March 31, 1995

EPA-SAB-RAC-95-006

Honorable Carol M. Browner
Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

Re: Future Issues in Environmental Radiation

Dear Ms. Browner:

This report was developed by the Radiation Environmental Futures Subcommittee (REFS), an ad-hoc subcommittee formed by the Radiation Advisory Committee (RAC) as part of the Environmental Futures Project of the Science Advisory Board (SAB), which you requested that the SAB undertake in Fiscal Year 1994. The intent of the REFS report is: (1) to provide you and the Agency with a forward-looking and broad-based perspective on future issues in environmental radiation that are likely to have significant impact on society, and particularly on the Agency's activities in a 5-30 year time horizon; and (2) to make recommendations to position the Agency in a proactive stance toward recognizing and effectively managing those future issues.

Specifically, the charge given to the Standing Committees of the SAB, and delegated by the RAC to the REFS, was:

a) to conduct both a short-term scan and a long-term scan of future developments in its field of expertise; and

b) to conduct an in-depth examination of future developments using an approach chosen by the Subcommittee.

Furthermore, the Environmental Futures Committee (formed by the Executive Committee of the SAB) also charged the Subcommittees as follows:

c) to identify baseline information and trends that may be expected to have future impacts on human health and the environment;

d) to focus on one or more case studies relevant to their expertise; and

e) to suggest a procedure by which future environmental concerns can be recognized at an early stage.

The attached report analyzes the present-day situation on many significant technical issues in environmental radiation, and defines those which the Subcommittee felt would be most likely to require the attention of the Agency to plan, prepare and manage for the future. This report attempts to establish a foundation upon which the Agency can continue its own short- and long-term scans of those future environmental issues and presents suggestions pertaining to the technical aspects of policy choices that may lead to a desirable future outcome in each of the issue areas.

Having gone through this exercise, we sincerely believe that there is much to be gained from a systematic and periodic exploration of the future. This type of exercise may help the Agency to focus proactively as a driver toward a more healthy environment in the future, as opposed to the more limited, and less effective, role of a regulator reacting to events under circumstances that limit its ability to act effectively.

The Subcommittee believes that EPA should consider the following in its long-term efforts for the environment:

1) Place a greater emphasis on providing scientifically credible information in order to assure overall enhancement of the environment's health from society's activities - the original vision which accompanied the Agency's formation.

2) Participate positively in the joint development of national energy policies, focusing on an examination of the overall environmental consequences of different energy production options; such as the roles of alternative energy sources, including nuclear electricity generation, in curtailing greenhouse gases; potential releases of radioactive materials to the environment; radioactive waste management issues; and possible increases in ultra violet (UV) radiation and other harmful effects.

3) Incorporate into its program activities important research findings related to radiation exposures, dose-response models, and radiation effects, and be prepared to provide leadership on how to deal with a world in which differences in individual susceptibility to radiation and other hazards are understood and in which the technology exists for identifying individuals with heightened or decreased susceptibility.

4) Provide an environmental perspective to assure control of nuclear weapons materials through conversion to energy use and/or secure disposal.

5) Stimulate and track research on the potential health effects of exposure to non-ionizing radiation and provide non-regulatory Federal guidance and advice on the prudent avoidance of unnecessary risks from potential sources of exposure, if such risks are shown to exist.

6) Assume a Federal leadership role in activities involving pollution prevention, the management and disposal of radioactive wastes, and the development of criteria and standards for cleanup of sites containing radioactive and mixed wastes.

7) Exercise its Federal radiation guidance role, in collaboration with other Federal and state agencies, to promote reduction of population exposure in medical uses of radiation.

8) Continue efforts to focus on characterizing high-risk radon potential regions, improving knowledge about radon risks, and developing more accurate methods of measuring and mitigating radon in buildings. Particular emphasis should be placed on empowerment of stakeholders by dissemination of all available scientific information.

9) Become the source of choice for information on environmental radiation by providing advice, guidance, and standards, where appropriate, on the scientific basis for risk management decisions and by identifying research needs in radiation-related areas. The continued existence and funding of the Radiation Effects Research Foundation, and its work with the A-bomb survivors will be crucial to these efforts.

10) Use a process of foresight to develop a systematic capability for scanning the future in order to be proactive, rather than reactive, in shaping environmental radiation policies.

During the past year, EPA has undertaken several very important actions that pertain to the recommendations presented in this report: a) the generally applicable standard for high-level radioactive waste has been promulgated, although its potential applicability to Yucca Mountain is under external review; b) the Agency has formed a group charged with developing a program to address the issue of harmonizing chemical and radiation risks; c) work is in progress on developing generally applicable standards for residual radioactivity and low-level radioactive waste; and d) work has resumed on electromagnetic field (EMF) issues. The RAC has been involved in consultations and briefings on these issues and has scheduled reviews for some of them in Fiscal Year 95.

It is hoped by the Radiation Environmental Futures Subcommittee that the Agency will consider its degree of institutional readiness and what is necessary to achieve its desired goals in light of the future issues and challenges in environmental radiation identified in this report.

The RAC appreciates the opportunity to provide this report to you. It is our hope that you will find our analysis to be useful in focusing priorities and in setting the course for the future goals and activities of the Agency in the radiation area. We look forward to receiving your reaction to our exploration of the future, and particularly to our specific projections and recommendations highlighted in this letter to you.

Sincerely,

Dr. Genevieve M. Matanoski
Chair, Executive Committee
Science Advisory Board

Dr. Raymond C. Loehr
Chair, Environmental Futures Committee
Science Advisory Board

Dr. James E. Watson, Jr.
Chair, Radiation Advisory Committee
Science Advisory Board

Dr. Ricardo González-Méndez
Chair, Radiation Environmental Futures Subcommittee
Science Advisory Board

NOTICE

ABSTRACT

The Radiation Environmental Futures Subcommittee (REFS) of the Radiation Advisory Committee (RAC) of the EPA Science Advisory Board (SAB) has prepared a report on future issues and challenges in the study, management, and regulation of environmental radiation. The REFS developed a process by which it scanned baseline data and trends that would give an overview of future developments related to environmental radiation. The result of that process and hence the focus of the report was seven major topics that included: energy production and environmental quality, radioactive waste management, non-ionizing radiation, dose-response models and population susceptibility, radon in indoor air, control of nuclear materials from dismantled warheads, and institutional readiness to deal with future issues in environmental radiation.

It was the consensus of the Subcommittee that these issues will be the ones that will occupy the EPA's study, management, and regulation of environmental radiation in the foreseeable future, both in the short (3-5 yr) and long (5-30 yr) time frames. Most issues were found to be closely related to the future of energy production and distribution, and to the perspective, policies, and practices of dealing with nuclear and radioactive materials. New and emerging knowledge of population genetic susceptibilities may make current regulatory paradigms for radiation exposures inadequate in the future. Societal concerns and individual value judgments may play a major role in any new paradigm that would be adopted. An expansion of the EPA's foresight and issues management capabilities for scanning the future may be necessary for the development of a proactive role in shaping environmental policies. This capability will be needed to address some of these future issues before a crystallizing event limits the Agency's ability to ensure that the best science is brought to bear on environmental problems. Development and/or maintenance of technically strong programs and policies will also be required in order for the Agency to maintain its leadership role.

Key Words: Environmental Futures Project, Environmental Radiation, Radiation Futures, Future Radiation Issues and Challenges, Energy Production, Energy Distribution, Environmental Quality, Dose-Response Models and Population Susceptibility

SCIENCE ADVISORY BOARD
RADIATION ADVISORY COMMITTEE
RADIATION ENVIRONMENTAL FUTURES SUBCOMMITTEE

TABLE OF CONTENTS

TABLE OF CONTENTS: CONTINUED:

TABLE OF CONTENTS: CONTINUED:

LIST OF FIGURES

LIST OF APPENDIX FIGURES

LIST OF TABLES

LIST OF APPENDICES

1. EXECUTIVE SUMMARY

1.1 The Charge to the Radiation Environmental Futures Subcommittee

On July 16, 1993, the Science Advisory Board (SAB) was asked by the Environmental Protection Agency (EPA) to develop a procedure for conducting a periodic scan of the "future horizon" and to choose a few of the many possible future public and corporate developments and issues for in-depth examination of potential environmental impacts. This initiative was named the Environmental Futures Project. The Executive Committee (EC) of the SAB considered and accepted this request. The SAB EC then established an ad-hoc committee, the Environmental Futures Committee (EFC), to coordinate this effort.

The Radiation Advisory Committee (RAC) formed a subcommittee, the Radiation Environmental Futures Subcommittee (REFS), to address this topic from the perspective of environmental radiation. The REFS met in publicly advertised meetings on December 2 and 3, 1993, February 22, 1994, May 6, 1994 and July 11, 1994 to develop this report. Additional meetings occurred in the form of publicly advertised two-hour teleconference editing sessions. The teleconferences were held on January 21, 1994, June 20, 1994, August 29, 1994, and September 26, 1994. The charge given to the Standing Committees of the SAB, and delegated by the RAC to the REFS, was:

a) to conduct both a short-term scan and a long-term scan of future developments in its field of expertise; and

b) to conduct an in-depth examination of future developments using an approach chosen by the Subcommittee.

Furthermore, the EFC also charged the Subcommittees as follows:

c) to identify baseline information and trends that may be expected to have future impacts on human health and the environment;

d) to focus on one or more case studies relevant to their expertise; and

e) to suggest a procedure by which future environmental concerns can be recognized at an early stage.

1.2 Process for the Identification of Major Issues for the Future in Environmental Radiation

The REFS carried out a scan of future developments in the field of radiation, particularly as they pertained to environmental radiation. This scan was conducted after receiving short briefings about the expectations and ideas regarding the Environmental Futures Project from various staff representatives from the EPA Office of Radiation and Indoor Air (ORIA) and the EPA Office of Policy Planning and Evaluation (OPPE). The Subcommittee reached consensus on a list of 21 issues that it considered to be the most relevant ones in environmental radiation over the 5-30 year time frame. The REFS then created a matrix that evaluated these issues according to five criteria: present situation, current trend, future situation, concerns, and EPA role.

After a careful analysis of that matrix, the Subcommittee eliminated those issues which it felt would have at most a minor impact in the future, and grouped the remaining issues in environmental radiation into seven major topics that might have a significant impact in the future of our environment. The selection also took into account that EPA's principal role in the management of radiation risks is to give advice, provide guidance, and issue generally applicable standards on which other agencies in government must base their rules and regulations in radiation. The issue categories are as follows, with each topic expanded upon in the referenced section of the main report:

1. Energy and environmental quality (Section 4). Most radiation issues are directly or indirectly related to energy production and distribution, and particularly to policies and actions related to the nuclear energy fuel cycle.

2. Exposures, dose-response models, and population susceptibility. This category of issues concerns occupational exposures, exposure/dose/outcome information as reflected by differences in radiation susceptibility, and medical use of radiation. These issues are dealt with in Section 5 (changing patterns of exposure to ionizing radiation), and in Section 8 (exposures, dose-response models, and population susceptibility).

3. Management of radioactive waste material (Section 6). This group of issues includes civilian and military high-level radioactive waste; managed low-level waste (e.g., from nuclear, medical, and research activities) and currently unmanaged waste such as Naturally-Occurring or Accelerator-Produced Radioactive Materials (NARM); waste generated from the clean-up of U.S. Department of Energy (DOE) and military facilities and from decommissioning of civilian and military facilities; disposal of nuclear materials from warheads; accidents; and mixed hazardous/radioactive waste.

4. Non-ionizing radiation (Section 7). Included in this category are exposures to extremely low frequency (ELF) and radiofrequency (RF) electric and magnetic fields, static and quasi-static magnetic fields, and ultraviolet (UV) radiation. In the latter case, ecological exposures are particularly of concern.

5. Radon and the indoor environment (Section 9). The principal issue of concern in this category is improvements in methods to identify and protect that part of the population with the highest risks from radon exposure.

6. Loss of control of nuclear materials (Section 10). Diversion of fissile weapons material and/or its use in terrorist activities, or an accident with these materials, may happen at any time unless aggressive and coordinated action is taken by many agencies within the U.S. as well as governments of other nations.

7. How does the EPA become the source of choice for environmental radiation information (Section 11), such that it is perceived as a leader on these issues? In the area of environmental radiation, the REFS believes that EPA has the potential to substantially influence the future direction and magnitude of the above radiation issues through use of its authority to provide guidance and to set definitive, generally-applicable standards, both based on sound science. In addition to tracking pertinent research, the Agency could also identify and promote research needed in support of its regulatory activities.

Finally, recommendations regarding a process for scanning future issues and emerging environmental concerns were provided by the Subcommittee in a separate memorandum submitted to the EFC (See Appendix D, González-Méndez, 1994, as well as Appendix C on more details of the process).

1.3 Summary and Recommendations

The Subcommittee believes that it would be worthwhile for EPA to explore the following in its long-range planning efforts:

1) A decreased reliance reliance on strictly regulatory approaches to risk management would more likely lead to overall enhancement of the environment from society's activities, the original vision which accompanied the Agency's formation. This renewed role would focus on providing scientifically credible information to stakeholders as participants in resolution of environmental questions consistent with the SAB's Future Risk and Reducing Risk reports, as well as the Safeguarding the Future report (see Appendix D: U.S. EPA/SAB, 1988; U.S. EPA/SAB, 1990; and U.S. EPA, 1992).

2) This report presents arguments for EPA attention and focus, particularly on issues related to energy production and use, insofar as they are linked and interwoven into issues of radiation exposures and waste disposal. Based on our analysis of the future and the strong linkages of environmental quality issues to the Nation's energy issues, the Subcommittee recommends that EPA participate positively in the joint development of national energy policies, focusing on an examination of the overall environmental consequences of energy production options, the roles of alternative energy sources including nuclear electricity generation in curtailing greenhouse gases, possible increases in ultra violet (UV) radiation and other harmful effects, radioactive waste management issues, and potential release of radioactive materials to the environment.

3) Working with other Federal, state and local agencies, as well with as other national governments, in order to resolve problems in the management of radioactive waste materials. Appropriate and coordinated action is necessary in order to allow for: a) proper choices in nuclear energy production; b) control of nuclear materials from disassembled warheads; c) site restoration activities in Federal facilities and Nuclear Regulatory Commission (NRC) licensees; and d) continued use of radioactive materials in medicine and research. EPA could assume a proactive leadership role by:

   a) expediting the resolution of the problem of radioactive wastes by issuing generally applicable standards for radioactive waste disposal and residual radioactivity; and

   b) formulating clear policies for both naturally occurring radioactive material (NORM) and mixed hazardous/radioactive wastes.

4) Assuring control of nuclear materials from disassembled warheads through conversion to energy use, burn-up in reactors, and/or secure disposal is vital to a safe and clean environment. EPA could provide leadership in resolving environmental issues necessary to incorporate this assurance into national programs.

5) The largest potential for reducing population exposure to radiation (inasmuch as they are controllable) could occur in the areas of medical care and radon in indoor air. EPA guidance on public radiation exposures could influence reductions in radiation doses from these sources.

6) Advances will likely be made in understanding the significance of different measures of exposure, the relationship of exposures to risks, and how and why different people may respond differently to radiation. EPA will be faced with the need to incorporate new important findings in radiation research into its guidance and regulatory postures regardless of whether the findings point to greater or lesser health and environmental risks than previously thought. For example, information from the Human Genome Project and molecular biology research could allow for identification of individuals with genetic or other susceptibilities to radiation health effects, which may require major changes in regulatory approaches for radiation protection. EPA should begin to consider what kinds of policies will be pertinent for a future in which it becomes commonplace to identify genetic, chemical, and other factors that lead to enhanced susceptibility of individuals to radiation damage.

7) EPA should continue efforts to focus on characterizing high-risk radon potential regions, improving knowledge about radon risks, and developing more accurate methods of measuring and mitigating radon in buildings. Particular emphasis should be placed on empowerment of stakeholders by dissemination of all available scientific information .

8) Working collaboratively with other agencies, EPA should continue to assess the state of science regarding potential health effects associated with environmental exposures to

electromagnetic fields (EMF). To the extent warranted by future developments, the Agency should ensure that key research is pursued. In the meantime, in the absence of solid evidence demonstrating or refuting the hypothesis that exposure of some type to such fields causes cancer or other effects, EPA could provide practical guidance that will aid those who develop and apply EMF technologies to limit EMF exposures consistent with current knowledge. These actions will permit EPA to position itself to deal with the increases in environmental exposures to EMF that are likely to occur in the future as a consequence of increased electrification and technological developments such as magnetic resonance imaging in medicine, magnetic levitation in transportation, and the explosion in information processing and telecommunication technologies.

9) The development of a capability for scanning the future through a process of foresight may be necessary for the development of a proactive role in shaping environmental radiation policies. The REFS is unanimous in recommending this, given the fact that with a few exceptions, the research, the regulatory practices, and the paradigms used today as the basis for setting radiation standards may not be effective or efficient in resolving the issues of the future.

During the past year, EPA has undertaken several very important actions that pertain to the recommendations presented in this report: a) the generally applicable standard for high-level radioactive waste has been drafted and is under external review; b) the Agency is beginning to address the issue of harmonizing chemical and radiation risks; c) work is in progress on developing generally applicable standards for residual radioactivity and low-level radioactive waste; and d) work has resumed on EMF issues. The RAC has been involved in consultations and briefings on these issues and has scheduled reviews for some of them in Fiscal Year 95. It is our expectation that some of the desirable outcomes envisioned in this report will be assisted by the above initiatives.

2. INTRODUCTION

Environmental protection is embedded within the fabric of American life as it continues to evolve. The Environmental Protection Agency (EPA) came into being a quarter of a century ago in the spirit of the National Environmental Policy Act (NEPA) and its philosophy that the environment should weigh heavily in society's major decisions. A deliberate balancing of environmental, economic, and national security factors was envisioned to achieve environmental quality. Public recognition of the pollution consequence of the modern technological growth after World War II led to bold and definitive programs to impose control principally on point sources of environmental pollution, and to restore the environment from polluting activities of the past.

After more than 20 years of intense regulatory efforts designed to restore environmental quality, the focus of environmental efforts is shifting toward empowerment of all the stakeholders in both sustained economic strength and environmental quality. Empowerment of these stakeholders requires recognition of the environmental consequences of technological change and the enunciation of broad policies pertaining to those consequences. The role of government is evolving toward the design of policies and programs to prevent environmental degradation which will provide stakeholders with ample opportunity to participate in these efforts. This contrasts with the largely regulatory approach of the past.

As part of the Environmental Futures Project, the REFS developed a list of seven broad issues in environmental radiation that it felt would be most likely to have a significant impact on the future quality of our environment (see Section 3 for details about the process). Each of these issues is expanded upon in a separate section in the main body of the report.

1. Energy and environmental quality (Section 4). Most radiation issues are directly or indirectly related to energy production and distribution, and particularly to policies and actions related to the nuclear energy fuel cycle.

2. Exposures, dose-response models, and population susceptibility (Sections 5 and 8). This category of issues concerns occupational exposures, exposure/dose/ outcome information as reflected by differences in radiation susceptibility, and medical use of radiation. These issues are dealt with in Section 5 (changing patterns of exposure to ionizing radiation), and in Section 8 (exposures, dose-response models, and population susceptibility).

3. Management of radioactive waste material (Section 6). This group of issues includes civilian and military high-level radioactive waste; managed low-level waste (e.g., from nuclear, medical, and research activities) and currently unmanaged waste such as NARM; waste generated from the clean-up of DOE and military facilities and from decommissioning of civilian and military facilities; disposal of nuclear materials from warheads; accidents; and mixed hazardous/radioactive waste.

4. Non-ionizing radiation (Section 7). Included in this category are exposures to extremely low frequency (ELF) and radiofrequency (RF) electric and magnetic fields, static and quasi-static magnetic fields, and ultraviolet (UV) radiation. In the latter case, ecological exposures are particularly of concern.

5. Radon and the indoor environment (Section 9). The principal issue of concern in this category is improvements in methods to identify and protect that part of the population with the highest risks from radon exposure.

6. Loss of control of nuclear materials (Section 10). Diversion of fissile weapons material and/or its use in terrorist activities, or an accident with these materials, may happen at any time unless aggressive and coordinated action is taken by many agencies within the U.S. as well as governments of other nations.

7. How does the EPA become the source of choice for environmental radiation information (Section 11), such that it is perceived as a leader on these issues? In the area of environmental radiation, the REFS believes that EPA has the potential to substantially influence the future direction and magnitude of the above radiation issues through use of its authority to provide guidance and to set definitive, generally-applicable standards, both based on sound science. In addition to tracking pertinent research, the Agency could also identify and promote research needed in support of its regulatory activities.

In its analysis of these issues and their implications for the EPA, the REFS took into account that EPA's authority in radiation issues is, in general, different from its authority in most other regulatory programs. With the exception of a few regulatory mandates under the Clean Air Act, the Safe Drinking Water Act, and the Clean Water Act—which grant regulatory authority to the Agency to issue standards for radionuclides — EPA's mandates are limited to the issuance of guidance to other government agencies on radiation issues, and to the issuance of generally applicable standards for radioactive waste disposal and residual radioactivity under various statutes such as the Atomic Energy Act, the Nuclear Waste Policy Act, the Low-Level Radioactive Waste Policy Act, and the Waste Isolation Pilot Plant (WIPP). Thus, its role can be summarized as one of advising, providing guidance, and issuing generally applicable standards on which other agencies in government must base their rules and regulations in radiation. Such a role by definition involves a position of leadership within the government inasmuch as other regulatory agencies must prove that their regulations are at least as protective of the environment as are those of the EPA standards, or must justify their rules when compared against the radiation guidance issued by the EPA. Credible and effective leadership by the EPA in environmental protection involves the forging of partnerships with other Federal and state agencies, and having the best science available. It is within the context of this framework that the analysis and recommendations presented in this report must be taken.

Given the limitations on time, space, and resources, the REFS focused on the above seven issue categories. Therefore, if a particular issue is not within those categories, or is not mentioned in this report, that should not be taken to imply the issue is neither important nor meritorious. It should also be pointed out that other issues related to those categories are covered by other SAB committees in their futures reports, e.g., the increase in used batteries containing toxic components if there is a sharp increase in the usage of electric cars, etc. Finally, the order of discussion of the categories reflects the "historical build-up" of the development of the report, and not any assignment of importance or merit.

3. RESPONSE TO THE CHARGE AND PROCESS FOR THE IDENTIFICATION OF MAJOR ISSUES FOR THE FUTURE IN ENVIRONMENTAL RADIATION

3.1 The Charge and the Process for the Report

On July 16, 1993, the Science Advisory Board (SAB) was asked by the Environmental Protection Agency (EPA) to develop a procedure for conducting a periodic scan of the "future horizon" and to choose a few of the many possible future public and corporate developments and issues for in-depth examination of potential environmental impacts. This initiative has been named the Environmental Futures Project. This request was made by Mr. David Gardiner, Assistant Administrator for the Office of Policy Planning and Evaluation (OPPE) at EPA, and by EPA Administrator Carol Browner. (Appendix A lists in very brief form the charter that evolved from the original request.) The project is considered to be a logical extension of the SAB report on Reducing Risk (Appendix D, U.S. EPA/SAB, 1990), in which the SAB indicated that it was important to increase the Agency's ability to identify the future potential risks to human health and the environment. The Executive Committee of the SAB considered and accepted this request. The SAB then established an ad-hoc committee, the Environmental Futures Committee (EFC), to undertake this effort.

The Radiation Advisory Committee (RAC) formed a subcommittee, the Radiation Environmental Futures Subcommittee (REFS), to address this topic from the perspective of environmental radiation. The REFS met in publicly advertised meetings on December 2 and 3, 1993, February 22, 1994, May 6, 1994, and July 11, 1994 to develop this report. Additional meetings occurred in the form of publicly advertised two-hour teleconference editing sessions. The teleconferences were held on January 21, 1994, June 20, 1994, August 29, 1994, and September 26, 1994.

It is the intent of the SAB to focus on the scientific and technical aspects that may allow EPA and other interested agencies and organizations to better recognize, understand, and influence future events so that these developments may have (as much as possible) a positive effect on human health and the environment. It is hoped by the REFS that the Agency will consider its degree of institutional readiness and what is necessary to achieve its desired goals in light of the future issues and challenges in environmental radiation identified in this Subcommittee report.

The charge given to the Standing Committees of the SAB, and delegated by the RAC to the REFS, was:

a) to conduct both short-term and long-term scans of future developments in its field of expertise, and

b) to conduct an in-depth examination of future developments using an approach chosen by the Subcommittee.

Furthermore, the Environmental Futures Committee (formed by the Executive Committee of the SAB) also charged the Subcommittees as follows:

c) to identify baseline information and trends that may be expected to have future impacts on human health and the environment,

d) to focus on one or more case studies relevant to their expertise, and

e) to suggest a procedure by which future environmental concerns can be recognized at an early stage.

The Standing Committees and subcommittees involved in the project were instructed by the EFC to develop their own approaches.

3.2 Response to the Charge

3.2.1 To conduct short-term and long-term scans of future developments in its field of expertise

On the meeting held in December 2 and 3, 1993, the REFS carried out a scan of future developments in the field of radiation, particularly as they pertained to environmental radiation. This scan was done after receiving short briefings about the expectations and ideas regarding the Environmental Futures Project from various staff representatives from the EPA Office of Radiation and Indoor Air (ORIA), and the EPA Office of Policy Planning and Evaluation (OPPE). The two Offices presented very different expectations and outlooks. On the one hand, OPPE desired the Subcommittee to look at issues in the long view and to focus on processes that incorporated long-range planning in science and policy within a holistic view of the environment as presented in Figure 3.1. On the other hand, ORIA was interested in a 3- to 5-year time frame that would help it address some very significant regulatory issues in radiation that its program offices might tackle in the short view of the future.

In Figure 3.1, which was presented to the REFS by the staff of OPPE, the environment is presented as encompassing all aspects of the Earth's ecosystems, in which the Human System is only a single component. Furthermore, all five major input drivers for the future involve or include radiation in some way. A few examples of that connection are: a) biotechnology in many cases requires the use of radioactively labeled nucleic acids for gene cloning and signal transduction work, and may provide significant understanding of genetic susceptibility to radiation; b) communications technology involves electromagnetic fields; c) energy has nuclear power and radioactive waste issues; d) exposure assessment is an integral part of environmental radiation issues; and e) infrastructure will have electrification, transmission antennas, and energy production facilities as radiation-related issues.

FIGURE 3.1

ENVIRONMENTAL FUTURE INPUT DRIVERS

The REFS responded to this first item of the charge by compiling a list of radiation issues (Table 3.1) that it felt would be most likely to impact human health and the environment both in the short term (3 to 5 years) as well as over the long term (5 to 30 years).

3.2.2 To conduct an in-depth examination of future developments using an approach chosen by the Subcommittee

In response to the second item of the charge, the REFS had to select an approach for scanning the future. The Subcommittee was briefed by one of its members, a futurist, Mr. Joseph F. Coates, on a similar project he had organized called *Project 2025*. He presented the REFS with a summary of the results of that project titled *Thinking About the Year 2025* (see Appendix B). It lists a set of 83 assumptions about the year 2025 that the REFS reviewed and found to be a useful set of examples or guides of what might be included in constructing scenarios for the future on which it could base some of its analyses. These assumptions of what the year 2025 will be like are a robust set, that is, one can throw out those with which one disagrees and still have a complete and reasonable scenario for the future.

The REFS then created a matrix that rated each of the issues listed in Table 3.1 according to five criteria. The Subcommittee approached the issues from the perspective of whether or not the Federal government is ready to tackle the issue if a "crystallizing event" were to occur today and were to galvanize both the public and government into action and what EPA's role would be in each case. The criteria used are listed in Table 3.2 and are defined below.

TABLE 3.1
ISSUES IN ENVIRONMENTAL RADIATION
RELEVANT TO THE FUTURE

1. High-Level Radioactive Waste (HLW)
   a. Civilian
   b. Military
2. Low-Level Radioactive Waste (LLW)
   a. "Managed" (e.g., from medical, nuclear power, and research activities)
   b. "Not currently managed" by EPA (e.g., NORM)
3. Clean-up
   a. DOE Sites
   b. Military Sites
4. Decommissioning
   a. Civilian Sites
   b. Military Sites
5. Mixed Hazardous/Radioactive Waste
6. Control of Nuclear Materials
7. Accidents
8. Routine Emissions
9. New Energy Sources (Including nuclear power)
10. Extremely Low Frequency (ELF) Electric and Magnetic Fields
11. Radiofrequency (RF) Electric and Magnetic Fields
12. Static and Quasi-Static Magnetic Fields
13. Radon in Indoor Air
14. Ultraviolet (UV) Radiation
15. Terrestrial Radiation
16. Cosmic Radiation
17. Occupational Exposures
18. Medical Use of Radiation
19. Population Susceptibility
20. Exposure - Dose Response - Health Outcome Information
21. Risk Communication Paradigm (mortality vs. morbidity, effectiveness)

TABLE 3.2

CRITERIA FOR THE ANALYSIS OF FUTURE ISSUES IN ENVIRONMENTAL RADIATION

Present Situation	Trend	Time to crystallizing event	Concerns	EPA Role
√ - Existent ? - Unknown	↑ ↓ → ↗ −	Now (today) through 〉20 years, or ?	Tech. - Technical Pol. - Political Sci. - Scientific ● - Major ○ - Minor	R - Regulatory A - Advisory G - Guidance E - Exploratory P - Potential S - Seminal R&D - Research

Present Situation: Indicates whether the issue already exists and if there is already public awareness on the issue.

Trend: The projected trend is not only from the scientific perspective, but also with respect to public awareness or concern on the issue. The direction of the arrow indicates whether the issue is expected to remain unchanged [horizontal arrow (→)], or become more [up arrow (↑)] or less [down arrow (↓)] important, and at what rate [a vertical arrow is more rapid than one at an angle (↗)]. A dash (−) indicates that the trend is either not an issue or not known at this time.

Time-to-Crystallizing Event: The time presented is a "guesstimate" by the REFS using its collective judgment and expertise of when the "crystallizing event" might happen. It is the consensus of the Subcommittee that in many cases the date or time given can be replaced with "as soon as an Agency issues a regulation" without any loss of value in the table, insofar as Agency action in issuing a standard may become the rallying point for various groups in demanding political or legal action for or against the standard. A question mark (?) indicates that there may not be a crystallizing event for this issue in the future.

Concerns: This criterion indicates whether the concerns are of a political, scientific, or technological (engineering) nature and whether the concern is a major or minor one. Economic concerns are included under political concerns, given the REFS view that the allocation of funds and resources is a policy and/or political decision.

EPA Role: This criterion indicates what the role of the EPA could be in the government's handling of the issue. Three of the classifications in this item bear explanation:

a) Exploratory: The EPA may choose to provide a leading role in exploring whether an issue should be pursued for intervention. This exploration may be conducted through some futures scanning process.

b) Seminal: The EPA role may be that of a leader who lays the groundwork for intervening in a particular issue, and for defining the manner in which the issue is to be addressed.

c) Potential: The EPA has a potentially significant role in dealing with the issue, preferably before the "crystallizing event" occurs.

The above describes the process used by the REFS to scan future developments. The results of this scanning exercise are summarized in Table 3.3, which is also the basis for the response to the third item of the charge.

3.2.3 To identify baseline information and trends that may be expected to have future impacts on human health and the environment

The third item of the charge was addressed by implementing the process described above, resulting in the construction of the matrix shown in Table 3.3. The matrix represents the collective judgment and expertise of REFS members, and includes, in most cases, input from the EPA representatives from OPPE and ORIA present throughout the discussion. The value of Table 3.3 is in the following annotation of the items.

TABLE 3.3

SUMMARY OF THE REFS DISCUSSION ON ITS SCAN OF FUTURE DEVELOPMENTS IN ENVIRONMENTAL RADIATION

Issue		Present Situation	Trend	Time to Crystallizing Event	Concerns			EPA Role
					Tech.	Pol.	Sci.	
1a.	HLW, civilian	√	↑	5-10 yrs	○		○	R +?
1b.	HLW, military	√	↗	≤ 5 yrs	○	●	○	R
2a.	LLW, managed	√	↑	≤ 5 yrs		●		A / R
2b.	LLW, unmanaged	√	↗	<5 yrs	●			A / R
3a.	Clean-up, DOE	√	↑ as issue	?	●	●	○	R

3b.	Clean-up, military	√	↑ as issue	?	●	●	○	R
4a.	Decommissioning, civilian	√	↑	5-10 yrs	●	●		A / R
4b.	Decommissioning, military	√	↑	5-10 yrs	●	●		A / R
5.	Mixed hazardous/ radioactive waste	√	↑	today	●	●	●	S / R
6.	Control of nuclear materials	√	↑	any time	●	●	●	P
7.	Accidents	√	↗	any time	○	●	○	A
8.	Routine emissions	Not an issue	___					G
9.	New energy sources (includes nuclear)	New	→ ↑	> 10 yrs	●	●	○	R?
10.	ELF fields		↑	> 10 yrs?		●	●	A
11.	RF electromagnetic fields	√	↑ ↓ ↑ ↓	< 10 yrs	●	●		S
12.	Static/quasi-static magnetic fields	√	↗	> 10 yrs	●	●	●	S / R
13.	Radon in indoor air	√	→	—	●		●	A
14.	UV radiation	√	↑	> 20 yrs?	●	●	●	A / S
15.	Terrestrial radiation	Not an issue	_					
16.	Cosmic radiation	Not an issue	___					
17.	Occupational exposures	√	↗	?	●	○		G
18.	Medical use of radiation	√	↗	any time	●	●		R&D / G
19.	Population susceptibility	?	___	—	●	○	●	G
20.	Exposure/dose-response /outcome	?	___	—	●	●	●	R / A / G
21.	Risk communication	√	↗	?		●	●	R&D / A

1. The first two pairs of issues listed in the matrix concern civilian and military high-level radioactive waste. The issue exists at this time, and the trend is for high priority and public awareness on it. A crystallizing event may occur toward the end of the decade, as more becomes known about the magnitude of the military problem, and as we approach the time to start decommissioning civilian nuclear power plants. The dominant concerns are of a political nature, particularly public fears about radiation and radioactivity, although many technical issues need to be resolved. Today, the Federal government is not ready to cope with the high-level waste problem, insofar as the site selection and licensing of a repository are continually delayed, and because the magnitude of the military waste problem is not yet well-characterized. The role of the EPA is largely a regulatory one. In the case of the WIPP program, Congress has also assigned EPA an advisory role (through its position on the National Advisory Committee on Environmental Policy and Technology) as well as a policing role in the certification of various parts of the process of bringing WIPP on-line as a waste disposal facility.

2. The second pair of issues in the matrix is that of low-level radioactive waste, both "managed" as well as "unmanaged." The issues exist at this time, and the trends are for high priority and increasing public awareness on them. A crystallizing event may occur sometime toward the end of the decade, as we approach the time to start decommissioning civilian nuclear power plants, although the closing of the low-level disposal site in Barnwell, S.C., to "out of region" shipments has become a crystallizing event for many institutions needing a place for disposal of their wastes (The Barnwell, S.C. facility is scheduled to close to the South East Compact state members in 1995.). The dominant concerns are of a political nature, particularly public fears about radiation, although technical issues remain for regulated wastes; technical issues dominate the concerns for "unmanaged wastes." Today some regions are not ready to cope with the low-level waste problem, site selection and licensing of waste-disposal sites are continually delayed, the magnitude of the "unmanaged" waste is not well characterized, and it is unclear who if anybody has the authority to manage these wastes at the national level. The role of the EPA is both advisory and regulatory.

3. Clean-up of radioactively-contaminated sites is an issue of increasing concern to the public. The situation remains poorly defined, as the assessment of the problem is still in the early stages. Technical, political and scientific concerns are all dominant issues. For example, basic research is being conducted at the national laboratories on the interactions of microorganisms with radiation and chemical wastes, and on the potential for genetic alteration of microorganisms to increase their ability to scavenge radioactive materials from soils. EPA's role is regulatory.

4. Decommissioning of radioactively contaminated sites is a problem of high priority and large magnitude. A crystallizing event will happen within the next decade. There are significant technical and political concerns, and insufficient data to properly address the issue. EPA's role is regulatory. A major concern for decommissioning of radioactively contaminated sites is the lack of low level waste disposal sites.

5. <u>Mixed hazardous and radioactive waste</u> is a major radioactive waste disposal problem that is continuing to get worse, with a high awareness in the user communities. There are limited storage and disposal alternatives, mostly incineration followed by management as radioactive waste. Political concerns dominate discussions on this issue but knowledge is greatly lacking about the combined effects of exposures to radiation and toxic chemicals on human and environmental health. Various agencies and groups keep passing the problem from one to another. The EPA's role is both seminal and regulatory because Agency actions could set the course for the solution to this issue.

6. <u>The control of nuclear materials from dismantled warheads</u> is potentially a large problem. A crystallizing event, such as a major accident or a nuclear incident involving terrorist use, could happen at any time in any nation that has engaged in nuclear weapons programs. Many technical and political concerns need to be explored and addressed. Significant policy research is being done on the issue in the United States, and EPA hopes to be given some authority to participate in the U.S. involvement in international efforts to address this issue.

7. <u>Accidents involving radiation</u> are an issue of medium magnitude, with increasing public awareness of the issue. Such accidents may happen at any time and are by definition crystallizing events. Technological and political concerns are dominant. The plan currently in place for a radiation accident is untested with regard to a major accident (e.g., greater or equal in magnitude than Chernobyl). EPA's role is advisory.

8. <u>Routine emissions</u> of radionuclides from various sources were not considered to have a significant impact in the future. EPA's role could be one of guidance.

9. <u>New energy production facilities (including nuclear)</u> could become an emerging issue. The trend for nuclear energy is flat at this time, but may become high in the future as new reactor designs—such as those for fusion—are put forth. The time horizon for a crystallizing event is beyond the next decade. There are both technical and political concerns. Existing programs and regulations should be able to handle new nuclear energy programs. EPA's role is difficult to define, but could be a regulatory one through its authority for issuing standards for air and water emissions, and for issuing generally applicable standards for radioactive waste disposal.

10. <u>Extremely low frequency (ELF) electric and magnetic fields</u> are an issue for which public concern is high, and the lack of definitive scientific knowledge give it a high priority. A crystallizing event, if any, may lie well beyond the next decade, and only if continued research on the scientific questions that exist today provides unambiguous evidence for a health effect from some form of exposure. The dominating concerns are scientific and political, because technical solutions exist but may place large economic burdens on the public. The EPA has not given this issue a very high priority at the present time, and its role is advisory.

11. <u>Radiofrequency (RF) electric and magnetic fields</u> have been an issue for over a decade. The trend of the issue will see up and down swings as new technologies bring public awareness on the

subject. The time horizon for a crystallizing event may be within the next decade. Significant technical and political concerns need to be resolved, but the development of knowledge about the interactions of electric and magnetic fields with living systems (tissues) is especially critical. The Agency could have a seminal role in the issue, given that its guidance on the issue could have a large future impact on many public and private organizations.

12. There is an increasing concern about exposures to static and quasi-static magnetic fields. The time horizon is greater than 5 years for any kind of a crystallizing event. The dominant concerns are scientific and political. The EPA's role will be seminal, with its guidance setting the tone for future events.

13. Radon in indoor air is a continuing problem. The trend here is flat, without major increases in the problem or in the public's perception of the problem. We do not foresee a crystallizing event in the future. The issues are dominated by technological and risk communication concerns as well as by research on the mechanism of radon-induced cancer induction and the combined effects of exposure to cigarette smoke and indoor air pollutants. The EPA role is advisory.

14. Ultraviolet (UV) radiation is deemed to be a potentially important issue for ecosystems, e.g., through its effects on microplankton populations. There will be increased awareness of the issue in the future. The time horizon may be greater than 20 years, because effects may not be noticeable for a very long period of time. The concerns are largely scientific and technical. Other concerns such as skin cancer, immune system problems, and risk communication issues were considered to be well handled by the agencies concerned. The EPA's role will be advisory and seminal.

15, 16. Terrestrial and cosmic radiation were not considered to be significant issues for the future. Although they are significant contributors to risk, they are widely viewed as being beyond control.

17. Occupational exposures are generally an issue of low concern. Barring an unexpected event or discovery, a crystallizing event is not foreseen for this issue. Technical aspects are the dominant factor in the problem, although there are some political problems. Existing guidance and regulations are adequate to address the issue at this time. The role for EPA is to issue guidance on the subject.

18. Medical use of radiation was considered as an issue for the future, with increasing magnitude in the near future. A crystallizing event may occur at any time. The concerns are political and technical, but there is good institutional readiness in the Federal government on the subject. EPA's role could be in research and guidance.

19, 20. Population susceptibility and information on exposure, dose-response, and health outcome are not major issues at this time, but may become so in the future. Information from the Human Genome Project may trigger new awareness on these items. The concerns have scientific as well as political and technical aspects. The EPA role is one of guidance, with advisory or regulatory mandates on exposure-outcome problems pertaining to some of the above issues.

21. Risk communication paradigms were seen as an existent issue for the future, particularly as new endpoints (morbidity) beyond the standard body count (mortality) are sought. There may not be a crystallizing event for this issue in the future. The concerns are mostly scientific and political, with a poor-to-moderate institutional success. EPA roles are research and advisory.

3.2.4 To focus on one or more case studies relevant to their expertise

After a careful analysis of Table 3.3, the REFS categorized the issues listed into seven major topics to be discussed in the sections that follow. It is the consensus of the REFS that, processes to deal with these issues that incorporate the best scientific knowledge should be in place before crystallizing events occur. If these processes are not in place, then the science might be "steamrollered" by public opinion and politics, in which case the best outcome one could hope for might be actions to satisfy public and political concerns, and which are based on reasonable science, but not necessarily on the best science. By achieving a position of leadership in environmental sciences and information, the EPA could influence positive outcomes and forestall the crystallizing events that may take away the Agency's ability to bring the best science to bear on environmental problems.

It was the consensus of the REFS that the major environmental radiation issues with the most impact in the future are as follows:

1. Energy and environmental quality (Section 4): Excluding the weapons program, most radiation issues are directly or indirectly linked to energy production and distribution, and particularly to policies and actions related to the nuclear energy fuel cycle.

2. Exposures, dose-response, and population susceptibility (Sections 5 and 8): This category of issues concerns occupational exposures, exposure/dose/outcome information as reflected by differences in radiation susceptibility, and medical use of radiation. These are longer term future issues, but require action in order for EPA not to be surprised by developments. These issues are dealt with in Section 5, changing patterns of exposure to ionizing radiation; and in Section 8, exposures, dose-response models, and population susceptibility.

3. Management of radioactive waste material (Section 6): This group of issues includes civilian and military high-level radioactive waste; managed low-level waste (e.g., from nuclear, medical, and research activities) and unmanaged waste such as NARM; waste generated from the clean-up of DOE and military sites and from decommissioning of civilian and military facilities; disposal of nuclear materials from warheads; accidents; and mixed hazardous/radioactive waste. The consensus was that in many cases the crystallizing event may be the issuance by the EPA of generally applicable clean-up and disposal standards,

because the proposal of a standard often becomes a rallying point for various groups in society.

4. Non-ionizing radiation (Section 7): Included in this category are exposures to extremely low frequency (ELF) and radiofrequency (RF) electric and magnetic fields, static and quasi-static magnetic fields, and ultraviolet (UV) radiation. In the latter case, ecological exposures are particularly of concern. In general, a crystallizing event may not occur until far into the future, unless EPA issues guidance on the subject, or unless a dose-response relationship and mechanism of action are found.

5. Radon and the indoor environment (Section 9): The principal issue of concern in this category is improvements in methods to identify and protect that part of the population with the highest risks from radon exposure. In particular, the Agency should continue efforts to focus on characterization of high-risk radon potential regions, improving knowledge about radon risks, and developing more accurate methods of measuring and mitigating radon in buildings. Particular emphasis should be placed on empowerment of stakeholders by dissemination of all available scientific information.

6. Loss of control of nuclear materials (Section 10): Diversion of fissile weapons material and/or its use in terrorist activities, or an accident with these materials, may happen at any time unless aggressive and coordinated action is taken by many agencies within the U.S. as well as governments of other nations.

7. How does the EPA become the source of choice for environmental radiation information (Section 11), such that it is perceived as a leader on these issues? In the area of environmental radiation, the REFS believes that EPA has the potential to substantially influence the future direction and magnitude of the above radiation issues through use of its authority to provide guidance and to set definitive, generally-applicable standards, both based on sound science. In addition to tracking pertinent research, the Agency could also identify and promote research needed in support of its regulatory activities.

3.2.5 To suggest a procedure by which future environmental concerns can be recognized at an early stage

The final item of the charge was addressed by the Subcommittee in a separate memorandum to the EFC in which the REFS proposed a series of recommendations regarding a process for scanning future issues and environmental concerns (Appendix C). A good starting point for the EPA would be to strengthen and expand its existing issues management capabilities and processes, such as those in place at OPPE and the EPA Office of Research and Development (ORD), into the program offices throughout the Agency. Such a step presupposes that the Agency will be able to maintain technically strong programs and policies in all areas of critical concern. To be efficient and effective, the issues management process will have to consider and integrate all aspects of the issues involved: societal and value judgments, economic concerns, human health concerns, environmental aspects of remediation programs, cost-effectiveness and cost-benefit analyses of the various alternatives, and, finally, the best science available. The Subcommittee is unanimous in recommending the above and notes that, with few exceptions, the research, regulatory practices, and paradigms used today as the basis for setting radiation standards may not be effective or efficient in resolving the issues of the future.

4. ENERGY AND ENVIRONMENTAL QUALITY

4.1 Introduction and Overview

Energy supply and use are inextricably linked to environmental quality. Fuel use is a major source of environmental aerosols and greenhouse gases. Inefficiencies in energy conversion and end use produce thermal effluents, and resource extraction, processing and shipment also have environmental consequences. Energy-related waste products require environmentally sound disposal or reuse (e.g., fly- and bottom ash, spent nuclear fuel, hydrocarbon wastes from petroleum refining). Energy availability and use—more precisely, the costs of energy—are embedded in decisions about resource extraction (i.e., recycling and reuse), land use planning and policies (urban sprawl vs. infilling), and many other choices affecting economic development which can have environmental consequences.

The achievement of environmental improvements, both in the short as well as the long term, will depend in a large part on energy policies. In many cases, critical energy policy decisions are made by state and local authorities. National environmental policies must be cognizant of those decisions, and in some cases must accommodate them. Many states have adopted a variety of energy efficiency codes for buildings and appliances, and in some cases have incorporated energy conservation and energy-efficient technologies as part of utility rate structures. Some state and local authorities have adopted policies that require dramatic reductions in mobile source emissions, leading to a demand for technologies heading toward zero-emission vehicles.

Significant changes have occurred in energy use and the economy since the 1973 oil embargo, as shown in Figure 4.1. Although overall energy use has decreased significantly relative to economic growth, electricity growth has continued to increase with economic growth, although at a much slower rate than before 1973 (Appendix D: U.S. DOE/EIA, Monthly Energy Review, June 1994). Improvements in overall energy use efficiency are largely a result of increases in fleet average automobile fuel efficiency and of energy savings in refrigerators, furnaces, and air conditioners in homes and office buildings. These changes, along with slow but continuous changes in the industrial infrastructure, have resulted in a nearly continuous decline in the amount of energy consumed per unit of economic activity between 1973 and 1992 (Table 4.1). These energy savings undoubtedly minimized

FIGURE 4.1

ELECTRICITY DEMAND AND THE ECONOMY HAVE GROWN TOGETHER WHILE NON-ELECTRIC ENERGY DEMAND HAS DECLINED

Data sources: U.S. Department of Energy (DOE)/Energy Information Administration (EIA), Annual Energy Review, Washington, D.C., 1993; and Edison Electric Institute, Capacity and

TABLE 4.1

TRENDS IN ENERGY AND THE ECONOMY IN THE U.S.
(data from EIA, 1993)

ENERGY MEASURE	**1973**	**1992**
1. Primary energy use (quadrillion Btu)	74.3	82.4
2. Gross domestic product (GDP) (billion 1987 dollars)	3,270	4,920
3. Energy/GDP ratio (Btu/1987 dollar)	22,720	16,750
4. Energy use projected from 1973 Energy/GDP ratio (quadrillion Btu)	---	112
5. Energy "savings" (quadrillion Btu) (difference between rows 4 and 1)	---	30 (40% of 1973 actual)

significant (further) environmental degradation over this 20-year time span.

Changes in the patterns of energy production and use are integral to any consideration of future environmental radiation issues in that they directly and indirectly affect the potential for occupational and general population exposures to both ionizing and non-ionizing radiation. Three of the most important energy-related drivers for environmental radiation issues are:

a) *Trends in the electrification of energy use.* Increased electrification of energy use (for example, the use of electric vehicles as a means of reducing combustion engine emissions) has the potential to increase exposures to low frequency electric and magnetic fields and the possibility of adverse health effects. The EFC report (Appendix D, references U.S. EPA/SAB, 1995a and U.S. EPA/SAB, 1995b; also see these same futures reports listed at the end of Appendix D, as EPA-SAB-EC-95-007 and EPA-SAB-EC-95-007a) also expresses concern for another aspect associated with increased electrification, that is, the large-scale use of batteries containing toxic metals, and their dispersal in the environment. The issue of non-ionizing radiation exposures is explored in detail in Section 7 of this report and will not be treated in depth in this Section.

b) *Increasing attention to naturally-occurring radioactive materials (NORM) associated with oil and gas extraction and the coal fuel cycle.* NORM is recognized as a potentially significant issue for fossil fuel production and use (Appendix D, EPA/SAB, 1994a) but has not yet received much regulatory attention at the Federal level. This issue is discussed in detail in Section 6.

The major focus of the remainder of this section is on the third energy-related driver for environmental radiation issues:

c) *Trends in nuclear power generation versus other energy sources.* The most important determinants for trends in nuclear energy use are the general demand for electricity, recognition of the impacts of fossil fuel energy production on the environment, and problems regarding radioactive waste disposal. All three factors have social, economic, scientific, and political aspects that are very important in any analysis undertaken on this subject. Over the next 30 years, projected population growth implies pressure for increasing energy demand. While it is less clear whether total energy use per capita will increase, level off, or even decline, current trends suggest that electricity use will increase as the overall economy grows (Figure 4.1). In the past, the economic welfare of the United States has clearly benefitted from increasing energy use per capita, but this coupling may no longer be necessary and certainly is not desirable considering the many adverse environmental impacts of energy production and use. In particular, the combustion of fossil fuels is the principal contributor to greenhouse gases and the potential for significant global warming over the next decades. Nuclear power does not produce greenhouse gases and is environmentally desirable in that respect, but it produces radioactive wastes that must be properly managed to avoid endangering human health and the environment. Nuclear energy production has also been curtailed by fears of accidents and by concerns over the potential use of reactor byproducts for nuclear weapons (see Section 10 for discussion on the control of nuclear warhead materials).

Recognition of these conflicting pressures led the Subcommittee to construct two very different scenarios regarding the future use of nuclear power plants for the generation of electricity. In the first scenario, concerns about global warming and a belief in the economic benefits of energy use outweigh concerns about radioactive waste, nuclear accidents, and nuclear materials and foster continued reliance on nuclear power plants. In the second scenario, other solutions to the problems caused by greenhouse gases can be found, and public opposition to nuclear power continues, such that nuclear power fills an ever-decreasing role in the energy equation. These two scenarios represent the two most vocal and politically dominant viewpoints held about nuclear power in the United States. As will be explained further in the next two Sub-Sections, both scenarios lead to similar conclusions about the implications for EPA: a) barring an unforeseen breakthrough in technology, government actions and policies, along with market forces, will determine the future mix of energy sources; and b) radioactive waste disposal issues will continue to be important over the next few decades or even longer.

4.2 Scenario 1: Electrical Generation that Includes Nuclear Power

In this scenario, U.S. economic growth over the next two or three decades will be closely linked to electricity use as suggested by current trends (Figure 4.1). Provision of the electrical energy assumed to be needed for sustained economic vitality of the Nation without increased pollution will therefore require both greater efficiency of use in the current supply and more use of renewable resources, or else will require that we manage our traditional non-renewable energy resources in such a way as to minimize potential environmental problems. International concerns about global climate changes may also affect future policies on energy production and use.

While this scenario acknowledges that opportunities for further improvements in energy efficiency and use still exist, it assumes that they are not sufficient to offset the need for additional energy supplies over the next 25 years. Any increased use of fossil fuels in this scenario would bring increases in greenhouse gases and other pollution. Therefore, the Nation will either accept increased atmospheric levels of greenhouse gases, or will seek alternatives to fossil fuels, e.g., solar energy, other renewable sources, or nuclear power.

Renewable resources such as solar and geothermal energy currently provide only a small percentage of energy use despite tax credits and governmental promotion policies since the 1970's. Use of solar energy currently requires decentralized individual efforts because of the costs and reliability problems associated with its use in centralized generation. In this scenario, these facts are interpreted to mean that renewable resources cannot gain a significant share of the energy mix over the next 20-30 years (Appendix D: Energy Daily, July 28, 1994; San Francisco Chronicle, July 25, 1994; Faruqui et al., August 1994) and that non-renewable resources will continue to dominate energy supply over that period. Given that renewable resources cannot meet the energy needs arising from continued economic growth assumed to result from population growth and technological change (such as computers, energy-saving devices, transportation), the use of non-renewable energy supplies will also increase in this scenario.

As urban areas increasingly demand non-polluting vehicles, energy use will shift from petroleum to natural gas and electricity. If electric vehicles become common, international trade imbalances attributable to U.S. dependency on foreign oil will decrease, but growth in electric power generation will need to increase beyond the 2-3% per year forecast by most energy analysts. This reorientation and growth will be met, in this scenario, by centralized power stations serving electricity grids and will be supplied principally by fossil fuels (oil, coal, natural gas, and possible future use of oil shale) and nuclear energy, with some wind energy facilities.

With the assumed increase in electricity demand tied to economic growth, the assumed continuation of reliance on non-renewable sources of energy, and the assumed national commitment to reducing greenhouse gases and other conventional pollutants, this scenario leads to an increased reliance on nuclear power. Such a policy will also have the economic and national security benefit of lowering the U.S. dependency on imported oil. However, it will require prompt action to remove a major deterrent to expanded nuclear power, that is, the lack of a permanent solution to the problem of radioactive waste disposal, especially high-level waste. Final disposal of high-level radioactive waste in this scenario is found to be straightforward technologically, but difficult to implement because of political opposition. The Nation is then faced with the difficult choice between (a) dealing with greenhouse gases and other pollutants from an expanding fossil-fueled generating capacity, or else (b) removing some of the deterrents to the expansion of nuclear power. EPA could establish an historic milestone for the planet by educating the public on the environmental consequences of increased reliance on fossil fuels, and by convincing it of the need for policies to reduce the use of such fuels. If the Nation decides to continue to meet its increased electrical needs through the use of nuclear power plants, then EPA could play a role in assuring that safety controls are dependable, especially in the management of radioactive wastes. Issuance of generally applicable standards for residual radioactivity, radioactive waste clean-up, and disposal (see Section 6) would be important to continued use of nuclear power plants.

4.3 Scenario 2: Decline of Nuclear Power

In this scenario, a decoupling between total energy use and economic activity is found to be sufficiently feasible to offset increases in electricity use as the economy grows. Combining a mix of technological options (none of which are new or untested) and assumed policy choices, it projects essentially no increase in net primary energy demand and an overall reduction in carbon emissions over the next 15 years or more. (See Appendix D, Geller et al., 1991, for a detailed scenario on which Scenario 2 was based.) With no energy growth and with further penetration of the market by renewable resources, this scenario projects no need for expanded nuclear energy and in fact predicts that the energy supplied from nuclear power plants has already peaked. The absence of orders for new nuclear power plants and the cancellation of several plants are seen as evidence that the obstacles limiting the growth of nuclear power include more than just those associated with waste disposal.

Because energy savings can have important environmental benefits, this scenario assumes that future policies will encourage the development and adoption of methods to reduce further the ratio of energy use to economic welfare (Table 4.1). To some extent, the success of such policies will depend on marketplace acceptance of energy-saving technologies and the political climate for those policies. They may need to mandate an energy pricing scheme that gives more credit for the pollution-prevention aspects of energy conservation.

As does Scenario 1, Scenario 2 projects changes in the sources of energy supply and in the forms of energy delivered for final use. Oil production is assumed to continue its decline both in Alaska, where it has only recently begun to decline, and in the lower 48 states, where it has declined since 1970. Coal-based energy is also assumed to be limited by environmental concerns. With the projected decline in nuclear power, alternative—mostly renewable—energy sources will need to be developed faster than in Scenario 1 in order to replace the 22% of current electricity generation provided by nuclear power plants and to offset the 2-3% annual growth of electricity forecast by most analysts (Appendix D, Edison Electric Journal, June 1993).

The availability of alternative energy sources, either for direct primary use or for energy conversion, will depend much more on government policies and/or incentives than on technological readiness or traditional economics (with the exception of nuclear fusion energy, which is neither technologically nor politically ready). This scenario accepts the argument that renewable resources have not gained greater acceptance because the government has provided substantial direct and indirect subsidies to coal, oil, and gas industries as well as to the nuclear industry in the past, and because pricing of renewable resources vis-à-vis non-renewable resources has not properly accounted for their economic and social benefits in terms of minimizing or preventing pollution and avoiding the costs of waste disposal, site remediation, and health impacts.

The composite price of fossil energy in 1992 (a weighted average of crude oil, coal, and natural gas prices) was $1.41 (1987 dollars) per million Btu, the lowest since 1973. Because U.S. resources have difficulties being profitable at this price, U.S. reliance on imported oil has increased by about 30% since 1973, such that imported oil supplies about 54% of the total U.S. oil needs at the present time, with the Organization of Petroleum Exporting Countries (OPEC) supplying about half the imports (Appendix D, U.S. DOE, Energy Information Administration (EIA), 1993). These facts are interpreted in this scenario as evidence that the marketplace does not adequately capture concerns about sources of energy supply or environmental effects such as carbon emissions.

4.4 Discussion and Recommendations

Regardless of the scenario, changes in the energy supply mix are not likely to occur quickly; yet energy policies, to the extent they currently exist, have not always been developed with long-term objectives in mind. Any desired reduction in the reliance on fossil fuels will have to take place incrementally, and will not occur without government intervention in the short term. Efforts to reduce environmental impacts in some sectors of energy supply and use may increase impacts in other sectors. For example, introduction of electric vehicles as a means of achieving a "zero emissions" goal will demand more conversion of energy resources to electricity and, at least in the short run, more use of fossil fuels for electrical generation because nuclear plants are running near capacity. However, this scenario projects an overall net reduction in carbon emissions from the use of electric vehicles when reduced emissions from the vehicles are credited. Similarly, decentralization of generation with alternative energy technologies (e.g., photovoltaic solar energy) is assumed not to degrade the reliability of electrical supply.

Scenario 2 therefore projects that the need for the development of an integrated approach to energy and environmental policy will be just as important as in Scenario 1. With respect to radiation, the decline of the nuclear power industry will make in-facility storage of high-level radioactive waste increasingly less secure, thereby again arguing for the federal government, including EPA, to find ways to expedite the approval of a high-level waste repository. Similarly, the need for safe disposal of materials from decommissioned nuclear power plants implies that EPA should move rapidly to promulgate low-level radioactive waste disposal standards.

The REFS also considered a future in which energy production by nuclear fusion would be both technically as well economically feasible within the next 30 years. The Subcommittee believes that this scenario is substantially less likely than the one in which energy conservation and greater use of non-nuclear renewable resources are used to keep the generation of greenhouse gases from fossil fuels and biomass combustion under control. First, the prospects for commercially available fusion energy still depend upon a number of major scientific and technical breakthroughs (Appendix D, Anderson 1994). Second, although fuel costs would be relatively low, the costs of facilities and infrastructure are unlikely to make fusion power cheap within our 30-year time horizon. Third, nuclear fusion shares with nuclear fission power the need for control by large institutions (viewed with suspicion by some) and the potential for confusion with nuclear weapons.

Fusion-generated energy is not expected to become available within the next 30 years, and so will not be a feasible alternative source of electric power to offset production by power facilities responsible for producing greenhouse gases. If and when fusion power does prove feasible, then the Nation and EPA would face a new set of environmental radiation issues: concern about neutron-activated waste materials, and the need to ensure a large and reliable supply of tritium (hydrogen-3), a fuel that would require production in target material placed in fusion or fission reactors. Except at decommissioning, fusion reactors are not expected to generate large quantities of radioactive wastes, and, if components in these reactors are carefully controlled, neutron-activated byproducts will generally consist of relatively short half-life radionuclides.

Despite differences in assumptions about sociopolitical issues, technological capabilities, and economic pressures, the two scenarios involving greenhouse gases and potential roles of nuclear energy generation suggest a role for EPA in providing national and international leadership on energy production and use and their environmental implications. The EPA could provide such leadership by undertaking an in-depth examination of the environmental consequences of alternative energy production and use policies, particularly with regard to generation of greenhouse gases. It is evident that carbon combustion will need to be curtailed if world emissions are to be kept within current levels. Avoiding further buildup of greenhouse gases in the atmosphere is likely to require incentives and other actions either to incorporate energy efficiency and increased reliance on renewable energy sources into the

U.S. energy economy, or else to allow for continued or expanded use of other alternatives, including nuclear-generated electricity.

This report presents arguments for EPA attention and focus, particularly on issues related to energy production and use, insofar as they are linked and interwoven into issues of radiation exposures and waste disposal. Based on its analysis of the future and the strong linkages of environmental quality issues to the Nation's energy issues, the Subcommittee recommends that EPA consider taking the following actions:

a) Participate positively in the joint development of energy and environmental policies at the national level, taking into due consideration the interests and activities of state and local authorities and focusing on examination of the impacts of alternative energy production and use policies on the environment, particularly with regard to those alternatives that preclude generation of greenhouse gases;

b) Expedite resolution of the problem of radioactive wastes by issuing final standards for high level (Yucca Mountain) and low level radioactive waste disposal; and

c) Adopt policies and incentives that factor the economies of pollution prevention and control for all kinds of energy production and use into the overall energy and environment equation.

It should be noted that, since the start of the Environmental Futures Project, the EPA has taken significant steps in the direction of issuing the aforementioned standards for radioactive waste disposal and that regulatory proposals for residual radioactivity may be published by early 1995.

5. CHANGING PATTERNS OF EXPOSURE TO IONIZING RADIATION

A number of trends suggest changing patterns of radiation exposure of the public. Some are in the direction of reducing population exposures to ionizing radiation, and some in the direction of new or increased exposures. EPA can influence how these exposure patterns change through its authority to issue guidance to the Federal government regarding exposure to radiation.

The most important exposures that will be faced by the general population, inasmuch as they are controllable, will continue to be medical exposures, occupational exposures, and exposures to radon in indoor air. There are also population exposures to NORM, radioactive wastes, and radioactively contaminated sites; but it is the opinion of the REFS that these exposures are small for the general population (although possibly significant for critical population groups or maximally exposed individuals), and are not expected to increase in significance, when compared to the first three types of exposures. However, although they are not considered in this section, they are discussed elsewhere in this report.

5.1 Key Drivers

5.1.1 Medical Exposures

A major source of current population exposure is medical uses of radiation and radioactive materials. The following forces may affect population exposure:

a) Population growth will increase the demand for medical procedures that could involve radiation.

b) Aging of the population will likely increase the number of radio-diagnostic procedures a typical person undergoes in a lifetime. The incidence of cancer also increases with age, but the increase in cumulative dose (for an individual) with radiotherapy is not likely to be important in the case of the patient, but may increase the potential exposure to medical personnel.

c) Continued advances in x-ray technology will maintain the trend toward lower patient and technician exposures during any particular procedure.

d) Clinical diagnosis will increasingly rely on techniques such as ultrasound, magnetic resonance imaging, and plethysmography, that do not entail the use of ionizing radiation, thereby reducing population exposures (although increasing exposure to other types of radiation; see Section 8).

e) Pressure from the threat of malpractice lawsuits and increasing dependence on reimbursements from health insurance plans may encourage physicians to order more diagnostic tests involving radiation, thereby increasing individual and population exposures.

f) Pressure to contain health care costs, whether or not tied to a comprehensive national health care system, could counter the pressure for more tests detailed in the previous item.

Overall, individual exposures will probably decrease except for the older segment of the population, in which exposures are less likely to result in clinically important radiation effects. Such decreases will probably offset the increase in population exposure driven by population growth. EPA could influence patient exposure by an aggressive program of Federal guidance. It could also use this authority to issue occupational radiation guides that could influence the radiation dose received by radiologists, technicians, and personnel involved with other medical radiation procedures with x-rays and radioactive materials. Whether EPA's influence would result in better technology, fewer procedures, or more radiologists doing fewer procedures each, is not clear at this time. If EPA does not take any actions in this area, then changes will occur largely as a result of changes in diagnostic procedures and medical practices.

Nuclear medicine procedures involving the administration of radioactively labeled pharmaceuticals for diagnosis of disease continue to increase, requiring production and use of more radioactive materials (mostly from nuclear reactors and some from accelerators). Many of these radionuclides are relatively short-lived, and in general these procedures involve smaller doses than a typical radiograph. Universal health care coverage could increase these uses further, because of their role in preventing disease and/or its severity by early diagnosis and treatment. It could also decrease them through cost containment pressures. Assistance in stating medical goals, provision of clear policies on reducing patient doses, encouragement on research and development of more sensitive radioanalytical techniques, and of new, more specific radiopharmaceuticals for diagnosis, and programs to allow wise management of mixed biomedical/radioactive wastes can foster beneficial uses of nuclear medicine materials. It should be noted that continued use of radioisotopes in the medical sciences will require the continued existence of operational production facilities—in particular, nuclear reactors and accelerators—which will also involve occupational exposures.

A potential issue in both medical and other uses of radionuclides is that many users are presently shifting their source material from reactor byproduct materials regulated by the Nuclear Regulatory Commission (NRC), to naturally-occurring or accelerator-produced radioactive materials (NARM), which in many states are not regulated as thoroughly (if at all). This change in the source of radioactive material may or may not pose risks to health and the environment, because they will surely be managed to varying degrees under state regulation or perhaps under EPA regulation through RCRA or TSCA.

Whether nuclear medicine needs are supplied from reactors or from NARM, a significant future radiological issue is the state of the waste management system for medical radionuclides in the years to come (see Section 6). The current practice of incineration of mixed wastes from this source may generate exposures to the public from isotopes whose health effects may not be adequately understood.

5.1.2 Occupational Exposures

Recognizable trends may also change patterns of occupational radiation exposure. Not only may more people work in radiology, radiotherapy, and nuclear medicine, but also in site restoration activities in the Federal Complex Clean-up, decommissioning of NRC licensees, and Superfund sites. The International Commission on Radiation Protection (ICRP) has recommended an effective reduction of the basic occupational exposure standard by a factor of 2.5 (Appendix D, U.S. NRC, Federal Register, 1991; ICRP, 1990). This tightening of worker standards, while clearly desirable in terms of reducing maximum individual exposures, may be less successful or even counter-productive in reducing population exposures. A larger workforce might have individuals incur a greater fraction of their allowable dose each, thereby increasing population risks. Using more workers to accomplish the same amount of work could also have an adverse impact on health care costs. EPA could contribute to an informed decision on occupational standards by evaluating the impact of different approaches: keeping the current system of upper limits with As Low As Reasonably Achievable (ALARA) levels (Appendix D, U.S. EPA, Federal Register, 1987), versus a lower overall limit with less room to practice ALARA.

5.1.3 Exposure to Radon (see also Section 9)

Radon is the largest source of ionizing radiation exposure for members of the general population. There are currently no trends that would tend to consistently alter indoor radon concentrations significantly, either in terms of interstate or interregional population migration, choice of housing, or lifestyle. To the extent that smoking is declining among the general population, the absolute health risks associated with exposure to radon decay products will also decline due to the synergism between smoking and health effects of radon decay products.

Construction of radon-resistant homes in certain regions of the country will reduce overall radon exposures, although such reductions will occur slowly as new buildings incorporating these features become part of the housing stock. Even then, more than half of the total population risk arising from radon exposure occurs in houses with average concentrations below 2 pCi/L air. Current radon reduction methods, as applied in either existing or new houses, do not consistently reduce concentrations below this level. These reductions are nonetheless important and should be one part of the Agency's efforts to limit radon-related health risks.

5.2 Recommendations

EPA should continue efforts to focus on characterizing high-risk radon potential regions, improving knowledge about radon risks, and developing more accurate methods of measuring and mitigating radon in buildings. Particular emphasis should be placed on empowerment of stakeholders by dissemination of all available scientific information.

EPA should consider the establishment of stronger collaborative agreements with other Federal agencies to monitor the changing patterns of exposure to ionizing radiation by the general population. This collaboration could provide the Agency with more of the data necessary to make better informed choices when exercising its authority to issue guidance on exposures to radiation. A research program that explores the implications of the social, economic, and health issues that drive changes in exposures by the population may be desirable at a time when large numbers of individuals may be exposed to low amounts of radiation in site restoration activities as part of the Federal Complex Clean-Up Program that is scheduled for the next decade. Similar consideration applies to health care issues related to the use and disposal of radioactive material. The radiation protection community and DOE might not agree that clean-up activities will lead to greater collective dose than occurred during the weapons production days. However, what is being called for is more than the typical Regulatory Impact Analysis (RIA), given that it involves societal concerns, cost-effectiveness, and probably a futures exercise of narrow scope, which looks only at individual and population exposures. Social value judgments would play a big role in this analysis.

6. RADIOACTIVE WASTE MANAGEMENT

6.1 Introduction and Overview

Opportunities for prevention of environmental pollution exist in managing several categories of low-level and high-level radioactive wastes. The major categories are as follows:

a) waste byproducts of medical applications and research;

b) low-level radioactive wastes from nuclear power and industrial facilities;

c) naturally-occurring radioactive material (NORM) contained in waste byproducts, e.g. oil and gas production, phosphate production, and mining and beneficiation processes;

d) contaminated buildings, equipment, and site media on DOE and DOD facilities, old radium and uranium enterprises, and commercial reactor sites;

e) radioactive materials commingled with hazardous substances (as defined in RCRA or TSCA), i.e. "mixed waste," (Appendix D, U.S. EPA, 1990);

f) transuranic wastes and byproducts associated with nuclear weapons production;

g) plutonium, uranium, and tritium from the manufacturing and dismantling of nuclear weapons;

h) stored high-level radioactive wastes from the defense program; and

i) stored spent commercial reactor fuel and highly radioactive reactor components.

The first five categories are generally considered as "low-level" radioactive wastes because nuclear fuel and highly irradiated compounds have been removed or are not present. The latter four generally require management as "high-level" wastes because they are highly radioactive and/or have long-lived toxicity, i.e., their safe disposal requires extreme isolation and security. Regardless of their categorization, radioactive wastes and the solutions proposed for the disposal problem are feared by many members of the public. This creates a challenging dilemma: on the one hand, the public's perception of the risk of the materials argues strongly for ultimate disposal (Appendix D, U.S. NRC, 1992); on the other, potential risks of the disposal itself are used by opponents to argue against these efforts (Appendix D, Shrader-Frechette, 1993). As a result of this conflict, disposal is in a stalemate. Although a majority of the public indicate that radioactive wastes should be disposed of permanently, progress toward this goal is slow, with numerous setbacks, for any form of wastes. On-site storage of high-level radioactive waste is reaching capacity at some locations, and the risks of such storage can only increase as these wastes accumulate. The closing to "out of region" shipments of the low-level waste disposal site at Barnwell, SC, in 1994 has increased the pressure to find a low-level waste solution.

The absence of an integrated procedure for dealing with mixed hazardous/ radioactive wastes will increasingly lead to institutional paralysis and suboptimal solutions for its management (Appendix D, U.S. EPA, 1992). This situation could be of great importance to issues in the management of naturally-occurring radioactive materials (NORM) (Appendix D, U.S. EPA/SAB, 1994a), the management of wastes from the Federal Complex Clean-Up Program (Appendix D, OTA, 1991a), and many small amounts of wastes from research and development laboratories in the USA (Appendix D, OTA 1989, Gershey et. al., 1990). As the stalemate continues, waste material inventories continue to accumulate on-site in less-than-optimal places such as hospitals, comingled with biologic/pathogenic wastes; in laboratory and university storage rooms and buildings, comingled with various types of hazardous materials; and on reactor sites. Most of these locations were selected for features other than isolation of waste materials, such that continued reliance on their use increases the likelihood of the development of radioactive contamination on these sites, and/or release to the environment. Current strategies for the disposal of mixed waste, such as incineration (followed by storage as radioactive waste if needed), are increasingly encountering difficulties of their own, particularly as more strict air quality regulations come on-line through the Clean Air Act.

Proper disposal of radioactive wastes should contribute to a policy of pollution prevention. The scientific community believes that feasible disposal options exist to ensure the long-term isolation of most forms of radioactive wastes; what is lacking is the requisite public support for applying the technologies (Appendix D, U.S. NRC, 1992).

Two future scenarios are possible. In the first scenario, there is a continuation of the present-day stalemate for radioactive waste disposal; in the second scenario, early and effective actions are found and implemented to resolve the obstacles to radioactive waste disposal. These two scenarios are presented below.

6.2 Scenario 1: Continued Stalemate on Radioactive Waste Issues

Even if all nuclear plants and nuclear energy uses, including weapons, are to stop generating additional wastes today, major actions would still be necessary to ensure proper management of the existing inventory of radioactive waste. For example, it has been estimated by the Office of Technology Assessment (OTA) of the U.S. Congress that the Federal Complex Clean-Up Program costs alone may exceed 300 billion dollars (Appendix D, OTA, 1991a, OTA, 1991b).

In this scenario, protracted litigation becomes the order of the day, with various public groups suing the government agencies at every attempt to issue standards or regulations for radioactive waste disposal. Some groups would sue to have standards issued, other groups because they disagree with the standard issued. Local governments and the public that reside in the areas selected as repositories would litigate to prevent those sites from being used for disposal because of fears of radiation and loss of property values. Good science would not be given high priority in any decision-making, as political pressures would overwhelm scientific issues. Final resolution would not be attained until a crisis ensued. Some examples of possible crises could be a nuclear waste accident; discovery of widespread contamination within a major environmental resource, such as a major waterway; or as illegal dumping of radioactive wastes into isolated areas becomes an issue. At this point, political pressure to resolve the waste problem would surpass all other concerns, but the costs of solving the problem would be in the higher end predicted.

OTA 1989 (Appendix D) estimates the costs of low-level waste disposal to vary between $\approx$\$50/ft^3 to $\approx$\$500/ft^3. These figures translate to $\approx$\$1,750/m^3 to $\approx$\$17,500/m^3. EPA/ORIA briefings to the RAC in July 1994 showed an actual cost today of $\approx$\$8,000/m^3. They also estimated the volumes at $20X10^6$ m^3 to $80X10^6$ m^3 in the U.S., with a central estimate of $\approx$30-$40X10^6$ m^3. Using these values we can calculate a gross estimate of the waste disposal costs associated with low-level waste disposal between 35 billion dollars at the very low-end, to 1.4 trillion dollars at the high end, with a central estimate of 320 billion dollars. This does not include high-level waste, transuranics, weapons materials, or clean-up.

6.3 Scenario 2: Early and Effective Resolution of Radioactive Waste Issues

Under a scenario in which early and definitive actions are taken to control and dispose of both low- and high-level radioactive wastes, Federal policy and social concerns are likely to play a dominant role, with the marketplace playing a less dominant role, in determining whether nuclear energy would continue to be a significant component of the nation's energy supply in the future. A firm policy toward greenhouse gases may also influence the relevance of nuclear energy as the Nation moves towards a more comprehensive environmental approach to energy management. Over the next 50-100 years, the inventory of radioactive waste would increase significantly, but probably less than an order of magnitude, for both low-level and high-level radioactive waste. These figures, although inexact, appear to be of this limited magnitude and would not require a major deviation from any policy implemented to manage existing and near-future inventories. In the long-term future, as the feasibility and safety of proper disposal were demonstrated in the new disposal sites, societal fears about radiation are likely to lessen, such that its beneficial uses in society could proceed without undue restrictions because of those fears. Furthermore, risks from managed radioactive wastes could then be dealt with in the context of the recommendations of the Reducing Risk report (Appendix D, EPA/SAB, 1990). Two potential actions (among many) that could be taken by the Federal government (or EPA) in this scenario are:

a) to commission national forums, as was done by EPA in 1978, to bring all viewpoints into open dialogue and publish findings and national recommendations for action; and

b) to advocate to Congress the permanent setting aside of large tracts of public lands where all types of radioactive wastes can be managed in harmony with other sensitive environmental values and the protection of valued species of plants and wildlife.

The first of these actions could help regain the public's trust in the solutions available to the waste disposal problem, and achieve a national consensus on policies, standards, rules, and regulations for the disposal of radioactive wastes. The second action could minimize the problems of distrust and loss of property value that are often faced when searching for disposal sites. Most of the contentious political issues would disappear (except in the states selected for these sites). This second option would also achieve economies of scale not available within the currently projected system of regional compacts. Furthermore, no state or territory would face an embargo for the disposal of its radioactive waste, as is the case today.

Under these advantageous conditions, a comprehensive national plan for radioactive waste clean-up and disposal would be drafted, and the process of disposal would proceed smoothly and safely. The economic impact under this scenario would be in the middle range of projected costs (See the last paragraph in Section 6.2 for a discussion on the cost estimates of low-level waste disposal).

6.4 Implications for EPA

Issues attendant to waste management clearly pose circumstances with huge economic and social consequences. Because of existing polarization on radioactive waste issues, there is a compelling need for credible leadership on managing these materials to minimize environmental degradation, assure economic vitality, promote environmental equity, and involve all stakeholders in national policies. Although EPA's primary role thus far has been to promulgate guidance and/or generally applicable radiation standards, recent congressionally mandated activities under the WIPP legislation make it clear that the Nation has chosen the EPA as the governmental entity to provide the impartial leadership that the public trust requires on this issue. EPA could assume a leadership role in five major areas related to radioactive waste materials: low-level radioactive wastes, high-level radioactive wastes, residual radioactivity, NORM, and mixed wastes. Such leadership is needed for:

a) low-level radioactive waste disposal where issuance of generally applicable environmental protection standards for the disposal of these materials will remove a major obstacle to the continued use of radionuclides in research and medicine and the permanent disposal of byproduct materials and waste from nuclear energy production;

b) achieving permanent disposal of high-level commercial and defense radioactive wastes, assuring control of nuclear materials from disassembled warheads, and for balanced decisions on nuclear energy if this alternative continues as part of the Nation's energy strategy;

c) managing residual radioactivity, and harmonizing radiological and chemical risks for levels of residual materials related to site restoration activities, through definitive policies, approaches, and standards;

d) stating a clear policy for NORM, including guidelines by which industries that produce large quantities of wastes containing NORM can plan for proper management of these materials; and

e) dealing with mixed radioactive and hazardous wastes to break the bureaucratic deadlock among Federal regulatory agencies by lobbying for the authority to issue a set of standards specifically for such wastes or alternative standards that allow the use of existing regulations where possible or applicable.

Regardless of which specific actions are taken by the government or EPA, assuring the proper management of radioactive wastes affects major environmental futures issues discussed elsewhere in this report relative to prevention of pollution from the materials, a balanced perspective in national energy policy, and assuring control of nuclear weapons materials. The future health of the planet with respect to radioactive wastes requires a mechanism through the democratic process to balance the larger common good and the interests of small numbers of individuals vis-à-vis consideration of economic vitality, and other different perspectives on these materials.

6.5 Recommendations

It is crucial that Congress provides the budgetary and fiscal resources needed by EPA in order for the Agency to develop and maintain technically strong programs and policies regarding the problem of radioactive waste disposal, in all of its aspects or categorizations (high-level, low-level, mixed, NORM, NARM, etc.). This allocation could be part of the development of a comprehensive national plan to deal with the radioactive waste disposal issue. That approach would consider all aspects of the issues involved: it needs to bring into consideration societal and value judgments, economic concerns, human health concerns, environmental aspects of remediation, and cost-effectiveness and cost-benefit aspects of the various remediation and disposal alternatives.

A process to develop foresight about the future that continuously evaluates the policies and alternatives implemented will be crucial given the fact that these wastes will be around for the next millennium and beyond.

7. NON-IONIZING RADIATION

7.1 Introduction and Overview

An increase in population exposures to electric and magnetic fields is likely to occur in the future as a consequence of technological developments in many areas, such as magnetic resonance imaging (MRI) in medicine, magnetic levitation (MagLev) in transportation, and the explosive growth in information processing and telecommunication technologies that involve electromagnetic radiation. A high research priority is to obtain solid evidence supporting or refuting the hypothesis that exposure to electric and/or magnetic fields (EMF) can cause cancer, especially in the power frequency (50-60 Hz) range (Appendix D, Hendee et. al., 1994). If the hypothesis were proven correct, then the magnitudes of the associated risks would need to be established, that is, we would need an understanding of a dose-response relationship. Essentially the entire U.S. population has the potential to be exposed to some type of EMF at some level. However, at this time, given the lack of an exposure metric(s) and of the dose-response relationship, it is very difficult to determine whether any significant exposures—as defined in risk assessment—exist at all (Appendix D, Foster, 1992).

Non-ionizing radiation is not sufficiently energetic to strip electrons and produce free radicals and may not be able to produce alterations in genetic materials. Other biological effects have been demonstrated, however, especially when the flux of energy is sufficient to raise tissue temperatures ("thermal effects"), or cause discharges ("shock"). Furthermore, there is significant molecular evidence that EMF couple to, and affect reaction rates in, metalloproteins, and that electric fields couple to, and induce conformational changes in, membrane proteins which may affect cellular proliferation and/or signaling (Appendix D, Tsong, 1990).

All frequencies of electromagnetic radiation from the ultraviolet downward are considered non-ionizing, including visible light, infrared, microwave, radio frequency, and power line frequency radiation. Although not technically radiation, near-field EMF from power lines and electrical appliances is also included in this discussion. Currently, power frequency fields are under intense scrutiny as potentially carcinogenic, but the evidence for this effect is controversial, and no firm conclusions have yet been reached. Higher frequencies may also carry health risks, especially if modulated or pulsed at frequencies near the 50-60 Hz power frequency range. For example, the experimental literature has shown that radio frequencies (RF) that are either modulated or pulsed (a burst every 1/50 to 1/60 second) may have similar biological effects as RF in the 50 to 60 Hz power frequency range.

Non-electromagnetic radiation, in particular sound, can also be included as non-ionizing. Ultrasound (high frequency mechanical vibrations beyond the hearing range) is extensively used in medicine and is the focus of continuing investigations regarding safety. Although ultrasound is presently associated mostly with medical diagnosis and treatment (and therefore largely beyond EPA's area of concern), it is finding increasing use in other areas, such as pest repulsion. If research were later to show a relationship between low-level exposure to ultrasound and any health effect, EPA would need to become involved.

7.2 Societal Trends

Basic characteristics of the population, lifestyles and other trends such as changes in the economy will have impact on the environment of the Nation. Some trends are predictable, such as the size and makeup of the population, whereas others may not be readily predictable over a period of 30 years or more. However, within the span of the next ten years, barring a major catastrophe, many characteristics will remain much as they are today.

The overall population growth has slowed down in the U.S. and today is just slightly above replacement. However, population growth patterns differ considerably among the various sub-populations. Increasing population size occurs among the poor and minorities (who are often the same group), especially those living in large cities. Changes in population growth patterns cannot be expected to occur rapidly. Therefore, the growth of low-income populations in the inner cities will continue, together with increased deterioration in the condition of physical facilities. The long period of poor economic climate in many states and cities makes it unlikely that this situation will be turned around very rapidly. Therefore, our environmental picture will have to include planning for large cities. These cities will require large power supplies and have increasing need for communication and transportation. Many service industries will locate in the suburbs, requiring that the labor group employed in the industry travel to the suburbs to work. However, these industries will also be able to allow many in middle and upper level management to work at home and communicate with their businesses through various electronic media, which will put special demands on the need for electric power, radio, microwave and other forms of non-ionizing radiation. Some of these sources can be generated locally, whereas other sources will need to be generated outside the area and require the same types of transmission across lines to the point of use as is employed today.

Exposures to magnetic fields of various frequencies and magnitudes will likely increase because of increased use of MRI in medicine and other areas and through the introduction of MagLev in transportation. Advances in superconductors that can operate near ambient temperatures will make these technologies increasingly achievable over the next decade or two. Over a much longer time frame, NANOBOTS (<u>nano</u>meter-scale self-actuated ro<u>bots</u>) may be developed and implanted in the human body for medical and other purposes. The types of electromagnetic field exposures associated with these latter devices cannot be predicted at present.

The need for electric and even magnetic energy for power will increase in the future. The use of electric equipment has continued to increase. The use of electric cars may solve some of the ground transportation problems, particularly at the local level, and MagLev trains may solve some of the power costs. The technology for these transportation devices exists, and there will be continued pressure to utilize these forms of energy in areas with high population density because of the perception that this will lead to a cleaner environment.

The current power and communication grids transmit radiation usually above ground. This has led to questions about the impact of such activities on the aesthetics, ecology and possibly the safety and health effects that result. The siting of these transmission facilities require land clearance in localized areas. Public reaction to these sitings has led to mounting problems in regard to approval.

The general increase in energy consumption per capita carries the potential for more exposure to power line frequencies from generation, transmission, distribution, and use of 60-Hz alternating currents. More electrically operated appliances are available than ever before. However, concerns about health effects from EMF are causing both utilities and appliance manufacturers to consider low-field designs in pursuit of "prudent avoidance." Furthermore, some advanced energy technologies such as photovoltaic generation and fuel cells could, over the long run, cause less centralized generation and less need for long runs of higher voltage transmission and distribution lines.

A potentially more significant trend is the explosion in use of electrically powered communications and information technologies. The cellular telephone has already been questioned as a potential health threat, and electromagnetic radiation from radio to microwave frequencies is transmitting information across the U.S. and around the world. Computers, from mainframes to personal computers to automobile controllers, are becoming pervasive. If low power, mid-frequency non-ionizing radiation carries health risks, EPA will need to become involved in its regulation.

Technology will be a major driver for the increased use of non-ionizing radiation. Therefore, we need not postulate a sudden breakthrough in technology to recognize that the increase in use will persist. However, the possibility exists that new uses and new technologies will develop. With the increase in use will come greater demands for methods of transmitting non-ionizing radiation to the users.

In considering the full range of non-ionizing radiation, it is important to determine the influence of the visible spectrum on the environment. Because sunlight provides natural benefits, its risks are likely to be overlooked. However, with the identification of breaks in the stratospheric ozone layer, increased exposures to sunlight, especially its ultraviolet light (UV) component, may present environmental problems that require attention. At higher frequencies, UV has been associated with human skin cancer, with immune dysfunction, and with a variety of adverse effects on non-human biota, especially with microplankton at the surface of the sea. Although CFC ozone depleters have largely been removed from use except in closed systems, other depleters may yet be identified and will need to be controlled. UV radiation from terrestrial sources could also become an increasing concern; the UV from unfiltered fluorescent lights has already been suggested as a potential hazard for humans. Furthermore, increased migration to the Sunbelt of the U.S. may continue to contribute to the increase in skin cancer rates.

Visible light is usually not considered a threat at low energy density, yet visible-light lasers can generate enough power to burn or blind. However, lasers will probably remain largely an occupational safety issue (although, lasers are available for hobbyists and others) as long as the beams from lasers in consumer products (printers, laser discs, etc.) and in medical equipment are contained.

In summary, current trends in demographic, technological, and economic development suggest that the present uses of all types of non-ionizing radiation will continue to increase. There will be enhanced demand for electricity and it will continue to be transmitted to the large cities. Outlying areas where businesses may be located will also need the resources. Not only will the use increase at the very low frequency end of the electromagnetic spectrum, but also in the radio and microwave wavelengths, as will the attendant exposures of both humans and the environment. As a consequence, EPA will continue to face current and new questions with respect to the health, safety, and environmental effects of non-ionizing radiation.

7.3 Issues

The issues that attend the use of non-ionizing radiation fall into the areas of hazard and exposure identification, potential effects on ecological systems, impact on the general environment from production at the source of non-ionizing radiation and building of systems for transmission, and the method of regulating the environmental impact of these agents. The current situation differs for each of these, depending on the specific type of non-ionizing radiation involved.

7.3.1 Hazard and Exposure Identification

Certain types of non-ionizing radiation are clearly associated with risks. UV is known to be associated with cancer and immune dysfunction in humans. The effects on the immune system differ, depending on the intensity and duration of the exposure. If changes in the ozone layer subject populations to persistent high UV exposure, or if the components of UV radiation are changed by atmospheric alteration, the human race could be permanently affected. The controversy over whether extremely low frequency EMF act alone or interact with other agents to cause cancer is being debated. The scientific evidence to answer this question will not likely be available in the near future so, in the interim, steps must be developed to answer public demands for preventive action. The complexity of response vs. exposure at different frequencies, power levels, deposition patterns, and modulations suggests that exposure scenarios related to risk will not be identified until a better understanding of the underlying processes is obtained. Tying a specific exposure to a human health outcome may take a decade or more. Exposure to other non-ionizing radiations, such as radar and microwave, are known to produce heating effects, but little is known about long-term outcomes. Recent data suggest possible effects on the retina in animals, and questions have been raised about cancers from exposures to radar and telephone equipment. The problem again is one of identifying the effects and the specific types of exposures which may be related to these effects. Lacking this type of information makes it difficult to decide on the long-term actions which might be needed to protect the public and ecological systems from potential hazardous effects.

7.3.2 Potential Effects on Ecological Systems

The impacts of exposures to non-ionizing radiation on ecological systems are not well known. Clearly, if effects can be shown in humans, other living creatures would also be expected to be at risk[1]. Several issues are likely to be important in creatures other than humans. Many animals navigate via magnetic fields; thus, exposure to EMF could produce special problems for these creatures. In addition, the production of heat by these non-ionizing radiation sources could influence the life patterns of ecological systems. Also, new evidence has surfaced about the detrimental effects of UV radiation on phytoplankton and zooplankton, which are poorly understood, and may present fundamental changes at the base of the food chain in the future if UV exposures of ecosystems increase (Appendix D, Bothwell et. al., 1994). Consequences may range from none to drastic evolutionary changes in the food chains of the Earth's ecosystems. What will happen is impossible to predict with existing information.

7.4 Implications for EPA

If power frequency EMF exposures and other non-ionizing radiation exposures come to be generally perceived as dangerous, even if not proven so, then the public will demand lower exposures and the utilities and communications industries will likely adjust in that direction even without government intervention. The nearly paradoxical result is that non-ionizing radiation may never need to be addressed by EPA no matter whether it is dangerous or not. Nevertheless, EPA will undoubtedly be asked by Congress and other parties to study various types of non-ionizing radiation and provide conclusions regarding their degree of hazard. Whether or not any hazards exist at current or reasonably anticipated levels of exposure, EPA may need to move forward with guidance and/or regulatory initiatives even while industries are taking voluntary measures to reduce exposures.

7.5 Recommendations

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[1]Indeed, EMF, UV, RF and other radiation/magnetic induced or promoted effects have been reported in plants and animals, particularly in work in the former USSR. Most of this work is 40-60 years old, and difficult to replicate in terms of exposures (Appendix D, Polk et. al., 1986).

EPA should at least track and help stimulate the research conducted by other agencies on the health and environmental risks of exposure to non-ionizing radiation, such as through official interactions with other agencies and by authorizing studies by the National Academy of Science and National Research Council (e.g., the BEIR reports). It should not limit its attention to power frequency EMF but should also follow the research on radiofrequency EMF, quasi-static magnetic fields, ultrasound, possibly other forms of non-ionizing radiation, and their interactions with related agents. If EPA is to be perceived as the primary source of advice on these environmental radiation issues, it will need greater internal resources including a research program, together with a contingency plan for regulatory initiatives (e.g., guidance) for known hazards (thermal effects, shock) and any new significant hazards that may be identified in the future.

8. EXPOSURES, DOSE-RESPONSE MODELS, AND POPULATION SUSCEPTIBILITY

8.1 Introduction and Overview

EPA must be prepared to incorporate important findings in radiation research into its regulatory and guidance postures, regardless whether the findings point to greater or lesser health and environmental risks than previously thought. The future of health and environmental concerns for both ionizing and non-ionizing radiation could be critically influenced by advances in scientific knowledge. Advances in three areas are potentially relevant: measurement and modeling of exposures to radiation, knowledge of the relationship of response to exposure (dose), and differences in susceptibility among different segments of the exposed population.

Significant improvements in the detection limits of analytical techniques (e.g., identification of a single molecule of a substance; see Appendix D, Moerner, 1994) could lead to public demands for stricter regulatory limits in radiation exposures (e.g., radon or plutonium in ground water) as long as stated public policy is that there is no threshold for radiation health hazards. In fact, laws such as the Delaney Clause of the Food and Drug Act, and the Safe Drinking Water Act, require that carcinogen concentrations in food and drinking water be as close to zero as is practically achievable. Because radiation is a carcinogen, indiscriminate application of this policy has led to many controversies such as the limits for radon in drinking water [Appendix D, U.S. EPA/SAB, 1993a, and U.S. EPA/SAB, 1993b].

It is widely assumed that risks can be predicted from knowledge of the total doses to various organ systems, that is, the amounts of energy deposited per unit mass of tissue. Some assessment systems also consider dose-rate effects (the time over which the dose is delivered), with high dose rates generally considered to be more damaging than lower rates. For radiations that deposit energy very locally (high-LET radiation), however, biological damage is greater for the same dose than for low-LET radiation, and empirical adjustments are made by defining a "dose-equivalent." The effects of high-LET radiation also do not show the same variation with dose rate as for low-LET radiation. Many scientists are not satisfied that either the form or the magnitude of the adjustments used to deal with dose-rate or type of radiation are entirely justified.

The shape of the dose-response relationship will still be an issue, particularly as to whether there is a real or perceived threshold of exposure below which effects are for all intents and purposes non-existent; whether the dose-response relationship is essentially linear at low doses or departs from linearity at higher doses; whether saturation of response occurs below 100% incidence; and whether dose rate and type of radiation influence only the magnitude of the response or also the shape of the dose-response relationship. Of particular interest is whether important interactions exist among different types of radiation exposure or between radiation and other agents, for example as exposures to radiation and tobacco smoke appear to interact to produce increased incidence of lung cancers, especially in the case of radon exposures.

Related to the last question is the issue of population susceptibility. Are there identifiable subpopulations who are more susceptible to either ionizing or non-ionizing radiation than are other groups? Does the differential susceptibility depend on age at exposure, genetic factors, co-factors (other exposures), general health status, or other factors? Of particular interest is whether some people are essentially immune to radiation carcinogenesis in some tissues because they do not carry a specific oncogene, or whether some people are protected from radiation effects as the result of consuming antioxidants. Scientific advances in these areas could profoundly affect how EPA views the risks of radiation and how risk reduction is best accomplished.

8.2 Key Issues

8.2.1 Significant Changes in Our Understanding of Models for Dose-Response

Risk assessment and management of exposures to ionizing radiation would be completely restructured if a threshold for the dose-response relationship were established. Although some scientists believe that the radium dial painter and bone cancer studies may support a threshold, there is in actuality little chance of achieving a consensus from observational studies alone. Neither epidemiology nor experimentation with laboratory animals is capable of rejecting the no-threshold hypothesis, because of statistical limitations. On the other hand, mechanistic studies may eventually resolve the threshold question unequivocally. Some scientists believe that the existence of robust DNA repair mechanisms implies a threshold. However, it can easily be argued that repair will sometimes fail and that unavoidable exposure to other agents may provide the defect needed for radiation mutagenesis and carcinogenesis. Continuing research into the mechanisms of ionizing radiation mutagenesis and carcinogenesis may yield convincing proof for or against a threshold, or at least a different model for the shape of the dose-response relationship, including the possibility that some effects have a dose-response curve that has a greater slope in the low-dose region, as would be expected in the case of a more sensitive subpopulation.

One promising area of research is molecular biology, in which the specific DNA loci for radiation-inducible mutations are being identified. At the same time, mechanistic research may also be able to identify important dose metrics other than total dose, such as dose rate or range in tissue. A fuller mechanistic biological explanation might be found for the observed differences in effectiveness per unit dose and the influence of dose-rate for low-LET and high-LET ionizing radiation. Advances in the identification of oncogenes, tumor suppressor genes, and the processes that affect them are being reported at an astounding rate. New information in these areas could well affect how EPA manages risks from radiation, hazardous chemicals and mixed waste.

Other mechanistic findings would also influence our perception of the susceptibility of different age groups or those with different life styles. For example, dietary factors (such as consumption of antioxidants in large quantities) might influence susceptibility to radiation, such that dietary interventions might be at least as effective in reducing radiation-induced health effects as small reductions in radiation exposure. For any radiation-related condition that also has a genetic component, the prospect of genetic engineering could influence our management of radiation risks. While most of these remarks are directed at the risk of cancer from ionizing radiation, they could apply equally well to other endpoints and to the risks of exposure to non-ionizing radiation as we gain more knowledge about the latter.

The condition, configuration and values of future society can vastly affect both the search for, and the use of, scientific findings in the assessment and management of radiation risks. At present, society seems to place more value on equity and "rights" than on efficiency or effectiveness in risk management. Risk reduction for maximally exposed individuals has become more important than reduction in aggregate population risks; thus, a finding that a small group of people is especially susceptible to radiation may currently be seen as a call for more stringent regulation of radiation in general. However, in a world dominated by an efficiency or effectiveness criterion, general regulation of radiation might be relaxed while ensuring that the susceptible group could avoid excessive exposure, say, by identifying "hot" environments. The latter view would also be more favorable to the concept of involving stakeholders through dissemination of information. Obviously, a society stretched by resource shortages may be somewhat more tolerant of efficient approaches to radiation risk management, and may welcome the research results that would allow that choice.

A dose threshold or a strong dose-rate effect could alleviate concerns about very low levels or low-dose rates of exposure and provide a basis for a practical approach of not controlling situations when the estimated risks do not justify action. However, the existence of background radiation exposures negates this argument if the threshold is below background and the dose-response is linear in the region of background.

Advances in the molecular and genetic biology of cancer and other radiation-related diseases and environmental stresses will undoubtedly produce information of vast potential significance for EPA's regulatory mission. Whether or not EPA decides to directly support such research, it needs to monitor and guide it so that appropriate information can be gained and incorporated into decisions. It may be advisable for EPA to conduct policy research on the proper use of information about radiation-susceptible populations.

8.2.2 Differences in Radiation Susceptibility

New approaches to risk management will be required if greater susceptibilities can be established for various subgroups relative to that of the general population, as now appears likely from the human genome research. It may soon be possible to demonstrate that people with a specific gene are substantially more likely to develop a certain type of cancer at a given level of exposure to radiation (or some other carcinogen) than are other members of the population. These people are therefore at greater risk from that level of exposure than previously thought, while the remainder of the population is at lesser risk. How should risk management change to accommodate this knowledge?

One approach would be to invoke "environmental equity" in a regulatory framework. This approach could involve setting standards to reduce the allowable level of exposure for all people, with the goal of achieving the same targeted risk level for the more susceptible group as had previously been found appropriate for the population as a whole. If the number of people with the susceptibility gene is large and the difference in risk is relatively small, then such an approach would probably be widely viewed as appropriate. However, if the number of people with the susceptibility is relatively small, reduction of exposure standards would probably not be viewed as appropriate. For members of the small subpopulation, the risk reduction could be significant; however, for the vast majority of the population, the cost of the reduction in allowable exposure might not be considered justified. At some point, the cost of protection of a few people with an unusual gene (or an increased susceptibility) could become an issue.

One approach for managing (controlling) risks for such radio-sensitive persons is the current approach used for hazardous air pollutants, in which the target risk level may be less stringent if the size of the population potentially exposed to that level is relatively small. EPA would probably allow the target risk level to rise less rapidly than the risk per unit exposure, thereby reducing population impacts in comparison to the case in which susceptibility differences are not yet recognized.

Another approach could be to involve persons as stakeholders in decisions about their own health. One example is the information and guidance paradigm being followed with indoor radon. Instead of regulating the source of radiation directly, EPA would inform people of the existence of specific susceptibility factors (genetic or otherwise), would explain the significance of the factors and their influence on risk, would indicate the possibilities for self-identification of susceptibility class (e.g., genetic screening), and would outline self-protective behaviors (e.g., stop smoking, relocate residence, avoid certain jobs or products, make dietary changes, stay out of the sun, use sunscreen).

Many issues arise in radiation risk management for susceptible individuals, such as the following:

a) Where does society's obligation to protect individuals leave off and where does the individual's obligation begin? What is the environmental equivalent of "reasonable accommodation" with respect to disabled persons in the work force?

b) Which susceptibilities are beyond the individual's control and which are his or her simple choice (genetics versus poverty versus residence location versus smoking)? Would EPA's attitude change if a genetic basis of tobacco addiction is discovered, or an inexpensive genetic engineering capability surfaces?

c) Does identification as a member of a susceptible group represent a stigmatization?

d) Does a person's refusal to get a genetic screen waive rights for claims of damage from radiation exposures that do not exceed the regulatory limits for the general population?

e) If knowledge of cancer etiology improves to the point at which it is possible to identify two environmental exposures necessary for cancer development (say, for instance, radiation and a specific chemical exposure), which is the susceptibility factor and which the environmental insult? Does it matter if one of the factors is "natural" and the other is "anthropogenic"?

f) Are there similar susceptibility issues in the non-human environment that cannot be managed with information and guidance?

In any case, policies will need to be developed for dealing with carcinogenic and other risks of radiation and other agents in a world where identification of genetic and other susceptibilities may become commonplace.

8.3 Recommendations

EPA should identify radiation research issues fundamental to further work in the molecular and genetic biology of cancer and other diseases resulting from exposure to radiation and environmental stresses. Whether or not EPA decides to directly support such research, it needs to identify, monitor, and stimulate this work so that the Agency can benefit when making radiation protection policy and decisions.

At the least, EPA needs to monitor closely all research on exposure, dose-response, and susceptibility in order to use such research findings in its radiation programs, to inform stakeholders in radiation issues, and to the extent possible through leadership in internal and extramural radiation research programs, become the source-of-choice for information about the effects of radiation on health and the environment. EPA also needs to work with other Federal agencies to ensure continuation with adequate funding of those studies that have the potential for making significant contributions to our knowledge of dose-effect relationships; this includes, but is not limited to, the study of the Japanese atomic bomb survivors by the Radiation Effects Research Foundation, the several studies of Chernobyl exposed populations by the National Cancer Institute and other organizations, and studies of miners exposed to radon.

9. RADON AND THE INDOOR ENVIRONMENT

Radon gas and its immediate radioactive decay products—themselves radioactive and the principal causes of health risks—constitute the largest single source of ionizing radiation exposure for members of the general population. Most of these exposures occur indoors in residential environments, where EPA's statutory authority is limited to a guidance function rather than direct regulation. However, if current estimates of exposure levels and corresponding risks are correct, radon causes more cancers than any other agent with which EPA is concerned, and EPA actions with respect to indoor radon can have a very large impact on public health. Consequently, any future development that would change our estimates of radon exposures, radon risks, or the effectiveness of radon control measures could be very important to EPA's radon program.

Although radon is in many ways better understood than other environmental hazards, important questions remain about the geographic distribution of residential exposure across the United States, about the risks of a given exposure to radon in different subgroups of the population, and about the effectiveness of various proposed radon mitigation methods (Appendix D, U.S. EPA/SAB, 1994c). Any future findings that substantially modify our current understanding of radon risks and controls should generate appropriate changes in EPA's radon guidance.

9.1 Key Drivers

The distribution of exposure to indoor radon is influenced principally by the geographical distribution of residences and the types of residential construction. Changes in actual radon exposures will therefore occur if population migration changes the distribution of the population with respect to geographical features that correlate with the capacity to produce radon—the "radon potential." Key elements that influence indoor radon concentrations in similar buildings are the radium content of the soils, other soil characteristics such as permeability, and climate. As those characteristics vary by region, even within state boundaries, net migration from regions with high radon potential to ones with lower potential (or vice versa) could change not only the shape of the exposure distribution but also its mean. Population mobility without net migration does not affect mean exposures but does reduce the number of extremely low or extremely high exposures. Therefore, a decrease in population mobility would increase the number of extremely high and low exposures, while an increase in mobility would tend to make exposures more uniform across the population. The Subcommittee was unable to identify any clear trends that suggest major population migration with respect to radon potential or any major changes in population mobility.

The features of residential construction that can influence indoor radon levels include basic structural and design features such as basement, slab-on-grade, or crawl space, number of floors, pathways for entry from the soil (e.g., utility penetrations, drains, cracks), designs that influence inside/outside pressure gradients, and building operation practices such as heating, ventilation and air conditioning (HVAC) systems or open versus closed windows and doors. Any trend that would modify the mix of these features in the Nation's building stock could therefore also change the distribution of exposures across the population. Changes might occur through considerations other than radon (e.g., energy efficiency, housing economics, regional migration, personal preferences) or through deliberate efforts to reduce radon exposures (retrofits and new buildings codes). Any changes effected through new construction (whether or not incorporating radon-resistant features) will occur relatively slowly, because only about 1% of the housing stock is replaced annually (1 million out of 100 million residential units, 70 million of which are single-family dwellings). Therefore, only 20 to 25% of the housing stock will be replaced within 30 years, taking into account growth in the total stock.

For a given radon exposure, the distribution of risks depends principally on the distribution of individuals' susceptibility to radon-induced lung cancer and how it varies with the level of exposure, time of exposure, exposure to co-pollutants, and so forth. For example, existing information suggests that smokers are at much higher risk of lung cancer than are non-smokers exposed to the same levels of radon; this difference is estimated to range from a factor of 3 to perhaps more than 20, but the exact nature of the increased risk to smokers has not been settled. Resolution of this issue, or discovery that some subgroups of the population may be genetically more prone to radon-induced cancers, could change our understanding of the distribution of sensitivities.

Although available information on radon-induced lung cancer (principally from studies of uranium and other hard-rock miners) provides methods for assessing time-varying radon exposures and suggests that low exposure rates may pose a greater risk for the same total exposure, EPA currently assumes that the lifetime risk of cancer is proportional to the lifetime cumulative exposure to radon decay products. This assumption implies that, although individual risks may be low for persons exposed to low levels of indoor radon, the bulk of radon-related cancers will occur in the low-exposure population. Because of uncertainties in projecting high-exposure observations to low exposures and from mine environments to the home, the estimates of annual radon-related cancers could be substantially in error. Any elucidation of the low exposure risks to persons exposed indoors to radon, including the potential discovery of a threshold for cancer induction, could make important changes for EPA estimates of population-wide risks.

9.2 Trends and Assumptions

The following are reasonable assumptions for the future of indoor radon risk assessment and control:

a) No fundamental changes in major building techniques and practices will occur in the next 5 years, nor probably in the next 30 years. Any significant changes will occur through the incorporation of radon considerations in building codes, a complicated political process.

b) Unless there are significant and/or sudden changes in the price of energy, no important shift will occur in the current trend toward increased use of extensive mechanical systems for HVAC in non-residential buildings. Increases in efficiency of HVAC systems may also make them more attractive to builders and designers.

c) Regional characteristics will continue to dominate the methods of building design and construction (this will be especially true for residential buildings).

d) Single-family or low-rise multi-family dwellings (e.g., townhouses) will be the predominant type of suburban residential construction.

e) The overall risk assessment methods for radon will remain fundamentally unchanged, although the differences among risks for smokers, former smokers, and nonsmokers will become more clear.

9.3 Implications for EPA

Several issues are likely to affect the position of radon as a continuing problem (risk), given the assumptions above. To some extent, the outcomes depend upon research results (Appendix D, U.S. EPA/SAB, 1994c); in other cases, they depend upon government policy choices. Assuming that EPA's role in radon control remains restricted to one of guidance, EPA will likely be faced with the following issues:

a) EPA will be solicited to provide the scientific basis for identifying high "radon potential" homes (on the basis of both regional location and building design).

b) EPA will be challenged to recommend radon testing methods that are more reliable and accurate indicators of actual exposures than are currently popular short-term tests, even for the purposes of real estate transactions.

c) EPA should verify that its recommendations for the design and implementation of methods to reduce radon entry into new buildings will yield average indoor concentrations below guideline levels, and the Agency should modify its guidance as necessary.

d) EPA has also provided guidance for retrofit of radon reduction techniques on existing buildings. These too could benefit from follow-up evaluations of effectiveness and, if necessary, modification.

e) Clarification of the link between smoking and the risks of indoor radon will put pressure on EPA to consider different strategies or guidance for smokers and non-smokers.

f) Any discovery about genetic susceptibility to radon-induced cancer (see Section 8) will raise an issue similar to that for smokers.

g) Any substantial revision in the estimates of risks from low exposures to radon could require EPA to re-evaluate its guidance.

9.4 Recommendations

The following recommendations flow directly from the issues identified above:

a) EPA should continue to foster the development of methods that will reliably characterize the "radon potential" of regions and house designs.

b) EPA should continue to investigate and encourage the development of more accurate testing methods, more energy-efficient and effective retrofit equipment, and more radon-resistant building designs.

c) EPA should plan to conduct a survey of housing built to its model codes in order to verify that the codes are achieving their intended purpose of reducing indoor radon concentration to acceptable levels.

d) EPA should track—and possibly encourage, support or even conduct—research to elucidate the relationship between exposure, susceptibility factors, and radon risk. In any case, EPA should be prepared to adopt new risk-reduction strategies, depending on the results of such research.

10. CONTROL OF NUCLEAR MATERIALS

Recent thaws in cold war activities and the breakup of the Soviet Bloc call for increasing attention to potential environmental impacts of excess nuclear materials, especially weapons-grade uranium and plutonium. It is essential to the health of the planet that these materials receive the greatest possible control and management because loss of control could lead to massive contamination of the environment from terrorist or unauthorized weapon use and/or similar contamination from poor management.

10.1 Key Issues

The world's stockpile of nuclear materials is enormous, representing tens of billions of dollars in invested resources, and contains energy that has the potential to be extremely dangerous to health and the environment but also of to be of value if used properly. As components of weapons, nuclear materials pose a dilemma: in this form they are most stable for isolation from the environment, but they are also most attractive for unauthorized diversion because they could be used as a blueprint for weapons production in addition to their potential for direct use as weapons. Keeping these materials in stable form by remaining contained in weapons parts could be a reasonable approach only to the extent that security can be provided. Unfortunately, this form of storage would require a national will not to use these weapons, nor to exchange weapons for hard currency in times of economic need, a prerequisite that in the past has not always been successfully met on a worldwide basis. Furthermore, the possibility of components being stolen and used by terrorists makes this option untenable for many in the international community.

Another alternative would be to use the materials beneficially as fuel for nuclear power plants. The advantages include "burning up" the material so as to make it unavailable to anyone and meeting future energy needs without generating more greenhouse gases. The deterrents to this option are all those that would argue for a limited role of nuclear power in the future energy supply of the world. Effective waste management policies will be required whether the materials remain in their current state or are converted to other wastes during their use as fuel.

Even though the potential for a Superpower confrontation is diminished at present, theft or diversion of nuclear materials will continue to be a threat if these materials remain in their current form. This problem puts considerable pressure on the need to find a permanent (or at least irreversible) disposal method, especially for materials in excess of a prudent stockpile. Under most reasonable scenarios, excess materials exist beyond those that might be put aside for national security. Both the mix of radionuclides and the weapons-grade nature of the material make it significantly different from radioactive waste generated by most parts of the civilian nuclear fuel cycle—at least as practiced in this country.

To pursue an aggressive effort to develop international controls, the U.S. might even solicit—under international controls—the importation of materials to this country for "burning up" in reactors. The technology and institutions necessary to handle such imports under internationally accepted methods appears to require a degree of commitment and internal stability that only a few countries can provide in the foreseeable future.

A third aspect of this issue is the disposal of defense-related materials over and above production reactor wastes. Fuel-cycle waste disposal from and decommissioning of military (mostly naval) reactors also represent problems to be dealt with. The WIPP plan does not currently anticipate accepting these wastes or decommissioning wastes. Most importantly, this issue is international; notably, what should be done about military reactors from the nations that constituted the former Soviet Union and other Eastern European states? Obviously, the Russian approach of sinking some submarine reactors in the Baltic Sea or the Arctic Ocean needs to be halted. The U.S. interest in assuring that these disposal methods are not used is vital, and international controls and methods are required.

Finally, there is the issue of cleanup and remediation of the contamination and environmental degradation from uranium mining, and fuel and weapons production facilities in the nations of Eastern Europe and the former Soviet Union. What little is known indicates that these problems are of a magnitude unheard of in the U.S. The potential for further spread of these radioactive contaminants is huge (Appendix D, Feshbach et. al., 1992).

10.2 Recommendations

Assuring control of nuclear materials would require leadership and coordinated action by several Federal and international agencies on nuclear waste disposal. Regardless of whether or not EPA chooses to be a catalyst in the government-wide efforts to control nuclear materials, it should consider the impact of its actions—positive or negative—on such efforts before committing to a course of action in the waste disposal issue.

The EPA roles may be threefold:

a) being an active part of any international efforts to control nuclear materials (as has been the case in other environmental issues with an international flavor, such as global climate change);

b) vigorously working to push for the development of domestic nuclear waste disposal technology and institutional readiness so that it becomes available if needed for the safe disposal of these materials; and, finally,

c) advising other countries on the cleanup and remediation of their environment that resulted from uranium mining and weapons-related activities.

By these approaches, EPA could catalyze U.S. and international efforts, that is, it could "lead the charge" by clearly and persuasively enunciating the national environmental interest in controlling, and hopefully reversing, any further spread of nuclear materials. However, without a clear, unambiguous policy to obtain secure disposal sites for such materials, the benefits of isolation and security that could be provided by permanent storage will tend to be supplanted by the less desirable but more expedient solution of on-site storage.

11. SUMMARY AND CONCLUSIONS: FOCUS FOR THE FUTURE

11.1 Summary of Recommendations

This report has analyzed seven major topics in environmental radiation which the REFS selected through a process for scanning the future and which the Subcommittee believes will be the most important issues to confront EPA in the 5-30 year time horizon considered. Three recurring themes have appeared throughout the main body of this report, as listed below and discussed in the following subsections:

a) waste management to prevent pollution will be very important in the future of environmental radiation;

b) new understanding of population exposures, dose-response models, and genetically-linked susceptibility to radiation risks among subpopulations could require new regulatory paradigms for environmental radiation; and

c) EPA will continue to require technically strong programs and policies in place to be in a position to deal with the issues coming under its purview in the future.

11.1.1 Energy production, radioactive waste management, and nuclear weapons materials issues

The previous sections have presented arguments for EPA attention to energy issues as they are linked to radiation exposures and waste disposal. The Subcommittee analyzed two very different scenarios for the future of energy production. Based on its analysis of the linked futures of energy and the environment, the Subcommittee recommends that EPA consider the following:

a) Participate positively in the joint development of energy and environmental policies at the national level, taking into due consideration the interests and activities of state and local authorities.

b) Adopt policies and incentives that factor in the economics of pollution prevention and control of all kinds in the overall energy and environment equation.

c) Take steps to expedite the resolution of the problem of radioactive waste by issuing the generally applicable standards for radioactive waste disposal and residual radioactivity.

d) State a clear policy for NORM and mixed hazardous/radioactive wastes, including guidelines by which industries that produce large quantities of these wastes can plan for proper management of these materials.

Issues attendant to radioactive waste management clearly pose circumstances with huge economic and social consequences. Because of existing polarization on radioactive waste issues, there is a compelling need for credible leadership on managing these materials to minimize environmental degradation, assure economic vitality, promote environmental equity, and involve all stakeholders in national policies. EPA could assume a leadership role in five major areas related to radioactive waste materials: low-level radioactive wastes, high-level radioactive wastes, residual radioactivity, NORM, and mixed hazardous/radioactive wastes. In particular, there is a need to harmonize radiological and chemical risks in order to deal with mixed hazardous/radioactive wastes so that the bureaucratic deadlock among Federal regulatory agencies can be broken. This harmonization could be accomplished by seeking authority to issue a set of standards specifically for such wastes or a set of alternative standards that would allow the use of existing regulations where possible or applicable.

It is crucial that Congress provide the budgetary and fiscal resources needed by EPA in order for the Agency to develop and maintain technically strong programs and policies regarding the problem of radioactive waste disposal in all its aspects or categorizations (high-level, low-level, mixed, NORM, NARM, etc.). This allocation could be part of the development of a comprehensive national plan to deal with the radioactive waste disposal issue. A process to develop foresight about the future that continuously evaluates the policies and alternatives implemented will be very important given the fact that these wastes will be around for the next millennium and even longer.

Assuring control of nuclear materials could require EPA action and leadership on nuclear waste disposal. The EPA roles may be threefold: being an active part of any international efforts to control nuclear materials (as has been the case in other environmental issues with an international flavor, such as global climate change); vigorously working to push for the development of domestic nuclear waste disposal technology and institutional readiness so that it becomes available if needed for the safe disposal of these materials; and, finally, advising other countries on the cleanup and remediation of their environment that resulted from uranium mining and weapons-related activities. Without a clear, unambiguous policy to obtain secure disposal sites for such materials, providing this essential element of environmental protection will be much more difficult because long-term storage will supplant the isolation and security that permanent disposal would achieve.

11.1.2 Population exposures, dose-response models, and genetic susceptibilities to radiation risks

REFS recommendations pertaining to the second theme—population exposures, dose response, and susceptibility to radiation—are as follows:

a) The EPA could consider the establishment of stronger collaborative agreements with other Federal agencies to monitor the changing patterns of exposure to ionizing radiation by the population. This collaboration would provide the Agency with more of the data necessary to make better informed choices when exercising its authority to issue guidance on exposures to radiation. A research program that explores the implications of the social, economic, and health issues that drive changes in exposures by the population may be desirable at a time when large numbers of individuals may be exposed to low amounts of radiation in site restoration activities as part of the Federal Complex Clean-Up Program that is scheduled for the next decade.

b) EPA could identify radiation research issues fundamental to further work in the molecular and genetic biology of cancer and other diseases resulting from exposure to radiation and environmental stresses. In any case, EPA will probably be faced with the need to develop policies for dealing with the carcinogenic and other risks of radiation and other agents in a world where identification of genetic and other susceptibilities may be commonplace.

11.1.3 Exposure to Non-Ionizing Radiation

REFS recommendations pertaining to exposure to non-ionizing radiation are as follows:

a) Working collaboratively with other agencies, EPA should continue to assess the state of science regarding potential health effects associated with environmental exposures to electromagnetic fields (EMF). To the extent warranted by future developments, the Agency should ensure that key research is pursued. In the meantime, in the absence of solid evidence demonstrating or refuting the hypothesis that exposure of some type to such fields causes cancer or other effects, EPA could provide practical guidance that will aid those who develop and apply EMF technologies to limit EMF exposures consistent with current knowledge. These actions will permit EPA to position itself to deal with the increases in environmental exposures to EMF that are likely to occur in the future as a consequence of increased electrification and technological developments such as magnetic resonance imaging (MRI) in medicine, magnetic levitation (MagLev) in transportation, and the explosion in information processing and telecommunication technologies.

b) EPA should track and help stimulate research conducted by other agencies on the health and environmental risks of exposure to non-ionizing radiation. It should not limit its attention to power-frequency EMF but should also monitor research on radio-frequency electromagnetic radiation, quasi-static magnetic fields, ultrasound, possibly other forms of non-ionizing radiation, and their interactions with related agents. EPA will need greater internal resources including a research program, together with a contingency plan for regulatory initiatives (e.g., guidance) for known hazards (thermal effects, shock) and any new significant hazard that may be identified in the future.

11.1.4 Radon

Radon in indoor air is a prime example of the issue of population exposure, dose-response models, and enhanced susceptibility of a subpopulation. Clarification of the link between smoking and the risks of indoor radon will raise the issue of whether the Agency should provide differential guidance to smokers and non-smokers. Any discovery about genetic susceptibility to radon-induced cancer will raise similar issues. Any substantial revision in the estimates of risks from low exposures to radon will require EPA to re-evaluate its guidance.

Several actions may be worthwhile to ensure that the EPA's radon program continues to be founded on the best available science. The Agency should:

a) Continue efforts to focus on characterization of high-risk radon potential regions, improving knowledge about radon risks, and developing more accurate methods of measuring and mitigating radon in buildings. Particular emphasis should be placed on empowerment of stakeholders by dissemination of all available scientific information.

b) Continue to foster the development of methods that will reliably characterize the "radon potential" of regions and house designs.

c) Continue to investigate and encourage the development of more accurate testing methods, more energy-efficient and effective retrofit equipment, and more radon-resistant building designs.

d) Plan to conduct a survey of housing built to its model codes in order to verify that the codes are meeting their intended purpose of reducing indoor radon concentration to acceptable levels.

e) Continue to track—and possibly encourage, support or even conduct research to elucidate the relationship between exposure, susceptibility factors, and radon risk. In any case, the Agency should be prepared to adopt new risk-reduction strategies, depending on the results of such research.

11.2 Focus for the Future

Many of the recommendations in this report deal with EPA's need for a strong in-house scientific staff that will approach the issues in environmental radiation from the perspective of pollution prevention, ecosystems protection, and good science. EPA is undergoing a massive re-structuring of its research organization, and is streamlining its operational arm throughout the Agency.

11.2.1 Becoming the Source of Choice for Information on Environmental Radiation

This is a crucial moment for EPA, and it is a particularly important one when viewed from the perspective of EPA's mission with regard to radiation-related issues. The role of EPA in radiation within the Federal government can be summarized as one of giving advice, providing guidance, and issuing generally applicable standards on which other agencies in government must base their rules and regulations pertaining to radiation. Such a role by definition involves a position of leadership within the government inasmuch that other agencies must prove that their regulations are at least as protective of the environment as are those of the EPA radiation standards, or must justify their rules when compared against the radiation guidance issued by the EPA. It involves the forging of partnerships with other Federal and state agencies. It involves having the best science available in order to provide credible leadership. This reorganization presents an opportunity to shift the reactive and strictly regulatory focus of the radiation programs in the Agency toward one of proactive leadership and recognition as the source of choice for information and guidance on key radiation-related issues.

It will be crucial for EPA to obtain fiscal resources to implement the strong programs required to achieve and maintain such a position of leadership. This budgetary authority should contain within it the flexibility needed to allocate those resources in the most efficient and cost-effective manner possible. EPA should at least track and help guide the research conducted by other agencies on the health and environmental risks of exposure to radiation. Guidance could take the form of identifying and stimulating research in support of the Agency's regulatory functions, not only by carrying out the research itself, but also by persuading other agencies—through existing or new interagency partnerships—to allocate some of their research efforts in the desired directions, or by stimulating research through extramural grants and contracts. Through such direct involvement, the Agency will be in the best position to effectively use research results in its radiation protection policy and decisions, especially in policy research on the proper use of information about populations that are genetically susceptible to radiation risks. EPA could also request that Congress clarify the responsibilities of the various Federal government agencies with regard to radiation research, given that many areas of relevance are falling through the cracks.

11.2.2 Developing a Foresight Capability

One approach that may be particularly useful in gaining this leadership role is a process of looking at the future called foresight, which is described in detail in Coates et. al. (Appendix D: Coates et. al., 1986) and which is also proposed in the EFC report, Beyond the Horizon: Protecting the Future with Foresight (Appendix D: U.S. EPA/SAB, 1995a and U.S. EPA/SAB, 1995b). A version of this process may already exist within OPPE or ORD (e.g., EMAP). Foresight is the process of creating an understanding of information generated by looking ahead (Appendix B for Coates, 1993; also Appendix D, Coates et. al., 1986, pp. 7-13, and Coates, 1993). It includes qualitative and quantitative means for monitoring indicators of evolving trends, and is most useful when linked to the analysis of policy implications. Foresight cannot define policies, but can ensure that they are sufficiently flexible and robust so as to take into account changes in circumstance. The process of foresight must be systematic and comprehensive. It should accommodate a wide variety of viewpoints and information. It must be a public process, and the data, assumptions, and information used must be available for independent analyses. It avoids predictions, that is, conclusive or probabilistic statements that particular events will occur. It tries to fan out all the possible and/or available alternatives compatible with the assumptions and the quality of the data. Foresight is not forecasting or modeling, although it uses both as techniques. It also uses consultative processes and aggressively seeks feedback. It works in the service of the decision-maker to clarify choices. Therefore it must feed information effectively to the decision-makers. The Environmental Futures Project falls within the scope of what would be considered a foresight process.

Instituting a process such as that described in the previous paragraph will make the Agency's radiation programs stronger, more ready to tackle new issues, and more able to identify new issues before a crystallizing event occurs and limits the options and alternatives that may be available to handle the issue. Following such a new direction will go a long way toward establishing EPA as the source of choice for information and guidance on environmental radiation issues.

11.3 Conclusions

This report on future issues in environmental radiation is consistent with the EPA Administrator's fundamental principles for environmental protection (Appendix D, U.S. EPA, 1994a) in the following manner:

a) An ecosystem approach to environmental protection, as opposed to an approach considering only human health impacts, was used by the Subcommittee to elucidate significant energy use and trends relative to various environmental stresses related to radiation.

b) Good science, improved management, and interagency partnerships would form the building blocks for shifting EPA's approach to environmental protection from a reactive mode toward one of increasingly proactive leadership. The Agency would then secure its role in the future as the source of choice for environmental information and guidance on key radiation-related issues.

c) Pollution prevention and environmental justice and equity for citizens of the United States and the rest of the world were seen to provide fundamental perspectives for issues related to radon, radon exposure trends, management of waste materials, and control of nuclear materials.

The Subcommittee believes that it would be worthwhile for EPA to explore the following in its long-term planning efforts:

1) Pursuing efforts to achieve less reliance on a regulatory role in risk management, in favor of assuring overall enhancement of the environment from society's activities, the original vision which accompanied the Agency's formation. This renewed role would focus on providing scientifically credible information to stakeholders as participants in resolution of environmental questions consistent with the SAB's Future Risk and Reducing Risk reports, as well as the Safeguarding the Future report (See Appendix D: U.S. EPA/SAB, 1988; U.S. EPA/SAB, 1990; and U.S. EPA, 1992, respectively.)

2) This report presents arguments for EPA attention and focus, particularly on issues related to energy production and use, insofar as they are linked and interwoven into issues of radiation exposures and waste disposal. Based on our analysis of the future and the strong linkages of environmental quality issues to the Nation's energy issues, the Subcommittee recommends that EPA participate positively in the joint development of national energy policies, focusing on an examination of the overall environmental consequences of energy production options, the roles of alternative energy sources, including nuclear electricity generation in curtailing greenhouse gases, possible increases in UV radiation and other harmful effects, radioactive waste management issues, and potential release of radioactive materials to the environment.

3) Working with other Federal, state and local agencies, as well with as other national governments, in order to resolve problems in the management of radioactive waste materials. Appropriate and coordinated action is necessary in order to allow for: a) proper choices in nuclear energy production; b) control of nuclear materials from disassembled warheads; c) site restoration activities in Federal facilities and Nuclear Regulatory Commission (NRC) licensees; and d) continued use of radioactive materials in medicine and research. EPA could assume a proactive leadership role by:

    a) expediting the resolution of the problem of radioactive wastes by issuing generally applicable standards for radioactive waste disposal and residual radioactivity; and

    b) formulating clear policies for both naturally occurring radioactive material (NORM) and mixed hazardous/radioactive wastes.

4) Assuring control of nuclear materials from disassembled warheads through conversion to energy use, burn-up in reactors, and/or secure disposal is vital to a safe and clean environment. EPA could provide leadership in resolving environmental issues necessary to incorporate this assurance into national programs.

5) The largest potential for reducing U.S. population exposure to radiation (inasmuch as they are controllable) could occur in the areas of medical care and radon in indoor air. EPA guidance on public radiation exposures could influence reductions in radiation doses from these sources.

6) Advances will likely be made in understanding the significance of different measures of exposure, the relationship of exposures to risks, and how and why different people may respond differently to radiation. EPA will be faced with the need to incorporate new important findings in radiation research into its guidance and regulatory postures regardless of whether the findings point to greater or lesser health and environmental risks than previously thought. For example, information from the Human Genome Project and molecular biology research could allow for identification of individuals with genetic or other susceptibilities to radiation health effects, which may require major changes in regulatory approaches for radiation protection. EPA should begin to consider what kinds of policies will be pertinent for a future in which dealing with carcinogenic and other risks of radiation, and the interaction of radiation damage with the damage from other agents, is done in a world in which identification of genetic and other susceptibilities is commonplace.

7) EPA should continue efforts to focus on characterization of high-risk radon potential regions, improving knowledge about radon risks, and developing more accurate methods of measuring and mitigating radon in buildings. Particular emphasis should be placed on empowerment of stakeholders by dissemination of all available scientific information.

8) Working collaboratively with other agencies, EPA should continue to assess the state of science regarding potential health effects associated with environmental exposures to EMF. To the extent warranted by future developments, the Agency should ensure that key research is pursued. In the meantime, in the absence of solid evidence demonstrating or refuting the hypothesis that exposure of some type to such fields causes cancer or other effects, EPA could provide practical guidance that will aid those who develop and apply EMF technologies to limit EMF exposures consistent with current knowledge. These actions will permit EPA to position itself to deal with the increases in environmental exposures to EMF that are likely to occur in the future as a consequence of increased electrification and technological developments such as MRI in medicine, MagLev in transportation, and the explosion in information processing and telecommunication technologies. Specifically, EPA should prepare to deal with a world in which differences in individual susceptibility to radiation and other hazards is understood and the technology exists for identifying individuals with heightened or decreased susceptibility.

9) The development of a capability for scanning the future through a process of foresight may be necessary for the development of a proactive role in shaping environmental radiation policies. The REFS is unanimous in recommending this, given the fact that with a few exceptions, the research, the regulatory practices, and the paradigms used today as the basis for setting radiation standards may not be effective or efficient in resolving the issues of the future.

Many of these issues analyzed, and recommendations presented, are a logical extension of previous SAB/RAC review activities. These issues are, and will continue to be, a concern for EPA today and in the future. This continuity is especially evident when one reads this "futures report" in the context of the background presented in the RAC's Retrospective Review Report (Appendix D, U.S. EPA/SAB, 1994d). During the past year, EPA has undertaken several very important actions that pertain to the recommendations presented in this report: a) the generally applicable standard for high-level radioactive waste has been promulgated, although its potential applicability to Yucca Mountain is under external review; b) the Agency has formed a group charged with developing a program to address the issue of harmonizing chemical and radiation risks; c) work is in progress on developing generally applicable standards for residual radioactivity and low-level radioactive waste; and d) work has resumed on EMF issues. The RAC has been involved in consultations and briefings on these issues and has scheduled reviews for some of them in Fiscal Year 95. It is our expectation that some of the desirable outcomes envisioned in this report will be assisted by the above initiatives. In addition, it is hoped by the REFS that the Agency will consider its degree of institutional readiness and what is necessary to achieve its desired golas in light of the future issues and challenges involved in environmental radiation identified in this report.

APPENDIX A - THE CHARGE TO THE SAB

The SAB was asked to take on an initative on environmental futures, in a memo dated July 16, 1993 oginially sent from David Gardiner, Assistant Administrator to Carol M. Browner, Administrator of EPA. The Executive Committee (EC) of the SAB considered and accepted this request and established an ad-hoc SAB committee, the Environmental Futures Committee (EFC) to undertake this effort. The EFC refined a charge with the Agency personnel and the standing committees of the SAB that wished to undertake this exercise. The EFC, in the course of its monthly meetings, also developed a procedure for conducting a periodic scan of the future horizon and to choose a few of the many possible future developments for in-depth examination of potential environmental impacts.

The SAB EC accepted the following specific goals for this project:

A. Develop procedures for conducting a short (five to ten-year horizon) and long-term (20-year horizon or longer) scan of future developments that will affect environmental quality and the nation's ability to protect the environment over a medium to long term time frame.

B. Conduct as comprehensive a scan as practical to identify important future developments and environmental consequences.

C. Choose a limited number of short- and long-term future developments for in-depth evaluation of their environmental consequences.

D. Develop appropriate procedures for conducting in-depth examination of those future developments and consequences.

E. Apply procedures described in D.

F. Draw implications for EPA from the in-depth examination of future developments.

G. Recommend possible actions for addressing the developments and consequences.

H. Propose possible approaches for continuing EPA programs that address evaluation of future developments and environmental consequences.

I. Develop a method for communicating the results of the Futures study so that it will have an impact on appropriate professionals in EPA (added by the SAB).

APPENDIX B
THINKING ABOUT THE YEAR 2025[2]

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THINKING ABOUT THE YEAR 2025[3,4]

What follows is a presentation of highly reliable statements about the year 2025. Their origins are in **Project 2025: Anticipating Developments in Science and Technology and their Implications for the Corporation** which is sponsored by 18 large organizations in the U.S. and Europe.

The goal of Project 2025 is to explore how science and technology are likely to reshape U.S. and global society from now to that time. Consequently, it is important to identify our most solid conclusions in the complex of forecasts.

Assumptions about the year 2025 are not like assumptions in a geometry exercise. These are not presented as abstract statements from which consequences can be derived with mathematical precision. Their origins lie in many different places. Some are conclusions drawn from the project. Others, such as the estimates of future population, come from public or highly credible private statistical and mathematical analyses of trends. Others are the integration of a wide range of material, such as the assumption that we will be moving toward a totally managed globe. To present the underlying arguments supporting each of the highly reliable statements which amount to forecasts would require a massive report. We have, therefore, presented these statements about the future as simply and in as straightforward a manner as possible.

A few of the assumptions have more of a normative, that is, goal-oriented, aspect to them than others. The assumption, for example, that per capita energy consumption in the advanced nations will fall to 66% of the 1990 level is definitely not a trend extrapolation but a judgment about the confluence of social, political, economic, environmental, technological,

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3. We appreciate the willingness of the sponsors of *Project 2025: Anticipating Developments in Science and Technology and their Implications for the Corporation* to allow us to use this material.

and other concerns. In a key statement of this sort the reader is not only invited but urged to review his or her alternatives that might characterize that period and to test how those alternatives affect any other thoughts, concepts, beliefs, or conclusions about the future.

What follows is an inventory of high probability statements about the year 2025 in two categories:

- **Scientific discoveries and research, and technological developments and applications**

- **Contextual, that is, those factors forming the social, economic, political, military, environmental, and other factors which will shape or influence scientific and technological developments. These contextual areas form the environment for the introduction and maturation of new products, processes, and services in society.**

These high probability assumptions are the underpinnings to understanding how any particular area may develop under the influence of new scientific, technological, social, political or economic developments.

It would be convenient to claim 98% probability for all the statements, but that does not fit all the cases. It would also be nice to suggest that these developments are inevitable. But few developments are inevitable. Nonetheless, the convergence of evidence indicates that these developments are of such high likelihood that they are an intellectual sub-structure for thinking about the year 2025. The 83 statements are intended to be robust. They are not a house of cards where one failing causes them all to fail.

Few of these statements can be taken as perfect, that is, beyond question or representing the best formulation of the subject. Vocabulary is a continuing and insoluble problem. Readers will come from many backgrounds and have a wide range of preconceptions; hence, the words cannot have exactly the same meaning for each reader. We suggest that when the reader faces a problem of uncertainty, ambiguity, or basic disagreement, that the statement be reexamined for alternative meanings, that is, alternatives to those the reader brings to the statement. In summary, this set of statements forms the background for more detailed analysis and speculation about the year 2025 and the intervening period.

The numbering of the assumptions is not significant. The items are in more or less random order in sets A and B, pushing the reader to think about each one on its own merits.

A. Scientific and Technological Assumptions About the Year 2025

1. Movement toward a totally managed environment will have proceeded substantially at the national and global level.

   Oceans, forests, grasslands and water supplies comprise major areas of the managed environment. Macroengineering, or planetary scale civil works will comprise another element of that managed environment. Finally, the more traditional business and industrial infrastructure: telecommunications, manufacturing facilities, chemical plants, electric generating facilities, and so on, will be a part of managed systems and subsystems.

   Note that total management does not imply full understanding of what is managed. But expanding knowledge will make this management practical. Management also does not imply control.

2. Everything will be smart, that is, responsive to its external or internal environment.

   This will be achieved by two strategies alone or in combination. The first will be the inclusion of microprocessors and associated sensors in physical devices. The second strategy will involve materials which are responsive to physical variables such as light, heat, noise, odors, and electromagnetic fields.

3. All human diseases and disorders will have their linkages, if any, to the human genome identified.

   For many diseases and disorders, the intermediate biochemical processes that lead to the expression of the disease or disorder and its interactions with a person's environment and personal history, will also have been explicated.

4. In several parts of the world explicit programs will have begun for the aggregate enhancement of populations' physical and mental abilities (as opposed to disease prevention) based on the understanding of human genetics.

5. The genome of prototypical plants and animals, including insects, will have been worked out. This will lead to more refined management, control, and manipulation of their health, propagation, or elimination.

6. There will be a worldwide, broadband network of networks based on fiber optics, with other techniques such as communications satellites, cellular, and microwave as ancillary.

   Throughout the advanced nations and the middle class/prosperous crust in the Third World, face-to-face, voice-to-voice, person-to-data, and data-to-data communication will be available to any place, at any time, from anywhere.

7. The chemical, physiological, and genetic bases of human behavior will be generally understood.

   Direct, targeted interventions for disease control and individual human enhancement will be commonplace. Brain/mind manipulation technologies to control or influence emotions, learning, sensory acuity, memory and other psychological states will be available and in widespread use.

8. In-depth personal medical histories will be on record and under full control of the individual in some form of a medical smart card, or disk. Similar cards will function in other non-medical areas.

9. Robots and other automated machinery will be commonplace inside and outside the factory in agriculture, building and construction, undersea activities, space, mining, and elsewhere.

10. There will be universal, on-line surveys and voting in all the advanced nations. In some jurisdictions this will include political voting.

11. Per capita energy consumption in the advanced nations will be at 66% of per capita consumption in 1990.

12. Per capita energy consumption in the rest of the world will be at 160% of per capita consumption in 1990.

13. Foods for human consumption will be more diverse as a result of agricultural genetics.

There will be substantially less animal protein in the advanced nations' diets, compared to the present.

14. More people will be living to the middle of their ninth decades (approximately 85) while enjoying a healthier, fuller life. There will be a notable "squaring off" of the natural death curve.

15. Ubiquitous availability of computers will facilitate automated control and make continuing performance monitoring and evaluations of physical systems routine.

16. Manipulation at the molecular or atomic level will customize materials designed for highly specific functions.

17. Totally automated factories will be common but not universal.

18. Remote sensing of the earth will lead to monitoring, assessment, and analysis of events and resources, at and below the surface of the earth and the ocean. In many places, *in situ* sensor networks will assist in monitoring the environment.

    Worldwide weather reporting will be routine and more reliable.

19. Custom designed drugs such as hormones and neurotransmitters, will be as good or better than those produced naturally within humans or other animals.

20. Synthetic and manipulated food will fit the individual consumers' taste, nutritional needs, and medical status.

21. Prostheses (synthetic parts or replacements) with more targeted drug treatments will lead to radical improvements in the status of people who are injured, deteriorated, or for natural or environmental reasons have otherwise degraded physical or physiological capabilities.

22. Virtual reality will be commonplace for training and recreation, and will be a routine part of simulation for all kinds of physical planning and product design.

23. In printed and, to a lesser extent, in voice-to-voice telecommunication, language translation will be effective for restricted but practically significant vocabularies.

24. Expert systems will be developed to the point where the learning of machines, systems, and devices will mimic or surpass human learning. Certain low level learning will evolve out of situations and experiences, as it does for infants.

25. Synthetic soils, designed to specification, will be used for terrain restoration and to enhance indoor or outdoor agriculture.

26. Genetically engineered microorganisms will do many things. In particular, they will be used in production of some commodity chemicals as well as highly complex chemicals and medicinals, vaccines, and drugs. They will be widely used in agriculture, mining, resource upgrading, waste management and environmental clean up.

27. The fusion of telecommunications and computation will be complete. There will be a new vocabulary of communication.

28. Many natural disasters, such as floods, earthquakes and landslides, will be managed, mitigated, controlled, or prevented.

29. Factory manufactured housing will be the norm in the advanced nations.

30. Resource recovery along the lines of recycling, reclamation, and remanufacturing will be routine in all advanced nations.

31. New life forms in microorganisms, plants, and animals will be commonplace.

32. In the design of many commercial products such as homes, furnishings, vehicles, and other articles of commerce, the customer will participate directly with the specialist in design.

33. New infrastructures throughout the world will be self-monitoring.

34. An interactive vehicle-highway system will be widespread with tens of thousands of miles of highway either so equipped or about to be. This will not necessarily require complete reconstruction of highways. It may be done with retrofit technologies.

35. Robotized devices will be a routine part of the space program, effectively integrating with people.

36. Restorative agriculture will be routine with crop design and greater sophistication in optimizing climate, soil treatments, and plant types.

37. Applied economics will lead to a greater dependency on models.

    These models will have expanded capabilities and will routinely integrate environmental and quality factors into economic calculations as well as calculus involving the economic value of information. A Nobel prize will be granted an economist for a new theory of the economics of information.

38. There will be routine genetic programs for animal enhancement, directed at food production, recreation and household pets; and in less developed countries, for work.

B. Social, Demographic, Political, Military, and Other Contextual Assumptions About the Year 2025

1. World population will be about 8.4 billion.

2. World population will divide into three distinct tiers.

    - advanced nations and middle class around the world living in the relative prosperity of Germany, the U.S., and Japan.
    - a bottom cut living in destitution.
    - a broader cut living comfortably in the context of their culture.

3. The population of advanced nations will be older, with an average age of 41.

4. The less developed world will be substantially younger and will have made spotty but significant progress in reducing birth rates.

5. The majority of the world's population will be metropolitan, including people living in satellite cities clustered around metropolitan centers.

6. Family size in advanced nations will be below replacement rates but well above replacement rates in the less developed world.

7. A worldwide middle class will emerge.

8. There will be worldwide unrest reflecting internal strife, border conflicts, and irredentist movements. They will have settled down substantially from the peak period of 1995 to 2010.

9. Under international pressures, the United Nations will effectively take on a peacemaking role to complement its historic peacekeeping role.

10. The multinational corporation will be the world's dominant business form, economically.

11. Economic blocs will be a prominent part of the international economy, with many products and commodities moving among and between blocs. Principal blocs will be:

- Europe
- East Asia
- The Americas

12. Widespread contamination by a nuclear device will have occurred either as an act of political/military violence, or an accident. On a scale of 1 to 10, with Chernobyl being a 3, and Three Mile Island a 0.5, this event will be a 5 or higher.

13. English will still be the global common language in business, science, technology, and entertainment.

14. Schooling on a worldwide basis will be at a higher level than it is today.

15. Increasing Third World economic and political instabilities will deter business involvement in specific countries.

16. Despite technological advances, epidemics and mass starvation will be common occurrences.

17. Global environmental management issues will be institutionalized.

18. Quality, service, and reliability will be a routine, global business criteria.

19. Global government will become prominent and effective but not complete with regard to environmental issues, war, narcotics, design and location of business facilities, regulation of global business, disease prevention, workers' rights, and business practices.

20. There will be substantial, radical changes in the U.S. government. The period of computer assisted gerrymandering will pass and will move to electronically assisted referenda.

21. World wide there will be countless virtual communities based on electronic linkages.

22. Throughout the advanced nations people will be computer literate and computer dependent.

23. Global currency will be in use.

24. Tax filing, reporting, and collecting will be computer managed.

25. There will be new metrics of economic health involving considerations of environment, quality of life, employment, and other activity and work. These new metrics will become important factors in governmental planning.

26. In the advanced nations lifelong learning will be effectively institutionalized.

27. There will be a worldwide popular culture. The elements of that culture will flow in all directions, from country to country.

28. There will be substantial environmental degradation, especially to the Third World, with budgetary commitments to amelioration and correction.

29. Within the U.S, there will be a national, universal healthcare system.

30. There will be shifts in the pattern of world debtor and creditor countries.

31. Genetic screening and counseling will be universally available and its use encouraged by economic incentives.

32. There will be more recreation and leisure time in the advanced nations for the middle class.

33. Birth control technologies will be universally accepted and widely employed, including a market for descendants of RU486.

34. The absolute cost of energy will rise, affecting the cost of transportation and goods movement, leading to reallocations in the use of terrain and physical space.

35. NIMBY (Not In My Backyard) will be a global scale problem.

36. In the U.S. the collapse of the Federal Social Security system will have led to a new form of old age security.

37. There will be a rise in secular substitutes for traditional religious beliefs, practices, institutions, and rituals for a substantial portion of the population of the advanced nations and the global middle class.

38. Identification cards will be universal.

39. Global migration will be regulated under new international law.

40. Transborder terrorism will continue to be a problem.

41. Customized products will dominate large parts of the manufacturing market.

42. Socially significant crime in the advanced nations will be increasingly economic and computer based.

43. Universal monitoring of financial and business transactions on a national and international basis will prevail.

44. GNP and other macroeconomic measures and accounts will include new variables such as environmental quality, accidents and disasters, and hours of true labor.

45. Sustainability will be the central concept and organizing principle in environmental management, while ecology will be its central science.

APPENDIX C
A PROCESS FOR SCANNING FUTURE DEVELOPMENTS IN ENVIRONMENTAL ISSUES

A Process for Scanning the Future Developments in Environmental Issues

The consensus of the REFS was that the EPA needs to strengthen and expand the "issues management" capabilities and processes, such as those in place at OPPE and ORD, into the program offices throughout the Agency. In order to achieve this, the EPA must ensure that technically strong programs and policies are developed and maintained at all times. The approach needs to consider all aspects of the issues involved: societal and value judgments, economic concerns, human health concerns, environmental aspects of remediation programs, cost-effectiveness and cost-benefit analyses of the various alternatives, and finally the best science available. A scheme of how such a process might function is presented as an alternative in Figure 2.

Figure 2 presents an alternative to the life cycle of health and environmental issues presented in the Charter for the Environmental Futures Project (Figure 1). It involves a dynamic process of foresight and issues management at the top of the cycle, and it aggressively looks for feedback at all times to maintain optimal policies to address the environmental issues.

The objective of a process such as that depicted in Figure 2 is the early identification of emerging problems, and translating that information into effective strategies to deal with those emerging issues in both the short and long term. One of the most important items is the implementation of a scanning process. Scanning will involve a mechanism for broadly sweeping all available information about issues and forces that may affect the organization. This should go hand in hand with a monitoring process - a more sophisticated and detailed procedure in terms of the information provided which incorporates the fact that the scanning and analytical functions have already identified issues as potentially important. The analytical function is one that defines (or redefines) the implications for the organization of the information gathered. Furthermore, it focuses sharply on what is to be monitored. It then feeds into a mechanism for setting priorities in terms of probabilities of trends for the emerging issues evolving into significant issues. The priority setting process then feeds forward into two functions: strategic planning (looks at long term time horizons) and policy implementation (short term time horizons). Priority setting also feeds back into the monitoring function. The strategic planning and the policy implementation processes interact with each other and feed back into the monitoring process. This cyclic process is always scanning, monitoring, and refining information in order to produce flexible yet robust policy alternatives in a continuous way (Coates et. al., 1986). The process described above would be a possible implementation of the recommendations of the Reducing Risk report into the regulatory arena. The implementation of a scheme such as that shown in Figure 1 will require that future scanning processes be in place. Two alternatives are : 1) a process of foresight; and 2) a process on issues management (Coates et. al., 1986).

FIGURE 1

EVOLUTION OF HEALTH AND ENVIRONMENTAL ISSUES

FIGURE 2

THE LIFE CYCLE OF HEALTH AND ENVIRONMENTAL ISSUES APPLYING ISSUES MANAGEMENT TECHNIQUES

Some small version of these processes may exist already within OPPE, or ORD (e.g., EMAP), but they need to be expanded and have the support of the middle and upper echelons of management in the EPA in order for them to be taken seriously and be successful.

Foresight is the process of creating an understanding of information generated by looking ahead. It includes qualitative and quantitative means for monitoring indicators of evolving trends, and is most useful when linked to the analysis of policy implications. Foresight cannot define policy, but can make them more flexible and robust to take into account changes in circumstance. It must be systematic and comprehensive. It should accommodate a wide variety of viewpoints and information. It must be a public process and the data, assumptions, and information used must be available for independent analyses. It avoids prediction, that is conclusive or probabilistic statements that particular events will occur. It tries to fan out all the possible and/or available alternatives compatible with the assumptions and the quality of the data. Foresight is not forecasting or modeling, although it uses both as techniques. It also uses consultative processes and aggressively seeks feedback. It works in the service of the decision maker to clarify choices. Therefore it must feed information effectively to the decision makers (for a more detailed discussion see Coates et. al., 1986, pp. 7-13, from which the above borrows heavily).

Issues management is a tool used to come to an earlier understanding of the issues an organization such as the EPA may face in the next few years. It can make the EPA an active participant in shaping its future and that of the environment, rather than be a reactive victim of various political, legislative, and regulatory responses to problems (for a more detailed discussion see Coates et al., 1986, Chapter 2). It is a process that does three things: 1) identifies, monitors, and analyzes social, technological, scientific, political and economic forces and trends which will affect the future; 2) it defines implications and options; and 3) it sets in motion short and long term strategic actions to deal with the situation. In looking at the environment it includes social and attitudinal values, technical and scientific developments, political and administrative trends, markets, trade, and any other forces that may affect the Agency or its functions.

These processes could become extremely valuable tools to explore future environmental issues, and help forestall the occurrence of crystallizing events that will put the government into a reactive mode with very limited alternatives.

Reference:

Coates JF, Coates VT, Jarratt J, Heinz L. Issues Management: How You Can Plan, Organize, And Manage For The Future, Lomond Publications, MD, 1986.

APPENDIX D
REFERENCES CITED

1) Anderson C: Fusion Research at the Crossroads, Science, 264:648-651, 1994

2) Bothwell M.L., Sherbot, D.M.J., Pollock C.M., Ecosystem Response to Solar Ultraviolet-B Radiation: Influence of Trophic-Level Interactions, Science 265:97-100, 1994

3) Coates, J.F., "Thinking About the Year 2025," Coates & Jarratt, Inc., Washington, DC, 1993

4) Coates, J.F., Coates, V.T., Jarratt, J., Heinz, L., Issues Management: How You Can Plan, Organize, and Manage for the Future, Prepared by J.F. Coates, Inc. for the Electric Power Research Institute (EPRI), Lomond Publications, Inc., MD, 1986

5) Edison Electric Institute, Capacity and Generation of Non-Utility Sources of Energy, Washington, D.C., 1992

6) Edison Electric Journal, June 1993

7) Energy Daily, McGraw-Hill, New York, N.Y., July 28, 1994

8) Faruqui et al., Electricity Journal, August 1994

9) Feshbach M., Friendly, Jr. A., Ecocide in the USSR: Health and Nature Under Siege, Basic Books, NY, 1992

10) Foster K.R., Health Effects of Low-Level Electromagnetic Fields: Phantom or not so Phantom Risk?, Health Physics Vol. 62, pages 429-435, 1992.

11) Geller, H.S., Hirst, E., Mills, E., Rosenfeld, A.H., and Ross, M., Getting America Back on the Energy Efficient Track: No-Regrets Policies for Slowing Climate Change, American Council for an Energy Efficient Economy, Washington, DC, October 1991

12) Gershey E.L., Klein R.C., Party E., Wilkerson A., Low-Level Radioactive Waste: From Cradle to Grave, Van Nostrand Reinhold, NY, 1990

13) González-Méndez, Ricardo, Chair, Radiation Environmental Futures Subcommittee, Memorandum to the Science Advisory Board's Environmental Futures Committee (EFC), entitled "Model Process for Scanning Developments in Environmental Issues," July 28, 1994, 8 pages

14) Hendee W.R., Boteler, J.C., The Question of Health Effects From Exposure to Electromagnetic Fields, Health Physics, Vol. 66, pages 127-136, 1994

15) ICRP, 1990, 1990 Recommendations of the International Commission on Radiological Protection (ICRP) Publication Number 60, Pergammon Press, 1991

16) Moerner W.E., Examining Nanoenvironments in Solids on the Scale of a Single, Isolated Impurity Molecule, Science, Vol. 265, pages 46-53, 1994

17) OTA, 1989, Partnerships Under Pressure: Managing Commercial Low-Level Radioactive Waste, Office of Technology Assessment (OTA), Congress of the United States, 1989

18) OTA, 1991a, Complex Clean-Up: The Environmental Legacy of Nuclear Weapons Production, Office of Technology Assessment, Congress of the United States, 1991

19) OTA, 1991b, Long-Lived Legacy: Managing High-Level and Transuranic Waste at the DOE Nuclear Weapons Complex, Background Paper, Office of Technology Assessment, Congress of the United States, 1991

20) Polk C., Postow E. (eds.), Handbook of Biological Effects of Electromagnetic Fields, CRC Press, Boca Ratón, Fla., 1986

21) San Francisco Chronicle, July 25, 1994

22) Shrader-Frechette K.S., Burying Uncertainty: Risk and the Case Against Geological Disposal of Nuclear Waste, University of California Press, Berkeley, 1993

23) Tsong T.Y., Electrical Modulation of Membrane Proteins: Enforced Conformational Oscillations and Biological Energy and Signal Transductions, Annual Reviews of Biophysics and Biophysical Chemistry, pages 83-106, 1990

24) U. S. DOE, 1993, Energy Information Administration (EIA), Annual Energy Review 1992, Report DOE/EIA-0384(92), U.S. Department of Energy, EIA, Washington, DC, June 1993

25) U.S. DOE, 1994, Energy Information Administration (EIA), Monthly Energy Review, June 1994

26) U.S. EPA, 1987, Federal Register, Guidance to Federal Agencies for Occupational Radiation Protection, Federal Register Vol 52, No. 17, pages 2822 - 2834, 1987 (EPA's Federal Guidance on Occupational Exposures.)

27) U.S. EPA, 1990, Guidance on the definition and identification of commercial mixed low-level radioactive and hazardous waste, EPA 530/SW-90-016, 1990

28) U.S. EPA, 1992, "Safeguarding the Future: Credible Science, Credible Decisions," The Report of the Expert Panel on the Role of Science at EPA (transmitted to Mr. William K. Reilly, Administrator, U.S. EPA by Drs. Raymond C. Loehr, Bernard D. Goldstein, Anil Nerode, and Paul G. Riser on January 8, 1992), U.S. EPA, EPA/600/9-91/050, March 1992

29) U.S. EPA, 1994a, Administrator Carol Browner's Report Entitled, "The New Generation of Environmental Protection, A Summary of EPA's Five-Year Strategic Plan," (This Contains the Administrator's High-Priority Issues for Environmental Protection), U.S. EPA, Office of the Administrator, EPA 200-2-94-001, July 1994

30) U.S. EPA/SAB, 1988, "Future Risk: Research Strategies for the 1990's," EPA-SAB-EC-88-040, September 1, 1988

31) U.S. EPA/SAB, 1990, "Reducing Risk: Setting Priorities and Strategies for Environmental Protection," EPA-SAB-EC-90-021, September 25, 1990

32) U.S. EPA/SAB, 1993a "Multi-Media Risk Assessment for Radon: Review of Uncertainty Analysis of Risks Associated with Exposure to Radon," (EPA-SAB-RAC-93-014), July 9, 1993

33) U.S. EPA/SAB, 1993b, "SAB Review of Multimedia Risk and Cost Assessment of Radon in Drinking Water," (EPA-SAB-EC-LTR-93-010), July 30, 1993

34) U.S. EPA/SAB, 1994a, "Review of Diffuse NORM Draft Scoping Document," EPA-SAB-RAC-94-013, May 16, 1994

35) U.S. EPA/SAB, 1994b, Briefings provided by the EPA Office of Indoor Air and Radiation to the SAB Radiation Advisory Committee, May and July 1994

36) U.S. EPA/SAB, 1994c, "Radon Science Initiative", draft dated September 1994

37) U.S. EPA/SAB, 1994d, "A Retrospective Review of SAB/RAC Activities," draft dated September 1994
[NOTE: The final report is EPA-SAB-RAC-95-009, dated March 1995.]

38) U.S. EPA/SAB, 1995a, "Beyond the Horizon: Protecting the Future with Foresight," Prepared by the Environmental Futures Committee (EFC) of the Science Advisory Board's (SAB's) Executive Committee, EPA-SAB-EC-95-007, January 1995

39) U.S. EPA/SAB, 1995b, Futures Methods and Issues, Technical Annex to the Report entitled "Beyond the Horizon: Protecting the Future with Foresight," Prepared by the Environmental Futures Committee (EFC) of the Science Advisory Board's (SAB's) Executive Committee, EPA-SAB-EC-95-007a, January 1995

40) U.S. NRC, 1991, Federal Register Nuclear Regulatory Commission: Standards for Protection Against Radiation: Final Rule, Federal Register 56: 23360-23474, 1991 (specifically Section 1, subsection I, on p 23363, "ICRP 1990 - recommendations")

41) U.S. NRC, 1992, Radioactive Waste Repository Licensing: Synopsis of a Symposium sponsored by the Board on Radioactive Waste Management, National Research Council, National Academy Press, Wash. DC, 1992

****

NOTE: The entire set of Futures Reports, of which this is a part, are listed below as follows:

1) Environmental Futures Committee EPA-SAB-EC-95-007
   [Title: "Beyond the Horizon: Protecting the Future with Foresight," Prepared by the Environmental Futures Committee of the Science Advisory Board's Executive Committee.]

2) Environmental Futures Committee EPA-SAB-EC-95-007a
   [Title: Futures Methods and Issues, Technical Annex to the Report entitled "Beyond the Horizon: Protecting the Future with Foresight," Prepared by the Environmental Futures Committee of the Science Advisory Board's Executive Committee.]

3) Drinking Water Committee EPA-SAB-DWC-95-002
   [Title: " Safe Drinking Water: Future Trends and Challenges," Prepared by the Drinking Water Committee, Science Advisory Board.]

4) Ecological Processes and Effects Committee EPA-SAB-EPEC-95-003
   [Title: "Ecosystem Management: Imperative for a Dynamic World," Prepared by the Ecological Processes and Effects Committee, Science Advisory Board.]

5) Environmental Engineering Committee EPA-SAB-EEC-95-004
[Title: "Review of Environmental Engineering Futures Issues," Prepared by the Environmental Engineering Committee, Science Advisory Board.]

6) Indoor Air and Total Human Exposure Committee EPA-SAB-IAQ-95-005
[Title: "Human Exposure Assessment: A Guide to Risk Ranking, Risk Reduction and Research Planning," Prepared by the Indoor Air and Total Human Exposure Committee, Science Advisory Board.]

7) Radiation Advisory Committee EPA-SAB-RAC-95-006
[Title: "Report on Future Issues and Challenges in the Study of Environmental Radiation, with a Focus Toward Future Institutional Readiness by the Environmental Protection Agency," Prepared by the Radiation Environmental Futures Subcommittee of the Radiation Advisory Committee, Science Advisory Board.]

APPENDIX E - GLOSSARY OF TERMS AND ACRONYMS

AAAS	American Association for the Advancement of Science
ALARA	As Low As Reasonably Achievable (EPA's Federal Guidance on Population Exposure)
BEIR	Biological Effects of Ionizing Radiation
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFC	Chloro Fluoro Carbons
CIRRPC	Committee for Interagency Radiation Research Policy and Coordination
CIS	Commonwealth of Independent States
Ci	Curie ($3.7x10^{10}$ disintegrations per second)
CSTP	Council on Science and Technology Policy
DNA	DeoxyriboNucleic Acid (The genetic material in higher organisms)
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
EC	Executive Committee of the SAB
EFC	Environmental Futures Committee (a Ad Hoc Subcommittee of the U.S. EPA/SAB/Executive Committee)
EIA	Energy Information Administration (U.S. DOE)
ELF	Extremely Low Frequency (30 -300 Hz)
EMAP	Environmental Monitoring and Assessment Program
EMF	Electro Magnetic Field
EMR	Electromagnetic Radiation
EPA	U.S. Environmental Protection Agency (Also known as U.S. EPA, or "the Agency")
EPRI	Electric Power Research Institute
ETS	Environmental Tobacco Smoke
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FY	Fiscal Year
GDP	Gross Domestic Product
GNP	Gross National Product
HVAC	Heating, Ventilating and Air Conditioning
Hz	Hertz (a unit of frequency of a periodic process equal to one cycle per second)
ICRP	International Commission on Radiation Protection
INTERNET	Inter-Connection of Networks
L	Liter
LET	Linear Energy Transfer
LTR	Letter Report (Refers to SAB Letter Reports)
MagLev	Magnetic Levitation
MRI	Magnetic Resonance Imaging

APPENDIX E - GLOSSARY OF TERMS AND ACRONYMS: CONTINUED:

NANOBOTS	Nanometer-Scale Self-Actuated Robots
NARM	Naturally-Occurring or Accelerator-Produced Radioactive Materials
NEPA	National Environmental Policy Act
NIEHS	National Institute of Environmental Health Sciences
NOAA	National Oceanic and Atmospheric Administration
NORM	Naturally-Occurring Radioactive Material
NRC	U.S. Nuclear Regulatory Commission
NSF	National Science Foundation
NIMBY	Not in My Back Yard
OPEC	Organization of Petroleum Exporting Countries
OPPE	Office of Policy, Planning and Evaluation (U.S. EPA)
ORD	Office of Research and Development (U.S. EPA)
OTA	U.S. Congressional Office of Technology Assessment
p	Pico (one trillionith, $1x10^{-12}$)
RAC	Radiation Advisory Committee (U.S. EPA/SAB/RAC)
REFS	Radiation Environmental Futures Subcommittee of the RAC (U.S. EPA/SAB/RAC/REFS)
RF	Radio Frequency Radiation (an electromagnetic wave frequency intermediate between audio and infrared frequencies used in radio and television transmission)
R & D	Research and Development
RCRA	Resource Conservation and Recovery Act
RIA	Regulatory Impact Analysis
SAB	Science Advisory Board (U.S. EPA)
SARA	Superfund Amendments and Reauthorization Act
TSCA	Toxic Substances Control Act
U.S.	United States
U.S.A.	United States of America
U.S.S.R.	United Soviet Socialist Republic
UV	Ultra-Violet (radiation)
UVR	Ultra-Violet Radiation (a wavelength shorter than visible light and longer than those of X rays)
vs	Versus
W	Watt (a unit of power equal to one joule per second)
WIPP	Waste Isolation Pilot Plant

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