Summary of Findings and Conclusions

This report is an interim summary of crosscutting findings arising from an analysis of the R&D efforts of four major industrialized nations (the United States, Japan, Germany and the Netherlands) and of the European Union. The second phase of this project will continue to refine these five case studies and will expand to include case studies of Canada, France, Italy, Switzerland, and the United Kingdom. This ongoing research effort seeks to assess the adequacy of the industrialized world's energy R&D programs, particularly in the light of the significant energy technology challenges that global climate change could soon pose. Since the nine countries mentioned above collectively account for over 95% of the world's energy R&D investments, their current commitments to energy R&D will determine in large part the range of technology options at the world's disposal in upcoming decades.

We find:

- Overall national R&D efforts (i.e., public and private sector research in all fields of inquiry) have grown strongly over the past decade. But the fraction of national R&D activities sponsored by national governments has declined steadily. Moreover, publicly sponsored R&D is not keeping pace with economic growth over the past decade, i.e., public sector R&D as a percent of gross domestic product is in decline. In many countries, the absolute level of public support for R&D in the 1990s has exhibited relatively slow growth, compared either with recent private sector investments or the public investments of previous decades.
- Unlike overall national R&D, national energy R&D efforts have not experienced significant growth over the past decade. In the nations surveyed, the dominant trend has been toward significant reductions in publicly funded energy R&D. Energy R&D as a percent of total public sector R&D and as a percent of gross domestic product has also been in decline in all of these nations. Where data are available, it is evident that private sector energy R&D investment is also in decline. The absence of a perceived energy crisis, the deregulation of the energy industries, and pressures to reduce governmental spending appear to be significant explanatory variables for this disinvestment in energy R&D. These same drivers are likely to continue to depress energy R&D investment levels for the foreseeable future.
- The performance of energy R&D is highly concentrated in a very small number of countries. The top 9 nations account for 95% of the industrialized world's publicly supported energy R&D. The US and Japan, the countries with the largest public energy programs, both fund approximately the same level of energy R&D, slightly more than $2 billion in 1996. No other country funds even half the level of these two nations. In fact, Japan's fission energy R&D budget alone is larger than the sum of the Netherlands, EU, and German total energy R&D budgets.
- The beginning of a potentially significant transition in fossil energy research programs is now discernible, wherein programs are seeking to develop zero carbon dioxide emitting fossil fuel technologies. Key technologies that are beginning to receive budget preference include methods to "decarbonize" fossil fuels, fuel cells, and methods to dispose of or sequester carbon dioxide wastes. The total amount of resources committed to these technology areas is currently small, however.
- The concept of "fossil fuels" is being expanded by research designed to assess the viability of developing methane hydrate and coal bed methane reservoirs. The emergence of these advanced fossil programs, in conjunction with programs to develop carbon sequestration technologies, signals the possible continued viability of potentially abundant and cheap fossil

fuels for the next century, even in the face of greenhouse gas emissions restrictions. Of the countries surveyed, Japan is the largest supporter of these non-conventional fossil energy research efforts.

- Among the countries studied, renewable energy R&D programs have become more concentrated in the area of solar photovoltaics. Perhaps surprisingly, renewable energy R&D programs have had relatively stagnant budgets throughout the past decade even though the nations that fund this research have adopted energy policies advocating increased use of renewable energy as a means of reducing both carbon dioxide emissions, local air pollution, and dependence on foreign energy sources.
- Energy efficiency R&D programs have experienced the most consistent budget growth of all technology areas. Industrial energy efficiency programs appear to be receiving preference for R&D funds over buildings or transportation related energy efficiency programs. This preference for industrial energy efficiency R&D reflects both a desire to improve international economic competitiveness and environmental quality.
- The future of nuclear energy and related technologies is in a period of great uncertainty in many countries. Many nations are shifting an ever-larger share of their fission energy R&D programs away from the development of new reactors and components to focus on research activities concerned with the nuclear fuel cycle, waste disposal, and reactor decommissioning. Major international fusion technology R&D programs, particularly the International Thermonuclear Experimental Reactor (ITER), are also going through a period of turbulence, as sponsoring nations such as the U.S. reassess their commitments to this technology area.

We conclude:

- Budgetary pressures, energy deregulation, and the perceived lack of an "energy crisis" are likely to suppress government energy R&D budgets for the foreseeable future. In the absence of major shifts in the world energy outlook, government energy R&D investments appear unlikely to be restructured and expanded in a way that is optimal for developing the technologies needed in the middle to long term to avoid global climate change.
- The current turmoil in private sector energy R&D programs brought about in large measure by the push to deregulate energy industries will continue to place downward pressure on private sector investments in longer term energy R&D.
- Public energy R&D is evolving in important ways from the perspective of climate change. Research programs aimed at the development of fuel cells, hydrogen infrastructure technologies, and carbon capture and disposal technologies represent a small but growing percentage of government energy R&D investment.
- There is an increasing gap between governments' aspirations to curb carbon dioxide emissions, as expressed in policy statements and their funding commitments to energy R&D. Many nations appear to have adopted a *de facto* policy of relying on the further deployment of existing energy efficiency technologies, fuel switching and emissions trading as the primary means of reducing carbon dioxide emissions.