UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

AN ENERGY RESEARCH AND DEVELOPMENT PLAN: ECOLOGICAL EFFECTS PROGRAM

NATIONAL ECOLOGICAL RESEARCH LABORATORY
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DRAFT

The Regional and Ecological Effects Research Program

A. Recommended Action Summary

1. Define the following specific objectives for the ecological effects research program:

a. To minimize the ecological effects of pollutants from new or expanded energy sources by achieving, relating and applying environmental scientific knowledge to decision-making processes, including cost-risk-benefit trade-offs, concerning energy sources technology development, alternate energy processes, site selection, etc.;

b. To assist in guiding the direction taken by control technology decision-makers in pursuit of new methods of pollutant control to minimize environmental impact, the cost of control technology R&D as well as to minimize the potential cost involved in retrofitting facilities at some future time;

c. To improve the existing data base for determining air and water quality standards.

2. Define energy research areas for which each Federal agency will be responsible.

3. Determine the output and time desired from each Federal agency.

4. Define specific energy research sites (ERS) that will serve as focal points for particular energy research activities.

5. Establish a technical synthesis group which will be responsible for guaranteeing the credibility of the output, particularly in multimedia problem areas.

6. Establish a management synthesis group to establish and guide all energy research for which EPA has a responsibility.

B. Introduction

Public concern for the health, environmental, and social and welfare impact of energy-related activities has become the single most important issue limiting the growth of domestic energy production. These public concerns are directed at observable as well as suspected deleterious aspects of the discovery, extraction, transport, and conversion of fuels as well as their ultimate use in energy production. While health-related consequences of energy activities are not discussed in detail here, there are many aspects of pollutant transport and ecological effects of pollutants which are relevant to both the health and ecological effects problem areas.

During the next several years, the nation will be faced with a series of critical decisions of utmost priority and importance. A need for increasing the nation's energy capability must be balanced against the need for minimizing environmental impacts caused by energy-producing facilities. Any environmental research program that is implemented must provide to the nation the basic understanding necessary to evaluate and measure environmental impacts, determine environmental effects, and to suggest the need for minimum cost control technology where required. Successful implementation of an environmental research program will affect all aspects of the energy self-sufficiency program that will be a definitive determinant of optimal energy resource use.

The production of energy will be accomplished by using a number of alternative sources. Some of these are nuclear conventional burner reactors, nuclear breeder reactors, geothermal power, solar power, hydroelectric power, fossil-fuel power and a number of forms including direct combustion of coal, coal gasification, shale oil usage for electric power production as well as for conversion to other petroleum products, and conventional crude oil. There are a number of problems associated with each of the elements of this mix of potential energy sources. The expansion of coal use, in part the result of a shift from low sulfur oil and natural gas to coal, and the introduction of new synthetic and shale oil products will require improved siting criteria and enhanced environmental impact assessment techniques. Large-scale introduction of new energy technology such as shale oil, geothermal, and advanced oil and gas recovery techniques, and advanced power production facilities will also have an environmental impact. Rapid expansion of nuclear generating capacity (long lead times and licensing, environmental impact review, and construction not withstanding) at associate requirements for nuclear fuel processing, disposal of radioactive cooling and other water, and other radiation problems will create increased pressures for acceptable means of disposal of radioactive wastes and fuel reprocessing.

While each of the above technologies does carry certain unique environmental consequences, there are a number of common threads of environmental concern which run through nearly all. For example, the difficulty of disposing of waste heat, and the adverse effects of waste heat discharge are problems found with nearly all methods of power production. Another example of a similar type concerns the use of cooling water. There are cooling water intake design problems, entrainment effects, closed versus open cycle cooling, cooling towers versus lagoons, and other cooling system issues which are common to electric power production from geothermal, nuclear and fossil-fuel based facilities. Because there are common threads running through all the energy-production, conversion, extraction and usage issues, a program which addresses those common threads has been developed.

An additional aspect of the ecological effects research program concerns technology. The technological deveopment and implementation of energy systems must be sensitive to the effects that effluents and residuals from the system will have on health, welfare, and the ecological system. If this sensitivity is incorporated into the development and implementation process, domestic resources can be broadly utilized with minimal deterioration of the environment. Knowledge of the effects of the energy-production system before it is implemented will avoid the enormous cost associated with the need to retrofit controls on an operational system where they clean up the waste once they have been discharged. Therefore, in order to minimize R&D costs of alternate technologies and to support energy-technology-related decisions, an ecological effects research program is needed which addresses all aspects of pollution impact. In this way, technology research can be related to ecological effects research such that both technology dollar and environmental impact cost can be minimized.

It is clear that any ecological effects research program cannot be accomplished solely by the Environmental Protection Agency. Over the past several years, other organizations besides the EPA have been actively involved in funding studies of the transport and effects of stressants on the environment. Many of these studies have dealt with the effects of particular pollutants on individual organisms or processes. A relatively small amount of the research effort in all branches of the Federal government has been directed toward the ecosystems or holistic approach. The National Science Foundation, the Atomic Energy Commission, the Department of the Interior, the Department of Health, Education and Welfare, and the Department of Commerce have worked closely with the EPA in performing research in the areas of health effects, ecological effects, social and welfare effects, and in support activities such as pollutant transport processes and characterization, measurement, and monitoring. Accordingly, a well-coordinated energy effects research program involving several agency needs to be implemented.

C. Objectives of Energy Program

The National Energy Effects Research Program must prepare its objectives to follow closely with the development of the nation's energy-production resources in the areas of coal, oil, oil shale, coal conversion, nuclear power, and geothermal power. The objectives must be faced so that the information necessary to make intelligent cost-benefit decisions will be available as the nation's energy-producing priorities are transferred from one energy source to another or the mix or proportion of energy-producing activities from each source changes. Therefore, the following objectives are listed below, each objective applies to all energy-producing activities (coal, oil, oil shale, coal conversion, nuclear, etc.), and by region or whole ecosystem (coastal zone, Rocky Moutain region, Northern Great Plains, watershed, etc.).

a. To minimize the ecological effects of pollutants from new or expanded energy sources by achieving, relating and applying environmental scientific knowledge to decision-making processes, including cost-risk-benefit trade-offs, concerning energy sources technology development, alternate energy processes, site selection, etc.

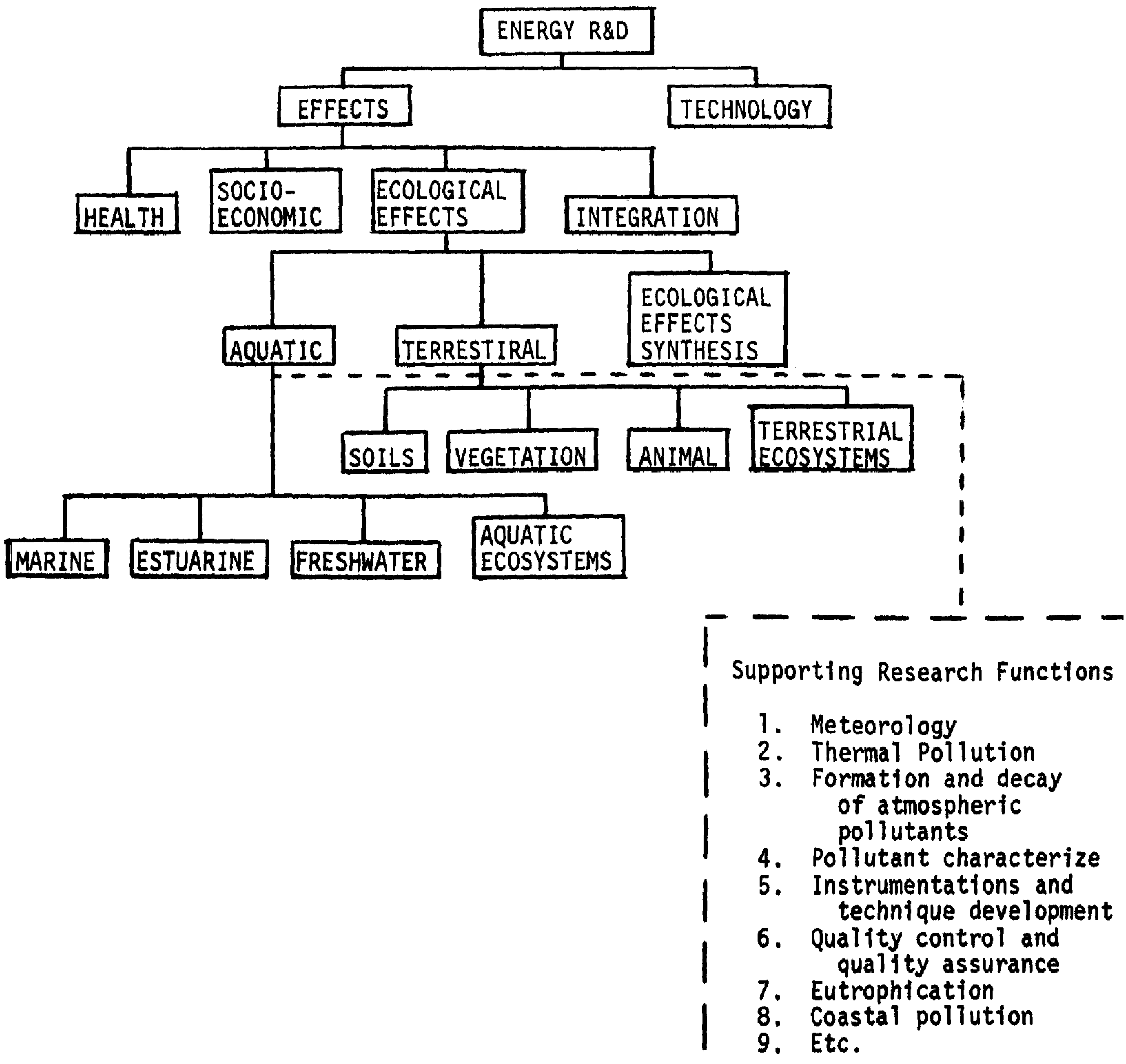
b. To assist in guiding the direction taken by control technology decision-makers in pursuit of new methods of pollutant control to minimize environmental impact, the cost of control technology R&D as well as to minimize the potential cost involved in retrofitting facilities at some future time.

c. To improve upon the existing data base that establish air, water, and solid waste pollution standards.

D. Description of Energy Program

As can be seen in Figure 1, which depicts the overall program, the energy R&D program has a number of components. The two primary components from an EPA point of view are the research involving technology, and the research into the effects of energy extraction, production, conversion, transmission, and dissipation. We will be concerned primarily with the research on energy effects. The next level of subdivision within the effects category is into four major components. The first of these compartments embodies the health consequences associated with energy production. The second compartment consists of all the social and economic effects of energy production, including trade-offs in terms of changing job conditions, job markets, industry types, an assessment of comparative costs of alternate technologies and energy sources. The third major component is entitled Ecological Effects which will be discussed at some length below. This category includes all of the non-health and non-socio-economic effects of energy production. The fourth major category is entitled Integration. The Integration component would be responsible for synthesizing and integrating the results obtained from health research, socio-economic research, and ecological effects research.

FIGURE 1. OVERALL PROGRAM



The purpose of the integration and synthesis component is to coordinate and assure the meshing of programs between the EPA and other Federal Agencies concerned with energy R&D. In addition, the synthesis function will serve to mesh the output from technology R&D with effects R&D. By having a combination of representatives from the Headquarters and the technical level field personnel, it is possible to adequately address both the operational aspects and the Headquarters' planning function of other Federal Agencies.

The next level of components in Figure 1 is comprised of the following major subdivisions:

Ecological Effects Synthesis

The ecological effects synthesis component deals with the synthesis and total integration of all knowledge acquired in the aquatic and terrestrial ecological effects research area.

Aquatic

The aquatic effects component deals with all of the energy production, extraction, conversion, and other problems in the marine, estuarine, and fresh water environments.

Aquatic Ecosystems

The aquatic ecosystems component would be responsible for integrating all information in the aquatic environment which relates to the effects of energy production.

Terrestrial

The terrestrial compartment of the ecological effects component has analogous sections which would involve the effects of energy production, extraction, conversion, and other problems on soils, vegetation, and animals (including domestic livestock and wildlife).

Terrestrial Ecosystems

The terrestrial ecosystems component would be responsible for integrating all effects information in the terrestrial environment which relates to the effects of energy production.

The box formed by dotted lines in Figure 1 has some representative support services listed. It is clear that any effects research program will require input from related research programs. For example, in the dotted box we list support services which would be obtainable for the effects program. For example, it is possible, through optimizing the management of the on-going EPA research program, to have each of the listed programs slightly reorient its existing program toward an energy effects program. For example, the effects of thermal discharges are a problem that the EPA is concerned with in regard to setting thermal discharge standards, thermal problems are also concerned in an energy R&D program because of the consequences of a cooling system design, cost of alternative technologies, the use of different types of cooling systems, etc.

What we have in Figure 1 is an overall energy R&D effects program. We assume that appropriate people will be contacted in the health, socio-economic and integration areas to develop their programs in more detail.

If the proposed research program is implemented, then the integration responsibilities for the energy program would be great. There are many scientific inputs that will be generated from within the agency as well as from other Federal organizations. Data derived from laboratory and field studies will be synthesized and integrated into an energy research strategy which will be carried out in the various regions of the United States.

At the present time, several Federal agencies are involved in identifying specific research projects and principal investigators who could wisely spend a large amount of energy dollars. The National Science Foundation, the Energy Research and Development Agency, the Federal Energy Administration, the Department of the Interior, the United States Department of Agriculture, and the Environmental Protection Agency are moving toward identifying potential candidates for grants and contracts in the Northern Great Plains area as well as other regions.

There are so many Federal agencies proposing to fund research projects that are all similar in scope that the Northern Great Plains area is rapidly becoming impacted by researchers studying the impact of energy-producing activities on the environment. This seemingly humorous situation is rapidly going to develop into one that will limit the scope of research that can be performed in that region of the country. For example, the Colstrip, Montana, area is already being researched by Federal, State and local governments. New research that is proposed by several agencies focuses in on the Colstrip area for major programs. It is unclear as to whether the Colstrip area will be able to absorb the new researchers that will be drawn to the area to implement the projects that will be funded by these agencies. In addition, it is unclear as to where the talent will be located who will perform the research on grants or contracts.

Several of the research organizations (University of Montana, University of North Dakota, etc.) have submitted grants to most Federal agencies. With the large number of dollars being proposed for Federal research, a great many of these proposals will in fact be funded. If so, the local talent probably will not be able to absorb very many new starts over the next year or two. More than likely, outside researchers (Battelle Northwest, Livermore, etc.) will initiate research investigations that will have to fill the gap. These "foreigners" coming into the area may cause further pressures on the study sites. Each of the study sites that are being investigated are being impacted by researchers being drawn to the area. Housing facilities, research laboratories, monitoring laboratories, facilities support (police protection, library service, sewage capability, water capability, etc.) are going to have to be provided to these individuals if they are able to carry out their research activities.

What is proposed to reduce the potential impact of the energy research programs in the Northern Great Plains area, is that specific sites be identified and selected for research investigation. Individuals performing research at these sites would be working on projects that complement one another and that all projects work toward the objectives that have been established for the output of the particular energy research activity for that site. For example, Colstrip, Montana, could be established as a coal-fired power plant energy research site. Biological activities, socio-economic analysis, health effects research, and support activities such as pollutant characterization of transport and modeling could be performed in and around the site. The management details could be established such that an on-site coordinator guarantees the research projects that are being planned meet the total objectives that have been selected for the site.

It is through the identification of the energy research site (ERS) that total integrated research projects can be implemented. For example, the Department of the Interior, the Energy Research and Development Agency, NSF, and EPA could develop integrated research programs that lend themselves toward site specific activities. The end product from these research activities would be directly applicable to the missions of all the agencies involved in the program. Costs and duplication in the various energy activity parts of the country could be eliminated or at least reduced to an acceptable level.

E. Research Program Milestones

The milestones for certain aspects of the research program should follow approximately the following pattern. For increasing petroleum and natural gas production, we can anticipate increases in production from secondary and tertiary recovery methods to have completed the pilot plant demonstration design stage by approximately 1978 or 1979. Stimulation, by both conventional and nuclear means, for oil and gas production we expect to have the pilot plant demonstration phase completed by mid-1977. Oil shale in situ processing including conventional and nuclear fracturing and retorting, can be anticipated to be through the pilot plant demonstration design stage by 1977 or 1978. Obviously, by the above mentioned dates, it is necessary to have a completed protocol for site evaluation, selection, and impact assessment, as well as many other aspects of the ecological research program. Because the high probability areas for these methods of increasing petroleum and natural gas production are in the Rocky Mountain area and in the Southwest, we can anticipate that we should be performing research programs in that part of the country. Project milestones should correspond to the above dates for the completion of assessment protocols, and effects identification.

Under activities such as substituting coal for oil and natural gas, the mining of coal and shale have already begun in many parts of the country, and effects research programs should be mounted immediately in those areas. For direct combustion of coal either by fluidized bed or combustion modification methods, we have until possibly mid-1977 before the completion of pilot plant demonstration design stages. Therefore, project milestones designed to develop impact assessment protocols and evaluate the ecological effects of plants to perform energy-producing functions are these methods should be in mid-1977 time frame.

For high BTU gasification, coal liquifaction, low BTU gasification, and synthetic fuel pioneer program, the pilot plant demonstration design stages are anticipated for completion in late 1975 to late 1977. Therefore, ecological effects research protocols in areas where those activities are expected to occur should begin immediately. Project milestones to assure completion of protocol development by those dates should be specified.

For other fuel cycles, for example, liquid metal fast breeder reactor, pilot plant and demonstration design stages are not expected to be completed until early 1980's, research on the protocol development for plant siting for these energy sources can be delayed. The same reasoning also applies to other advanced energy systems, fusion, solar, other exotic energy sources. The necessary ecological effects information base is not required until 1980 at the earliest.

For geothermal power, we already have pilot plants and demonstration plants as well as commercial application in some parts of the country, but the method of power production is so limited in terms of its geographic distribution that serious ecological effects assessment at only a few sites is sufficient. However, since it is clear that geothermal power will be developed in the West and along the ridge of the Rocky Mountains, it would be prudent to begin a terrestrial ecological effects research program in the Western Montana/Northwestern Wyoming area or in parts of Oregon and California.

FIGURE 2

FUEL CYCLE

Region	Light Water Reactor	Breeder	Coal Combust	Coal Gasification	Shale Oil	Crude Oil	Geo-Thermal	Solar
Great Plains			1	2				
Midwest	3		1					
Coastal Zone	3					1		
Rocky Mountains			1	2	2		2	3
Watersheds	3	etc.	1	2	2			
Southwest			1	2	2		2	3
Gulf Coast	3					1		
West Coast ETC.	3		1			1	2	3

Time to demonstration or pilot plant stage and site selection lead time dictates assessment protocol deadline. 1. 2-3 year. 2. 3-5 year. 3. 5-10 year. (priority)

Figure 2 indicates the principles followed in the development of the timing for scheduled program. Ecological studies for each of the fuel cycle types which apply to a given region should be conducted. That is, we should attempt to follow the complete pathway through which particular pollutants move, from sources to ultimate sinks, and their effects along the pathways. For example, it would be advantageous to determine the effects on the entire system of a conventional coal-fired power plant with SO_2 removal; to follow the passage of the effects of sulfur dioxide or nitrogen dioxide or heavy metals or other pollutants on the entire system from the point at which it is emitted from the stack through all of the atmospheric transformations which it may go through to be dispersed by meteorological process finally settling on a plant or on the soil. Having reached the side of a receptor, determine the effect of that pollutant on vegetation, soils, or animals. Following a determination of those effects, the secondary and tertiary effects of the pollutant should be determined. In addition, determine where within the system that pollutant was accumulated or in other words became hazardous or toxic to organisms. Through studies of this type, it is possible to determine the sinks for various air pollutants as well as water pollutants and to determine from the knowledge of those sinks and concentrations to which heavy metals or other pollutants might arise and therefore determine the toxicity of that material to local organisms. Through determination of accumulative and acute effects, it is possible to rationally determine the short- and long-term consequences of introducing pollutants into the ecosystem. It is also possible through the knowledge of the rates and mechanisms of transfer and the effects of those pollutants to determine the possible hazards to humans. It is also possible to determine an economic cost or damage function which can be related to each fuel cycle type or each region or other pollutant. This then would form a more rational basis for local decision-making relative to alternate energy options that may be open to a locality for exploiting its energy sources.

The timing of such studies should be designed in order to have major milestones in terms of both transport processes and effects which would relate to the milestones and dates by which pilot plants and demonstration plants for technologies which use various fuel cycles are expected. For example, it would be desirable to have conducted a number of whole ecosystems studies in the Northern Great Plains and in the Rocky Mountain areas in anticipation of pilot plants and demonstration plants in shale oil recovery, coal gasification, coal liquifaction, and conventional coal-fired power plants. By having conducted such effects research during the next few years in those regions, we will be in a far better position to evaluate the types of control technology which would be recommended for both demonstration and full-scale production plants. By continuing to refine our information in that part of the country for fossil-fuel energy sources, by the time large numbers or large-scale power plants come on line in the next five-ten years, we will be in a better position to evaluate their potential effects and to make firmer recommendations on siting as well as all necessary control equipment.

A similar set of whole ecosystem studies should be mounted in the coastal zone. This is because we will have numerous off-shore drilling operations, oil tanker transfer points, and refining plants in the continental margins of the country. Whole ecosystems studies in the coastal zone area would be analogus and most respects to whole ecosystem studies in the mid-West or Rocky Mountain portion of the country in that the milestone in the near term would be to develop an assessment protocol or an assessment methodology for determing the potential impact of crude oil energy production facilities. In the longer term, the coastal zone will receive a far greater number of nuclear installations than it now has. For reasons similar to those mentioned above, it would be advantageous to having developed the short-term assessment protocol methodology, to project that into longer time scales in order to evaluate the impact of nuclear facilities.

F. Federal Interagency Cooperation

If the EPA establishes an energy research site (ERS) concept for integrating and centralizing its research activities, then it is of utmost importance to establish a break out of responsibilities among the Federal agencies involved in energy research. Table 1 represents a projected breakdown of energy research activities that could be supported by these Federal establishments. For example, ERDA has expertise in radiation monitoring, transport and fate, and the gathering of toxicity information. The National Bureau of Standards has a major effort in instrumentation development and standardization of pollution measurement devices. The NSF, the Department of the Interior, and the EPA all have on-going energy-related research projects.

At the present time, the National Ecological Research Laboratory in Corvallis is performing field research activities that have a modest amount of laboratory research support. Much of the field effort is conducted by extramural route, but do involve a small number of EPA personnel assigned to its energy research site (ERS) at Colstrip, Montana. The laboratory research activities are mainly to investigate further the anomalies that are occurring in the field. All studies, of course, are biologically oriented and are attempting to constitute a protocol that allows planning managers to assess the impact of energy-producing activities on the environment prior to the initiation of those activities. It is intended that the ERS concept will be adopted for the following actual or potential sites:

Table I
Projected Agency Energy Research Activities

Research Activity	EPA	NSF	ERDA	DOI	USDA	NBS	NOAA
Instrumentation Development	X	X	X			X	X
Monitoring/Characterization	X	X	X	X	X		X
Transport/Fate	X	X	X	X	X		X
Microcosm	X	X	X		X		
Standardization of Measurements	X	X				X	
Population Modification -							
Indicator Organisms	X	X					
Toxicity Information	X	X	X				
Cost/Benefit/Land Use	X	X					
Holistic Field Research	X						
Land Reclamation	X	X			X		

Coal

1. LaCygne, Kansas.
2. Colstrip, Montana.
3. Gillette, Wyoming.
4. Utah
5. The Four Corners Area.
6. Northeastern Portion of the United States

Oil Shale

1. Wyoming.
2. Colorado.
3. Utah.

Coal Conversion (gasification and liquifaction)

1. Utah.
2. Colorado.
3. Wyoming.
4. South Dakota.

Geothermal

1. Oregon.
2. California.

The National Ecological Research Laboratory field efforts are mainly terrestrial effects research projects and multimedia synthesis activities. The first two studies (LaCygne, Kansas and Colstrip, Montana) are coal-fired power plant terrestrial effects projects. In addition to these activities, NERL is planning to mount terrestrial research efforts in the shale oil, coal conversion, nuclear, and geothermal areas. The components of the NERL field effort are summarized in Table 2. These components are used in the following:

1. Temporal and spacial quantitative inventory of components of the study area.

2. Detailed measurement of biological structure and function, including energy flow, nutrient cycling, and species conditions, composition, and diversity.

3. Pollution characterization, transport, and fate.

4. Meteorological measurements.

Table 2

EPA, NERL Field Component Measurements

Plants

Population biology
Standing crop
Productivity
Species diversity
Injury, disease and condition
Rate of nutrient uptake
Biochemical analyses
Photosynthetic rates
Respiration rates

Animals

Population biology
Condition
Measures of physiological stress, homeostasis, adaptation
Disease and histopathology
Immunosuppressive responses
Nutritional biology and food web analyses
Growth metabolism, bioenergetics
Behavioral patterns including dispersion to movements with respect to pollution intensity

Biochemical analyses

Soils

Soil respiration
Soil chemistry
Macroorganism Community Analysis By Group and Rates of Activity

Microbial Community Analysis By Group and Rates of Activity

Support Activities

Meteorological and air quality measurements

Development of remote sensing as tool for detecting stress on ecosystems.

Measurement of loss of inventory attributed to strip mining, human activities, water use, etc.

Use of ecosystem level models to describe and predict effects of stress.

Use of models to aid in design of experiments.

Use of models to help separate pollutant effects from natural variation in system dynamics.

Meteorological and dispersion modeling to describe the mode of entry of pollutants into ecosystems.

5. Utilization of remote sensing as a tool for detecting effects of challenges on the ecosystem.

6. Experimentally-controlled challenges to an ecosystem.

7. Laboratory experiments to measure and evaluate physiological, biochemical and behavioral mechanisms of response to challenge (i.e., experiments designed to test field-generated hypotheses).

8. Utilization of ecosystem level models and atmospheric pollution dispersion models to describe and predict effects from challenges to ecosystems.

In addition to its own field research efforts, the National Ecological Research Laboratory believes that there are a set of research activities that complement the existing program. These activities, are summarized in Table 3.

The research program that has been established in Colstrip, Montana represents part of a first ERS. Through formal and informal discussions with research organizations within and outside the Environmental Protection Agency, NERL is convinced that the necessary expertise to perform integrated research projects is resident in existing Federal establishments. Appropriate negotiations have begun at the laboratory level to invite various Federal agencies to participate in the future ERS activities that the National Ecological Research Laboratory will be establishing under its on-going energy research program.

Suggested funding allocations for this program are shown in Tables 4 and 5 under low and high funding options. The proportion of funds under high and low funding options for each ecological effects program area differ because of different capabilities which could realistically be developed under each option.

Table 3

Energy Specific Terrestrial Research Needs

1. Determine the atmospheric chemistry of sulfur oxides including sulfate formation and the mechanisms by which sulfur oxides are removed from the atmosphere.

2. Determine pollutant interactions in dry and wet-scrubbed power plant plumes.

3. Develop and verify air quality simulation models for power plants in complex terrains in order to accurately determine emission control levels required to achieve ambient air quality goals.

4. Develop the capability to predict low-level dispersion patterns from nuclear plants in light winds.

5. Determine the transfer mechanism of sulfur and other pollutants to soils, economic crops, wildlife, and indigenous vegetation.

6. Determine the effects of cooling system moisture, and heat on local climate.

7. Develop model for precipitation scavenging of sulfur,

8. Determine the mechanisms for dry deposition of atmospheric pollutants.

9. Develop data on physical and chemical characteristics and columetric discharge rates of effluents and emissions from new energy sources from extract to converstion to end utilization.

10. Improve accuracy and specificity of sampling and analytical procedures in:

a. Ambient air (SO_x, sulfates, NO_x, fine particulates, trace toxic metals, krypton-85, and tritium).

b. All sources of emissions (SO_x, sulfates, NO_x, fine particulates, trace toxic metals, krypton-85, and tritium).

11. Develop continuous monitoring instrumentation for:

a. Ambient air (SO_x, sulfates, NO_x, fine particulates, trace toxic metals, krypton-85, and tritium).

b. All sources of emissions (SO_x, sulfates, NO_x, fine particulates, trace toxic metals, krypton-85, and tritium).

12. Develop location models for in situ sampling and continuous instrumentation in:

a. Ambient air

b. Emission sources

13. Develop more precise information specifications for sample collection in emission sources.

14. The development of monitoring systems that allow for long-term low level effects determinations (e.g., SO_x concentrations of less than ppm.

15. The adaptation of existing IBP system models to energy source related environmental problems (e.g., the ELM model adapted to EPA Coal-Fired Power Plant Study in Montana).

16. The development of simulated ecosystems that (microcosms) serve to support field oriented activities involving studies of transport, distribution, food chain concentration, metabolism and toxicity of single or multiple compounds introduced. This system would especially be useful for supporting field trace element investigations (e.g., trace element emissions from coal-fired power plants).

17. Laboratory research that involves toxicity challenges to native organisms found in field investigations. This laboratory research should investigate the effects of pollutants (at varying concentrations) on communities, populations, and individuals. Productivity and diversity should be characterized for each laboratory system.

18. Normalized cost/benefit matrices should be established to minimize impact to affected ecosystems (i.e., the trade-off between the environment, land use, socio-economic, etc.).

Table 4

Proportion of Total Energy Ecological Effects
R&D Resources Devoted to Each Program Area

Low Funding Level

	Fiscal Year									
	75		76		77		78		79	
Aquatic	.4		.4		.4		.4		.4	
Marine		0		0		.05		.05		.1
Estuarine		.1		.1		.1		.1		.1
Freshwater		.25		.25		.2		.2		.1
Aquatic Ecosystems		.05		.05		.05		.05		.1
Terrestrial	.5		.5		.5		.5		.5	
Soils		.2		.2		.1		.1		.1
Vegetation		.05		.05		.05		.05		.05
Animals		.05		.05		.05		.05		.05
Terrestrial Ecosystems		.2		.2		.3		.3		.2
Synthesis	.1		.1		.1		.1		.1	

Table 5

Proportion Of Total Energy Ecological Effects
R&D Resources Devoted To Each Program Area

High Funding Level

	Fiscal Year									
	75		76		77		78		79	
Aquatic	.5		.5		.5		.4		.4	
Marine		.05		.05		.1		.1		.1
Estuarine		.05		.05		.1		.1		.1
Freshwater		.3		.3		.2		.05		.05
Aquatic Ecosystems		.1		.1		.1		.15		.15
Terrestrial	.4		.4		.4		.4		.4	
Soils		.2		.2		.1		.1		.1
Vegetation		.05		.05		.1		.05		.05
Animals		.05		.05		.1		.05		.05
Terrestrial Eco-Systems		.1		.1		.2		.3		.3
Synthesis	.1		.1		.1		.2		.2	