issues and concerns

The Indian power sector is undergoing the initial years of reform, which is expected to have a profound implication for environmental management. Hence, academicians and technocrats often identify this transition phase as critical to determine how best to take advantage of the opportunities it presents to protect the environment and avert threats to public health.

Currently, 70 per cent of India's electricity production is dependent on the coal reserves of the country. And the trend has been an increasing thermal: hydro mix. Thus, without a proper calculated mitigation strategy, the environmental impact could be critical for the nation. Hence the environmental cost calculation of each project, along with some sensitivity analysis incorporating more stringent norms, is a necessary exercise.

It appears pertinent to mention here that according to Metaplanners and Management Consultants study for India, none of the thermal power plants, not even in those located in the Singrauli Power Complex, have a provision for flue gas desulphurisation (FGD). It is argued that, since Indian coal has generally a very low sulphur content, it is enough to provide chimneys of heights prescribed by the CPCB. This needs to be reviewed in view of high concentration of mining, thermal power generation and industrial activities in and around Dhanbad and Singrauli. Here, regional approaches rather than a project-by-project approach is called for. If FGD is required and provided, the overall cost of the plant would go up by 15 to 20 per cent.

Though steps and initiatives have been taken as evident from the above section, there are still certain lacunae and problems, which need to be addressed. There are two aspects of the problem, firstly deficiencies in the valuation technique and secondly policy-level deficiencies.

Deficiencies in Present Valuation System:

Land

The environmental impact on land for development of a power project usually only accounts for rehabilitation cost and afforestation package. Recently, the development of a green belt surrounding the plant has been made compulsory. However, the issue of submergence of minerals and forests, especially in case of hydro power has not been addressed adequately.

Water

All thermal power projects require large quantities of water for cooling and other purposes. In most cases, such supplies are drawn from existing reservoirs, or dams and reservoirs are specifically constructed to cater to the need of the plant. In case of the former, the plants access the water on payment of a nominal cess. The thermal power project should either share the value of environmental losses, and the cost of environmental stability measures required for the dam or carry out separate environmental costing for the exclusive dams, constructed by them. Besides, ground water exploitation takes place too – for which neither is appropriate costing done, nor any cess levied. Thus, the environmental impact of ground water remains unaccounted for.

Again, due to low efficiencies of thermal power plants, a large amount of heat is condensed through heat plant condensors by circulating cooling water. The heated effluent leaving the condensors is often disposed off economically, (from the point of view of the plant) by discharging it to a nearby natural body of water such as a river, lake, or coastal waters. This causes significant impacts on the hydrologic environment, which is often not accounted for in the costing exercise.

Thermal power generation thus causes two kinds of impacts on water resources of an area – first, it places heavy demands on water supplies to meet the cooling water requirements, and second, it causes thermal pollution of natural water systems due to the addition of waste heat. Both the effects need to be considered in the valuation process.

Transmission Lines HV and EHV

The normal transmission voltage used in India is 132 kV, 220 kV and 400 kV. The right of way requirement for transmission lines is given in Table 3.8 (Balmukund Das, 1985).

Table 3.8 Transmission lines – right of wayS.

No.	Voltage in kV	Width in metres
1.	132	32
2.	220	36
3.	400	52

For about 100 km length of 400 kV transmission line, an area of about 520 ha is required. Assuming 50 per cent of this forest land 25 per cent as cultivable land, the environmental losses and capital cost of environmental control measures will be more than a crore. These are seldom provided in the cost estimates. Now that the

MoEF has made compensatory afforestation obligatory for transmission lines also, these costs can no longer be ignored. It is also to be noted that a vast amount of vegetation is cleared every year and, hence, compensatory plantation must be undertaken in nearby areas to maintain the ecology, which has associated costs too and is generally unaccounted for.

Then, there are the problems of (a) formation of corona and (b) formation of ozone. Besides, recent studies have observed a high incidence of cancer amongst residents near high-tension wires. These impacts might occur over substantial periods of time through regular exposure, nevertheless one needs to be forewarned of the same. All these issues are neither valued nor addressed in project evaluations.

Deficiencies in the policies

Though the country is moving towards reforms, Government policy still maintains certain fuel prices at artificial levels, with obvious harmful consequences on the environment. The rail freight for coal, though high, (as it cross subsidises food grains and passenger transport) is comparatively lower than the duty levied on imported coal. Hence the poor quality fuel (including transportation cost) when compared to better quality-imported coal is much cheaper. This encourages use of domestic fuel. The consequence of such a pricing policy is as follows:

- Indian coal is preferred as a fuel for power generation over other fuels with low ash content;
- Distorted prices for transport, affect choice between pit-head and load centre plants, shifting the location of environmental impacts;
- Demand is maintained at an artificially high level.

Besides, ideally environmental impacts should be internalized in the cost mechanism as per the polluters pay principle. But this requires rules set by the environmental management agencies to be both adequate and enforced. The emission target levels need to be stringent and, in case of non-compliance, the consequences significant. Moreover, market-based instruments, that alter the incentive and disincentives faced by the polluters, need to be such that the society is benefited. But the success of such a market mechanism requires the establishment of a suitable legislative and regulatory framework for administering the same.

Annexure 3.1

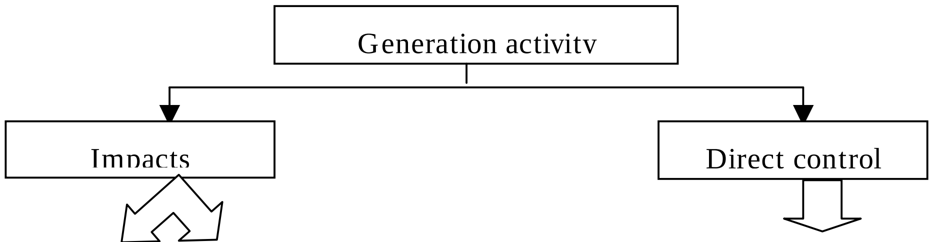
Environmental impacts of energy development

Energy sources	Air	Water (surface, underground/inland and marine)	Land and soils	Biodiversity	Others : Solid waste, risks, human health, noise, visual….
Hydropower	Micro-climatic effects	Effect on hydrological cycles Water quality and resources	Land irreversibly flooded Landslide risks	Rivers wildlife habitat of Forest land/life Change in ecosystems Fish migration affected	Visual impacts Risks of dam rupture Health effects Resettlement issues
Others : Biomass, geothermal wind and solar energies	Biomass combustion: air pollution, particulates Geothermal: air pollution	Biomass conversion: water pollution, water availability Geothermal: water pollution	Land use for energy plantations Land requirement of solar energy	Biomass: ecosystem disruption by energy plantations	Noise of wind generators Visual impact of wind generators Biomass risk to workers Photovoltaic toxic pollution when decommissioning
Electricity generation from fossil fuels (excluding nuclear power)	SO_2, NO_2, CO, CO_2, HC, trace elements, particulates, radio nuclides Long-range transport and decomposition of pollutants Climatic impact of cooling towers	Water availability Thermal releases	Land requirement	Secondary effects on water, air and land	Visual impact of cooling towers and power lines Solid wastes Ash disposal Noise
Extraction effect	Dust pollution	Mine liquid waste disposal	Land subsidence		Noise pollution Accidents

Transmission & Distribution	Land use issue	Visual effect Aesthetic effect

Annexure 3.2

i) Thermal power plant



Air

	Indirect	Direct
SO_x	Health: - Mortality - Morbidity	
No_x	Material corrosion Loss of crop yield	
$CO/HC/CO_2$	Acid rains	
Particulate	Smog	

Installation/control method
FGD Stack heights Low sulphur coal
Modification of combustion process
Efficient & controlled combustion
ESP

Water

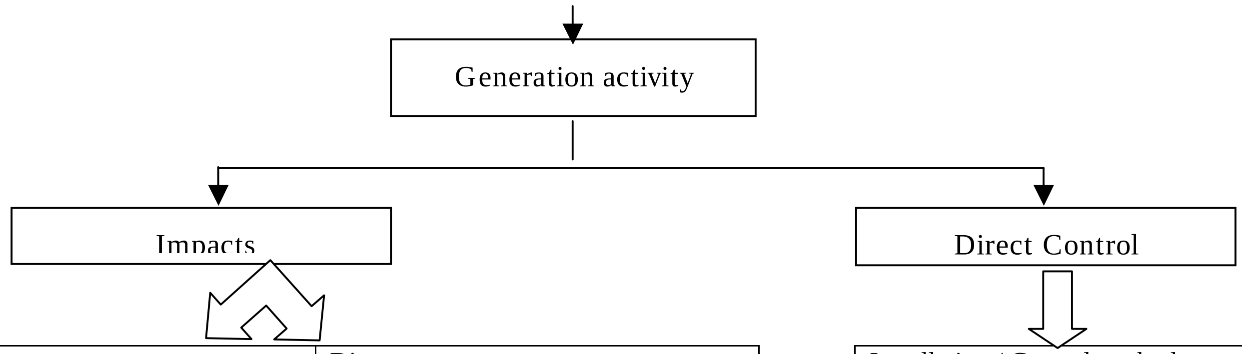
Local discharge	Marine life	
Ash disposal / slurry	Land/soil loss	
Thermal release	Marine life	

Treatment of effluents
Ash disposal measures
Monitoring equipment

Land/Forest

Land requirement	Suffering to oustees Plant productivity Soil erosion Upsetting ecological balance	Loss of timber & forest produce Loss of animal husbandry/fodder Loss of public facilities		Resettlement Afforestation
Deforestation				
Others				
Noise	Hearing loss Psychological problem			
Visual effect	Aesthetic loss			Landscaping

(ii) Hydel power plants



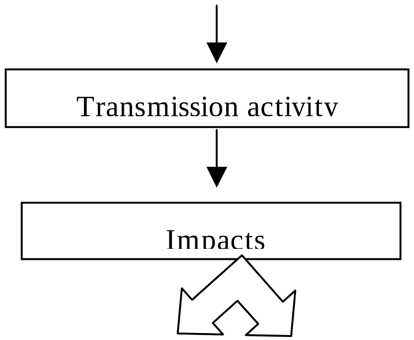
Water

	Indirect	Direct	Installation / Control method
Water quality	Marine life		
Siltation	Risk of flood (health)		
Bank & bed erosion	Soil productivity Land slide – accidents Health impact		Slope & landslide protection

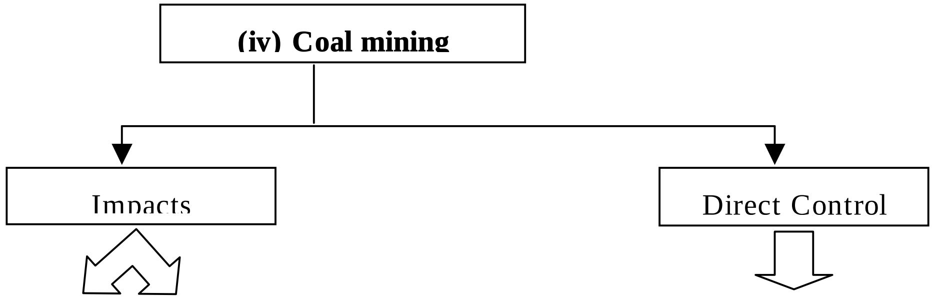
Land/Forest

Land degradation & submergence	Suffering to oustees Agriculture output loss	Agriculture land loss	Resettlement
Deforestation	Plant productivity Soil erosion Upsetting ecological balance	Loss of timber & forest produce Loss of animal husbandry/fodder Loss of public facilities	Afforestation
Mines & minerals submergence		Loss of mineral	
Catchment area	Risk of flood Health hazard		Treatment & development

(iii) Electricity business



	Indirect	Direct
Corona discharge	Radio interference Health	
Land requirement **Deforestation**	Agricultural land loss Plant productivity Soil erosion Upsetting ecological balance	Loss of timber & forest produce Loss of animal husbandry/fodder Loss of public facilities
Visual effect	Aesthetic loss	



	Indirect	Direct	Installation/Control Methods
Air			
Coal dust	Health -do-		Dust control in aux. CHP Water sprinklers for dust suppression Separate water tank
Water			
Chemical mine drainage	Marine life Ag o/p		
Siltation	Flood Marine life		
Effluent of washeries	Marine life Ag o/p		
Land/ Forest			
Transport : - **land requirement**	Accidents	Damage on roads	Metalled haul road
Mining: - **land requirement** - **deforestation**	Suffering to oustees Plant productivity Soil erosion Upsetting ecological balance	Agriculture land loss Loss of timber & forest produce Loss of animal husbandry/fodder Loss of public facilities	**Resettlement** **Afforestation**
Others			
Noise	As above		
Visual	As above		

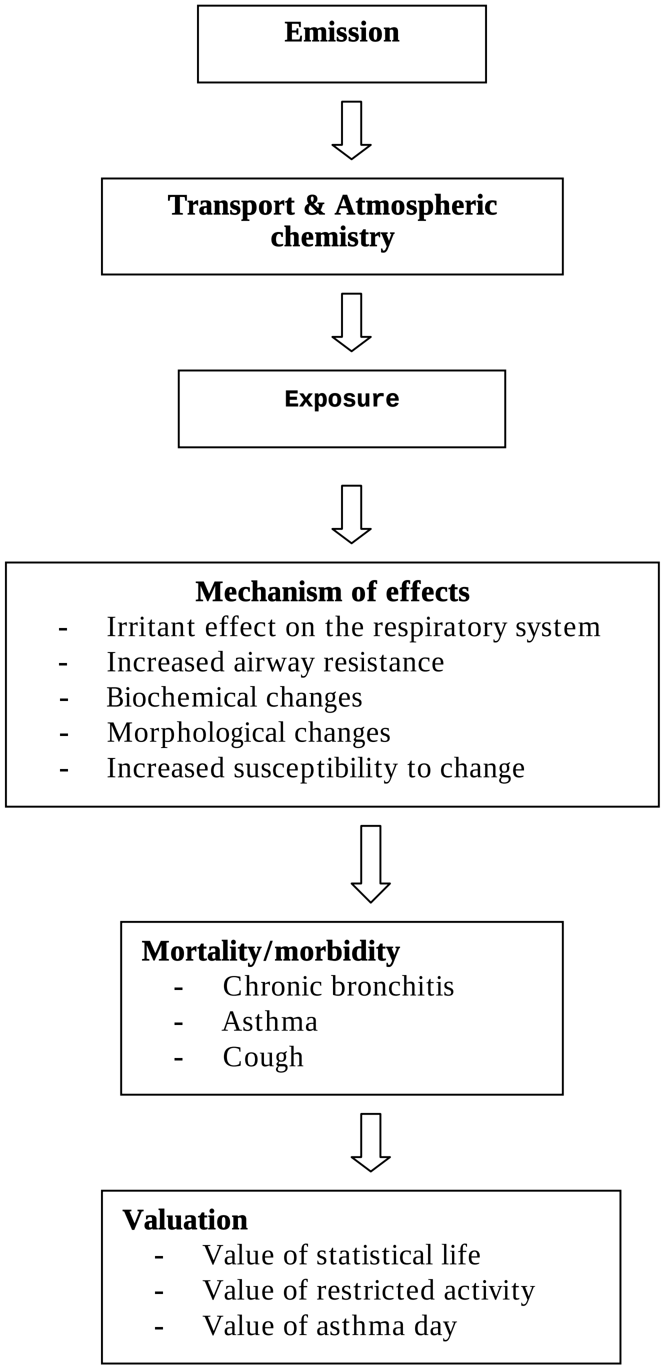
(v) Valuation of the impacts

Impacts/ valuation methodology	AC	BL						
		RC	PE	HC	HM		TCM	CVM
					PV	WD		
Health: - **Mortality** - **Morbidity**								
Material corrosion								
Acid Rain								
Smog								
Marine life								
Land/soil loss								
Plant productivity								
Soil erosion								
Soil productivity								
Loss of crop yield								
Loss of forest product								
Habitat loss								
Biodiversity loss								
Hearing loss								
Psychological problem								
Risk of flood (health)								
Land slide – accidents								
Accidents								
Aesthetic loss								
Radio interference								

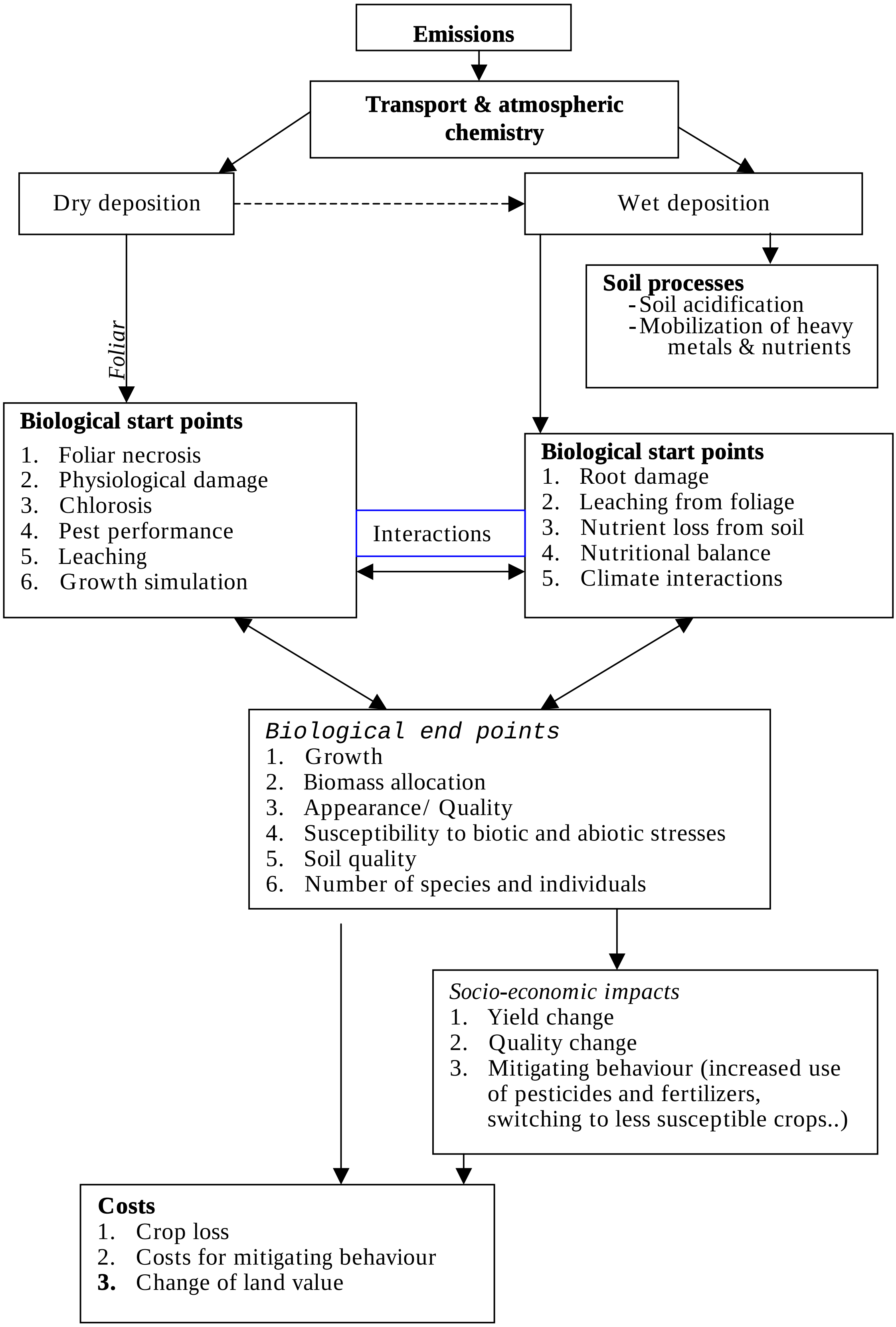
Note. PL: Physical Linkage Method; AC: Abatement Cost Method; BL: Behavioural Linkage Method; RC: Replacement Cost; PE: Preventive Expenditure; HC: Human Capital Approach; HM: Hedonic Methods; PV: Property Value; WD: Wage Differential; TCM: Travel Cost Method; CVM: Contingent Valuation Method;

Annexure 3.3

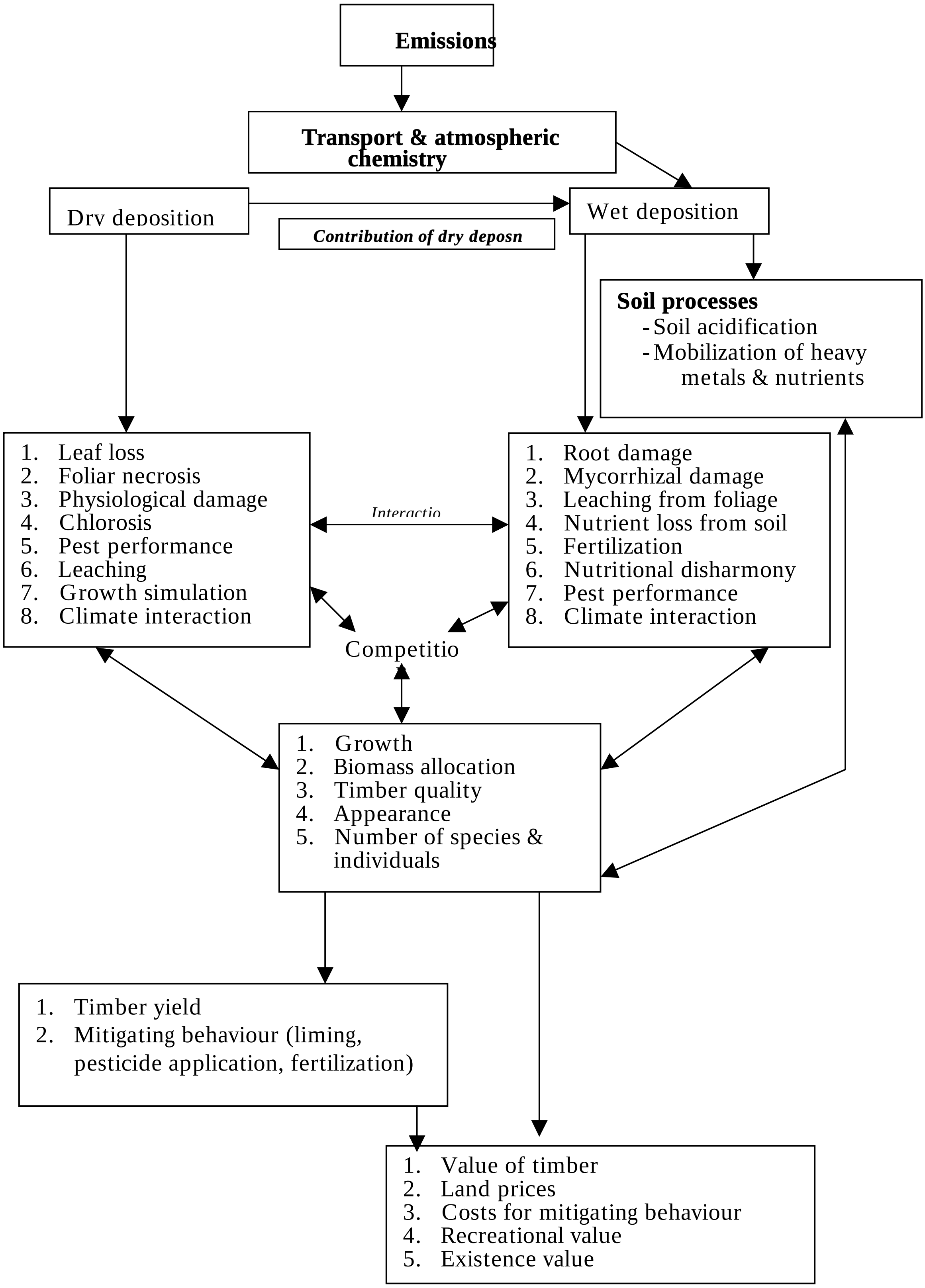
(i) The air pollution – human health impact pathway



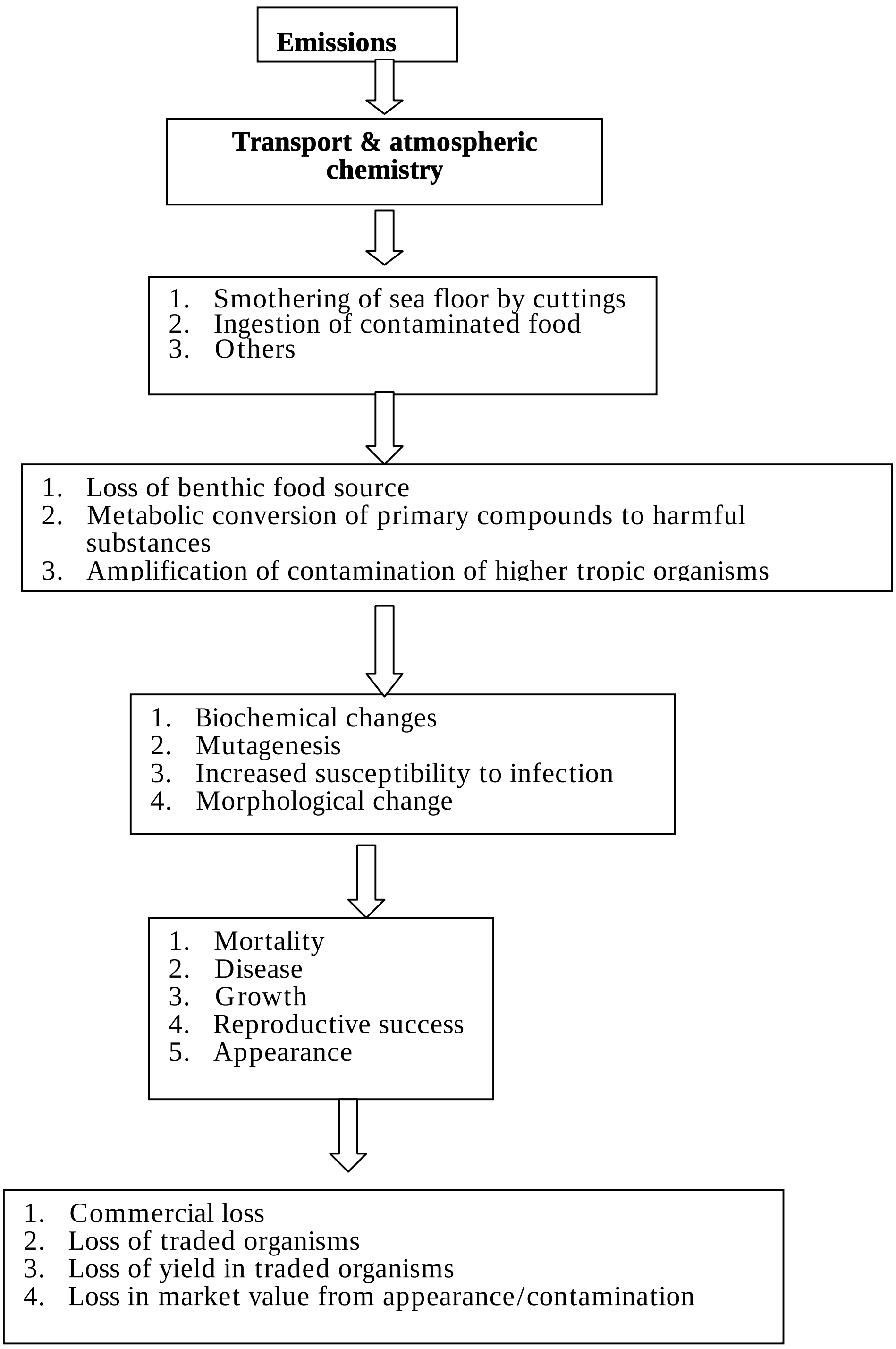
(ii) Impact pathway for effects of acidic pollutant and photo-oxidants on crops



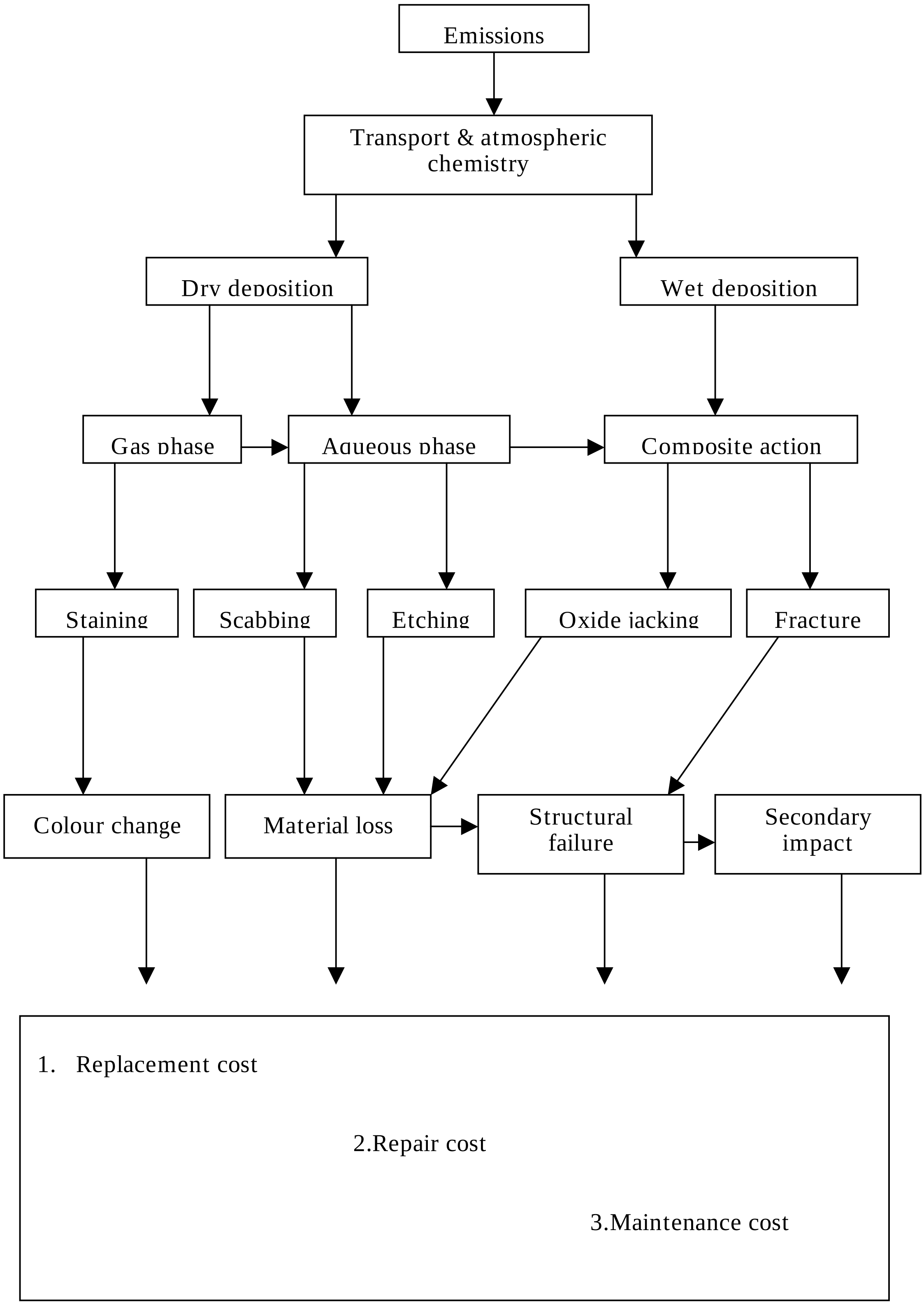
(iii) Detailed impact pathway for summary of full range of effects of photo-oxidants and acidic deposition on forests



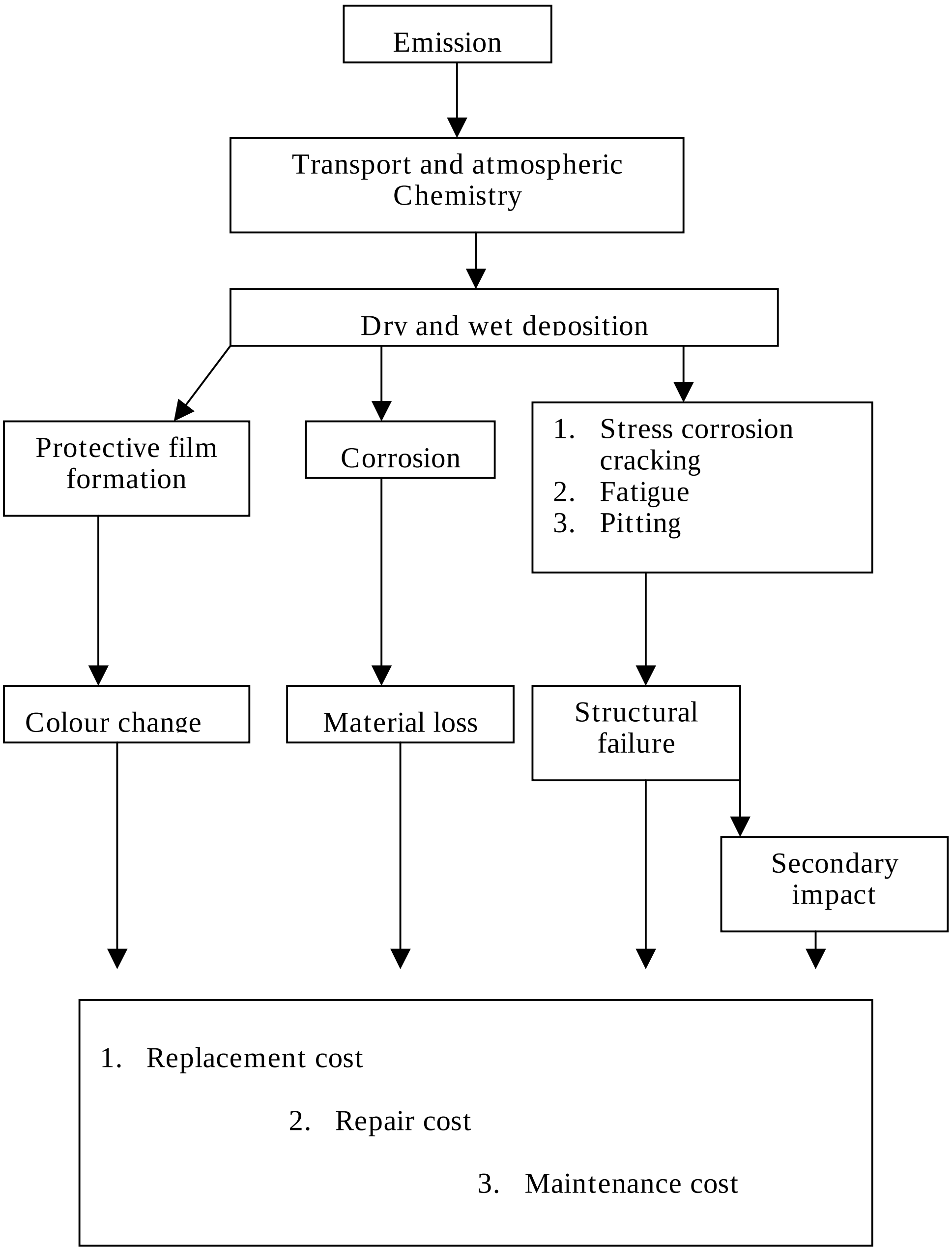
(iv) Impact pathway for the effects of contaminants on organisms in the marine environment



(v) Impact pathway for the effects of acidic deposition on stone



(vi) Impact pathway for the effects of acidic deposition on metals



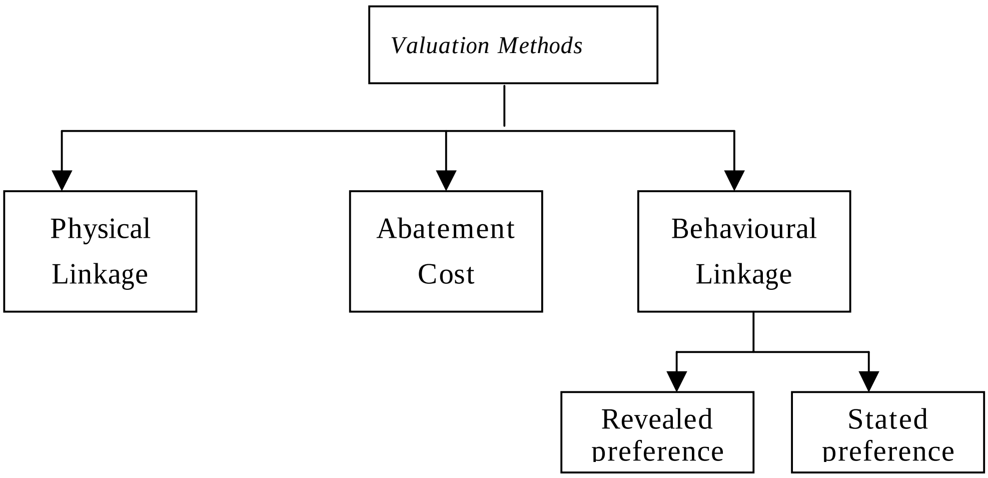
Annexure 3.4

Economic valuation methodology

The valuation process helps prioritise decision regarding resource allocation to improve environment quality. However, since market does not generate true prices for the resources, there is a tendency to operate at sub-optimal welfare level. With the help of economic valuation, true prices can be better reflected, hence leading to welfare optimisation due to decision making through informed choice.

For simplicity of explanation and discussion the valuation methods can be classified under three categories (Figure 1) as follows:

Figure 1: Valuation methods



a) In the *Physical Linkage methods* the loss in production, health or income is assessed in terms of financial transaction after the causal relationship as per the first step of valuation process is established. This approach is also known as the damage cost or **effect on production approach** (EOP) or **dose-response method** (DR method) (Figure 3). The relationships can in principle be objectively determined based upon scientific observations (Shin & others, 1993) hence is termed scientific by some.

The procedure for estimating health and productivity effects involves three subsequent steps. The first is to determine the effect of change in exposure to deteriorating environment, measured through **mortality or morbidity rate**. The second step involves prediction of the change in mortality and morbidity rates based on the above-established relationship. The third step is the derivation of monetary measure. Numerous academicians have carried out studies on the environmental mortality and morbidity effects namely, Lave & Seskin (1977), Ostro (1983, 1987), Krupnick and others (1990) etc. The values arrived at in these studies on different environmental impacts like that of sulphates, particulate pollution, lie within a band or range value for the different studies.

Drawbacks of the method

An important factor that needs to be discounted in the estimation methods is the presence of any underlying trend or influence of exogenous factors. The impacts or effects attributable solely to the cause under observation have to be isolated and evaluated.

However, one needs to be cautious while duplicating these studies for developing countries. These countries have along with the rising pollution level, a rise in the longevity and health status due to improved facilities. Thus one needs to account for the same while measuring the impacts. Moreover, the causal relationships already established are mostly applicable to developed economies, hence need to be adapted to the environment of developing economies. And since certain markets are absent or under-developed in largely subsistence economy, roundabout valuation methods need to be used or alternatively one needs to use strong assumptions about comparable products.

The valuation techniques

However, specifically for valuation of health impacts, which is widely discussed in the literature on valuation of environment, two measures are used, the **cost of illness approach** (COI) and the **Human Capital approach** (HC).

The **COI approach** is a simple measurement of environment damage cost in terms of direct outlays for treatment of illnesses (cost of medicine, expenses on physicians and hospital care) and indirect output losses due to illness measured by social cost of lost earning (Rezeler 1993). This method does not consider the averting behaviour of individuals. Moreover the value of personal pain, suffering and associated inconvenience are also not taken into consideration. And the measure also is an underestimate, since quite a few of the individuals affected by diseases do not have access or the means to proper healthcare, specially in developing countries. Moreover the entire health care system is highly subsidised.

The **HC approach** on the other hand treats individuals as units of economic capital and their earnings as returns on investments. The focus here is on the impact on human health of bad environmental conditions and the effect the same has on the individual's and society's productive potential. The HC approach is facilitated by the following conditions: (i) if the direct cause and effect relationship can be established; (ii) the illness is of limited duration and does not threaten life or has serious long-term effects; (iii) the economic value of lost productive time is calculable and the cost of health care known.

The basic technique requires identification of the feature in the environment, which causes illness and thereafter determining the precise relationship with the incidence of disease. Then the task is to assess the population size at risk and calculate the probable loss of productive time and resources in health care. The final step involves economic valuation of the time and resources taken up by the illness.

The problems of this technique are that the causal relationships are not clearly defined and are uncertain over important areas. In a typical situation, there are a number of causative factors and hence isolating one factor becomes quite difficult. Moreover HC does not do justice to non-productive workers or workers at the end of the human life-cycle. It also does not take into consideration WTP to avoid illness. The problems are further severe in most developing countries as

(i) the medical data is unsatisfactory

(ii) the life expectancy, health condition and availability of medical resources are also quite poor

(iii) some of the chronic and debilitating illness prevalent here, with long term effects on productivity and life expectancy cannot be easily valued.

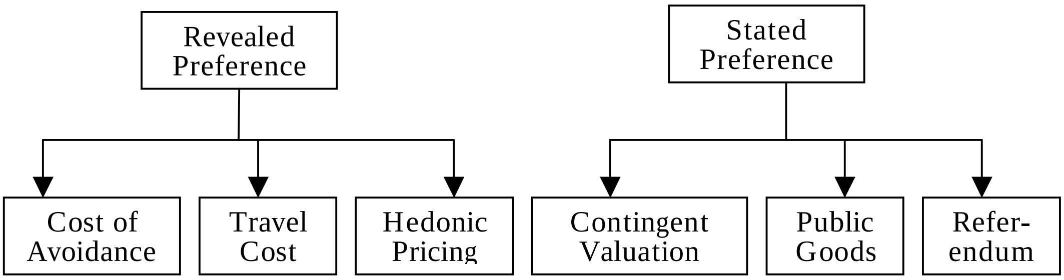
a. *Abatement cost* method is a technical assessment of the cost to environment. This method approaches the problem of valuation from the supply angle as opposed to the other two methods. This is a valuation, which reflects maintenance or abatement cost, i.e. the cost to maintain the environmental quality at a constant level.

In a developed country the abatement cost can be used as a proxy for social cost of environmental impact as the marginal costs would be equal with the environmental norms and conditions being stringent. However, in a developing nation this social cost generally far exceeds the abatement cost, thus for a correct estimation, the damage experienced by society in the absence of abatement measures have to be worked out.

b. Behaviour linkage method is an economic analysis of the environmental change, which assume that the value of the environmental goods should be based on the individual's **willingness to pay** (WTP) for a better environment quality or to avoid environmental deterioration. These techniques can be further classified depending on whether the preferences are revealed in the market place or obtained through survey statements. In the former the value of environmental amenity is estimated indirectly from the purchase price of a commodity whose market value is partly dependent on the quality of the environment. In the contingent valuation survey, respondents are provided with an opportunity to express their willingness to pay or be compensated for a change in the level of environmental amenity.

There are further several methodologies adopted to arrive at a monetary value under the two broad techniques of revealed preference and stated preferences as depicted in the Figure 2.

Figure 2: Behaviour Linkage Method



Revealed preference

The three methods of valuation under revealed preference, uses surrogates to determine the willingness to pay for a particular environmental amenity. The names of each of the techniques provide an indication of the surrogates used.

In **cost of avoidance**, the environmental valuation is carried on the individual willingness to pay to avoid a particular degradation or contamination. It is inferred from what they are prepared to spend to prevent degradation also termed as **preventive expenditure** (PE) (sometimes referred to as 'defensive expenditure') or to restore its original state after it has been damaged, which is termed as **replacement cost** (RC). There are three important variants of the same, which needs to be noted:

i) relocation, where the victim of the environmental damage, replaces the environment by physically shifting away from the afflicted area, a variant of RC

ii) environmental surrogates, a special case of PE, where substitute goods and services are bought for deteriorating service (eg. private water sources in lieu of polluted public water supply)

iii) shadow or compensating projects, a special case of RC, where the damage caused is offset by inclusion of an alternate project that would replace the damaged environment (eg. planting new trees to replace deforestation at some location). This offsetting project could be actual or notional. In case of the former actual costs are available and the latter is necessary for project evaluation purpose.

The PE and RC methods are applicable where the physical impacts are well perceived and for which there is the possibility of prevention or restoration. However, to measure the same, the information can be obtained and collated in the following ways:

(i) direct observation of actual expenditure to avoid environmental risk (eg. Terracing to prevent soil erosion, walls to keep out siltation);

(ii) through questioning individuals on their willingness to spend to defend themselves against a possible hypothetical environmental threat. This technique is similar to the contingent valuation method discussed later;

(iii) obtaining objective professional estimates of what it would cost for people to defend themselves effectively against a possible environmental damage or to restore an expected environmental loss.

There are certain inherent limitations to this method, which one needs to be conscious of when applying the method.

(i) PE takes for granted that the expenditure is worth incurring. Further it assumes that the combined cost of PE and the mitigated level of damage (MD) will ultimately equate to the original perceived level of damage (ADB, 1986), which does not hold good in situations where the scale of risk is increasing.

(ii) Both PE and RC are constrained by the ability to pay of the target population facing risk.

(iii)The RC method has an unrealistic assumption that full restitution is possible after a damage, i.e. it assumes away the possibility of uncompensated loss.

(iv)Both the methods are based on the assessing communities who are in a particular environment under threat and is hence unable to measure the impact on environmentally sensitive individuals who move out of the community well in advance. Hence there is a certain level of under-estimation involved.

The **travel cost method** (TCM) equates an individual's valuation of a particular amenity on the amount and time she is willing to spend on travelling to obtain the same. This method is primarily applied to public recreation sites with minimum admission charge or free. Once the basic relationship has been established, the value placed on the environmental quality can be deciphered by examining the changes in the visitation rates in the particular site or by comparing it with the rate of other comparable sites with similar travel cost. However the application of the method is primarily restricted to high income OECD countries.

The TCM method requires dividing the surrounding area of the site into concentric circles representing zones of equal travel distance. For each zone visitation rates are calculated and thereafter statistical regression is carried out relating the visitation rates to travel cost and other socio-economic variables to derive the demand curve and consumer surplus of visitors (Freeman, 1979). The required data is obtained through consumer survey.

This method also has its limitations, namely, for determining the individuals' demand curve, formal assumption of their behaviour is made. The method depends on collection of detailed data. The results are sensitive to statistical tools used. The method under-estimates as it omits option and existence values. Moreover changes on environmental quality are difficult to capture and model by this method. The only advantage of this method is its dependence on observed and not assumed behaviour of people.

In developing countries there are additional complications due to their difference in attitude to such recreational amenities and long distance travel. Moreover such areas have multipurpose use as well as individual visiting such places often have varied objective.

The **hedonic pricing method** (HM) determines the value of the environment on the premium an individual is willing to pay for certain environmental non-market goods. Here the price of a good is taken to be a function of non-market environmental amenities besides, the usual market parameters. In the absence of a direct market, surrogate goods are used. The most common surrogates used are land and labour. In case of land, the **Property Value** (PV) approach is applied, which consists of observing systematic difference in the values of property between locations, isolating the impact of ambient air quality on these values. For labour, the **Wage Differential** (WD) method is adopted. This method determines the extra wage needed to compensate workers for incurring environmental risk.

The data for calculating the two types of HM are obtained from the actual markets and subsequently statistical methods are applied to infer the influence of environmental factors on actual price differences. PV has been mainly used to estimate the impacts of water and air pollution in developed countries, while WD has been used to estimate the implicit value that workers place on the risk of death from occupational hazards. The PV and WD methods are operational in two stages. First through multiple regression analysis one identifies the proportion of the property value or wage difference that is attributable to environmental quality variance. Thereafter, it estimates how much people would be WTP for environmental improvements (Freeman 1979, Pearce & Markandya, 1989).

The methods are applicable only when the impacts of the environmental degradation or contamination is precise and well defined. Moreover the data requirement is quite cumbersome and the estimating equations are highly sensitive to the specifications. Besides, there are certain limitations specific to the PV method, namely the assumption of a well informed and developed property market and that the value of property embodies the impact of future environmental quality. The WD method also has certain specific limitations, the foremost being its assumptions regarding the labour market that people can make free choices with perfect information in the absence of discrimination, involuntary unemployment or barriers to mobility.

In case of developing countries, though the property and labour market are extremely active, but they often operate in ways different from that defined under HM. Moreover, the environmental issues are closely correlated and often submerged by the other important features of the property. The other concern is that WTP for environmental improvement is a far-fetched concept for developing communities in many cases. And the WD method is still less applicable in countries where the employment market has large scale unemployment providing very little choice of occupation and location to most of the workforce. In such cases the relative rewards are less sensitive to environmental quality.

Stated Preference

When the actual market data are lacking, the stated preference techniques are used where, the information is obtained through the questionnaire or survey process. All the three techniques under this process attempt to determine the market value of a hypothetical situation.

In the **contingent valuation method** (CVM) the respondent is asked to value an environmental benefit or loss. Their willingness to pay (WTP) for an environmental amenity or the value of compensation they would desire for a loss or degradation in the environment (also known as willingness to accept (WTA) compensation) is obtained through the survey. CVM is either used independently or in conjunction with some other valuation method (as in the case of PE described above).

The techniques adopted for conducting CVM is primarily questionnaire survey method and its variants. Some of the variants include bidding games, take it or leave it experiments and trade-off games. The results from the sample survey, which is collected are then grossed to represent the likely valuation to be placed by the population.

The CV technique has certain inherent biases, which arise due to the design of the questionnaire or the mindset and attitude of the respondents and their capacity to perceive the environmental change. Moreover, the grossing up technique for estimating the population valuation is quite tricky, specially for option and existence values.

For developing countries, there have been very few examples of use of CV technique. In these countries, the researchers would likely be faced with major hurdles of distrust, uneven income distribution leading to wide range of WTP values, the prevalence of poverty necessitating design on the basis of consumer profile. Under such circumstances the grossing technique used for the population is further rendered difficult.

The **public good market** model provides a range of prices to the respondent for valuation, which reflects a bidding game. The model is best suited for quasi-private goods, where application of exclusion principle is possible through permit to access process. In case of **referendum** too a range of prices or values are associated with environmental amenities, but is mostly used in relation to determination of voter’s tax or road tax etc.

The ultimate valuation of the environment is obtained from the mean or median of the values collated through the survey. However, there is no pre-determined norm for the use of mean or median and hence the methodology is subject to controversy and debate. But Haneman (1991) is of the view that the choice between mean and median can be derived from prior choice of social welfare criterion.

But broadly, the physical linkage method is applicable where scientific relationships are established. On the other hand the contingent valuation method can be used under all conditions, but the accuracy of the results is subject to the accuracy of the survey in terms of administration as well as understanding on the part of respondents. In some cases of economic evaluation of the environment, a combination of both the approaches might have to be used.

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