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DESIGN CHANGE DOCUMENTATION
FOR THE
NATIONAL COAL MODEL

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DESIGN CHANGE DOCUMENTATION FOR THE NATIONAL COAL MODEL

Several modifications are to be made to the National Coal Model (NCM) under contract number DE-AC01-79EI-10578. These are individually listed and discussed below.

ADDITIONAL DEMAND AND SUPPLY REGIONS

The model will be expanded to include two additional demand regions (increasing the total number of demand regions to 41) and one additional supply region (increasing the total number of supply regions to 31). Eastern Pennsylvania will be separated from New Jersey and lower New York, and Minnesota will be separated from the Dakotas to form the two new demand regions. Wyoming will be split into two regions--the Powder River Basin, and all other--to form the additional supply region.

Implementing this change in the NCM will be very simple. The relevant tables and lists will be expanded to include the new regions, and the dimensionality of all relevant arrays will be increased to 31 or 41, as required.

A more difficult task will be to appropriately modify the various input data files to reflect the new regions. This task will be the responsibility of the Coal and Electric Power Analysis Division (CEPAD) staff.

EXTERNALLY-SPECIFIED TRANSPORTATION RATES

The model will be modified to use externally-specified transportation rates for each origin/destination pair, rather than the linear transportation cost equations (based on mileage) that are used presently. Thus, an input file of transportation rates (prepared externally to the NCM, as are the coal supply curves) will be used directly to provide transportation rates (\$/ton) for each coal type/origin/destination activity (i.e., column) that is generated in the transportation portion of the matrix generator.

NEW/MODIFIED REPORT WRITERS

The current NCM output reports will be reviewed by CEPAD in terms of their completeness and design adequacy. Based on this review, requirements for various modifications to the current reports and/or completely new reports may be defined. Once this has been done, the contractor will design, program, and document the new/modified report writers.

INDUSTRIAL BOILER FUEL MODEL

CEPAD is currently reviewing available industrial boiler fuel models to determine which of these, if any, should be incorporated into the NCM to improve the model's representation of the non-utility industrial sector. One candidate model being considered is the MEMM industrial boiler fuel submodel. Once a model has been selected, the contractor will develop a design plan for incorporating it as a sub-model in the NCM.

PRICE-SENSITIVE NON-UTILITY DEMANDS

In the current NCM, non-utility coal demands are specified exogenously. For example, the total demand for export coal in each demand region is specified, as well as the allowable coal type(s) to be used for satisfying these demands. The model then determines which combination of the allowable coal types will satisfy the specified level of demand at lowest cost. The same structure is also used in the other non-utility demand sectors (e.g., industrial, residential/commercial, synthetic fuels, etc.).

The realism of the NCM would be improved if the level of non-utility coal demands were made sensitive to the price of coal. A concept for achieving this goal has been developed, and it will be tested in the model by implementing it for just one of the non-utility demand sectors; namely, the industrial sector. This concept is described in the following paragraphs.

Consider the demand and supply curves shown in Figure 1. Let d_i be the amount of coal associated with the i^{th} increment on the demand curve, and let P_{d_i} be the price associated with the i^{th} increment. Thus, at a price of P_{d_i} , an incremental amount d_i of coal will be demanded. Similarly, let s_j and P_{s_j} be the incremental quantity and price, respectively, associated with the j^{th} increment on the supply curve.

Figure 1. Demand and Supply Curves

Let $\bar{p}$ represent a market clearing price, and let $\bar{q}$ be the corresponding total amount of coal demanded (and supplied). $\bar{p}$ and $\bar{q}$ can be determined analytically by finding the lowest values for m and n such that the following relationships are satisfied:

$$P_{s_n} \leq \bar{p} \leq P_{d_m}$$

$$\sum_{i=1}^{m-1} d_i \leq \bar{q} \leq \sum_{i=1}^m d_i$$

$$\sum_{j=1}^{n-1} s_j \leq \bar{q} \leq \sum_{j=1}^n s_j$$

$$\bar{q} = \min \left(\sum_{i=1}^m d_i, \sum_{j=1}^n s_j \right)$$

In general, suppose the demand curve is given as $p=f(q_d)$, where p is the price and q_d is the total amount demanded. Similarly, suppose the supply curve is given as $p=g(q_s)$, where q_s is the total amount supplied. For a given p , let $q=\min(q_d, q_s)$. Then, let the producer's surplus, $PS(p)$, and consumer's surplus, $CS(p)$, be defined by

$$PS(p) = \int_0^q (p-g(x)) dx \text{ and}$$

$$CS(p) = \int_0^q (f(x)-p) dx.$$

The producer's and consumer's surplus associated with the price $\bar{p}$ are shown as the two shaded areas in Figure 1. It is evident geometrically that finding an equilibrium solution $(\bar{p}, \bar{q})$ is equivalent to maximizing the sum of producer's surplus and consumer's surplus.

Define $d'_i=d_i$ for $i=1, \dots, m-1$ and $d'_m=\bar{q}-\sum_{i=1}^{m-1} d_i$. Similarly, let $s'_j=s_j$ for $j=1, \dots, n-1$ and $s'_n=\bar{q}-\sum_{j=1}^{n-1} s_j$. Note that $\sum_{i=1}^m d'_i=\sum_{j=1}^n s'_j=\bar{q}$. Now, $PS(\bar{p})$ and $CS(\bar{p})$ can be expressed as

$$PS(\bar{p}) = \sum_{j=1}^n (\bar{p}-p_{s_j})s'_j \text{ and}$$

$$CS(\bar{p}) = \sum_{i=1}^m (p_{d_i}-\bar{p})d'_i.$$

Then, the sum of the two becomes

$$\begin{aligned}
PS(\bar{p}) + CS(\bar{p}) &= \bar{p} \left(\sum_{j=1}^n s_j' - \sum_{i=1}^m d_i' \right) - \sum_{j=1}^n P s_j' s_j' + \sum_{i=1}^m P d_i' d_i' \\
&= - \sum_{j=1}^n P s_j' s_j' + \sum_{i=1}^m P d_i' d_i'. \quad (1)
\end{aligned}$$

Let M be the total number of increments on the demand curve and let N be the total number of increments on the supply curve. Motivated by equation (1), one deduces that finding an equilibrium solution $(\bar{p}, \bar{q})$ is equivalent to solving the following linear programming problem:

$$\text{minimize } \sum_{j=1}^N P s_j' X_j - \sum_{i=1}^M P d_i' Y_i,$$

subject to

$$0 \leq X_j \leq s_j \text{ for } j=1, \dots, N$$

$$0 \leq Y_i \leq d_i \text{ for } i=1, \dots, M$$

$$\sum_{j=1}^N X_j \geq \sum_{i=1}^M Y_i$$

Suppose $\bar{X}=(\bar{X}_1, \dots, \bar{X}_N)$ and $\bar{Y}=(\bar{Y}_1, \dots, \bar{Y}_M)$ are a solution to the LP problem. Then, $\bar{p}$ and $\bar{q}$ are determined as follows:

$$\bar{q} = \sum_{i=1}^M \bar{Y}_i$$

and $\bar{p}$ is any price that satisfies

$$g(\bar{q}) \leq \bar{p} \leq f(\bar{q}).$$

One observes that the demand increments in this formulation are treated very similarly to the supply increments--the only difference being that the prices appear in the objective function with a negative sign. To further illustrate how price-sensitive industrial demand will be treated in the NCM, a portion of a sample matrix is shown in Figures 2 and 3. Figure 2 illustrates the current treatment of industrial demand, and Figure 3 shows how the matrix will appear with price-sensitive demands added.

Looking at Figure 3, one sees three increments of a supply curve for HB coal in region VA (Virginia). The prices are \$10/ton, \$12/ton, and \$14/ton, respectively. The first row is a material balance row for coal type HB. The column depicted in the transport sector shows HB coal being transported from supply region VA to demand region WP (Western Pennsylvania) at a cost of \$5/ton. In addition, coal type HB is put into the BB (bituminous-B sulfur level) coal pile in region WP. In the supply regions, the units for coal are millions of tons (MMTONS). In the demand regions, the units for coal are QUADS (10^{15} BTUs). Thus, the -.024 appearing in the TVAWPHB column is converting the 24 MMBTU per ton HB coal into units of QUADS.

Three material balance rows are shown for supply region WP in the sample matrix. There is one for each of three coal piles, MT (metallurgical coal), BB (bituminous-B sulfur level), and BD (bituminous-D sulfur level). The row labeled EUWPIN is where the industrial demand for coal in region WP is specified. The yearly industrial demand for coal in this region is 0.9 QUADS, which can be satisfied in one of two ways--either by BB coal (see the column labeled DWPINBB) or by a blend of 30 percent MT coal, 50 percent BB coal, and 20 percent BD coal (see the column labeled DWPIN01).

Turning now to Figure 3, one observes that the equality row (labeled EUWPIN) of Figure 2 has been replaced by a less-than-or-equal-to material balance row (labeled LUWPIN) for industrial coal use in region WP. The two allowable blends for satisfying this demand remain the same, the only difference being that the column names now begin with a "C" instead of a "D". Three increments for the demand curve for industrial coal in region WP are shown in Figure 3. The prices are 600 million dollars/QUAD, 500 MM\$/QUAD, and 400 MM\$/QUAD, respectively.

7 $\leq$ SVAN3HB 10 $\leq$ SVAN2HB 8 $\leq$ SVAN1HB	TVAMPHB 1 -.024 5	DWPIN01 DWPINBB .3 1 .5 .2 -1 -1 0 0	Other Demands	≤ 0 LCVAHB ≤ 0 LUWPMT ≤ 0 LUWPBB ≤ 0 LUWPBD $= -.9$ EUWPIN $= (\min)$ NUSCST
Supply	Transport	Industrial Demand		

Figure 2. Sample Matrix

Figure 3. Modified Sample Matrix

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