DATA NEEDS OF THE ENVIRONMENTAL MODEL FOR THE INTEGRATED ENERGY SYSTEM RESEARCH PROGRAM

Robin Dennis

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I. Introduction

This paper has the purpose of putting together under one cover a short diagramatic description and the data needs of the environmental submodels that will be used in the IIASA Integrated Energy System Research Program. The environmental impact model interacts with the energy conversion and supply sectors and the end-use demand sectors. The specific objective of the model is to simulate the year-to-year quantified environmental impacts resulting from direct energy use in the region of study. To remain within the purview of energy, impacts from indirect energy use or secondary pollution products are not considered in this model. Three major pathways of environmental impact can be identified and are shown in Figure 1. These are:

(1) the impacts due to the emission of pollutants from the direct combination of energy in the demand sector (non-electric),

(2) the impacts due to the physical presence and use of the combustion machinery, e.g. land use requirements of cars and power plants, and

(3) the impacts along the fuel chain of the supply sector (including electricity production).

The environmental impact model is directly concerned with (1) and (3). The impacts from (2) will be included in a qualitative manner in the analysis and discussion of the scenarios developed for this study.

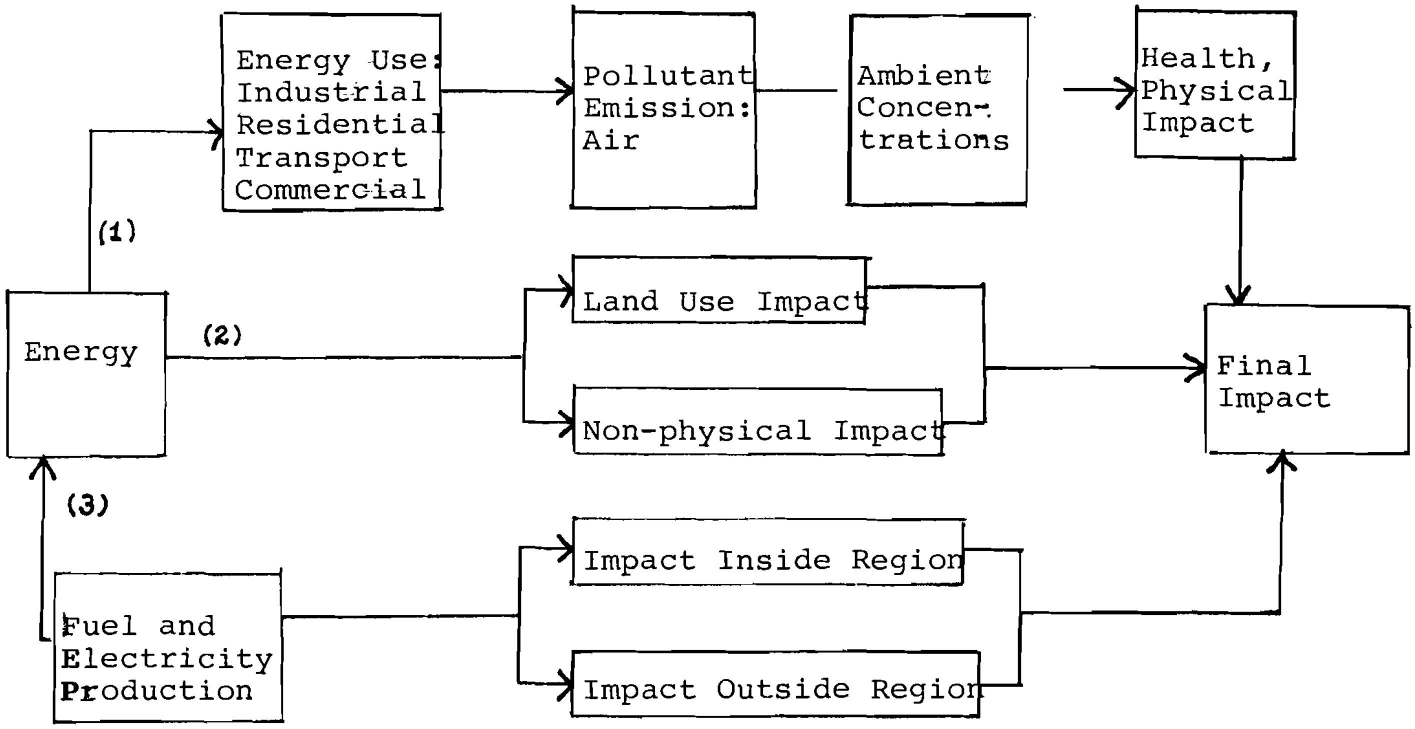


Figure 1 Pathways for Environmental Impact Analysis

Several IIASA people have primary responsibility for different submodels, and I list them here for reference sake.

Demand Sector Impacts

Emission Submodel - Koichi Ito

Dose-Impact Submodel - Robin Dennis

Supply Sector Impacts (Electricity)

Power Plant Impact Submodel - Bill Buehring

Thermal Pollution (Water) - Harold Stehfest

This same division will be used for the presentation of the submodel data needs. I am assuming here that energy use by subregion and economic sector as needed is available for both the past and for future projections. For a discussion of a method for calculating the subregional energy use from regional energy data, see Dennis and Ito (WP-75-61).

II. Demand Sector Impacts

A. Emission Submodel

The first part of the emissions submodel can be illustrated by the schematic diagram of Figure 2.

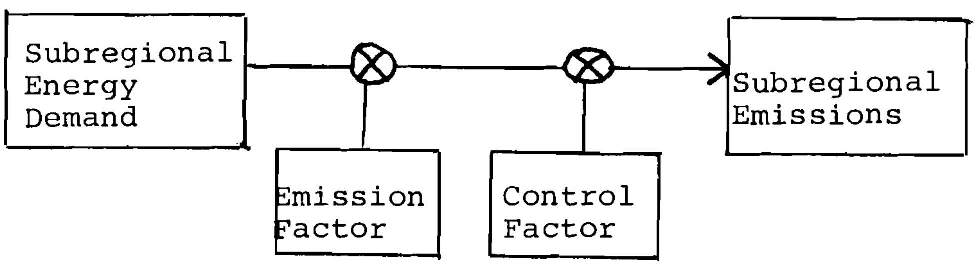


Figure 2

Data Needs

1. Residential and Commercial Sectors

   a. Emission Factors - these need to be by fuel type (coal, oil, gas) for SO_x, P.M., NO_x, and CO. In general there is a small difference between single home emissions and apartment or large building emissions. This should be ascertained.

2. Industrial Sector (by its subparts - sectors in France, SIC's in Wisc.)

   a. Emission Factors - there are two components to the industrial emissions

      (1) that due to energy combustion and
      (2) that due to the process.

      For the first, energy combustion, different industrial boilers have significantly different particulate matter (P.M.) emissions; therefore, a national average boiler type or emission factor needs to be either determined via data or assumed for each industrial sub-category by fuel type for P.M., SO_x, NO_x, HC and CO.

      For the second, process emissions, the interest is in determining the relative importance of the energy related emissions to the total emissions. Therefore, national average emission coefficients for the different industrial sub-categories is sufficient, again by fuel type for P.M., SO_x, NO_x, HC and CO.

   b. Control factors - the national average use of controls for P.M. and SO_2 need to be determined for each industrial category, either by type of control (e.g., cyclone or electrostatic precipitator) or by percentage of control. Control strategy for the future is also desirable to have.

3. Transportation Sector

   a. Emission Factors - by mode of transportation (generally gm/vehicle-mile) for NO_x, CO, HC, P.M. and SO_x.

   b. Control Factors - by mode of transportation and any control strategy planned for the future.

4. Fuel Characteristics

   a. percent sulfur (coal, oil)

   b. percent ash (coal)

The second part of the emissions submodel is concerned with a comparison of the emission influx into the subregion. (For a more detailed discussion see WP-75-61, pp. 18-21).

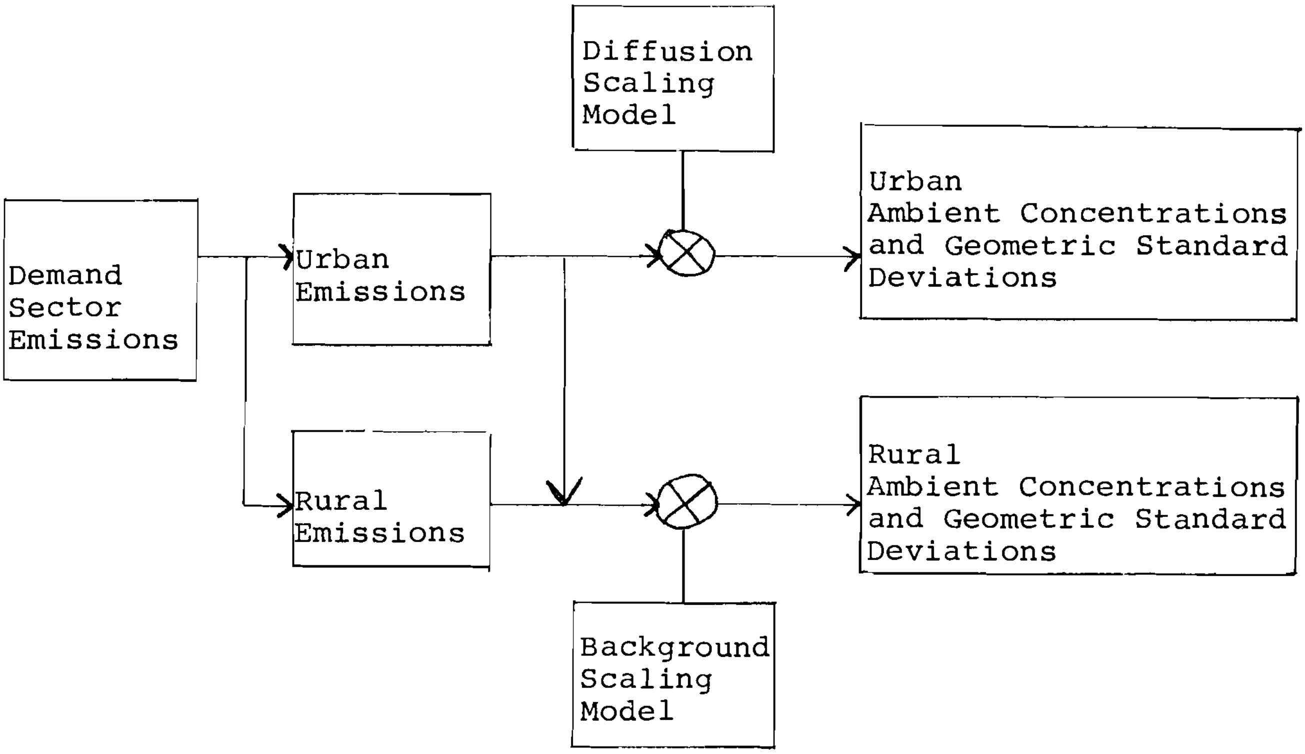
Data Needs

1. Urban area of subregion (total)
2. Rural (non-mountainous) area of subregion that is habitable.
3. Wilderness (mountain, forest, etc.) area of subregion
4. The fraction of industrial activity or energy use located in the urban area of the subregion, as a subregion average or in more detail, if possible.

B. Dose-Impact Submodel

The dose impact submodel consists of two parts. The first is a model to estimate ambient air concentrations of P.M. and SO_2 and the associated 24 hour geometric standard deviation, given the emissions. The model focuses mainly on urban areas and uses demographic, monitoring and diffusion modelling data. The second is a human health impact model that uses 24 hour average SO_2 concentrations as the health impact indicator of increases in morbidity and mortality in certain subgroups of the population. These are shown schematically in Figure 3.

(a) Ambient Concentration Model



(b) Health Impact Model

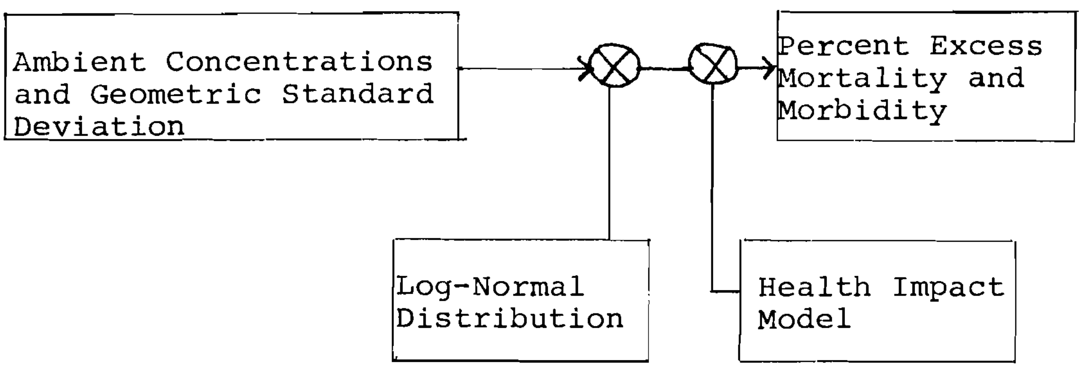


Figure 3

Data Needs

1. Ambient Concentration Model

   a. Demographic Data

      - urban population (1950, 1960, 1970 and future projections) by city.

      - urban area for the same years as population

      - total rural population for same years as urban.

      - number of industrial point sources in the urban area or the number of industries by city, if possible, and if possible their general location.

      - the general location of the industries in the rural areas, i.e., are they evenly spread out or clumped along certain major routes ar directions.

   b. Monitoring Data (for base year 1972 or 1973)

      - Geometric Annual Average Concentration of SO_2 and P.M. (SO_2 can also be Arithmetic Annual Average) by city and in rural areas.

      - Geometric Standard Deviation of SO_2 and P.M. data for the above, or as a surrogate, the 24 hour maximum observed and the number of observations taken during the year.

   c. Emissions Data

      - Percent of total P.M. and SO_2 emissions in the industrial subsectors that are related to direct energy combustion. This may require the use of production data and industry emission factors together with fuel use and boiler emission factors by industry subsection. See the above discussion for the emissions submodel.

   d. Meterological Data

      - Wind rose patterns (frequency of wind speed by direction)

      - Atmospheric stability frequency factors.

   e. Point Source Data

      - Average height of the industrial stacks (chimneys) and the power plant stacks.

      - Projections of the future heights of these stacks (as part of a control strategy).

      (Note: the following data is the most difficult to obtain and is included here more for completeness and should be attempted last).

- Stack characteristics for industries and power plants

  stack height (meters)
  stack exit diameter (meters)
  gas volume flow rate (m^3/min.)
  gas exit temperature (^oC)
  gas exit velocity (m/sec)
  thermal heat rate of boiler feeding stack (kilocal/sec.)

2. Health Impact Model

   a. Demographic Data

   - Death rates (1000/year)

   - Number of people over 65 with pre-existing heart and lung disorders, or if need be an estimate.

   - Percent of total population that is asthmatic, or an estimate

   - Number of children aged 0 - 13

   - Number of adults over 21 and the percent that smoke

III. Supply Sector Impacts

A. Electricity Impact Submodel

The electricity impact submodel calculates a set of environmental impacts associated with model power plants of five types: coal, pressurized water reactor (PWR), boiling water reactor (BWR), high temperature gas-cooled reactor (HTGR), and liquid metal fast breeder reactor (LMFBR). The impact pathways are shown in Figure 4. It should be noted that this model also considers impacts generated outside the region due to fuel use within the region.

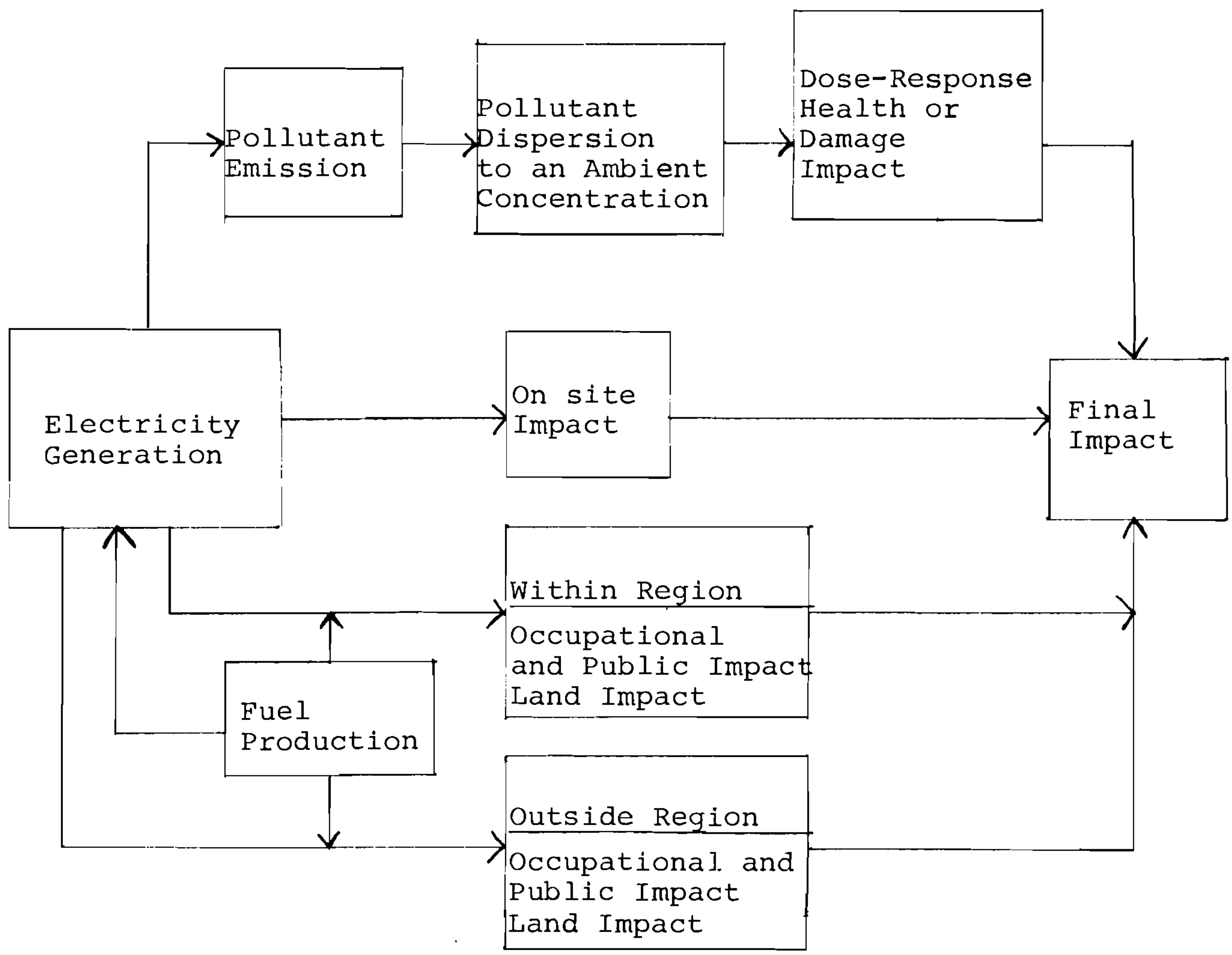

Pollutant
Emission
Pollutant
Dispersion
to an Ambient
Concentration
Dose-Response
Health or
Damage
Impact
Electricity
Generation
On site
Impact
Final
Impact
Within Region
Occupational
and Public Impact
Land Impact
Fuel
Production
Outside Region
Occupational and
Public Impact
Land Impact

Figure 4

Data Needs

The following list contains the most important elements of a longer list included as an appendix to this paper

1. Coal Power

   a. Coal characteristics

      - heat content per unit mass
      - sulfur content
      - ash content
      - trace element content

   b. Accident rates

      - fatalities per metric ton mined underground, fatalities per metric ton mined by surface mining
      - are time series data available for these rates? also, nonfatal injury rates.

   c. Freight train accident rates (or coal train , if available)

      - public fatalities per train mile
      - public nonfatal injuries per train mile
      - occupational fatalities per train mile
      - occupational nonfatal injuries per train mile
      - what is the average shipping distance for coal used in electric generation? Or are plants located at mine sites?

   d. SO_2, P.M.. NO_x, etc. emissions

      - are SO_2 controls contemplated
      - what fraction of ash is collected or emitted?

   e. What types of cooling systems are currently used and what types are expected to be used in the future

2. Nuclear Power

   a. What types of nuclear plants are expected in the future

   b. Uranium mining data

      - percent surface mined and percent underground
      - accident rates per unit mined by mining type

- grade of the ore (kgs of uranium per kg of ore mixed)

c. What is the equilibrium burnup (megawatt days thermal energy per metric ton fuel) for all reactor types being considered

d. What are the typical radioactive releases by specific radionuclide per year from the reactors? (per unit generation) Noble gases (Kr and Xe), iodine, tritium, cessium, strontium, etc.
specific radionuclider if possible, Kr-87, K4-88, Xe-133, etc.

e. Is the fuel fabricated and reprocessed in the region or elsewhere? What is the shipping distance (typical) between reactor and the reprocessing plant?

B. Thermal Pollution (Water)

The thermal pollution model calculates the increase in temperature of a river over its "natural" temperature due to the river water's use for power plant cooling and due to man's general activity on the river. A schematic of the model is shown in Figure 5.

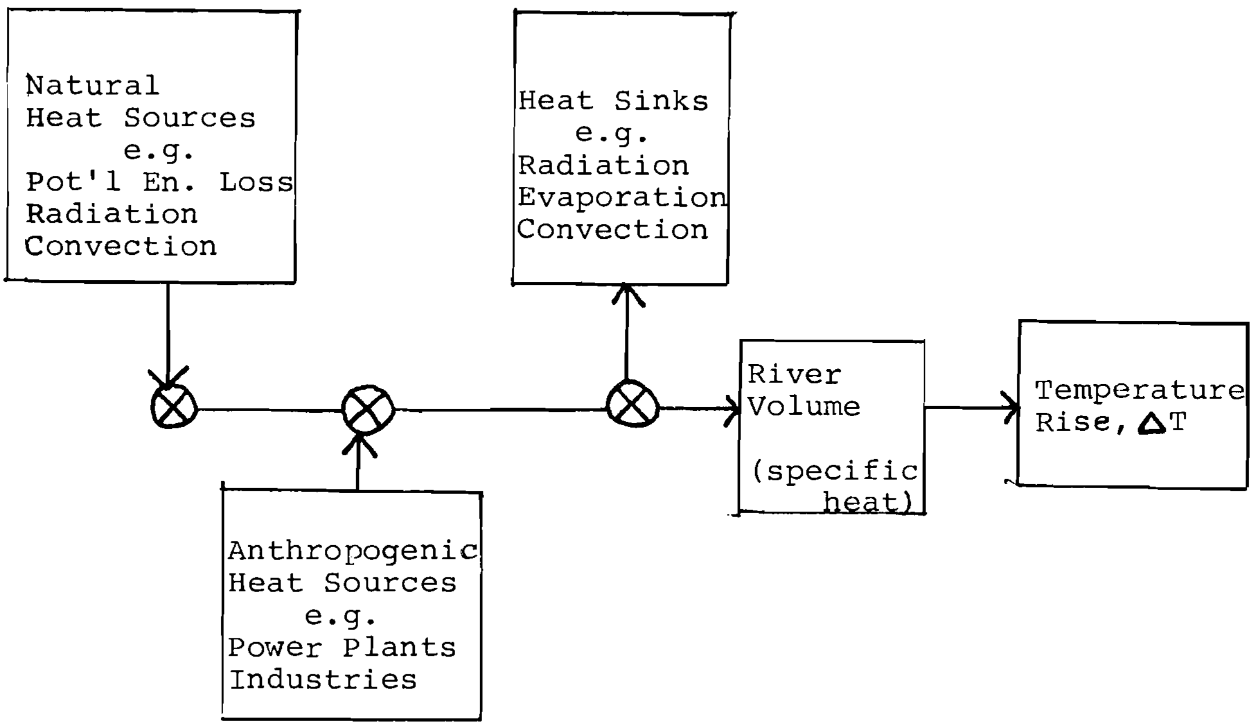


Figure 5

Data Needs

1. The Probability Distribution Function (pdf) of:

   - flow rates, Q, of the river in study (and other rivers leaving the region).

   - width of the river

   - water temperature, T_w, within the reach of river being considered for power plant siting

   - wind velocity, V, at any point near the river and near power plant sites or future sites, if possible, at a height of 2m (the height should at least be known).

   If the pdf's are not available, some characteristics of them are necessary (mean values, fractiles).

   Also, the mean values of Q, T_w, and V for each month of the year would be helpful.

2. Standards set for the maximum river water temperature

3. Data on fog frequency in the river valley (average number of days with fog for each month of the year).

APPENDIX

Important Data Requirements for Electricity Impact Model

(most important indicated by *)

Coal Power

* (1) Coal characteristics

  - heat content per unit mass
  - sulfur content
  - ash content
  - trace element content

(2) Land needed for mining

  - surface area disturbed per metric ton mined
  - subsidence from underground mining?

(3) What type of coal mining?

  - percentage surface
  - percentage underground

* (4) Accident rates -

  - fatalities per metric ton mined underground, fatalities per metric ton mined by surface mining
  - are time series data available for these rates? also, non-fatal injury rates.

* (5) Freight train accident rates (or coal train if available)

  - public fatalities per train mile
  - public nonfatal injuries per train mile
  - occupational fatalities per train mile
  - occupational nonfatal injuries per train mile
  - what is the average shipping distance for coal used in electric generation? Or are plants located at mine sites?

(6) Typical coal power plant characteristics

  - efficiency (Kwh/En in) or details of plant efficiency, e.g. boiler, cooling tower, emission controls
  - capacity at a single site
  - population within 80 kilometers

* (7) SO_2, particulate, nitrogen oxides, etc. emissions

  - are SO_2 controls contemplated?
  - what fraction of ash is collected or emitted?
  - (SO_2, ash) $\longrightarrow$ collected + emitted = total (SO_2, ash)
  - total trace element emissions

(8) Is the coal cleaned at cleaning plants to remove pyritic sulfur and other impurities? Or is coal processed?

(9) Incidence rate for disabling black-lung disease in underground coal mining

(10) What types of cooling systems are currently in use and what types are expected to be used in the future? Once through, material draft cooling towers, mech. draft cooling towers, artifical lake, spray canal, dry towers? Also for nuclear plants. Is there any difference between coal and nucelar as far as cooling system selection is concerned?

Nuclear Power

(1) What types of nuclear plants are expected in the future? My current lists indicate the following (Nuclear News, Feb. 1975):

Reactor	Size	Type	Completion Date
Rheinsberg 1	75 MWe	PWR	1966
Nord 1-1	440 MWe	PWR	1973
Nord 1-2	"	PWR	1975
Nord 2-1	"	PWR	1977
Nord 2-2	"	PWR	1978

Are other types of reactors being considered other than pressurized water reactor?

(2) Uranium mining data similar to coal if available

- * - percent surface mined and percent underground
- * - accident rates per unit mined by mining type, i.e. underground or surface
- * - grade of the ore (kilograms of uranium per kilogram of ore mixed - in the U.S. this figure is only 0.2% or 0.002 lbs/lb)
- land disturbed for surface mining per unit of uranium mined
- where is the uranium mined? outside region?

(3) Enrichment plant tails assay - what is the % U-235 in total uranium that is produced as tailings at the enrichment plant? U.S. value is typically 0.2-0.3%. Natural uranium is 0.71% U-235

(4) Will plutonium produced be recycled in the PWRs?

(5) What is the enrichment of fresh fuel for the PWRs? (% U-235)

* (6) What is the equilibrium burnup (megawatt days thermal energy per metric ton fuel) for all reactor types being considered?

* (7) What are the typical radioactive releases by specific radionuclide per year from the reactors? (per unit generation) Noble gases (Kr and Xe), iodine, tritium, cessium, strontium, etc.

specific radionuclider if possible,
Kr-87, K4-88, Xe-133, etc.

(8) Is the fuel fabricated and reprocessed in region or elsewhere? What are the shipping distances (typical) involved between

mine - mill
mill - conversion of U_3O_8 to F_6
conversion - enrichment
enrichment - fabrication
fabrication - reactor
* reactor - reprocessing
reprocessing - waste storage

Is spent fuel shipped by rail to reprocessing?

(9) Trucking accident rates per vehicel mile public and occupational fatalities, injuries

(10) Reprocessing releases - are Kr-85 and H-3 released? Other radionuclide release rates in curies or grams of the specific radionuclide per metric ton of fuel reprocessed.

(11) Population within 80 km of typical reactor site, capacity at site, expected capacity factors

$$\left(\frac{\text{annual hours of equivalent full power operation}}{8760}\right)$$

(12) Occupational accident rates at nuclear fuel cycle industries and at power plants

(13) Occupational radiation exposures at fuel cycle industries and at power plant

(14) Radioactive waste storage plans

(15) What fraction of new electrical capacity is expected to be nuclear in the coming years? The rest coal %?