ENVIRONMENTAL RESEARCH RELATED TO FOSSIL FUEL CONVERSION

by

Gerald J. Rausa
Environmental Scientist
Energy Coordination Staff
Office of Energy, Minerals, and Industry
U.S. Environmental Protection Agency
Washington, D.C. 20460

Abstract

The taxonomy of environmental research developed by the CEQ-OMB Interagency Working Group on Health and Environmental Effects of Energy Use is used to convey the ongoing environmental research related to conversion of solid fossil fuels to liquids and/or gases. The inventories of activities in the interagency (pass-thru) program and in the base programs of the contributing agencies is discussed. Research for all modules of the fuel cycle is addressed. As a consequence, some research which is generally applicable to all fossil fuel cycles is included in the discussion.

INTRODUCTION

Some difficulty is encountered in the attempt to categorize the environmental research which is solely applicable to fossil fuel conversion, since some aspects of environmental research are related in common to a number of industries, including the energy industry and its associated technologies. In particular, the various fossil fuel conversion cycles have problems in common with other fuel cycles as well as having technology-specific problems. In order to convey the scope of environmental research related to fuel conversion (liquefaction or gasification), it is appropriate to discuss the generally applicable environmental research as well as that which is process-specific.

It is debatable whether or not energy related environmental research can be partitioned into mutually exclusive categories that are acceptable to all interested parties. For example, one such grouping of tasks could be according to environmental agents, i.e., physical, chemical, and biological stressors. Another possibility could be a sorting according to the environmental media into which the agents are initially introduced, i.e., air, water, and land. A third sort could be according to the targets of concern, i.e., human health, environmental quality, ecological systems, social systems or economic systems.

In this presentation, the taxonomies developed by the two OMB-CEQ working groups[1,2] in the planning of energy related enviromental research will be used to categorize the research activity to be discussed. The subject working groups were assembled to respond to an inquiry as to whether or not energy related environmental research was being undertaken on a schedule compatible with the development of energy technology, and to indicate the additional environmental research needed. The categories utilized by the two working groups are displayed in Figure 1. The "Gage Committee" addressed the engineering aspects of control systems while the "King/Muir Committee" addressed the environmental processes and effects aspects of the energy systems. The categories were developed by the interagency working groups to provide a planing structure that could be used by each agency in order to permit the individual components of activity to be aggregated within the overall interagency (pass-thru) program, while still permitting each agency to fit the "pass-thru" component within its own base program structure. In essence, the interagency program is supplemental to the base programs of energy related environmental research of the individual agencies.

The interagency planning structure is depicted in Figure 2. For each major fuel cycle, the additional research needs for the working groups were listed for each module of the cycle. Common problems and pertinent research requirements were then aggregated and priorities were established according to the following major processes and effects categories:

1. *Pollutant Characterization, Measurement and Monitoring* (CM&M)

The objective of this research is to provide

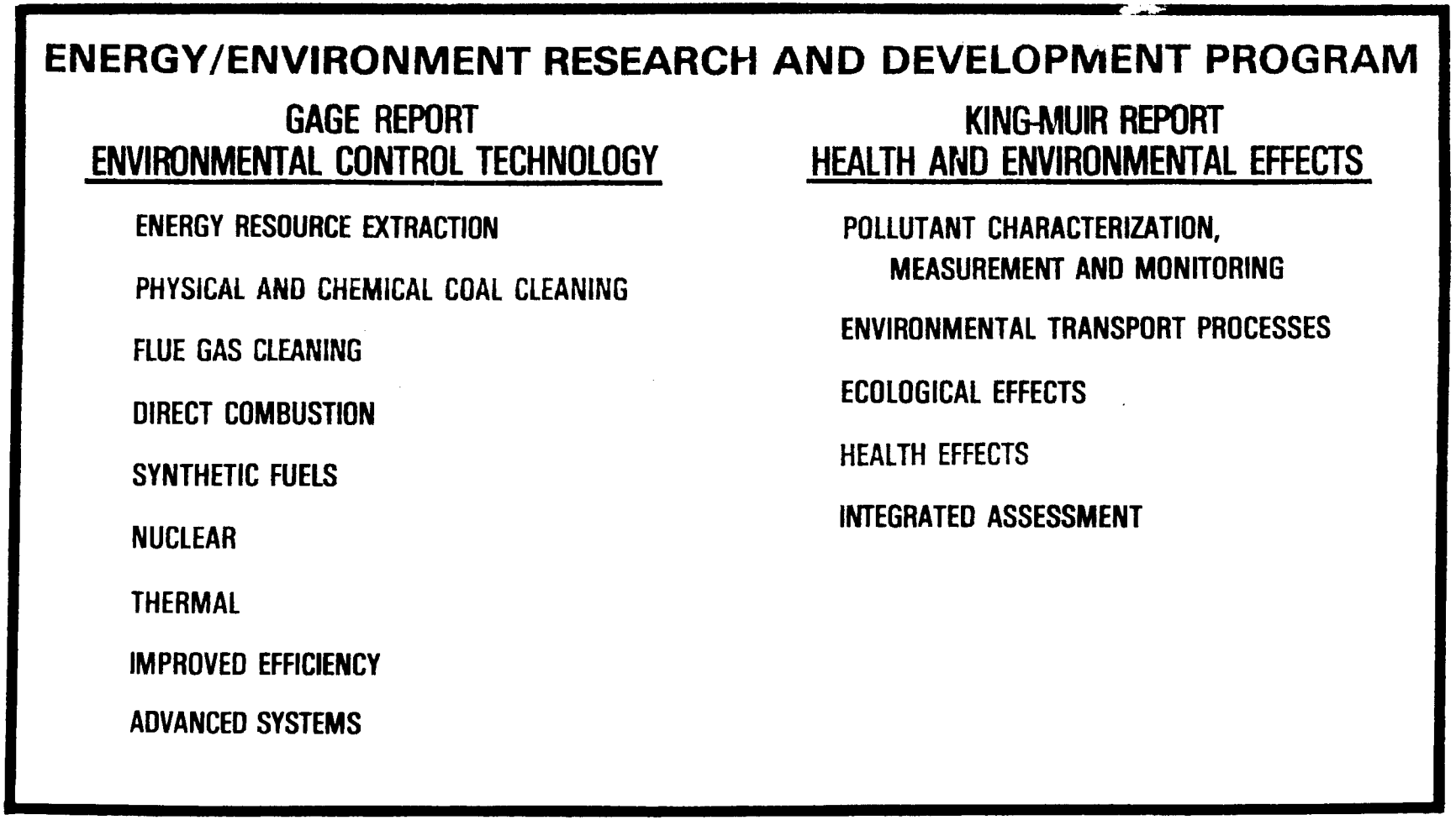

Figure 1. OMB-CEQ working groups on energy-related environmental research.

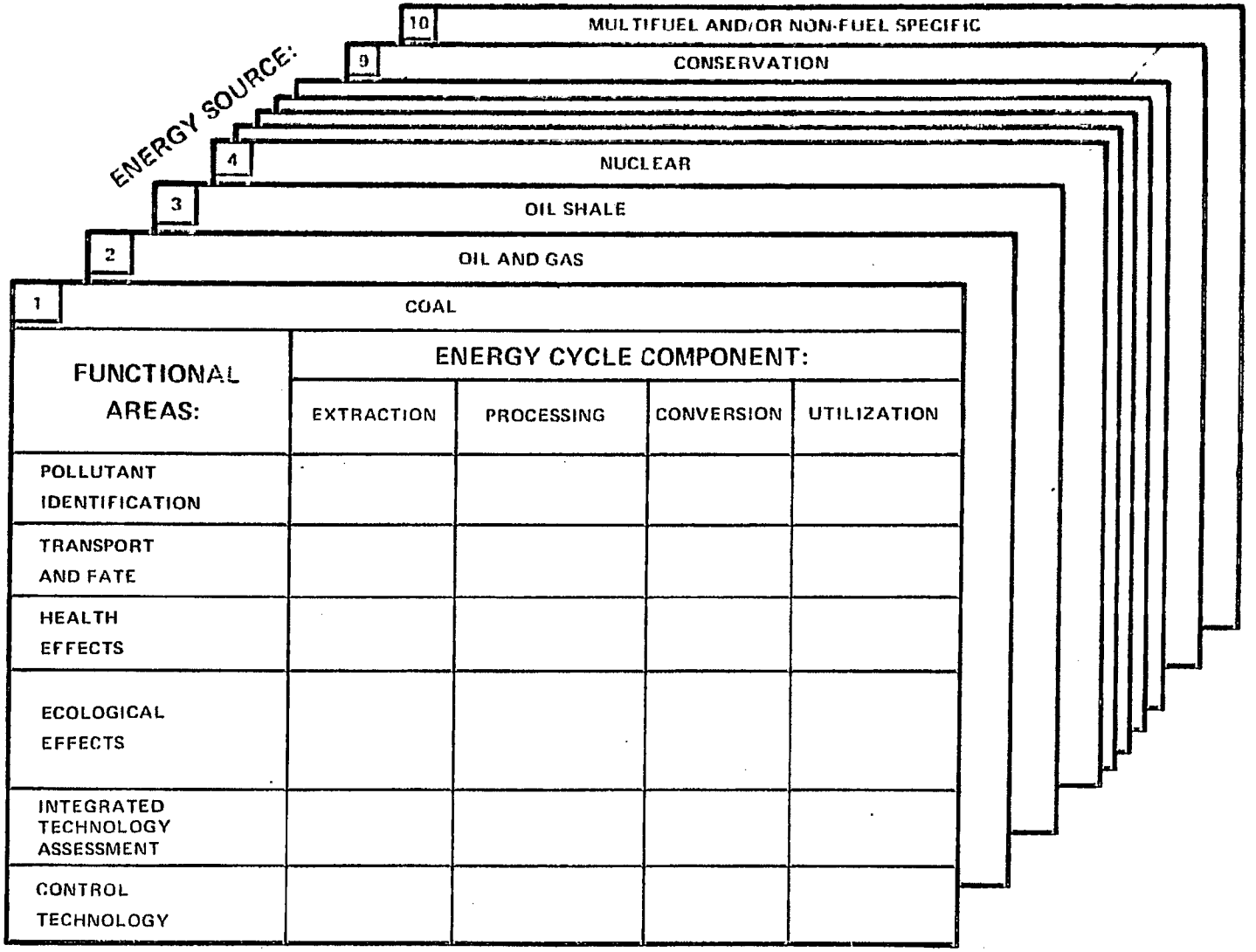

Figure 2. Interagency planning structure.

reliable and accurate measures of the quantities and characteristics of released pollutants, transformed products and indices of environmental impacts. The major subcategories of research include instrumentation development, source characterization, ambient monitoring and quality assurance.

2. *Environmental Transport Processes* (ETP)

The objective of research in this category (also occasionally titled Pollutant Transport, Transformation and Fate - TT&F) is to provide reliable estimates of the spatial and temporal relationships between emissions and ambient environmental quality which represents the exposures to the targets of concern. The major categories of research include atmospheric pathways, aquatic pathways, terrestrial pathways, and biological pathways (Figure 3).

3. *Ecological Effects* (EE)

The objective of this research is to determine the acute and chronic impacts to ecosystems and the components thereof - specifically the nature and extent of response to various stimuli associated with energy production. The components of concern include the habitats, populations, and processes in the atmospheric, aquatic, and terrestrial ecosystems.

4. *Health Effects* (HE)

The objective of this research is to provide reliable qualitative and quantitative estimates of effects on human health due to energy related agents - for long term, low level exposure, for all modules of energy production and use, and for susceptible occupational and general population groups. The major subcategories of research include:

1. The development of more rapid indicators for dose and biological damage;
2. The identification of hazardous agents associated with energy systems;
3. The development of understanding of biological mechanisms of metabolism and fate;
4. The development of understanding of mechanisms of damage, repair, and recovery in biological systems from energy related agents;
5. The development of estimates of risk to human health evaluated through human health studies and animal toxicological studies, and by improvement of techniques for extrapolation of data from animal to man and from high levels of exposure to low levels of exposure.

Figure 4 indicates the relationships amongst these areas of research.

5. *Integrated Assessment* (IA)

The objective of this research is to provide the methods for, and to undertake comprehensive evaluation of the impact of energy production and use on the total "human environment" from local, regional, and/or national perspective. To this end the subcategories of activity include:

1. integration of information;
2. social and welfare effects analysis;
3. cost/risk/benefit evaluation;
4. analysis of alternative methods of implementation of strategies; and
5. siting analysis.

ENERGY/ENVIRONMENT PROGRAM EMPHASIS

Before elaborating upon the research applicable to fuel conversion, it is appropriate to convey some perspective regarding the magnitude of the effort, and the emphasis being undertaken for all federally supported, energy related environmental research which is listed in two available data files.[3,4] The data bases used for this perspective include the EPA coordinated interagency program data file and the ERDA FY-76 inventory of energy related environmental research. The ERDA inventory may not have captured all of the subject research tasks because of the lack of a precise definition of the phrase "energy related environmental research," and the subsequent interpretation of that phrase by the respondents.

In the EPA coordinated interagency environmental processes and effects program, the relative emphasis has remained reasonably

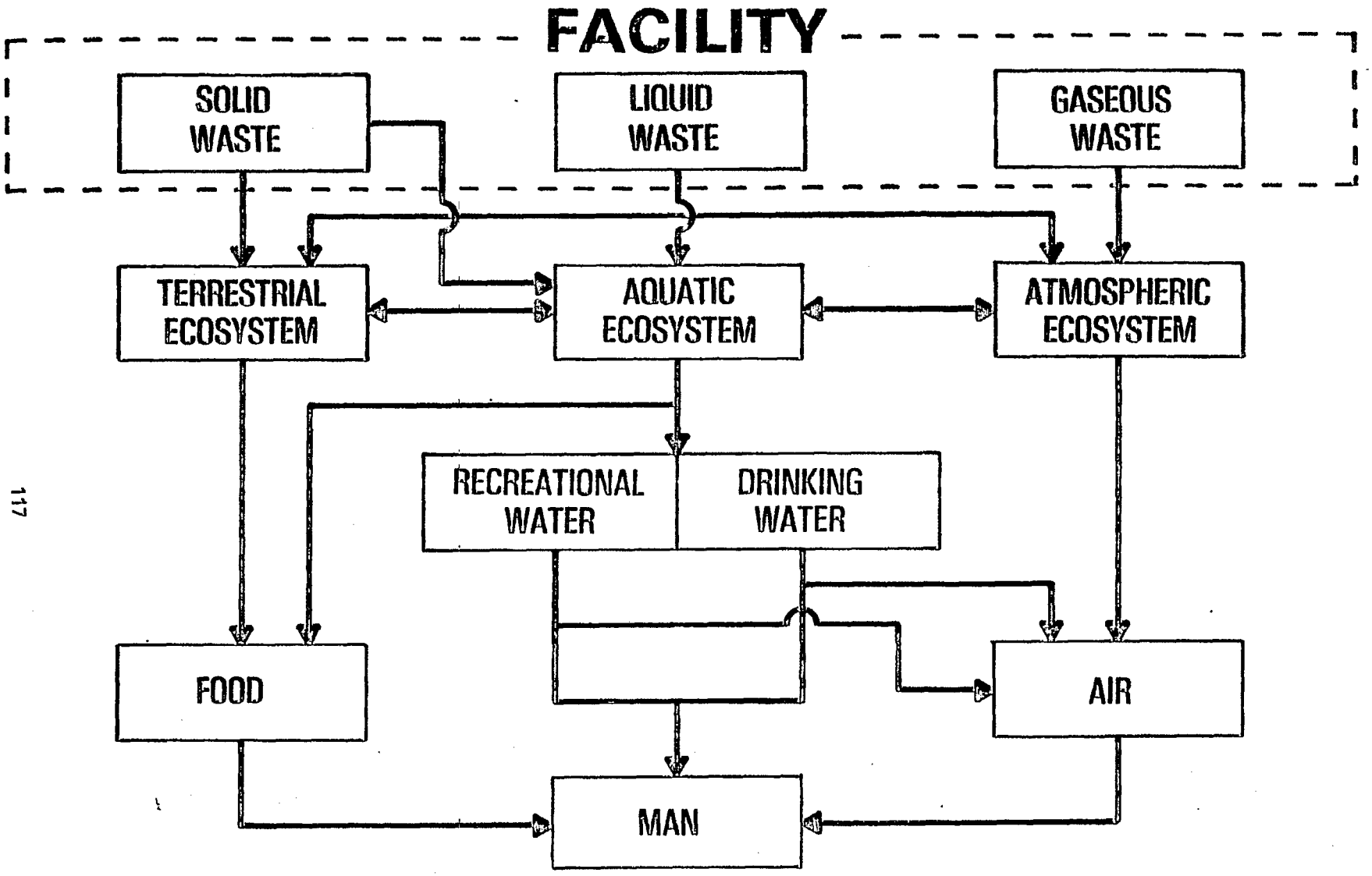

Figure 3. Environmental pathways model.

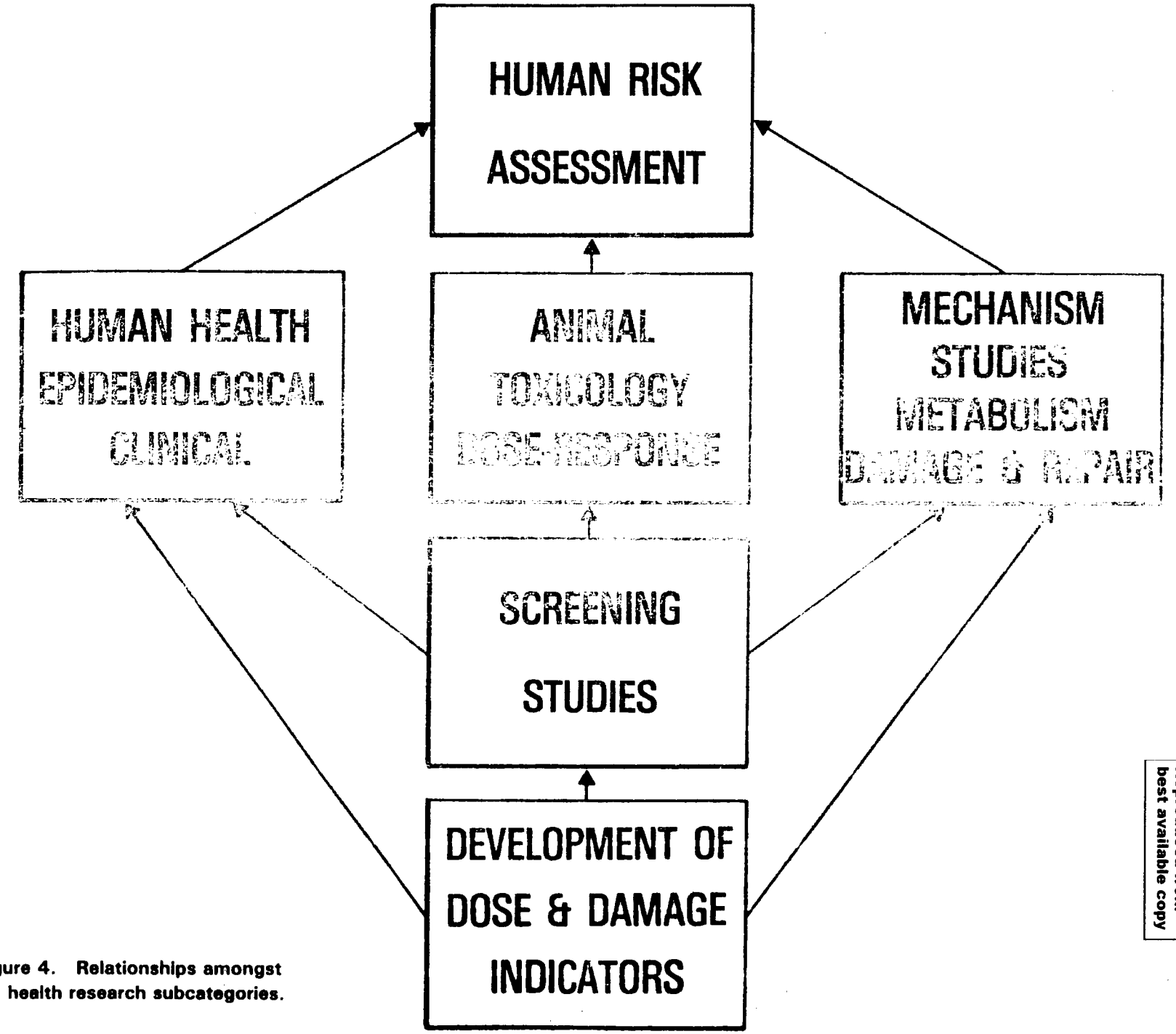

Figure 4. Relationships amongst health research subcategories.

stable for FY-75, FY-76, and FY-77 (Figure 5), with the major emphasis, approximately 32 percent, upon health effects research. A comparable evaluation for the total energy related environmental research program (base programs and interagency pass-thru program), which was obtained from the ERDA FY-76 inventory, is displayed in Figure 6. Comparison to the pass-thru program indicates that the supplemental interagency effort increased the relative emphasis on measurement and monitoring and on ecological effects research.

Disaggregation of the relative emphasis (FY-76) of the interagency program, according to components of the fuel cycles for all energy systems, indicates a relatively uniform emphasis for extraction, processing, and utilization (Figure 7). For the base programs the emphasis according to the same modules is 23 percent, 15 percent, and 62 percent, respectively. The emphasis on utilization is related to the research to resolve the nuclear waste management problem.

The distribution of effort for all energy related environmental research, categorized according to energy technology, was displayed in the ERDA inventory and is reproduced in Figure 8. As expected, the major efforts are for nuclear and fossil systems with an additional component applicable to several fuel cycles. A similar analysis for the supplementary pass-thru program indicates that most of that particular funding has been allocated to research applicable to fossil fuel technologies.

A more comprehensive breakdown of the emphasis in environmental research applicable to fossil fuel technology for both the interagency pass-thru program and for the base programs is presented in Figure 9. The data indicate that, while approximately 46 percent of the base funding for processes and effects projects are related to fossil fuel technology, approximately 92 percent of the pass-thru program was applicable thereto, thus making 52 percent of the total FY-76 funding reported applicable to fossil fuel technology. The data indicate that the major emphasis and the largest number of projects being undertaken address health effects issues. On the other hand, the largest average cost per task is for ecological effects research, while the lowest average cost per task is for health effects research.

ENVIRONMENTAL RESEARCH FOR ADVANCED FOSSIL FUEL CYCLES

As suggested previously, the advanced fossil fuel cycles will require resolution of some problems in common with the conventional fossil fuel cycles. The problems in common are those primarily associated with the extraction and/or utilization module of the full cycle. Examples of such common problems include the following:

1. Impacts upon water quality due to mine drainage or leaching from disposal of solid waste, and subsequent impact upon aquatic ecosystems;
2. Impacts upon water supply associated with aquifier disruption (mining), revegetation requirements or slurry transport;
3. Impacts upon air quality and weather/climate modification (local and regional) from surface mining and combustion;
4. Impacts upon health related to coal dust and waste products of combustion (SO_x, NO_x, hydrocarbons, particulates, trace metals, organometallics), and their environmentally transformed products;
5. The need to develop measurement tools and techniques and obtain the baseline information for likely sites; and
6. Comparative evaluation of alternative futures for likely sites and the addressing of "boom town" problems.

Specific problems within each of the categories are as follows:

Characterization Measurement and Monitoring - the process specific concerns associated with advanced fossil fuels systems stems from the spectrum of agents anticipated to be associated with the variety of proposed processes and products. Of major concern is the variety of organic agents in the products and waste streams. An example of a variety can be seen in the chromatogram of a coal liquefaction product, made by M. Guerin of Oak Ridge National Laboratory,[5] is displayed in Figure 10. Il-

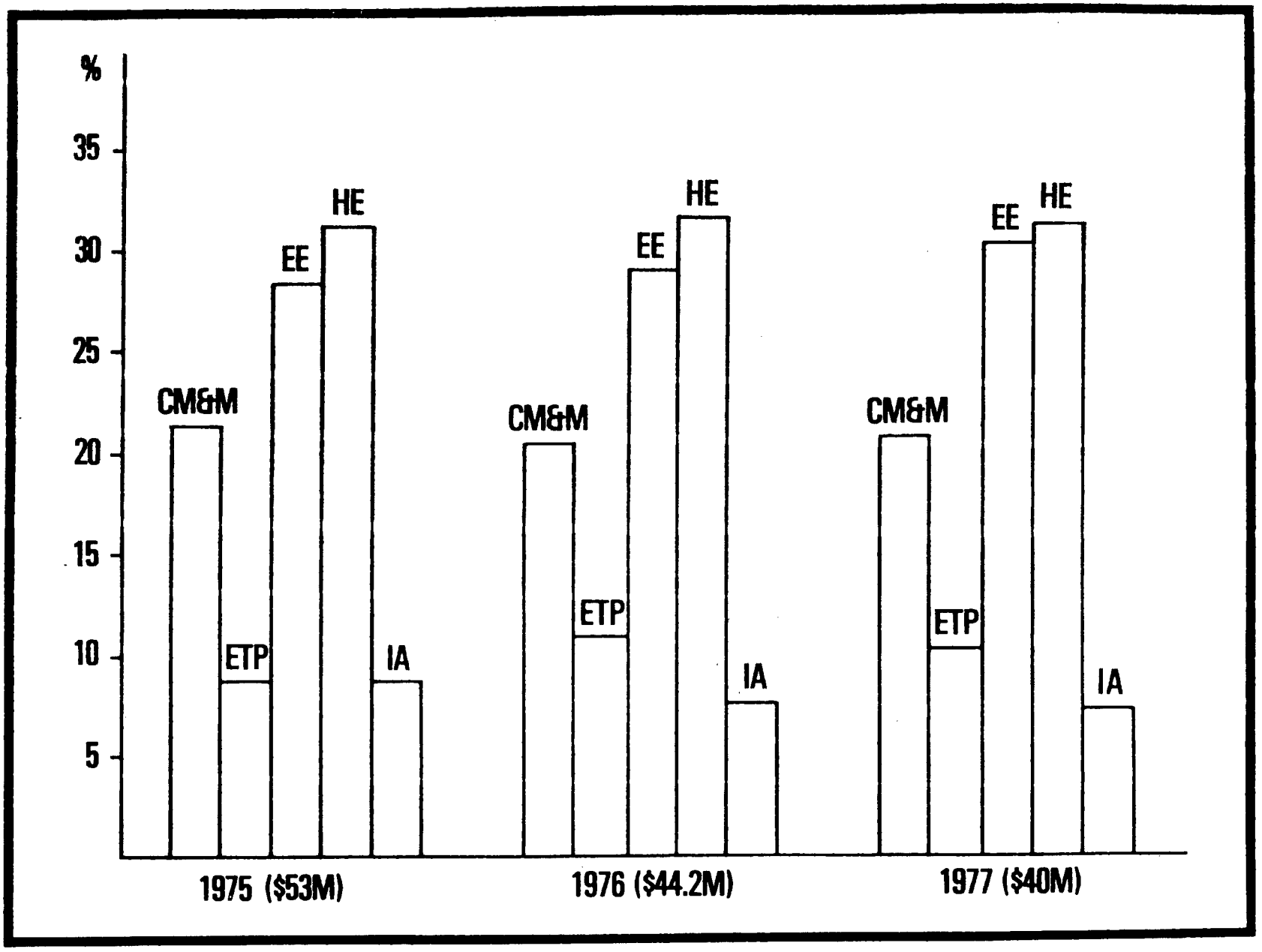

Figure 5. Interagency (pass-thru) energy/environment processes and effects program-funding by major categories (FY-75/76/77).

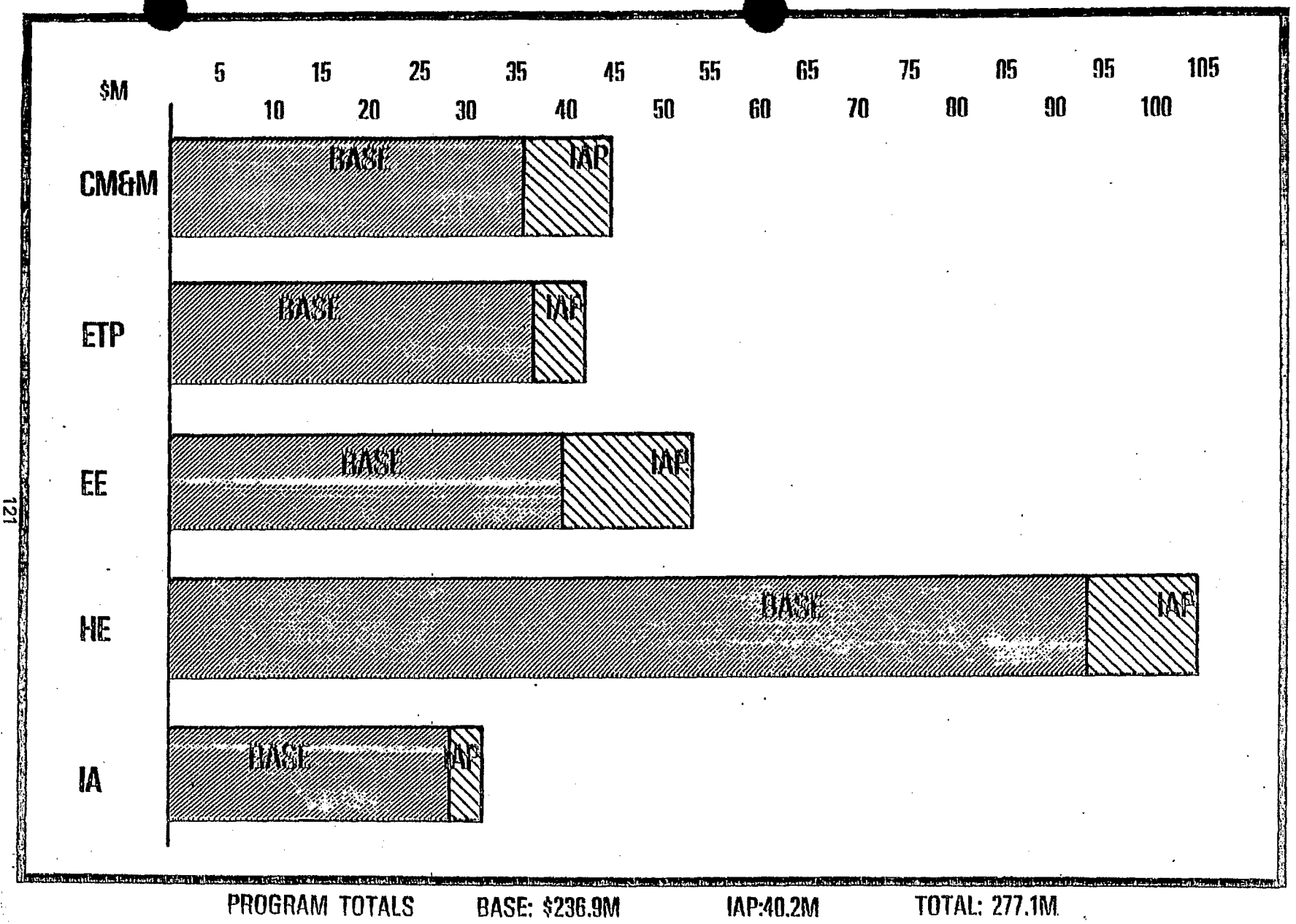

Figure 6. Total FY-76 federal funding - energy for related environment and safety biomedical and environmental subcategory.

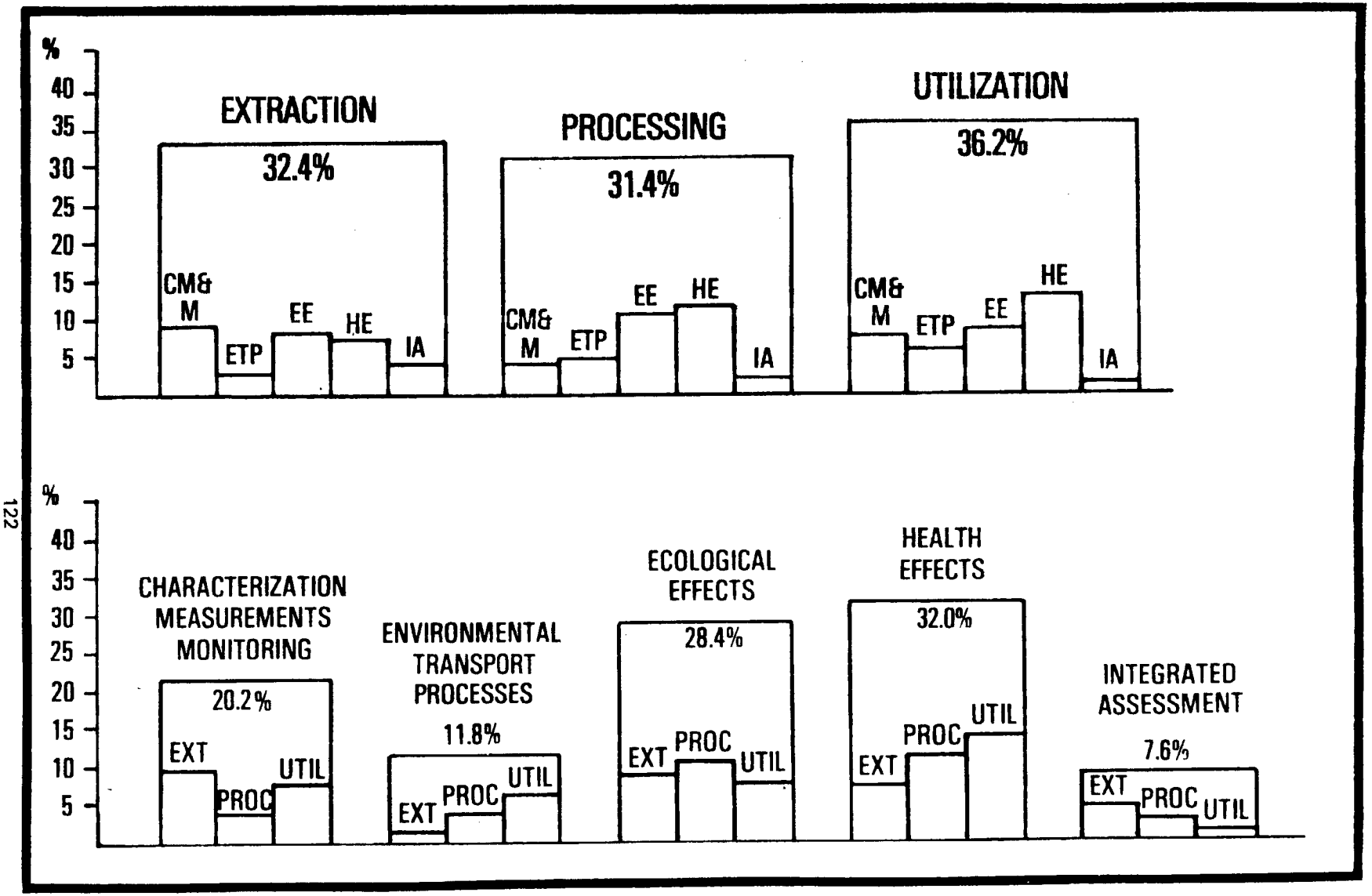

Figure 7. FY-76 interagency (pass-thru) energy/environment program by fuel cycle module.

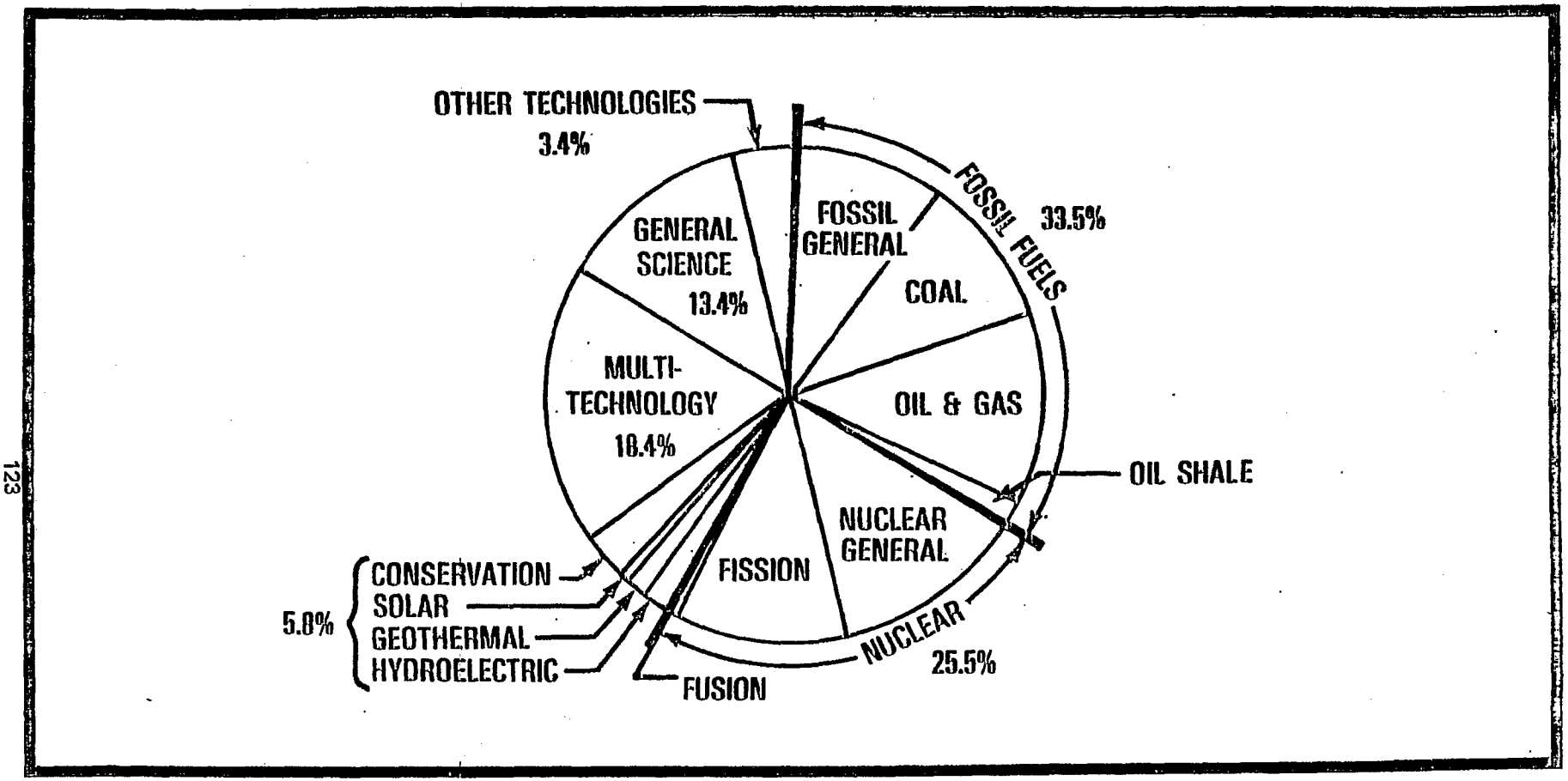

Figure 8. FY-76 base & pass-thru funding for energy/environment program - according to technology.

	BASE			INTERAGENCY PROGRAM (IAP)			TOTAL (ERDA INVENTORY)		
	# OF PROJECTS	$M	%	#	$M	%	#	$M	%
CHARACTERIZATION MEASUREMENT & MONITORING	166	17.4	7.3	129	7.5	18.6	295	24.9	9.0
ENVIRONMENTAL TRANSPORT PROCESSES	289	22.8	9.6	16	4.6	11.4	305	27.4	9.9
ENVIRONMENTAL EFFECTS	236	40	8.2	52	10.8	27.1	288	30.4	11.0
HEALTH EFFECTS	594	29.6	12.4	148	11.4	27.7	742	40.7	14.7
INTEGRATED ASSESSMENT	233	17.3	7.3	14	2.9	7.3	247	20.2	7.3
FOSSIL FUEL TOTAL		106.7	45.8		36.9	92.0		143.6	51.9
PROGRAM TOTAL		236.9	100		40.2	100		277.1	100

Figure 9. FY-76 federal base & pass-thru program - fossil fuel emphasis for each environmental research category.

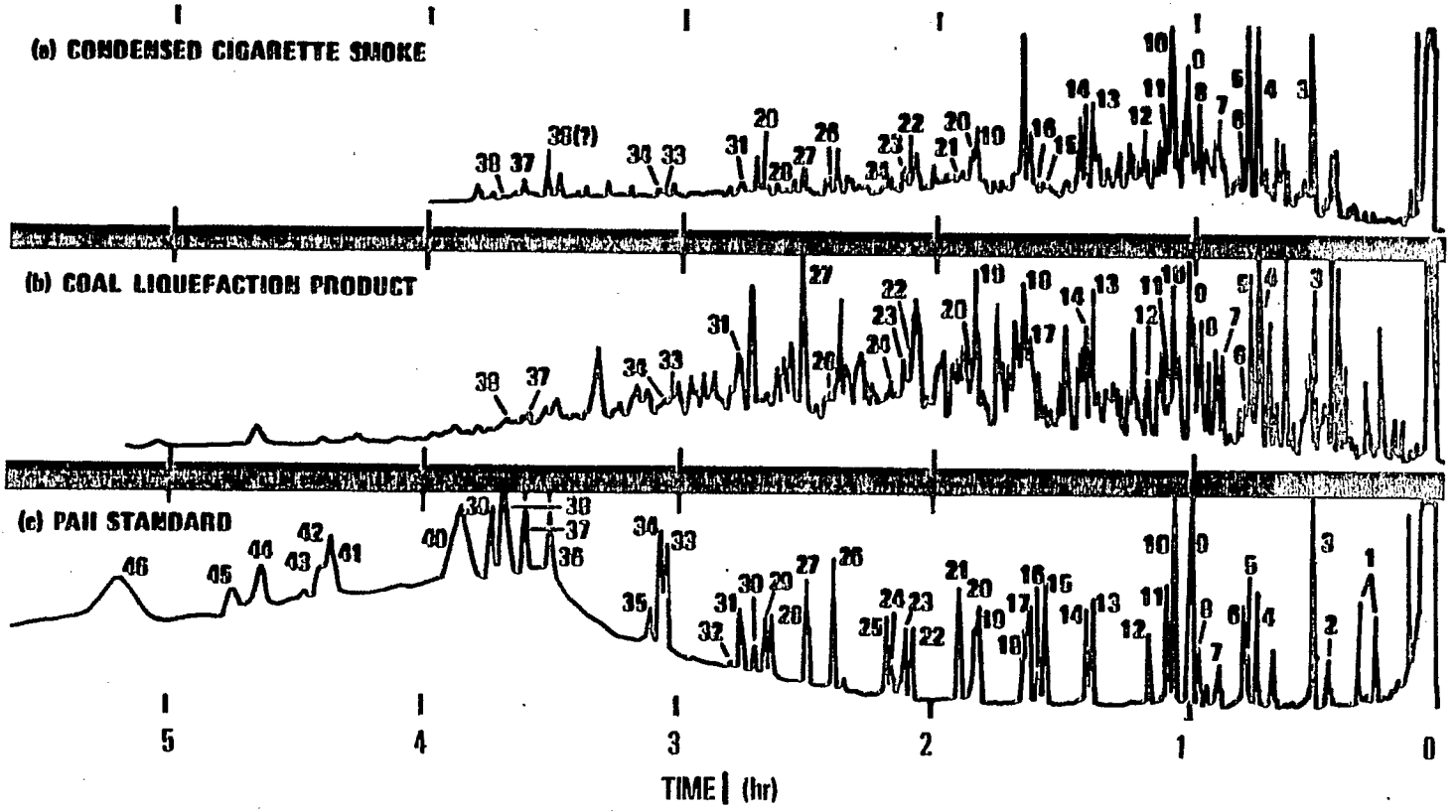

Figure 10. Gas chromatographic profiles of polynuclear aromatic hydrocarbon isolates.

lustrations of the various organic molecules in a chromatogram of condensed cigarette smoke and a polycyclic aromatic hydrocarbon standard are also displayed for purposes of comparison. Several attempts[6,7] have been made to categorize the agents in the waste steams and products. Gehrs, et al.,[6] have suggested that five groups may be sufficient to categorize the organics associated with aqueous wastes as follows:

1. Phenols,
2. Arylamines,
3. Alliphatic Hydrocarbons,
4. Mono and Polycyclic Hydrocarbons, and
5. Sulfur containing compounds (thiophenes and mercaptans).

More detailed listings of the variety of agents known or suspected to be associated with synthetic fuels have been developed. The anticipated adverse biological effectiveness of such agents have also been listed.[7,8,9]

Several recent literature surveys[10,11] suggest that quantitative chemical characterization of the agents in the various products and waste streams associated with each of the several advanced fossil fuel processes is still a major activity. The fractionation, chemical characterization, and bioassay of several products and waste streams have been accomplished. A listing of such materials is presented in Figure 11.

The problem area of characterization, measurement and monitoring has stimulated the following:

1. The development and use of more accurate analytical instrumentation for the quantification of the agents in the waste streams and in the ambient environment;[12,13]
2. The obtaining of baseline information at likely sites;
3. The development of a systematic monitoring meteorology for organic compounds;
4. A procurement of some surrogate standard reference materials.

Surrogate standard reference materials have been developed and distributed by NBS as part of a quality assurance program. The surrogates for polycyclic aromatic hydrocarbons, phenols and for N-heterocyclics have concentrations in the range of 100 ppm in the carrier (water or hexane).

Environmental Transport Processes - A major item of concern with respect to environmental transport processes is the fate of the organics in the various waste streams. Studies have been undertaken to develop models for terrestrial sorption of shale, oil, or aquatic transport and transformation (photo- and bio-) models of the organics in liquid effluents. There does not appear, however, to be an appreciable effort regarding phototransformation of the organics in gaseous waste streams or products.[4,14]

Ecological Effects - In the ecological effects research area, the subjects of major concern specific to synthetic fuels and receiving emphasis include the determination of toxicity of the organics to aquatic species and the bioaccumulation in the food web. Studies undertaken have reflected this concern as indicated by the toxicity studies on zooplankton and various species of fish, using whole effluents and fractions thereof from conversion processes. Bioaccumulation of metals and organics in aquatic species is also under active investigation.[15]

Health Effects - The agents in the products and waste streams associated with synthetic fuel production and use cause an increase in concern for the adverse health effects of carcinogenicity, mutagenicity, and teratogenicity. The health endpoints of behavioral modification, biochemical changes, pathophysiological changes and system dysfunction have also been under investigation. Targets of concern under investigation have ranged from subcellular components to whole animal for a variety of tissues and body fluids. All routes of administration (inhalation, ingestion, injection, and immersion) have been utilized in the experimental studies, but not for all agents of concern, nor for all of the species of interest. Integration of the information obtained from the variety of studies in the various disciplines (bioscreening, animal toxicology, cellular toxicology, clinical and epidemiological studies) to obtain estimates of risk to various population groups represents the most formidable aspect of the health problem, in view of the variety of

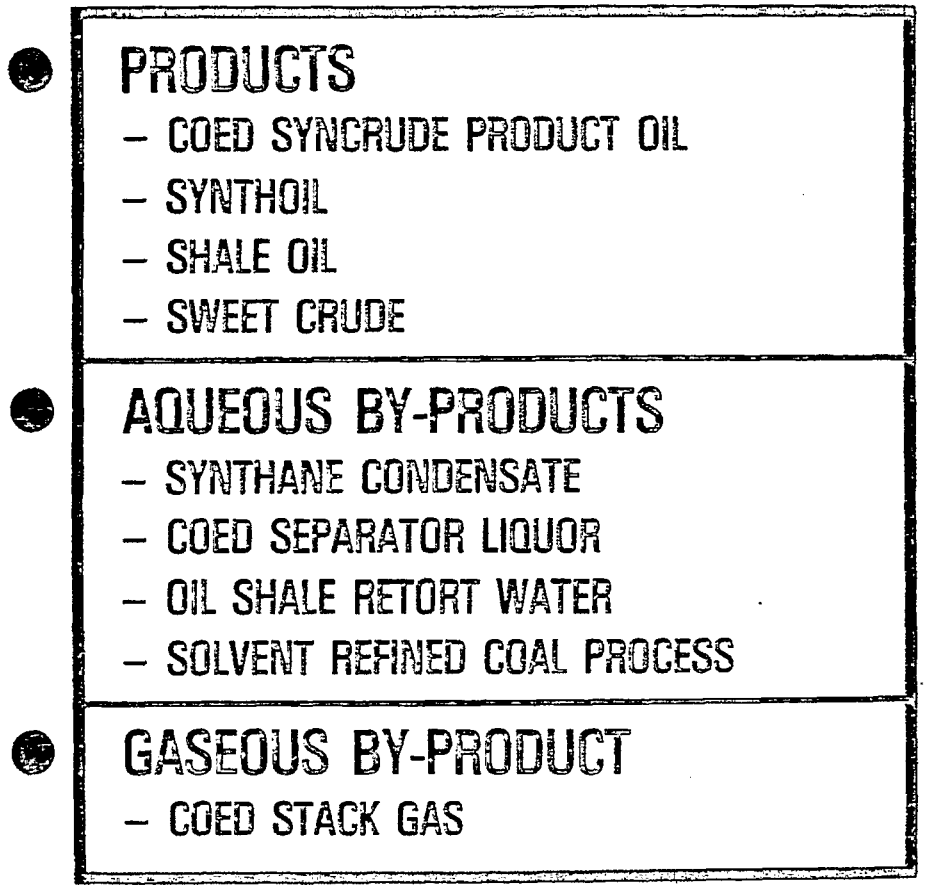

Figure 11. Characterized advanced fossil fuel products and wastes.

scientific opinions regarding the proper interpretation of the data.

As indicated previously, toxicity and mutagenicity evaluations have been undertaken for a number of products and by-products (aqueous and gaseous). The mutagenicity studies performed by Epler et al.,[16] indicate that all crudes and synfuels show some mutagenic potential, with the relative total varying over two orders of magnitude, and with the mutagenic activities of the natural crudes appearing to be appreciably less than those of the synfuels. The interpretation of these results regarding the hazard to man is still under active investigation, and considerable research is considered necessary before extrapolation is appropriate.

With respect to carcinogenicity, research efforts are addressing the problems of dosimetry at the cellular and organ level, the impact of multiple stressors, the impact of rates of exposure and the development of protocols for retrospective epidemiological studies of occupational population groups. Some investigators are now convinced that a linear non-threshold dose response model is appropriate to use for estimating impacts from primary chemical carcinogens.[17,18]

Integrated Assessment - Most integrated assessments regarding advanced fossil fuel systems suffer from the lack of precise data and require a regular updating.

The first phase of an integrated assessment of energy development in the Western United States[19] confirms the concern that such development may well produce regional as well as local air pollution problems. This study has cast doubt on the need for large quantities of water for synfuel production.

Integrated assessments are also underway

for other regions (Southeast, Pacific Northwest, Ohio River Basin) as well as on a national (i.e., electric utility ITA, National coal utilization assessment) or local scale.

Some Problems

As indicated previously, a major problem that exists is the lack of precise data that is useful for integrated assessments. Part of this problem stems from the lack of sufficient understanding of the most appropriate indicators to use for the assessment. This lack of understanding is reflected in the quantity and variety of data that are being obtained at great expense, in some cases, but of relatively little value. There appears to be a lack of integration of the data on a regular basis for each of the major items of concern. Some estimate of the uncertainties associated with the assessments should be made on a regular basis to assist planning of future research necessary to reduce the uncertainties.

In the health effects area, a major problem is the procurement of sufficiently large quantities of well-characterized pollutants, products, and environmentally transformed materials to engage in statistically valid in vivo experiments. Some efforts are underway to develop a repository at Oak Ridge National Laboratory under an interagency agreement between EPA and ERDA. Cooperation from all of those engaged in developing energy technologies will be necessary in order for the repository to function in a useful manner on a time scale compatible with the developing techniques.

An additional item of major concern is the lack of information pertaining to the modification of the spectrum of agents that are released, that occurs as a consequence of scaling up of processes and control systems. The developers of the processes and technologies consistently argue that the spectrum of agents from a full-scale commercial facility will be vastly different than those from a model.

Those engaged in health and ecological effects research could be more helpful to the designers of energy and control systems if a cooperative attack on the problem was utilized during the early stages of development.

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FIGURES

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