ENERGY

Twelfth National

INDUSTRIAL ENERGY TECHNOLOGY CONFERENCE

June 19-21, 1990
J.W. Marriott Hotel
Houston, Texas

PROCEEDINGS

Energy and Environmental Excellence:
A Partnership for Success

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Energy and Environmental Excellence:
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FOREWORD

A review of past Industrial Energy Technology Conference (IETC) attendees demonstrates that this is a conference for energy users. For this reason, the IETC is of major interest to every provider of a product or service to the industrial and commercial energy consumer. The IETC is a vehicle for upper-level energy managers, plant engineers, utility representatives, suppliers, and industrial consultants to present and discuss novel and innovative ideas on how to reduce costs effectively and improve utilization of resources. It is hoped that these proceedings may be used as a reference in the near- and long-term implementation of industrial energy management projects.

We at the Energy Systems Laboratory in the Department of Mechanical Engineering at Texas A&M University express our appreciation to everyone who helped make this conference a success. These include our sponsors (the Texas Governor's Energy Management Center, Electric Power Research Institute, Central Power and Light, Houston Lighting and Power, Center for Energy and Mineral Resources at Texas A&M University), our corporate sponsors (Union Carbide, Dow Chemical, SOLTEX Polymer), the IETC Advisory Committee members who took time from their busy schedules to provide guidance and suggestions, the exhibitors for displaying the latest and most advanced equipment and related services, and all authors, session chairmen, and keynote speakers for sharing their knowledge and experience.

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ABSTRACT

Electric energy is an integral element of today's economy and the standard quality of life. The availability of energy at an affordable cost has always been of basic concern because of the intimate relationship of energy to our societal development and progress.

Balancing the beneficial aspects of energy use (generation, transmission, distribution, utilization, and development) against its undesirable environmental effects and concerns is one of the major concerns.

Fossil fuel plants create air pollution while nuclear plants create radioactive wastes and disposal problems.

This paper briefly summarizes current environmental concerns. Particular emphasis in this paper is given to air pollution, solid waste, and land pollution and its effect on human health and concerns.

ELECTRIC ENERGY AND THE ENVIRONMENTAL ISSUES

Electricity is not itself a primary source of energy, but is produced by our use of basic energy sources: fossil fuels (coal, gas, and oil), hydroelectric, nuclear, and other energy sources. Various coal technologies like coal conversion, (gasification, liquefaction, washing), coal cleaning (washing, preparing), and coal utilization (coal oil mixture, fluidized bed combustion, flue gas desulfurization) are used to reduce and control the environmental impacts.

Alternative methods of power production: They help to reduce the environmental impacts (SO2 and CO2 leading to acid mine drainage and green house effect).

A. Power from fossil fuels:
   1. Solvent refining of coal.
   2. Coal liquification or Bitumen based liquid fuel (Venzuelan source).
   3. Coal gasification.
   4. Magnetohydrodynamics (MHD).
   5. Internal Combustion Engines.
   6. Fuel cells.

B. Power from Renewable Natural Resources:
   1. Solar Power.
      a. Thermal Conversion Systems.
      b. Direct Conversion Systems.
      c. Solar Sea Power.
   2. Geothermal Power.
   3. Tidal Power.
   4. Wind Power.

C. Fusion Power

D. Power from Garbage and Organic wastes

E. Power from Stored Energy:
   1. Pumped Storage.
   2. Compressed Air Storage.
   3. Hydrogen Fuel Economy.

With the rising cost of energy, increasing concerns about damage to the environment due to other modes of generation, and scarcity of major hydroplant sites close to load centers, it has become more economical during the last two decades to utilize small locally available hydropotential and other alternate energy sources as mentioned above, in addition to those based on coal or uranium.

The carbon production per unit of energy for different electric systems are given in the attached Figure (1).

POWER GENERATION: COAL AS A FUEL SOURCE

Coal and Uranium are the primary alternative energy sources for large electrical power plants. The use of fossil fuels for electric generation is intimately linked to the fact that coal, oil, and gas are and will continue to be readily available throughout the world. Oil and gas however, are premium products, their value as a chemical feedstock or as premium fuels (Figure 2) for transport, together with their limited reserves mitigate against their profligate use purely for electricity production. Coal remains the dominant fuel for electric generation. The United States possesses about 268 billion tons of mineable coal that would supply the nation for 250 years energy supply and industrial needs.

With increasing world energy demands and the ready availability of relatively cheap coal, the quantities of coal burned annually for the generation of electric power are growing significantly. Unless the undesirable emissions from coal-fired power plants are controlled, the effect on the global environment will be significant. Typical environmental factors associated with coal use in electric energy generation is depicted in Figure 3. The main pollutants which result from coal combustion are: Carbon Dioxide (Co2), Nitrogen Oxides (NOx), Sulphur Dioxide (SO2), Hydrogen Halides (HCI/HF), and Dust. The pressurized fluidized bed combustion technology has the potential of utilizing all types of coal, including coal with high ash, high sulphur, and high moisture content. Fluidized bed combustion is a firing technique which fulfills today's pollution control requirements without downstream flue gas cleaning plants like scrubbers, baghouses, and precipitators.

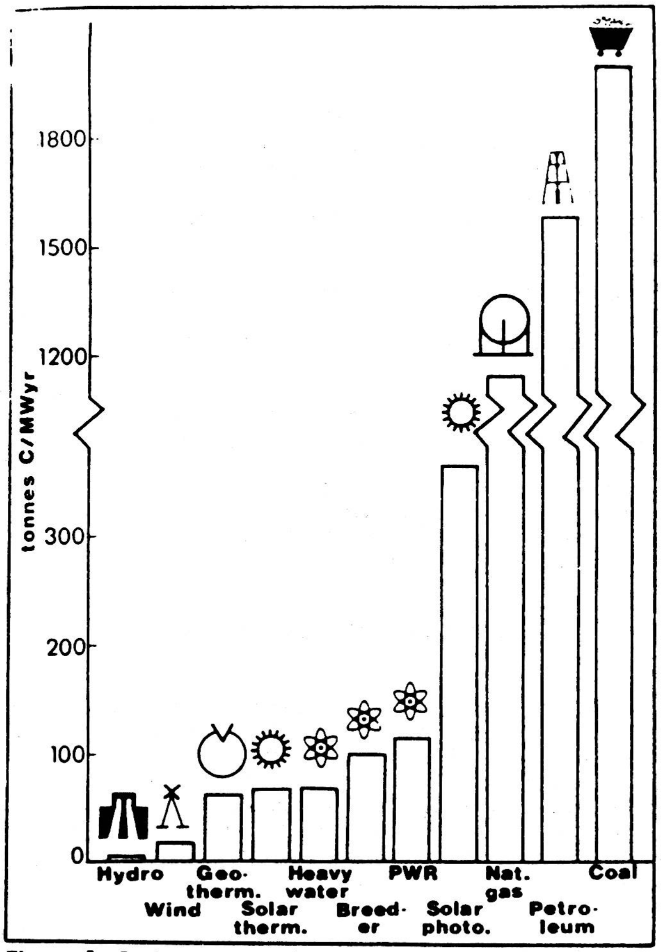

Figure* 1: *Carbon production per unit energy for eleven electricity systems. All three direct fossil fuel-burning systems are substantially above the other eight systems. Note the break in the graph to separate the two groups. Lowest is hydro, due to the relatively small amount of CO_2 intensive materials used per unit energy production.

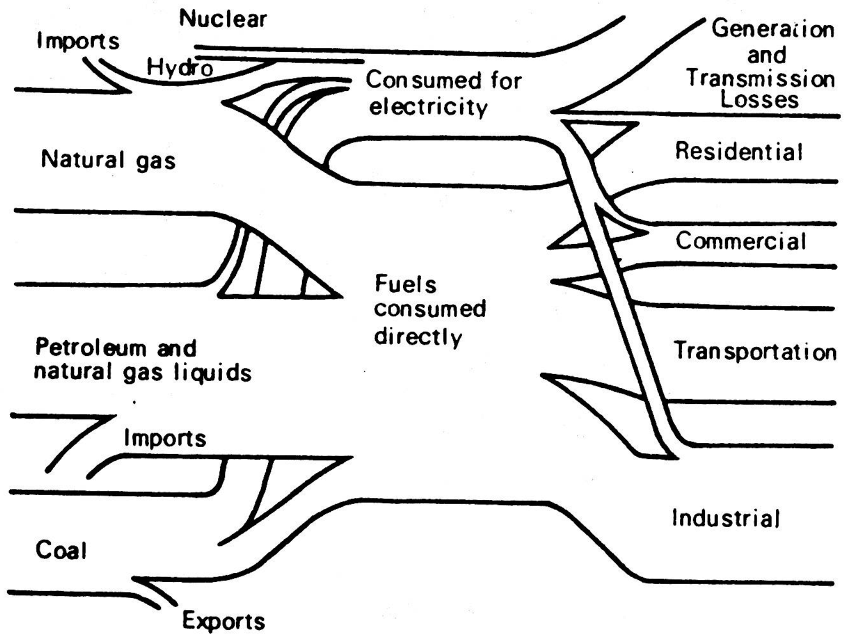

Figure 2: ENERGY PRIMARY SOURCE AND END-USE

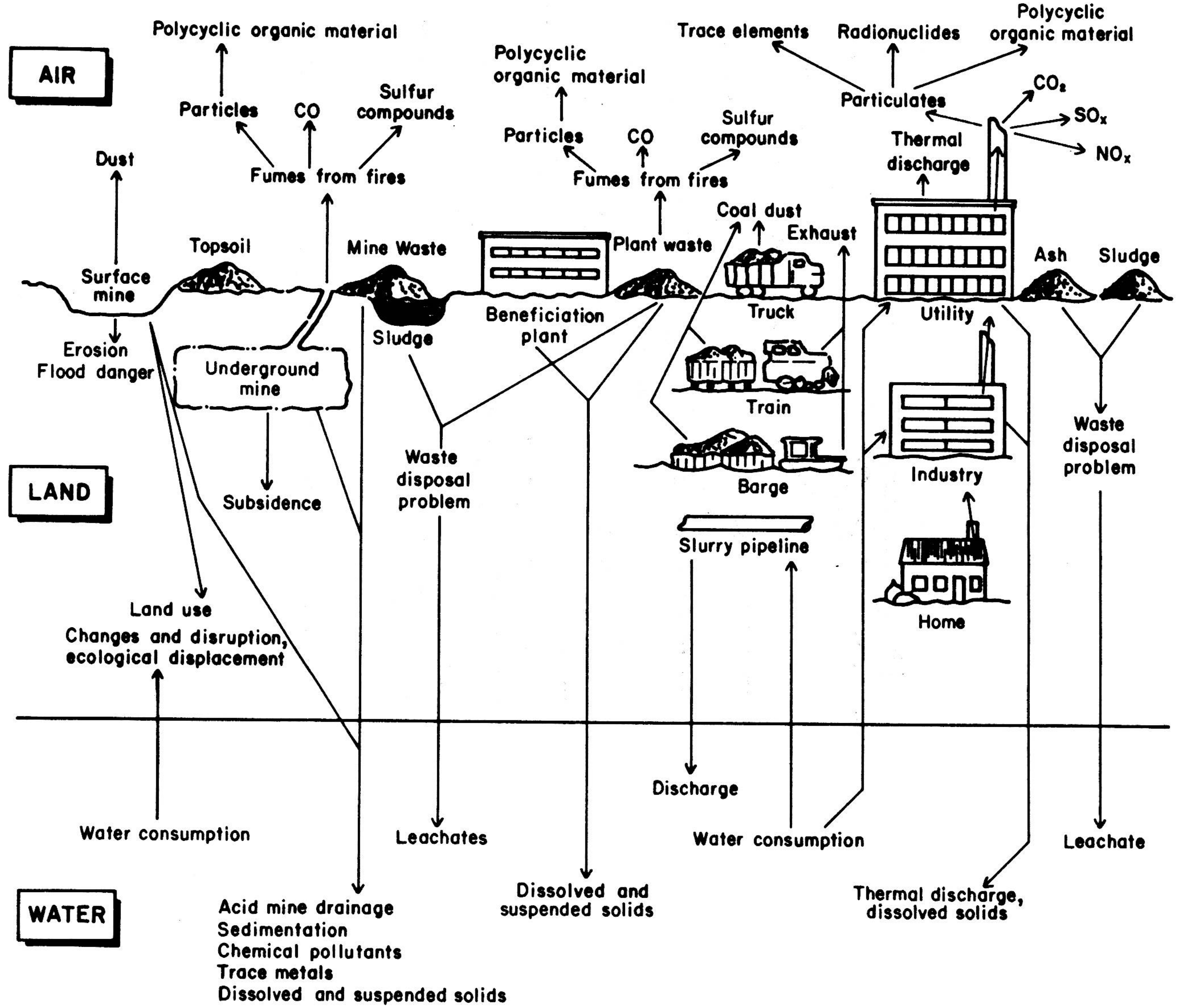

FIGURE 3: ENVIRONMENTAL IMPACT FROM COAL RELATED ACTIVITIES

The identification of health and ecological impacts of utilizing coal for generating electrical power requires an understanding of the entire coal cycle (coal extraction, processing, transportation, combustion, and waste disposal utilization). A typical annual environmental impact due to a 1000 MW coal-fired power plant, with a load factor of 70%, located in five regions is summarized in Tables 1 and 2 as shown. The physical and chemical characteristics of coal varies according to the regions. The analysis is based under the assumption that each plant is to be equipped with electrostatic precipitators for fly ash removal, if high-sulfur coal is used, and flue gas desulfurization limestone scrubbers for SO2 reduction.

The annual fuel requirements determine:

1. The land area disturbed by mining.
2. Potential transportation requirements.
3. Amount of waste generated from processing the coal.
4. Non-airborne wastes produced from combustion (fly ash, bottom ash, slag).
5. By-products from pollution control technologies (sludge).
6. Ultimate airborne emissions, SOx, NOx and heavy trace metals (with varying pollution control of stack gases and particulates). (The NSPS of 1.2 lbs SOx/106 Btu and Scrubbers with 90% SO2 removal efficiency is assumed in Table 1).

COAL MINING

There are two basic methods of Coal Mining: Surface and Underground.

Surface/Strip mining completely removes vegetation in the stripped area, and the stripped material (spoil) from the initial cut is deposited on adjacent vegetation. Topsoil and materials originally near the surface are generally placed at the base of the spoil, altering their important physical, chemical, and biotic characteristics. Topography is altered. Former land uses such as wildlife habitat, farming, or grazing are eliminated until the land is reclaimed. The destruction of soil structure and steep slopes of spoil piles can decrease soil permeability and increase compaction; resulting in the increased surface-water runoff and soil erosion. Small sized soil particles such as silt and clay will be exposed and moved by the wind, when dry. The application of lime prior to respreading the stored topsoil (having Ph under 4, acidity level where the plant establishment becomes difficult) has been shown to assist in successful plant reestablishment.

Underground mining has a major terrestrial impact. Subsidence is the settling of the ground due to downward movement of the overburden to occupy the void space remaining after coal extraction. The subsidence can cause damage to the above ground structures and injury to men and livestock. The duration of the subsidence risk is variable and site specific, depending on overburden geology and regional tectonics. The subsidence damaging effect can be controlled, when monitored by combinations of mining techniques.

Another terrestrial impact from mining is the disposal of the mine refuse and the necessary reclamation required.

The major environmental problem associated with the mine effluents are related to the formation and transport of acid mine drainage (AMD) containing dissolved colloidal products (metals, nutrients, and sulfate) to aquatic systems. AMD from inactive underground mines is particularly difficult to control. The toxic elements in AMD can be transmitted to humans through drinking water and the food chain. Most municipal and industrial water users have developed supply and treatment facilities to deal with acid mine drainage.

COAL CLEANING

Newly mined or raw coal frequently contains high percentages of unwanted noncombustible materials (shale, rocks, ash, fine particulates, sulfur, or pyritic minerals), and is therefore often mechanically cleaned or prepared to reduce the concentrations of these materials. Cleaning methods use the principles of gravity separation (float and sink) and sometime heavy media separation principles. The refuse is separated during processing into gob and slurry. Gob is course boulder to pebble sized material separated from the coal gravimetrically and disposed of close to the preparation plant. Slurry is clay-sized particles containing abundant coal fines suspended in the cleaning water and is usually piped to natural depressions or depressions created by mining or specifically constructed impoundments.

Spontaneous or accidental combustion is the major source of air pollution from uncompacted gob piles. Sulfur dioxide, hydrogensulfides, carbon monoxides, carbon dioxide, nitrogen oxides, amonia, hydrocarbons, particulates are among the emissions from burning and smouldering coal refuse. Proper vegetation and reconstruction are the best methods for reducing the impacts of gob and slurry. Coal is composed of highly complex and heterogeneous group of substances possessing a wide range of chemical and physical properties.

Lignite or Brown coal can contain up to 50% water and has the lowest carbon content (Btu). Hence, the larger quantities of lignite must be burned to equal the energy output of higher ranks of coal. Bituminous and Anthracite come next into higher rank, with lower moisture percentage and higher heat (Btu/per lb) value.

Particulate, fly ash control is achieved by the use of Electrostatic precipitators, Wet scrubbers (plate column, packed bed, Venturi scrubber, centrifugal, moving bed, fabric filter (baghouses)). As environmental control becomes more stringent, all power plant effluents eventually contribute to the solid waste stream. Solids are more costly to handle than liquids but easier to dispose of because they have far less tendency to disperse into the environment. The government regulations (federal, state, and local) mandate that solid wastes are properly handled. The enormous volume of wastes generated by a coal-fired central station dictates that solid waste handling be given top priority during

Table 1 Annual Environmental Impacts Associated with a 1000-Megawatt Coal-Fired Power Plant with a Load Factor of 0.70, Located in Five Regions of the U. S.

Impacts	Northern Appalachian	Southern Appalachian	Eastern Interior (Illinois Coal)	Eastern Interior (Wyoming Coal)	Four Corners	Pacific Northwest
<u>Extraction</u>						
Coal source	Pittsburgh seam (PA)	Upper Elkhorn No. 3 (KY)	Illinois No. 5 (IL)	Anderson, Canyon Wyodak-Anderson (WY)	Wepo Formation (AZ)	Anderson, Canyon Wyodak-Anderson (WY)
Btu content of coal	13,800	14,200	11,400	8,200	11,600	8,200
Coal ash content (%)	3.6	3.9	5.2	6.0	5.2	6.0
Sulfur content of coal (%)	1.26	0.9	2.45	0.45	0.6	0.45
Annual coal requirements (10^6 tons)	1.91	1.84	2.29	3.19	2.25	3.19
Land disturbed annually by surface mining (acres)	165	195	190	30	100	30
Occupational accidental deaths (persons/yr)	0.82	0.58	0.95	0.29	0.20	0.29
<u>Processing</u>						
Refuse produced annually (10^6 tons)	0.69	No coal processing	0.69	No coal processing	No coal processing	No coal processing
Land preempted annually for refuse disposal (acres)	16	--	16	--	--	--
<u>Transportation and Storage</u>						
Fatalities per year	0.14	0.18	0.11	1.45	0.16	0.15
Land preempted annually for coal storage (acres)	4.0	3.8	4.8	6.7	4.7	6.7
<u>Wastes Collected from Combustion and Emission Abatement</u>						
Bottom ash (tons/yr)	14,000	14,000	24,000	40,000	23,000	40,000
Fly ash (tons/yr)	54,000	56,000	95,000	153,000	92,000	153,000
Land preempted by ash ponds (acres)	20-30	20-30	20-30	20-30	20-30	20-30
Land preempted annually for ash disposal (acres)	1.5	1.6	2.7	4.5	2.6	4.5
Limestone scrubber sludge (10^6 tons/yr)	0.24	0.18	0.46	No scrubbing	No scrubbing	No scrubbing

Table 1. Continued

Impacts	Northern Appalachian	Southern Appalachian	Eastern Interior (Illinois Coal)	Eastern Interior (Wyoming Coal)	Four Corners	Pacific Northwest
<u>Wastes Collected from Combustion and Emission Abatement</u> (cont.)						
Land preempted annually for scrubber sludge[b] disposal (acres)	7	6	14	--	--	--
<u>Combustion Emissions</u>						
Sulfur oxides (tons/yr)	4800	3300	11,200	30,700	27,000	30,700
Nitrogen oxides (tons/yr)	9900	9900	9900	9900	9900	9900
Particulates (tons/yr)	280	280	485	765	460	765
Trace elements (tons/yr)						
Arsenic	0.55	0.20	0.23	0.04	0.07	0.04
Barium	0.88	0.95	0.67	2.56	0.53	2.56
Cadmium	--	--	0.18	0.03	0.03	0.03
Chromium	0.55	0.42	0.73	0.16	0.24	0.16
Cobalt	0.24	0.19	0.31	0.08	--	0.08
Lead	0.38	0.28	2.65	0.05	0.31	0.05
Manganese	0.23	0.27	0.87	0.18	0.11	0.18
Mercury	0.34	--	0.33	0.10	0.09	0.10
Selenium	1.02	0.82	0.60	0.26	0.62	0.26
Vanadium	0.67	0.56	0.78	0.37	0.21	0.37
Zinc	0.80	0.52	5.56	1.61	0.38	1.61
Public deaths/10^6 persons						
Winkelstein-based estimate						
Even distribution of population	2.8	5.4	2.8	3.0	3.7	2.6
Population concentrated in most heavily exposed 400-600 mi^2	9.7	26.8	8.2	8.4	15.7	8.8
Lave-Seskin-based estimate						
Even distribution of population	1.7	3.3	1.7	1.8	1.9	1.6
Population concentrated in most heavily exposed 400-600 mi^2	6.1	16.7	4.9	4.8	8.2	5.1

[b]Assumes that each acre at the disposal site contains 25 acre feet of waste material (refuse, ash and scrubber sludge).

plant design. One way to deflect public attention from power plant wastes is to treat and use them as by-products, giving them the same management attention as the utility's primary product, electricity. Disposal of power plant waste represents an expenditure on the balance sheet, and any revenue from the sale of products to offset that loss is as important as revenue from the power sales. The American Coal Ash Association is actively promoting the use as a by-product. Few power plant combustion wastes are presently listed as hazardous substances though this situation could change. The chief concern is runoff water because of its potential to contaminate ground and/or surface water. Hence, the disposal must confirm to several different environmental regulations (RCRA, CWA, SDWA, EPA). The lignite plants built before 1970 in the East Texas lignite belt are not presently required to utilize scrubbers. The clean air proposal by the Bush administration may force those utilities to meet the stringent clean air regulations with the costly retrofitting technology, thereby increasing the electric rates.

COAL EXTRACTION

The land disturbed annually by surface mining is directly affected by the amount of coal extracted (Btu content, thickness of coal seam, and the method of surface mining). Surface mining completely destroys the existing vegetation in the stripped area. Until the land is reclaimed, topography is altered, fauna are displaced and former land uses such as wildlife habitat, farming or grazing are eliminated.

Aquatic and forest growth impacts are the result of acid mine drainage and erosion induced siltation. The state and federal guidelines and standards for reclamation and effluent limitation have a minimized deleterious effects of coal extraction.

Accident fatality particularly due to underground mining and the pneumoconiosis due to coal dust has an undesirable impact.

PROCESSING

The problems associated with the refuse from coal cleaning (gob and slurry) have substantial adverse impact; including air pollution, water pollution, and damage to aesthetic value. This occurs if gob piles and slurry lagoons are not properly engineered and reclaimed.

Acid mine drainage can decrease water quality, coal waste ignition can increase air pollution, and waste dams can fail and cause flooding and disaster.

TRANSPORTATION AND STORAGE

Railroads, barges, slurry pipelines belt conveyors, and trucks are the transportation modes used to bring coal to the power plant. The impact due to new construction or upgrading facilities to provide coal supply and storage inventory work can destroy and disturb terrestrial vegetation and may produce erosion resulting in siltation. However, with the appropriate protective measures, these impacts (direct and indirect) can be controlled. The infiltration water and runoff from the coal piles contain coal fines, humic acids and inorganic ions. The leaching of soils and breakdown of soil structure is very common near the storage piles. Placement of an impermeable layer (clay) on the ground before stockpiling, can reduce adverse effects of infiltration water, although it will tend to increase runoff.

WASTES FROM COMBUSTION AND EMISSION ABATEMENT

These wastes include fly ash, slag or bottom ash, and scrubber sludge. The coal ash entrained in the flue gases as fly ash, 99.5% is collected by the electrostatic precipitators. Emission abatement consists of procedures to minimize the release of particulate matter and sulfur dioxide into the atmosphere via stacks. The stack emissions characteristically have four major types of health impacts: physiological irritation, direct toxicity, carcinogenesis, and physical synergism. These procedures result in the accumulation of waste material, whose disposal causes environmental concerns.

Scrubber sludge is a precipitate chemically formed when SO2 in the flue gas comes in contact with the limestone slurry. Seepage from ash and sludge dewatering ponds can add potentially toxic elements and salts to the surrounding soil, vegetation, groundwater, and eventually surface waters. Ultimate disposal of ash is usually in landfills and mine sites. Such disposal does not necessarily isolate it from the biosphere. Rainfall on these sites and rising or falling water tables can result in the leaching of potential toxic elements into the surrounding soils and ground water.

Utilization of fly ash in roads, building products, and soil stabilization has been encouraging, and has reduced the environmental impact concerns to some extent over the years.

COMBUSTION EMISSIONS

The impacts to aquatic ecosystems from gaseous combustion emissions (NOx, SOx, and Particulates) result primarily from acidification of the receiving water by acid precipitation formed from SOx and NOx.

POWER GENERATION NUCLEAR/URANIUM

Nuclear power plants generate many types of radioactive waste; including, dry combustible and noncombustible wastes, resins, sludges from treatment of liquid streams, and waste oils. A variety of treatment methods are in use at commercial nuclear plants to improve the waste form and reduce waste volumes prior to disposal at commercial shallow land burial facilities. Disposal of very low activity wastes (sufficiently low levels of radioactivity and their radiation hazard). BCR wastes are still subject to the application of regulations for nonradioactive materials, such as RCRA regulations. The disposal methods include landfill and on-site disposal of below regulatory concern waste. Waste processing includes supercompaction (55-70 lbs/ft 3 density with a high pressure press), incineration, and solidification. Technologies for processing can be grouped into two groups. One group is used to alter the form of the waste

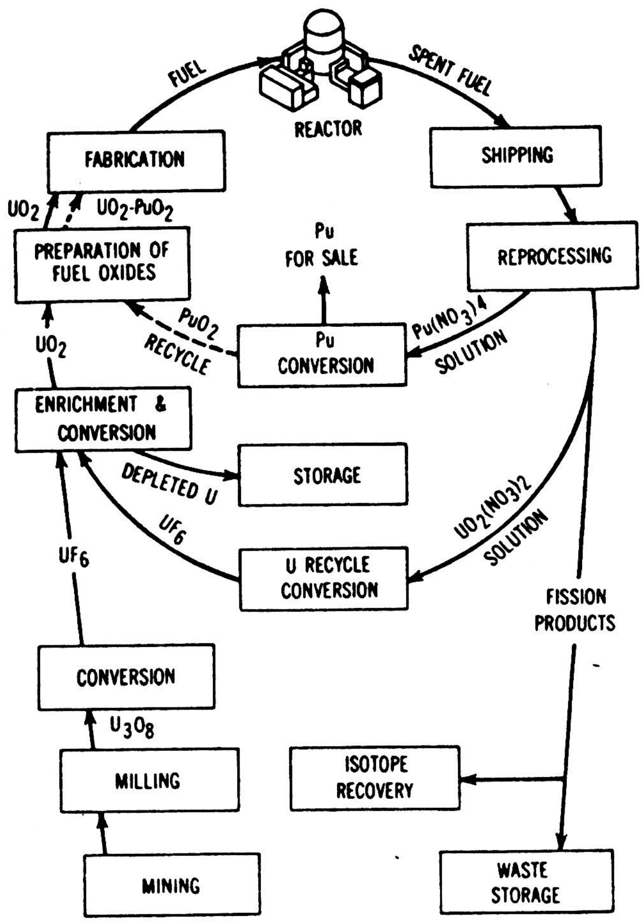

Figure 4: NUCLEAR FUEL CYCLE AND RADIOACTIVE WASTES

to improve its transportation and disposal properties. The second group acts to reduce the volume and/or radioactivity of the waste; in order to reduce the transportation or disposal costs and risks. The technologies currently used to prepare utility-generated low level waste for disposal at a licensed shallow land burial facility can be categorized as:

1. Mechanical treatment.
2. Dewatering.
3. Decontamination.
4. Solidification.
5. Sorting/Segregation.
6. Thermal and physiochemical treatment.

Decontamination methods include mechanical and chemical cleaning, electrolytic polishing, and ultrasonic cleaning. Cement and various grouts have been the principal solidification agents and Ion exchange has been the principal physiochemical method for treatment of dilute aqueous streams.

In May 1987, the Texas Department of Health adopted a BRC rule to allow wastes containing only radionuclides of specified concentrations with half lives less than 300 days to be disposed of in municipal landfills with appropriate engineered liner design and construction. The results of their study showed that short-lived materials would not result in an individual dose exceeding 1 mrem/yr. Reactor wastes containing significant quantities of radionuclides with half lives greater than five years (eg Co-60 and Cs-137 and some with very long half lives (Ni-63 and transuranics). The environmental impacts include the potential for pollution of air, water, and land from releases of radioactivity. They also include other environmental impacts, such as, land use, resource use, and noise pollution as the result of waste management options. Public acceptance is one of the most significant factors in determining the acceptability of the waste management strategy and the costs involved. The NRC regulations require that all licensed material be disposed of as authorized in the regulations.

The LLW waste management, including treatment and disposal, is governed by federal, state, and local regulations designed to limit radiation exposures to individuals and releases of radioactivity to the environment. The Low Level Radioactive Waste Policy Amendments Act of 1985 provides for the establishment by January 1, 1993 of regional facilities for the disposal of LLW.

Uranium is the basic nuclear fuel. Uranium mining disturbs land though not as much as coal mining. Major steps in the nuclear fuel cycle are shown in the Figure 4. Radioactive Wastes are associated with the nuclear fuel cycle operations.

NUCLEAR FUEL CYCLE

Various steps of the Nuclear Fuel Cycle consist of:

1. Mining and Milling of Uranium Ore.
2. Refining.
3. Conversion.
4. Enrichment of Uranium Ore, resulting in U235.
5. Fuel Preparation
6. Fuel Fabrication.
7. Power Generation.
8. Spent Fuel Transportation.
9. Reprocessing and Waste Recovery.
10. Waste Storage and Disposal.

Man-made radioactivity is introduced in the reactor (fissioning of the fuel, fission products, and transuranium materials) and the high-level liquid wastes at the processing plant.

RADIOACTIVE WASTE MANAGEMENT

The radioactive waste disposal is the major environmental concern in the use of nuclear power for electricity generation. The low-level radioactive and contaminated materials are in general disposed as follows:

1. Released materials to the environment under certain acceptable standards.
2. Shallow burial of low level solid radioactive waste.

GEOLOGIC DISPOSAL

Radioactive waste presents particular disposal problems due to the high level of radioactivity. It has the greatest need to shield the penetrating radiation (presence of strontium 90, and transuranium nuclides Plutonium 290) and to dissipate the heat produced by radioactive decay. The management of high-level radioactive waste is a shielding and confinement problem, but not a volume problem. Permanent isolation of spent nuclear fuel has significance beyond the immediate interests of nuclear utilities since the waste is expected to remain sufficiently radioactive to be a threat to human life and health for thousands of years. For thoughtful persons, the failure to date to develop a satisfactory method or place for permanent disposal is the strongest objection to the continuance of commercial nuclear energy. Storage in an underground repository is only one of the possible ways of getting rid of nuclear waste on a more or less permanent basis. Among the other methods that were considered, then shelved or slated for further analysis are:

1. Deep sea dumping.
2. Deep space garbage dump.
3. Burying the containers in the antarctic.
4. Deep hole disposal.

TABLE 2: STATE REGULATIONS

State regulations that limit field strengths on transmission line rights of way

State	Field Limit
Montana	1 kV/m at edge of RoW in residential areas
Minnesota	8 kV/m maximum in RoW
New Jersey	3 kV/m at edge of RoW
New York	1.6 kV/m at edge of RoW
North Dakota	9 kV/m maximum in RoW
Oregon	9 kV/m maximum in RoW
Florida	10 kV/m (for 500 kV), 8 kV/m (for 230 kV) maximum in RoW 2 kV/m at edge of RoW all new lines, 200 mG (for 500 kV single circuit), 250 mG (for 500 kV double circuit) and 150 mG (for 230 kV) maximum at edge of RoW

TABLE 3: ENVIRONMENTAL FACTORS IN THE PRODUCTION AND USE OF ENERGY

Energy Source	Effects on Land	Effects on Water	Effects on Air	Biological Effects	Supply
Coal	Disturbed land Large amounts of solid waste Mine tailings	Chemical mine drainage Increased water temperature	Sulfur oxides Nitrogen oxides Particulates Some radioactive gases	Respiratory problems from air pollutants	Large reserves
Oil	Wastes in the form of brine Pipeline construction	Increased water temperature Oil spills	Nitrogen oxides Some sulfur oxides	Respiratory problems from air pollutants	Limited domestic reserves
Gas	Pipeline construction	Increased water temperature	Some oxides of nitrogen	None detectable	Extremely limited domestic reserves
Uranium	Disposal of radioactive wastes Mine tailings	Increased water temperature Some radioactive liquids	Some release of radioactive gases	None detectable in normal operation	Large reserves if breeders are developed