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SELECTING THE INCREMENTAL USE OF THE FUEL CYCLE AND REGIONAL REFERENCE ENVIRONMENTS

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BY

ROBIN CANTOR

RANDY CURLEE

ED HILLSMAN

ENERGY DIVISION

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DISCLAIMER

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I. INTRODUCTION

To demonstrate the accounting framework and give some practical meaning to the concept of external costs of various stages of the fuel cycle, we will apply the approach to a limited number of case studies. These case studies will emphasize two of the major sectors for which energy sources are needed: electricity production and transportation. Because the intent here is to illustrate the approach and not to derive sweeping generalizations or comparisons, criteria and proposed selections for the two sectors were not constrained to be identical. However, applications to either sector require the resolution of a number of general issues that we address here.

(1) The purpose of this project is to address the external costs of fuel cycle activities for the delivery of energy services. There are two basic approaches to this problem that are not mutually exclusive, but do involve a substantially different perspective on the relevant questions that may be addressed. The first approach takes an investment view and addresses questions about the new incremental investment in the fuel cycle activity, e.g., an investment in new electricity generating facilities. The second approach takes an operating view and addresses questions about displacements or increased use within an existing system, e.g., displacing a peak load plant with more output from a marginal base load plant. The problem with the second perspective is that it requires a complete characterization of the existing system's activities to determine the marginal displacement. The investment strategy, however, can begin with the base level environmental conditions and examine the change to the base from the marginal additional. These marginal additions are defined by current and future technologies that are reasonably well-characterized for their input and output consequences. Therefore, there is a substantial difference in data requirements and availability between the two approaches. For this reason, we recommend that this project begin with the investment perspective, leaving the operations perspective for study as a possible future extension of the accounting framework.

(2) Fuel cycle impacts and the corresponding damages have ambiguous meanings in the absence of a specified increment of analysis. Because ecological systems often have important threshold properties and technological options are employed in particular scale levels, the incremental unit of analysis may not always conform to the notion of marginal use preferred by economists. A marginal change in the economist's sense may be too small to instigate many of the environmental impacts that are of interest in this study. Therefore, while we can specify a marginal change for the analysis that is logically consistent with market prices and quantities, we may have to examine incremental changes larger than the marginal unit to capture some important dose-response relationships. Once captured, these impacts can be scaled back to the marginal level for consistent comparison across fuel types.

(3) Because we are addressing the fuel cycle, which necessarily involves many related product markets, we selected the incremental use level at the main point of fuel conversion. That is, incremental use is defined by power generation for electricity production and vehicle operation in the transportation sector. Once so specified, a set of related quantities in each stage of the fuel cycle can be identified that are tied to the requirements at the conversion

stage. For example, a certain size coal plant will require so many tonnes of coal fuel per year.

(4) To apply the framework, we must characterize some ecological system that is affected directly by fuel cycle use. Because we are very limited in the number of case studies that can be completed successfully in the project's time frame, we wanted the selected case studies to illustrate diverse externality problems under different environmental conditions. Therefore, diversity was an overriding consideration in the selection of proposed regional reference environments. Additionally, we wanted to balance the analytical benefits of constructing a model environment, that could be manipulated in its underlying conditions to address diversity, with the realism offered by actual environmental conditions. Therefore, we propose a combination of at least one model environment and two actual environments for the electricity production and transportation applications.

(5) There is the issue that some time frame must be specified to limit the possibilities over technological options and environmental characteristics. We resolved this issue in the implementation plan for the study, where two time frames will be imposed: 1990 and 2010. The 2010 time frame will allow us to consider how reasonably assured changes in fuel cycle technologies may alter the externalities generated by their use. We will construct the 2010 world for analysis by relying on the future scenarios constructed for the U.S. National Energy Strategy analysis.

In the sections to follow, we provide further discussion of the incremental use and regional environment issues as applied to the electricity production and transportation sectors. Within each discussion, we propose options that best satisfy particular criteria to resolve these issues.

II. ELECTRICITY PRODUCTION

For the purposes of this study, the following fuel types are considered for the production of electricity -- coal, natural gas, petroleum, uranium, hydro, biomass, wind, and photovoltaics/solar. Conservation can also be accommodated by the framework to the extent that it offers an alternative strategy to capacity additions. Thus, conservation technologies can be evaluated for the external costs they generate and the external benefits of avoided environmental and health damages from saved capacity additions.

Table 1 gives information on U.S. operable generation capacity and planned capacity additions by energy source as of December 1988. Coal accounted for 43.9% of all operable capacity, followed by natural gas at 17.3%, nuclear at 14.3%, water/hydro at 12.0%, and petroleum at 11.9%. Capacity based on solar, wind, and wood accounted for less than 1% of total operable capacity. Examining planned additions for the 1989 to 1998 time frame, coal is expected to fuel 35.3% of additional capacity, followed by nuclear at 24.2% and natural gas at 23.6%. Petroleum and water are expected to account for 8.5% and 6.6%, respectively. Facilities utilizing solar, wind, and wood account for significantly less than 1% of all planned capacity.

Table 1. U.S. operable capacity and planned capacity additions by energy source as of December 1988

Primary energy source	Operable Capacity: Number of units		Operable Capacity: Generator nameplate (MW)		Planned Additions: Number of units		Planned Additions: Generator nameplate (MW)		Planned Additions: Average unit size (MW)
	Units	%	Capacity	%	Units	%	Capacity	%	
U.S. Total	10,305		723,852		301		44,206		
Coal	1,267	12.3	317,934	43.9	29	9.6	15,593	35.3	537.7
Petroleum	3,354	32.5	85,981	11.9	56	18.6	3,746	8.5	66.9
Gas	1,966	19.1	124,885	17.3	101	33.6	10,419	23.6	103.2
Water	3,496	33.6	86,886	12.0	89	29.6	2,919	6.6	32.8
Nuclear	108	1.0	103,397	14.3	9	3.0	10,681	24.2	1,186.8
Solar	6	0.1	2	--	3	1.0	3	--	1.0
Wind	17	0.2	4	--	--	--	--	--	--
Wood	11	0.1	223	--	--	--	--	--	--
Other	80	0.8	4,540	0.6	14	4.7	846	1.9	60.4

Source: Energy Information Administration, Inventory of Power Plants in the United States, 1988.

II.1 INCREMENTAL USE FOR ELECTRICITY

Our primary criteria for selecting an incremental use level are (1) capacity levels large enough to result in marginal social costs that are measurable and meaningful, and (2) capacity levels that are consistent with planned capacity additions and with new generation technologies in the development stage. Given the capacity level, we can scale damages to the kilowatt hour or megawatt for comparative analyses among fuel types.

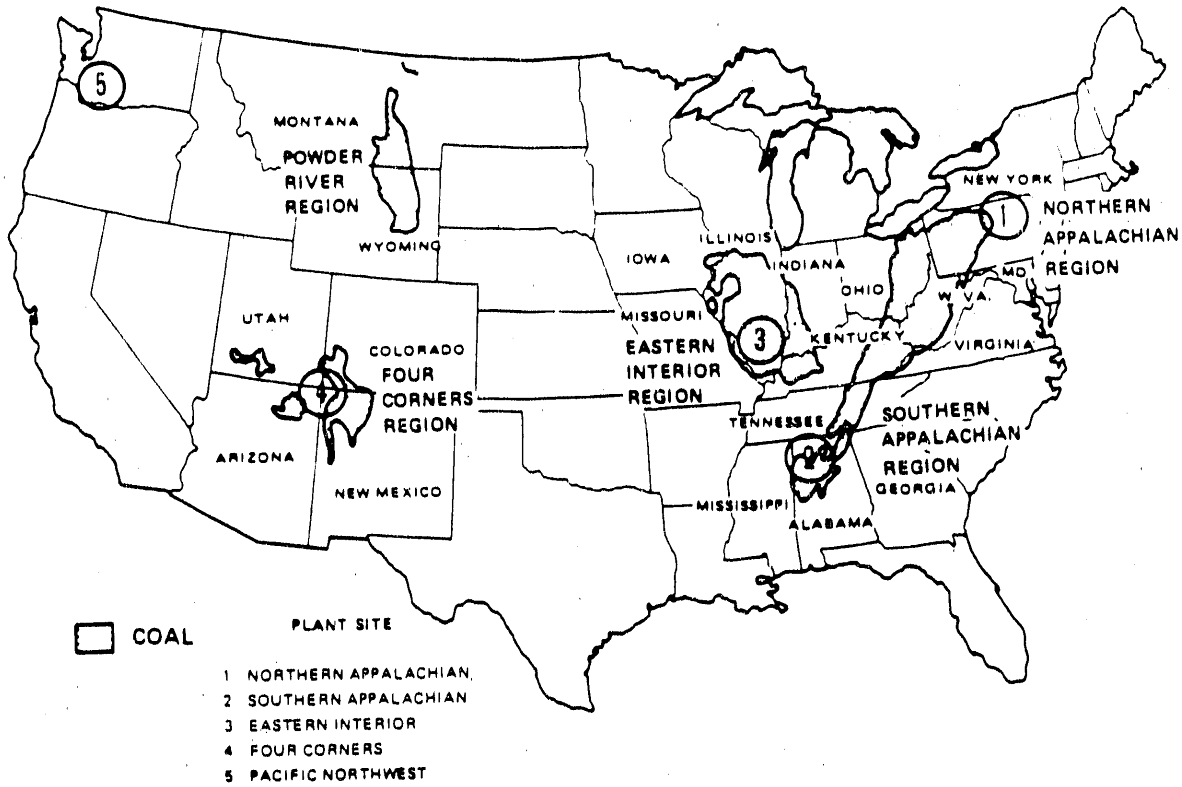
Based on Table 1, the following capacity levels are proposed: 500 MW for coal; 100 MW for oil and gas; 30 MW for hydro; 600 MW for nuclear; and 1 MW for solar, wind, and biomass. Having selected the capacity levels, we can use per unit analysis, supported by assumptions regarding the scaling of impacts, to determine damages by MW and KWh. While the 600 MW level is small for existing nuclear units, many recent studies of advanced nuclear concepts (Fulkerson et al. 1989) and economies of scale (Cantor and Hewlett 1988) support 600 MW as a reasonable increment for future capacity additions.

II.2 REGIONAL REFERENCE ENVIRONMENTS FOR ELECTRICITY

Social costs associated with the production of electricity will vary by fuel type, facility type, and geographical region. In the selection of regional reference environments, it is important to select sites that display a wide range of socioeconomic and environmental systems. Furthermore, sites for electricity production are limited to candidates that can reasonably be expected to host a coal or nuclear generating facility. It is also important to select sites that are candidates for additional generation capacity and can accommodate most, if not all, the electricity generating technologies to be considered in this study. Finally, to fully utilize existing information, sites that have been the focus of recent environmental impact assessments should be given special attention.

Five sites that meet all the above criteria are identified in a 1977 study by Argonne National Laboratory entitled "The Environmental Effects of Using Coal for Generating Electricity." Those sites include the Northeast (Northern Appalachian), Southeast (Southern Appalachian), Midwest (Eastern Interior), Southwest (Four Corners), and the Pacific Northwest. Three sites best fulfill the criteria stated in the previous paragraph: the Midwest, Southeast, and Four Corners regions. We suggest the Southeast and Four Corners regions are selected for analysis, and a model environment is constructed to capture any excluded environmental or economic considerations. Figure 1 shows the locations of the sites from the Argonne study. These sites are reasonably well characterized for important socio-economic and ecological considerations. They are regionally diversified and are likely to illustrate very different externality results for the electricity production analysis.

FIGURE 1: PROPOSED REGIONAL REFERENCE ENVIRONMENTS



III. TRANSPORTATION

At present, transportation energy supply for vehicle operation is dominated by petroleum products: 97.3% of the sector's energy is from petroleum, 2.6% is from natural gas (for pipelines) and .1% is from electricity (for pipelines and, to a lesser extent, rail). The mix in Europe and Japan is likely to be similar, with a higher proportion of electricity for electrified rail and, in Japan, probably less significant energy use by pipelines. In the US, automobiles and light trucks consume 62% of transportation energy,; heavy trucks 15%; commercial aircraft 9%; waterborne modes 6%; rail 2%; and pipelines 4% (these do not sum to 100% because of rounding).

Although it is common to think of transportation as linking cities, the use of transportation is concentrated in urban areas. Intraurban transportation accounts for roughly two-thirds of the use of automobiles and light trucks in the US. Even in modes where most transportation activity occurs between cities, activity and its impact are concentrated in cities. For example, most commercial airports, marine ports, truck terminals, and rail yards are in the urban areas they exist to serve, or are usually nearby. Vehicle manufacturing is concentrated in or near urban areas. There is a long history of urban expansion attributable to the availability or necessity of transportation facilities.

Many impacts of transportation either occur only in cities or are most evident within them. Congestion and effects on local air quality are greatest there. Impacts of emissions from transportation on biological systems tend to be downwind of large concentrations of emissions in urban areas. Other impacts occur both in urban and rural areas, but those in urban areas are representative of those in rural areas, especially when the suburban fringe is considered. Examples include the effects of port or waterway dredging, those of winter maintenance (de-icing), the community disruption associated with infrastructure expansion, and the conversion of land from agricultural to urban or suburban uses.

Some impacts of transportation occur primarily in rural areas but are specific to modes or locations. For example, infrastructure links can impede wildlife migration, and the impact of additional noise may be qualitatively different in some rural areas. Finally, some impacts of transportation (the potential impacts of greenhouse gas emissions, or of high-flying aircraft on the stratosphere) are global and, in a sense, aspatial, although they can be associated with consumption of services in urban areas.

In general, transportation tends to be capital intensive, and there is a tendency to avoid excess capacity if permitted to do so. On the service supply/use end, there are substantial indivisibilities and economies of scale in vehicles; adding a locomotive, pipeline, or plane, means adding quite a bit of capacity. There are on the order of 10^2 major pipelines, 10^3 (each) commercial aircraft, cargo ships, and barge movers, and 10^4 locomotives in the US. On the other hand, there are on the order of 10^6 heavy truck tractors and 10^8 automobiles and light trucks. As a rough rule of thumb, the US fleets are about a third of the world's fleets.

Finally, there are significant linkages between modes and between fuel choices and modes. Much of the non-highway transportation is linked to highway modes; air travel requires ground travel to reach airports at each end of the trip, and often is undertaken in order to consume ground transportation at the destination. Much waterborne commerce uses other modes to reach inland destinations. Much of the material moved by rail moves by truck on one or both ends of the trip. With regard to fuel, a major share of the cargo of pipelines and waterborne vessels is petroleum or petroleum products that, ultimately, is consumed in transportation. Petroleum transportation is a smaller but still significant share of truck traffic, as is coal for railroads. A shift from petroleum fuels to fuels from other energy resources would affect not only the impacts of consuming transportation, but also the amount of transportation consumed in different modes. For example, the present pipeline network was established to move oil and gas, and would have to be altered greatly if coal or biomass were used to produce liquids; alternatively, substantial amounts of coal would have to be moved to the heads of the pipelines for conversion to liquids.

III.1 INCREMENTAL USE FOR TRANSPORTATION

Transportation service consumption results from diffuse, decentralized decision making by millions of consumers. Although some of the impacts of one trip, one vehicle, or one consumer can be calculated, they are minuscule. Against a background of hundreds of millions of trips per day, the impact of an additional trip is essentially impossible to identify. In addition, some of the effects of increased consumption do not become apparent without cumulative growth; in general, one additional vehicle does not "cause" congestion, but "enough" additional vehicles do (there do appear to be thresholds in infrastructure capacity use that, when crossed, lead to generally noticeable reductions in trip speed, but even these are sufficiently variable that it is not possible to say precisely what level of traffic is critical). Finally, the impacts of different modes can vary greatly for a single vehicle (plane vs car) or traveler (additional car vs increased aircraft load factor).

The effects of even a 1% increase in transportation consumption would be difficult to analyze, because present increases in new-vehicle fuel economy in several modes are offsetting some of the increases in energy consumption that result from increased vehicle use. In addition, such a small increment can be difficult to isolate from a background of emissions and social costs from other sources (industry, building energy consumption).

For this reason, we recognize that in some cases, we must use a larger increment to capture important impacts and damages. As with the electricity production case, these non-marginal changes can be scaled back to the more logical vehicle mile or vehicle unit levels. Because in the U.S., automobile travel dominates transportation energy consumption, we recommend for this mode that the increment be chosen to facilitate analysis of increased automobile traffic. Consumption of automobile travel (vehicle miles traveled) is increasing at approximately 2% annually, and is forecast to increase at similar rates for the next several decades. In general, a year's change in traffic volumes does not appear to be noticeable to urban residents. With several years' growth, however, differences in noise and congestion at the consumer and neighborhood levels become apparent when considered retrospectively.

A 10% increment would yield about five years' increase in the base level of consumption. This is large enough to permit isolation of effects from the background. It also begins to be commensurate with some of the process of planning new infrastructure or expanding the capacity of existing infrastructure (although plan implementation often takes much longer).

For other modes, consumption of heavy truck transport (ton-miles) is increasing at 5% annually; of air passenger services (revenue passenger miles), 9%; air cargo (ton miles), 11%; waterborne commerce (ton-miles), 1%; pipeline transport (ton-miles for petroleum), 1%; and railroad (ton-miles), 3%. For impacts and damages that cannot be detected at the vehicle mile or single vehicle unit level, we will begin with a 10% increase in consumption which is equivalent to .9-10 years' growth, depending upon the mode being considered.

III.2 REGIONAL REFERENCE ENVIRONMENTS FOR TRANSPORTATION

Given the concentration of impacts in urban areas, we recommend that the reference environments be urban areas. Those impacts of transportation service consumption that are predominantly or exclusively rural can, as necessary, be noted in an "other" category. Given the number of modes to be considered, and the limitation of three reference environments for analysis, we recommend that the reference urban environments be selected where possible to allow diversity that emphasizes: mode-specific impacts; climate; ecological features; and demographic features. An additional criterion is the existence of recent data sources for the area, such as environmental impact statements, that can be used in our analysis. Finally, we recommend avoiding the very largest urban areas as reference environments, because their size makes them extreme for impacts related to congestion.

Based on these criteria and in addition to the model environment, we suggest the following actual urban areas as candidates, with the final set to include one of the first two and one of the last two. Although highway transportation and air transportation are present in all major urban areas, the following present special opportunities for these or other modes:

Memphis. Air passenger hub; air freight hub; inland waterway port; significant rail and truck center; humid, inland environment.

Denver. Air passenger hub; building the first new major airport in fifteen years (EIS should cover both air and related ground transport impacts); serious air quality problems similar to those in other cities in arid or semiarid environments.

Philadelphia. Seaport. Significant pipeline terminal. Significant tanker traffic.

Seattle. Seaport. Significant tanker traffic. Major railhead for transpacific shipping. Fragile ecological areas nearby. Presently analyzing potential impact of reducing transportation consumption growth on local air quality.

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