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Environmental Impacts of Fuel Chains Involved in Electricity Generation Systems and Ways for its Internalization

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Abstract— a comparative information on Environmental impacts of various electrical power generation schemes is helpful in evaluation of energy options. Over the last few decades various researchers and environmentalists have quantified these impacts for a wide range of energy sources. The results can provide useful insights and help to promote further studies of impacts for many more technologies, sites and regions. In this paper we have discussed the proper fuel cycle approach, where impacts from the point of fuel acquisition to waste disposal have been estimated. In addition, we have stated some internalization schemes to check and control the environmental impacts of fuel cycle involved in different electrical generating stations.

***Keywords*—Biomass power plant, fuel chain, Externalities, fossil fuel power plant, Hydropower plant, Internalization, Nuclear power plants, Regulation schemes, Solar power plant, transmission lines, Wind power plants.**

I. Introduction

With the growing world's population, the energy demand is increasing exponentially which needs to be met with the present conventional and non-conventional energy sources. It is necessary to use these resources in a way that is efficient, less harmful to environment and that reflects societies' other priorities.

Evaluations of renewable and conventional energy options should be made on the basis of comparable conditions and assumptions. In that regard, this paper provides general information, and the benefit of previous experience, to governments, utilities and other organizations that need to undertake comparative assessments of the environmental impacts of electricity generation options.

To achieve this objective, this paper provides:

a) Steps that can be taken to identify and estimate health and environmental impacts associated with electricity generation options.
b) Comparison of various technology options on the basis of their environmental impacts
c) Provide information on how environmental risk data (where quantitative data are available) can be considered along with other environmental information that sometimes is not quantifiable in purely scientific terms.

However, it is not the intention of the paper to present detailed guidelines on strict scientific risk assessment (i.e. the product of probability and consequence).

II. Impacts and Impact Assessment: Basic Concepts

In addition to various benefits of electrical energy, there are a number of disadvantages of the generation plants involved because of their detrimental effects on the environment. Some of these effects are visible and some are not, but they are equally hazardous for humans, materials, flora and fauna. It is increasingly being realized that the choice of the type of power plant to build and operate must involve an assessment of its impact on the environment. The effect of a power plant on the environment varies from one type of plant to another and from region to region.

A. Fuel Chains

While implementing a power plant technology in a region, the full consequences of the installation, operation and disposal of the plant must be taken into account. This means that not only the effects of operation, but also the impacts that occur before and after the electricity generation should be analyzed. For example, for a coal fired power plant the full fuel chain, from the extraction of coal from the mine to the disposal of the ash and final decommissioning of the power plant, should be taken into account in an assessment of the impacts of the plant.

The phrase "should be taken into account" in the previous paragraph means that analysts should consider every part of the fuel chain that may lead to significant impacts.

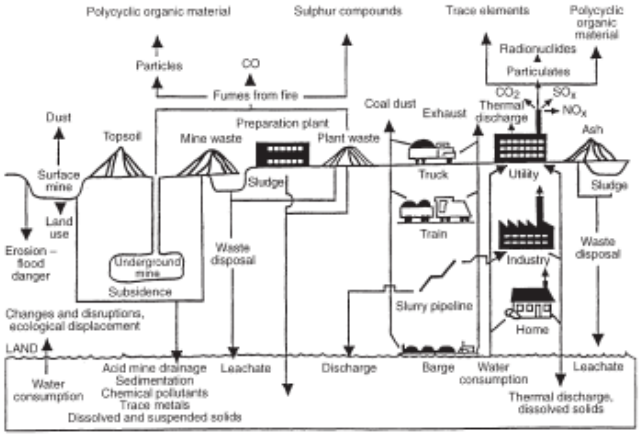

Fig 1 Illustration of Fuel chain concept [1]

B. Emissions And Other Burdens On The Environment

One of the major contributions of power generation to the environmental degradation is their emissions. These emissions can be in the form of solid, liquid, gaseous and radioactive emissions.

A few examples of emissions have been listed below[2-12]:

a) Fossil fuelled plant

1) Gaseous: sulphur dioxide, oxides of nitrogen, hydrocarbons, carbon monoxide and carbon dioxide.

2) Liquid: wastewater.

3) Solid: particulates emitted from the chimney stack, which remain suspended in the air and are transported like a

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gas, and solids collected as ash from the plant.

4) Secondary: in addition to the direct emissions, there are secondary components produced in the atmosphere from chemical reactions between the emissions and other substances in the atmosphere. These secondary pollutants include ozone formed from the oxides of nitrogen and volatile organic compounds (VOCs), sulphate particles formed from sulphur dioxide, and acid rain formed from sulphur dioxide and oxides of nitrogen.

5) Other: other burdens include aesthetic aspects such as the visual 'intrusion 'of the plant itself, noise, smoke and heat rejection from the cooling circuit.

b) Nuclear Power plant

1) Gaseous: radioactive off-gases.

2) Liquid: radioactive water effluent.

3) Solid: radioactive spent fuel elements, and chemicals from allied plants such as demineralizers.

4) Other: aesthetic aspects and heat rejection

The emissions mentioned above are normal emissions which occur during plant operation

In addition to these 'normal' releases there are potential releases and other environmental consequences as a result of accidents.

C. *Impacts*

Emissions from the generating stations affect the environment. For e.g., raised level of sulphates inhaled in combination with certain other emissions can increase the probability of premature death.

Since an impact is influenced by the concentration of an emission, the method by which emissions are dispersed in the environment is important. Thus, for emissions into air the height at which the release occurs, the turbulence of the atmosphere, the distance to the receptor (i.e. the human population, animal and plant species, ecosystems or materials that are affected), the topography between the emitter (i.e. the source of the emission) and the receptor, and meteorological factors are all important

Impacts can be divided into those affecting human health, animal health, flora and materials. Estimates of impacts due to an emission are usually based on a dose–response relationship.

D. *Indicators*

In order to facilitate the comparison of environmental effects of different energy options, there is a need for consistent, quantitative indicators of environmental impacts.

Primary indicators of health and environmental impacts are estimates of the specific effects themselves, such as increased rates of respiratory illness and damage to trees. Other indicators are often informative surrogates for these effects, particularly when they are difficult to estimate directly. The magnitude of pollutant emissions (and of other types of burdens) is one type of indirect indicator (e.g. tonnes of sulphur dioxide emitted).

Categorization of Indirect indicators can be done according to the geographical impacts:

- Global effects due to
  - Change in concentration of greenhouse gases;
  - Long lived radioactive substances.
- Regional, local and site specific effects from
  - SO2, NO x and particulates;
  - Heavy metals; • Radioactive gases;
  - Liquid and solid wastes containing toxic or radioactive material.

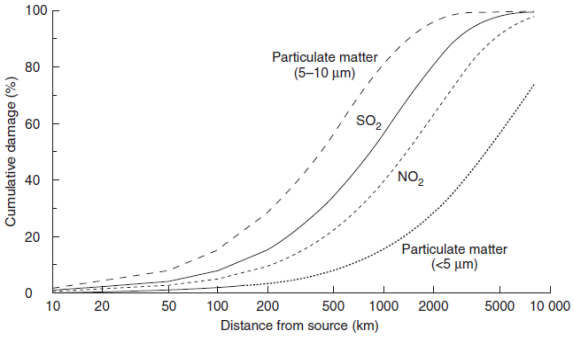

Fig 2 *Percentage of cumulative damage expected with distance from Source of emissions [13].*

Figure 2 [13] illustrates that dispersion occurs over long distances and that the concentration of pollutant decreases as the distance from the source increases. The functional relationship is a smooth curve.

III. Possible Impacts Of Different Fuel Chains

The environmental impacts of different fuel cycles involved in different types of generating stations are listed below:

(1) Fossil fuelled power plants

(a) Coal fired power plants

i. Loss of land for open pit mining, or mining damage in underground mine areas, including damage to urban infrastructure;

ii. Pollution of water due to liquid effluents from mines;

iii. Pollution of water due to solid and liquid wastes from the power plant;

iv. Loss of forests, crops and animals due to absorption of pollutants from coal combustion released during power plant operation;

v. Global warming due to CO_2 released during plant operation, material production and plant construction.

(b) Oil fired power plants

i. Pollution of water due to liquid effluents from oil transportation and accidents;

ii. Pollution of water due to solid and liquid wastes from the power plant;

iii. Loss of forests, crops and animals due to absorption of pollutants from oil combustion released during power plant operation.

iv. Global warming due to CO_2 released during plant operation, material production and plant construction.

(c) Natural gas fired power plants

i. Loss of forests, crops and animals due to absorption of pollutants from gas combustion released during power plant operation;

ii. Global warming due to CO_2 released during plant operation, material production and plant construction.

(2) Nuclear power plants

i. Loss of land for uranium mining;

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ii. Pollution of water due to liquid effluents from uranium mines;
iii. Effects of radiation on plants and animals in the case of severe reactor accidents;
iv. Water heating by waste heat;
v. Global warming due to CO_2 released during material production and plant construction.

(3) Hydropower plants

i. Changes of local or regional climate;
ii. Influence of reservoir on fishing;
iii. Water management, including positive aspects (e.g. the possibility to control floods);
iv. Negative influence on neighbouring land, which may become partly dry or partly wet, with significant changes in groundwater levels in the vicinity of the reservoir;
v. —Sedimentation of dams, leading to the filling up of the area before the dam and accumulation of toxic substances in sediments;
vi. Global warming due to CO_2 released during material production and plant construction, and methane released from decomposition of waterlogged vegetation;
vii. Loss of forests, land, crops, plant species, animals and their habitats, and historical sites;
viii. Displacement of population.

(4) Biomass power plants

i. Effects of diesel exhaust from harvesting equipment;
ii. Occupancy of land by a monoculture and associated problems with biodiversity;

(5) Solar power plants

i. Occupancy of land;
ii. Effects of discharges from energy backup or storage systems;
iii. Global warming due to CO_2 released during material production and plant construction

(6) Wind power plants

i. Global warming due to CO_2 released during material production and plant construction;
ii. Occupancy of land;
iii. Effects connected with energy backup or storage systems.

Name of impact and damage	Ways in which damages are internalized	Examples
Damage to aquatic life from mine runoff	Regulations that set standards on allowable discharges	Many countries have water regulations. However these regulations may over- or under-regulate from an efficiency standpointAlso, if there is non-compliance, externalities could occur
Human health effects from air pollution	Regulations on discharges and/or on maximum local concentrations	National ambient air quality standard of India and similar in other countries
Effect of global climate change due to CO_2	Taxes	Norway has Carbon taxes
Damage from oil spills	Payment or fines	In India, Oil Pollution Act requires the responsible party to pay the cost of an oil spill.
Ecological and human health effects from SO_2 emissions	Tradable emission permits	In India, there is a trading of SO_2 emission permits and also that one for NO_x emissions.
All types	'Voluntary' installation of pollution abatement equipments	Many electrical utilities install scrubbers, electrostatic precipitators, etc. Plant operators may not voluntarily install such equipments because it increases their costs. Alternatively they may install equipments a hedge against future, more stringent regulations

Table 1 Ways in which damages can be internalized [8-12]

Table 1[8-12] summarizes the various internalization schemes to check and control various impacts of fuel chain pollutants on the environment. Internalization is a method to compensate externalities. More is the internalization, lesser will be the externalities. Externalities are effects on the well-being or profits of third parties that are not taken into account in the market by the producers and consumers of a good or service.

IV. DISCUSSION

In our surrounding so many fuel cycles are running simultaneously and they are continuously affecting the environment to some extent. Here, in this paper, we have discussed some fuel chain cycle involved in electrical power generation which are severely affecting our atmosphere. From here we got a conclusion that some pollutants involved in fuel cycle of power plants cannot be fully eliminated or replaced by environmental friendly alternatives. So, we have discussed some internalization schemes for every fuel chain cycle by which we can control and compensate its effects to some extent.

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