Research, Development, and Demonstration 10

Research and development (R&D) on environmentally preferable technologies is important not only for solving environmental problems, but also for ensuring that U.S. environmental firms maintain competitive positions in world markets. R&D directed at lowering the costs of meeting and in some cases going beyond regulatory requirements can help both the environmental goods and service (EGS) and regulated sectors. But commercial benefits from much of the $1.8 billion the U.S. Government spends each year on R&D for the energy and environmental technologies covered in this report are limited.

Several factors are key. First, several agencies have mission-oriented programs, but there has been little strategic direction and coordination to Federal R&D efforts. Funding agencies generally have not worked closely with each other to identify critical environmental problems and common technology priorities, although the Clinton administration is making efforts in this direction.

Second, except for various cooperative R&D agreements (CRADAs) and a number of R&D and demonstration programs for cleaner energy technologies, individual programs pay scant attention to commercial applications. For example, a significant share of Federal environmental technology funds (over $650 million in fiscal year (FY) 1993) support R&D related to hazardous waste remediation technologies for Federal site cleanup. While these efforts could produce commercially relevant remediation technologies, their export potential is likely to be modest relative to other areas (see ch. 4 and ch. 5). Comparatively little R&D goes for pollution control, cleaner production, and recycling, which are of greater relevance to regulated industries and offer greater export potential. If recent legislation is vigorously implemented and new administration initiatives are pursued, this picture could change toward more government-wide coordination and commercial orientation; several pending bills before Congress aim in this direction (ch. 2).

Third, while CRADAs and other industry-government partnerships (e.g., SEMATECH) are becoming more prominent, programs operated principally by government agencies often have had only limited dialogue with industry. When industry is involved, it is often through single companies rather than through broad-based industry consortia. In such cases, government has not effectively leveraged and mobilized industry-wide resources, experience, and commitment to develop and deploy the most important environmental technologies for industrial application.

The picture is somewhat different in other nations. Government support for environmental technology R&D in Europe and Japan tends to center in agencies with industrial policy missions, such as Japan's Ministry for International Trade and Industry and Germanys Ministry of Research and Technology. In some cases, particularly in Japan, these missions are carried out by less bureaucratic quasi-public organizations, with industry involvement and governance, that usually focus on subjects and technologies with domestic and international commercial promise. R&D is also carried out in a manner designed to facilitate usefulness to industry; for example, Japan's New Energy and Industrial Technology Development Organization (NEDO) borrows industry researchers, who then return to their companies when the work is done, Moreover, industry-government cooperation in developing environmental technology is common, with emphasis on increasing communication of innovations among firms, including the use of industry research consortia. For example, Japanese steel producers formed the Steel Industry Foundation for the Advancement of Environmental Conservation Technology in 1973 to conduct joint R&D on pollution control and energy conservation technology in the steel industry. The Dutch and the Danish governments have focused their environmental technology policies on increasing successful cooperation between user companies, suppliers, developers, and consultants.[1] Such collaborative approaches appear promising in advancing technologies suited to industry environmental needs.[2]

In addition, at least one country, the Netherlands, has begun to think strategically about long-term technology development which supports principles of sustainable development. Its Sustainable Technology Development Program, funded at $2.9 million a year by five agencies, attempts to boost the capacity of Dutch institutions (industry, government, academia) to integrate environmental goals into technology development.[3] Througha‘‘backcasting process where they look at the demands which technology must meet in the future (e.g., low levels of resource use), the program attempts to identify and achieve consensus over sustainable technology goals in a variety of areas, including transportation, energy production, and manufacturing,

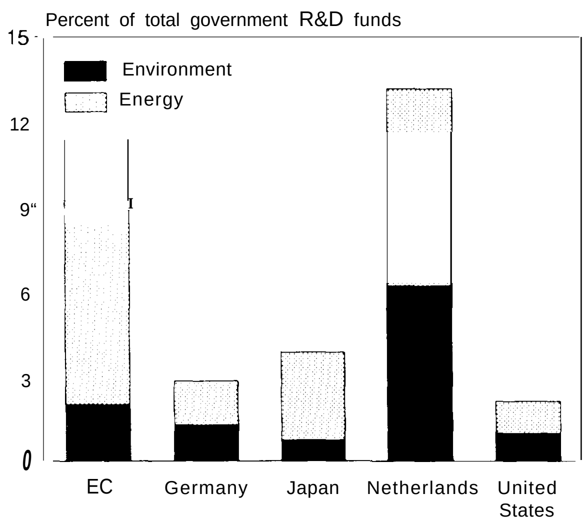
[1] Johan W. Scot, "Constructive Technology Assessment and Technology Dynamics: The Case of Clean Technologies,'' *Science, Technology and Human Values* vol. *17, No.* 1, winter 1992, pp. 36-56.

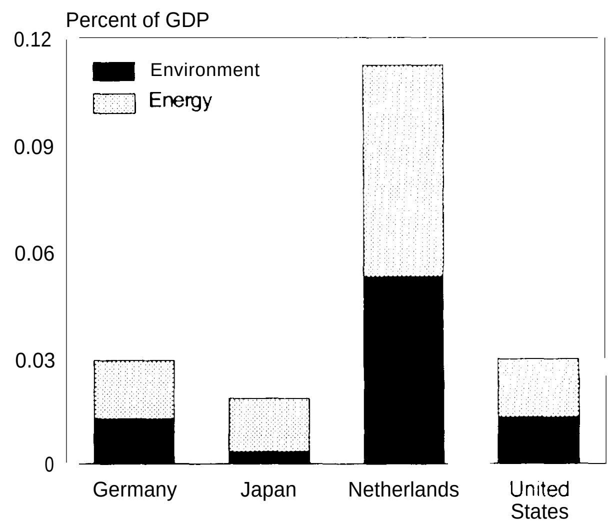
2 For example, the Canadian Government operated its Cooperative Pollution Abatement Research program in the 1970s to develop pollution control and prevention technologies for the pulp and paper industry. Development and guidance of the program were the responsibility of a joint industry-government committee, including representatives from Federal departments, pulp and paper companies, and the industry trade association and industry research organization, (Although many view the program as a success, it was eliminated in 1979 due to lack of government funds.)

3 J.L.A. Jansen and P.J. Vergragt, "Sustainable Development: A Challenge to Technology" (Leidschendam, Netherlands: Ministry of Housing, Physical PIarming and Environment, Directorate-General for Environmental Protection June 10, 1992).

Table 10-1—National Government Funding For Selected Categories of Environmental Technology R&D in Most Recent Fiscal Year ($ million)[a]

United States	
Clean coal	$375
Renewable energy	230
Energy efficiency	365
Remediation	650
End-of-pipe and prevention	150
Total	1,770
Japan	
Clean coal	85
Renewable energy	175
Energy efficiency	310
Environment	130
Total	700
European Community	
Energy	255
Environment	55
Total	310
Germany	
Clean coal	47
Renewables and efficiency	250
Environment	230
Total	527
The Netherlands	
Energy	198
Environment	175
Total	373





a Estimates are for environmental technology categories emphasized in this report, but the estimates may not include all national government expenditures. State and local and private spending are not included. Estimates cover environmentally preferable energy (e.g. renewables, energy efficiency, and dean coal); end-of-pipe technologies; pollution prevention; and remediation. Spending on science and technology related to environmental science and modelling, nuclear waste handling, agriculture, and manufacturing not primarily related to environmental aims were not included. Most U.S. and Japanese expenditures are for FY 1993, most spending by other nations is for FY 1992.

SOURCE: See Tables 10-3,4,5,6 and 7. GDP figures and exchange rates are from International Monetary Fund, *International Financial Statistics*, selected issues.

There are some broad similarities in national support for environmental technology R&D (see table 10-1). The majority of funding in all countries examined goes for environmentally preferable energy technologies (e.g., renewable, efficiency, clean coal). With the exception of the Netherlands, much less is spent on end-of-pipe or cleaner manufacturing technology development. In addition, in many nations, including Japan and the United States, energy agencies or programs have major responsibility for environmental technology development.

This chapter examines environmental technology R&D by the United States and some major trading partners.

UNITED STATES

Fragmentation makes it difficult to quantify Federal support for environmental technology R&D. Not only is it difficult to identify all of the programs, but there is no standard definition of ''environmental. OTA estimates that the major R&D programs pertinent to environmental technologies covered in this report amount to approximately $1.8 billion, divided among energy ($1 billion), remediation ($650 million), pollution prevention ($70 million), and end-of-pipe technology ($80 million). Other studies offering higher estimates have defined environmental technology more broadly, to include spending on items such as mass transit, nuclear waste transportation and storage technology, chemical toxicity assessment, and climate modeling R&D. Also, agricultural, forestry, fisheries, biodiversity, and land use related technologies, which are not examined in this assessment, may be included in some definitions. For example, a 1992 Congressional Research Service (CRS) study identified $2.2 to $2.5 billion in FY 1992 Federal appropriations for environmental technology development.[4] The Carnegie Commission on Science, Technology, and Government estimated that Federal spending for environmental R&D was $5 billion in FY 1992, but much of that is for basic science and global monitoring technologies for "Mission to Planet Earth" rather than for technologies that prevent, control, or repair environmental damage.[5]

Most Federal support for R&D on environmental technologies is devoted to cleaner energy technologies and hazardous waste remediation technologies. The latter technology is supported in large part to serve agencies' mission requirements of cleaning up contaminated sites. With some exceptions (e.g., clean coal and renewable energy R&D, programs often shared with industry), export promotion potential has not been a major consideration in setting R&D priorities.[6] Some technologies with stronger export potential now, particularly cleaner production processes and end-of-pipe pollution control technologies, receive relatively little Federal R&D support.[7] Cleaner energy and production technologies may come to have an advantage in international trade since they almost always provide a lower cost means of environmental protection than end-of-pipe or remedial clean up.

There has been little coordination of Federal environmental technology R&D. So far, EPA and other agencies that support environmental and energy technology development have not developed the necessary dialogue on the interplay between environmental problems, future environmental regulations, and needed technologies. Cooperation is critical, since EPA's regulatory process will dictate not only the technological needs of many industries, but also the approaches that might be taken.

This situation may be changing. With the end of the Cold War and the reorientation of the Federal science and technology system toward civilian technology, the Federal Government may have opportunities to integrate environmental technology concerns into new civilian technology

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[4] **John D. Moteff (coordinator),** U.S. **Library of Congress, Congressional Research Service,** *The Current State of Federal R&D in Environmental Technologies, 92-675* -SPR, **Aug. 25,** 1992.

[5] **Mission to Planet Earth consists of programs and projects to better understand the biological, chemical, and physical processes that influence and control the Earth's environment. Monitoring, modeling, and analytic technologies are key areas of technical development. Carnegie Commission on Science, Technology, and** Government, *Environmental Research and Development: Strengthening the Federal Infrastructure (New* York, **NY: Carnegie** Commission, **December 1982), pp. 35-37, 115-129.**

[6] **See Trade Promotion Coordinating Committee,** *Towarda National Export Strategy,* **Report to the United States Congress, Sept. 30, 1993, p. 43.**

[7] **Office of Conservation and Renewable Energy, Office of Industrial Technologies,** *Federal Agencies Active in Waste Minimization and Pollution Prevention (Washington* **DC: U.S. Department of Energy, July 31, 1992); also The Massachusetts Toxics Use Reduction Institute,** *Toxics Use Reduction Research Directory Owen, MA:* **University of Massachusetts Lowell, 1992).**

initiatives. Recent and pending legislation call for more commercial orientation of federally funded environmental technology R&D (ch. 2), although funding and implementation are uncertain.

Both the Bush and Clinton administrations have taken steps to coordinate Federal R&D. At the end of the Bush administration, a Subcommittee on Environmental Technology was established within the Committee on Earth and Environmental Sciences of the Federal Coordinating Council on Science, Engineering, and Technology (FCCSET), an interagency group chaired by the President's science adviser.[8] The Subcommittee is taking inventory of Federal environmental technology R&D, and considering how it might be better coordinated and ranked.[9] Pursuant to President Clinton's 1993 Earth Day address, the Commerce Department established an interagency Working Group on Environmental Technology and Trade, chaired by the Chief Scientist in DOC's National Oceanographic and Atmospheric Administration (NOAA). The working group, whose report was scheduled for release at press time, addresses environmental technology development, diffusion, and exports. It is working closely with the Environmental Trade Working Group of the interagency Trade Promotion Coordinating Committee (see ch. 6). FCCSET's Manufacturing Committee is also examining the place of environmental factors in federally supported manufacturing R&D.

The administration also established an Environmental Technology Initiative led by EPA to foster links with the Department of Agriculture, DOC, DOE, National Science Foundation (NSF), National Aeronautics and Space Administration (NASA), and other agencies. The Initiative seeks to promote an interagency approach to identify environmental problems and work toward potential technical solutions.[10] EPA is still in early stages of implementing the initiative. It remains to be seen whether EPA will develop a systematic and strategic process, involving other Federal agencies and industry, to best target these funds. Industry involvement is critical for identifying the most relevant technological needs and opportunities for a specific industry, particularly cleaner production technologies.

The FCCSET efforts and the export report are being advanced by a high-level interagency working group, formed by the Office of Science and Technology Policy (OSTP) and other White House offices. That group is working "with the research agencies to ensure that all technology programs, not just those focused on environmental technologies, are considering the environmental applications of the technologies they are developing."[11] OSTP is developing an environmental technology strategy to guide near-term and long-term Federal policies. Whether these coordinating bodies can bring coherence to Federal policy for environmental technology and trade, and integrate regulatory and technology issues into the policy process, is still an open question.[12]

[8] "Charter: Subcommittee on Environment Technology, Committee on Earth and Environmental Sciences, Federal Coordinating Council on Science, Engineering, and Technology," signed by D. Allan Bromley, Chairman, Federal Coordinating Council for Science, Engineering, and Technology, Jan. 4, 1993. The Subcommittee includes, among other agencies, NSF, EPA, DOE, NASA, the U.S. Department of Agriculture (USDA), and the Department of Health and Human Services (HHS).

[9] John H. Gibbons, *Assistant to the President* for Science and Technology, Director, Office of Science and Technology Policy, *testimony* at hearings before the House Committee on Science, Space, and Technology, Subcommittee on Technology, Environment, and Aviation, July 15, 1993, p. 8.

[10] Ibid.

[11] Ibid.

[12] The President's Council on Sustainable Development might also address how to prioritize Federal environmental technology efforts.

Public-Private and Private-Private Cooperation

The usefulness of Federal environmental technology R&D to industry depends to a large degree on the nature and extent of Federal/industry cooperation. Such cooperation is largely limited to some joint technology development at Federal labs and some direct funding of individual firms.

DIRECT FUNDING OF INDIVIDUAL PROJECTS

One common model for Federal-industry interaction is for the Government to directly fund specific industry projects proposed in response to a Federal solicitation. In many cases, industry must finance part of the research. A number of programs follow this model. The National Institute of Standards and Technology's (NIST) Advanced Technology Program (ATP) makes project specific grants for half of the cost of R&D. In ATP's first 3 years, NIST awarded $187 million in grants; 7 percent was for "energy and environment."[13] Many DOE programs, including the Clean Coal Technology Program, the Office of Industrial Technology's industrial waste minimization and energy conservation programs, the Photovoltaic Manufacturing Technology Program, and several other renewable energy R&D programs, also fund specific industry projects.

Such efforts can provide companies with funds to conduct research on specific projects that might be too risky to undertake alone. The programs fund promising projects—whether proposed by one firm or many. However, research by one firm does not necessarily diffuse through the industry. This is a drawback for many environmental technologies, for which wide industrial participation is often a key to effective diffusion. Moreover, funding of individual projects may not be enough to catalyze broader action on a longer term research agenda.

FEDERAL LABORATORY TECHNOLOGY COOPERATION AND TRANSFER

Since 1980, Congress has passed laws to promote the transfer of technology from Federal laboratories to industry.[14] Mechanisms include licensing of patents, industry use of laboratory facilities, researcher exchange programs, research for hire by companies, and research collaboration between a laboratory and industry, either informally or through work agreements.

One kind of formal agreement is the CRADA.[15] CRADAs have one major restriction: while the partner may contribute both money and in-kind resources (personnel, facilities, etc.), the lab may contribute only in-kind resources. Because industry puts up resources, it is likely to support only technology with commercial promise. This cooperative arrangement enables industry to tackle risky, long-term, or expensive projects that it might not be able to afford on its own. This leveraging of a fro's R&D resources is multiplied when the labs work with an industry consortium rather than just one firm.

It is difficult to accurately determine how much environmental R&D, including CRADAs, the laboratories do. One survey of the labs reported

13 "Technologies Funded by ATP: As a percent of $187 M Awarded: ATP Competitions 90-01, 91-01, 92-01," chart in presentation by George Uriano, NIST, entitled "The ATP: Current Status and Strategic Plan for Expansion," printed in Institute of Electrical and Electronics Engineers, Inc., United States Activities, "1993 National Forum: Conversion Modernization% and Restructuring of U.S. Resources: Goals, Strategies and Incentives: Proceedingraphs [sic]: June 29-30, 1993."

14 See U.S. Congress, Office of Technology Assessment *Defense Conversion: Redirecting R&D,* OTA-ITE-552 (Washington, DC: U.S. Government Printing Office, May 1993), pp. 97-99; U.S. Congress, Office of Technology Assessment, *Making Things Better: Competing in Manufacturing,* OTA-ITE-443 (Washington, DC: U.S. Government Printing Office, February 1990), pp. 184, 193.

15 Congress explicitly permitted CRADAs in 1986 for government-operated Federal laboratories and in 1989 for contractor-operated Federal laboratories (e.g., DOE's national labs). See Office of Technology Assessment, *Defense Conversion: Redirecting R&D,* op. cit., footnote 14.

environmental technology CRADAs and funding for some labs, but not others.[16] For example, the Army's Edgewood Research, Development and Engineering Center reported spending $1.8 million and signing four environmental technology R&D CRADAs in 1992. EPA reported having 50 active CRADAs in FY 1993, with over $5 million of total Federal funding (although $3.1 million is for a CRADA with Exxon for oil spill cleanup research).[17] Some of these CRADAs may be for technologies not covered in this report, such as climate modeling.

OTA found that of the 382 CRADAs signed by DOE through April 1993, with Federal funding totaling $321 million, 18 ($6 million) were in the areas of environmental restoration and waste management, and 68 ($24 million) were in the areas of energy efficiency and renewable energy (some of those, such as for superconductivity and bulk power transmission technologies, are beyond the scope of environmental technologies considered in this report).[18] DOE's Office of Industrial Technology also relies on the DOE laboratories to conduct joint research with industry on some clean technology and energy conservation technologies.

While CRADAs provide an opportunity to link the government's expertise in environmental technology with industry-they have proven to be cumbersome to negotiate, particularly at DOE's large weapons laboratories (Los Alamos, Sandia, and Lawrence Livermore).[19]

GOVERNMENT SUPPORT OF INDUSTRY CONSORTIA

Perhaps the model that brings industry and government in the closest partnership is government support of industry consortia. A well-known example is SEMATECH, a government-industry partnership to develop semiconductor manufacturing technology. Its industry members, including semiconductor manufacturers, contribute $100 million a year, matched by DOD's Advanced Research Projects Agency (ARPA), formerly the Defense Advanced Research Projects Agency (DARPA). While ARPA exercises some supervision over SEMATECH's operations, industry members are largely free to choose how to spend SEMATECH's budget. The conference report on SEMATECH's FY 1993 funding authorization states that at least $10 million of the $100 million in government funds ''should be utilized for development of pollution-preventing, environmentally safe microchip manufacturing processes.''[20] SEMATECH believes that more than $20 million of its calendar year 1992 R&D spending met this requirement. This figure takes into account both projects with environment as the sole or principal motivation (e.g., alternatives to the use of CFCs), and an appropriate share of funding for projects with environment as a subordinate motivation (e.g., efficiency improvements that reduce the waste generated).

The National Center for Manufacturing Sciences (NCMS), funded by industry and the Federal Government, established its environmentally conscious manufacturing program in 1991

[16] "Cooperative Technology RD&D Report,' Federal Technologies Profile Series, Profile 02: Federal Environmental Technologies and R&D Programs, issues January 1993, vol. 3, No. 1 through June/July 1993, vol. 3, No. 6.

[17] Discussion with Larry Fradkin, Federal Technology Transfer Act Coordinator, EPA, Office of Research and Development, Office of Science, Planning and Regulatory Evaluation, October 1993.

[18] Office of Technology Assessment, *Defense Conversion: Redirecting R&D*, op. cit., footnote 14, pp. 103-105 (entry for funding source "ER" in tables 4-1 and 4-2). The tables mistakenly report these amounts as $321,000 and $6,000. However, the amounts represented are millions, not thousands, as indicated by the text on p. 103.

[19] Ibid; also Don Walkovicz, Executive Director, U.S. CAR, personal communication, June 18, 1993.

[20] National Defense Authorization Act for Fiscal Year 1993 [Public Law 102-484], Conference Report to Accompany H.R. 5006, House Report 102-956, p 633.

Table 10-2—R&D Consortia Formed by the United States Council for Automotive Research*

1. Automotive Composites Consortium
2. Auto OIl/Air Quality Improvement Research Program
3. United States Advanced Battery Consortium
4. CAD/CAM Partnership
5. High Speed Serial Data Communications Research and Development Partnership
6. Environmental Science Research Consortium
7. Vehicle Recycling Partnership
8. Low Emissions Technologies Research and Development Partnership
9. U.S. Automotive Manufacturers Occupant Safety Research Partnership
10. Low Emissions Paint Systems Consortium
11. Automotive Materials Partnership
12. Supercomputer Automotive Applications Partnership

•Items listed in **bold** type are concerned entirely or in substantial part with environmental technology

SOURCE: United States Council for Automotive Research.

and developed a list of clean technology projects where increased collaboration and sharing would produce significant benefits. NCMS has funded approximately 35 projects to date, about half on ozone-depleting substitutes and solvent free alternative processes, and others on technologies including sensor development for better process control, plating emissions controls, reduced lead use in electronics manufacturing, and waste remediation. NCMS also established a program to help companies build environmental concerns into the design process.

The United States Council for Automotive Research (USCAR), an umbrella organization serving the big three U.S. automobile manufacturers (General Motors, Ford, and Chrysler), was formed in June 1992 to promote U.S. automobile manufacturing competitiveness, to monitor and coordinate cooperative R&D efforts, and to recommend further areas for cooperation.[21] Twelve R&D consortia are under this umbrella (see table 10-2).

For example, the Low Emissions Paint Systems Consortium will conduct research on alternatives to reduce volatile organic compound (VOC) emissions, including electrocoating, powder-based primers, surface coats, clear-coat paint systems, and water-based base coats (see ch. 7). Some consortia have Federal or State participation and funding, The Environmental Research Consortium, for example, cooperated with the Michigan Department of State's Bureau of Automotive Regulations and U.S. EPA to evaluate the effectiveness of remote vehicle emissions sensing devices and to measure the impact of routine maintenance on exhaust emissions.

The auto consortium with the most significant government funding is the Advanced Battery Consortium (ABC). Through ABC, industry funds are matched equally by DOE money. Total funding (industry plus DOE) for the ABC is $264 million. DOE's share is spent primarily through research contracts to participating companies; also, five DOE laboratories have signed a total of eight CRADAs with ABC.[22]

Although USCAR has not surveyed foreign country participation in its consortia, it is reportedly not very large.[23] At times, however, participation of a foreign firm with a key technology is deemed necessary. For example, the French fir-m Saft Batterie is participating in ABC because it holds the rights to a technology (lithium polymer battery) that is necessary for the progress of the project.

The Clinton administration recently announced a partnership with the Big Three automakers (through USCAR) aimed at strengthening U.S. competitiveness, in part by developing technologies for a new generation of vehicles up to three

21 In part, information about U.S. CAR comes from Don Walkovicz, Executive Director, USCAR, personal communication, June 18, 1993.

22 In addition, Calstart, a non-profit consortium designed to foster the development of an electric vehicle industry in California, received $4 million in Federal funds under the 1991 Intermodal Surface Transportation Efficiency Act.

23 Don Walkovicz, op. cit., footnote 21.

times more fuel efficient than today's car. The proposal relies heavily on the capabilities of the national laboratories to conduct the research in partnership with the automakers, and will be managed by the Undersecretary of Commerce for Technology.

Although not specifically intended to do so, coordination among U.S. auto manufacturers through US CAR has facilitated cooperation with Federal entities such as DOE's national laboratories. It is easier for those laboratories to work with an industry consortium than individual fins, because issues such as fairness and intellectual property are easier to address. (U.S. subsidiaries of foreign auto companies are not members of the consortium.) USCAR estimates that the number of CRADAs in which its consortia participate lies somewhere in the teens.[24]

Several other industry technology organizations cooperate with the government on R&D and demonstration projects.[25] The Electric Power and Research Institute (EPRI) and Gas Research Institute (GRI), which are supported by member utility companies but receive some Federal funds, are well-known examples. EPRI's 1993 R&D and demonstration plan includes $56 million for management of air and water quality and utility wastes; $30.4 million for improved energy-use technologies (including electric vehicles); and over $36 million for environmentally significant nonnuclear energy supply and storage technologies.[26] EPRI also supports research germane to manufacturing industry, in part to develop electrotechnologies. These include Brayton-cycle heat pumps to recover solvents in air, reverse osmosis for reusing water in the food products industry, and thermal reclamation of foundry sand.[27] GRI budgeted $39.3 million for environmental R&D in its 1993 plan, and much of the $64.9 million allocated for gas-use technology R&D might also be environmentally beneficial.[28] The American Water Works Association (AWWA), an organization of U.S. and Canadian water supply utilities, funded about $6 million of R&D related to drinking water quality and water conservation in 1993.[29] The Water Environment Research Foundation of Water Environmental Federation (WEF) funded approximately $2.6 million in research in 1993.[30]

EPRI, GRI, AWWA, and WEF all conduct or fund R&D jointly with Federal and State agencies, member firms, and each other in order to leverage their resources. As utility associations (except for WEF, which also includes manufacturers and services providers), these organizations may be better positioned to conduct cooperative R&D than some other kinds of industry associations. This is because utility companies do not usually compete directly against one another for business. In other industries, disputes over sharing technical data and patent rights could be more of an issue. However, such disputes may be less

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24 Ibid.

25 Individual utilities also conduct environmental R&D relevant to their own operations and to help their customers meeenvironmental requirements. For example, Southern Co., an electric utility holding company, has funded the development of several electro-technologies important to industrial customers.

26 Electric power Research Institute, Research, *Development& Delivery Plan 1993-1997* (Palo Alto, CA: Electric Power Research Institute, January 1993), p. 21.

27 John Svobada, *Foundry Technology—An Overview* (Pittsburgh, PA: The EPRI Center for Materials Production, Carnegie Mellon Research Institute, January 1991).

28 Gas Research Institute, 1993-1997 *Research & Development Plan and 1993 Research & Development Program (Chicago,* IL: Gas Research Institute, April 1992), p. 40.

29 James F. Manwaring, Executive Director, American Water Works Association Research Foundation, personal communication, Sept. 21, 1993.

30 Water Environment Research Foundation, *1992-1996 Research & Development Plan* (Alexandria, VA: Water Environment Research Foundation, 1992), p. 13.

prominent for environmental technologies, particularly add-on technologies, than for non-environmental product or process technologies closer to core areas of business.

Some consortia receive little or no government money, but could possibly serve as institutional vehicles for government to support environmental technology. For example, the Center for Waste Reduction Technologies of the American Institute of Chemical Engineering, which includes most of the leading U.S. chemical manufacturers, spends over $1 million a year principally to support university-based and industrial R&D on pollution prevention related to the chemical industry. Research projects include ultrafiltration, mass exchange networks, VOC emissions recovery, and total water reuse. It recently received a $25,000 grant from EPA to promote the development and dissemination of innovative pollution prevention technologies.[31] The Center also promotes transfer of cleaner technology to industry and supports educational and training efforts in pollution prevention.

Through the Petroleum Environmental Research Forum (PERF), 24 petroleum companies have privately funded a small number of environmental research projects, many addressing pollution prevention.[32] Member companies can fund specific projects. PERF projects so far have not involved government funding.

Channeling government research funds through industry consortia and associations has several advantages. First, industry members are more likely to know more about which of the many technical options for addressing environmental matters have the most promise for commercialization. Second, industry consortia can speed deployment of new technologies, due to strong internal communication links. Third, consortia can help avoid duplication in research, thus conserving funds. Fourth, working with a broad coalition, the government avoids favoring individual fins. Finally, the consortium can own the intellectual property developed on terms that give all members access. This lessens the possibility that the owner will not commercialize it or license it to others.

Specific Agency Programs

DEPARTMENT OF ENERGY

DOE supports more than $1.3 billion in R&D pertinent to environmental technologies covered in this report; most focus on energy and remediation. See table 10-3 for a list of selected U.S. Government environmental technology programs.

Remediation and Waste Management—DOE's Environmental Restoration and Waste Management Technology Development program supports R&D to cleanup environmental contamination from DOE facilities such as those for manufacture of nuclear weapons, and to manage radioactive and other hazardous waste generated at such facilities.[33] Funded at $362 million in FY 1993, this is one of DOE's largest environmental technology R&D programs. Almost half the funding goes to demonstration, testing, and evaluation of new technologies. Developing more cost effective ways to clean up contaminated Federal sites is likely to be a key Federal environmental priority for many years to come-given the tens of billions of dollars expected to be spent on this Federal responsibility. While these technologies have potential for use in other cleanup efforts in the United States, foreign efforts for cleanup are now much more limited than here. Even though the need for cleanup in areas such as Central and Eastern Europe and the former Soviet Union is high, it is unclear the amount of effort that will be devoted to this. Similarly, many developing nations are placing a higher priority on prevention

31 At one time it was slated to receive close to $500,000, but EPA reduced the ~@ available.

32 In 1992, 18 studies had been completed or were in progress, and 19 others were expected to begin shortly.

33 DOE has 3,700 hazardous, radioactive, and mixed waste release sites, although many are quite small.

Table 10-3-Selected Federal Programs for the Development of Environmental Technologies

Program	Public Funding ($ millions)	Period
Department of Energy		
Clean Coal Demonstration Program	225	1994
Coal R&D pertinent to cleaner coal[a]	142	1994
Solar and Renewable Energies	233	1993
Environmental Restoration Technology Development Program	362	1993
Energy Efficiency—supply and use (includes waste reduction)	316[b]	1993
Fuel Cells	51[c]	1993
National Industrial, Competitiveness through Efficiency Environment, Energy and Economics (NICE3)	2.5[d]	1993
Department of Defense		
Defense Environmental Restoration Program (DERP) Technology Program	26	1993
R&D in Environmental Compliance	129	1993
Strategic Environment R&D Program (SERDP)	170	1993
SEMATECH (supervised by ARPA)--environmental component	10[e]	1993
National Defense Center for Environmental Excellence	5[f]	1992
Environmental Protection Agency[g]		
Superfund Innovative Technology Evaluation Program (SITE)	17	1993
Environmental cleanup (excluding SITE)	19	1993
Global change and air pollution	24	1993
Pollution prevention, exploratory grants, and special projects	16	1993
Water and waste management	18	1993
Other Departments/Agencies		
Bureau of Mines -Environmental Technology	17	1993
National Science Foundation, environmental technology R&D	25[h]	1992

a Share of coal R&D devoted to cleaner burning, more efficient coal combustion; does not include liquefaction.

b Includes funding on energy efficient building technologies, industrial technologies including waste reduction, transportation technologies.

c Additional funds are spent on gas turbines and advanced engines.

d EPA also contributes a share of funds to the program.

e National Defense Authorization Act for Fiscal Year 1993 [public Law 102-484], Conference Report to Accompany H.R. 5006, House Report 102-956, p. 633. At least $10 million is earmarked for environment; actual spending on environmental R&D could be greater.

f NDCEE is a nonprofit organization separate from DOD.

9 EPA figure only includes activities funded through EPA's R&D account. Of the total listed, $39 million is for technology related regulatory support acitivites. Technology related regulatory support activities separately funded through media offices are not included.

h Estimates derived from U.S. Congress, Congressional Research Service, The *Current State of Federal R&D Environmental* Technology (Washington, DC: CRS, August 25, 1992).

and control of current sources of pollution than on clean-up of contaminated sites. However, there is growing concern in Western Europe and Japan over contaminated sites.

Fossil Fuels--DOE's Clean Coal Technology Program (CCTP), started in FY 1986, aims to develop and commercialize technology to burn coal with increased efficiency and reduced emissions from its use, including through end-of-pipe treatment and prevention. CCTP's funding grew to $415 million by FY 1992, making it DOE's largest program for environmental technology R&D, and one of the largest such Federal programs. The administration requested $250 million for FY 1994; funding beyond that year is uncertain. CCTP is oriented toward commercializing technology for sale at home and abroad. For example, it emphasizes demonstration projects, some aimed at foreign buyers; a subprogram, the Coal and Coal Technology Export Program, emphasizes development of technologies with export potential. In addition, DOE supports clean coal R&D that is not directly linked to CCTP demonstration projects ($141 million was requested in FY 1994). DOE R&D for improved engines and turbines and for fuel cells could allow fossil fuels to be used more cleanly and efficiently.

Renewable Energy—[34] DOE received $233 million for renewable energy R&D in FY 1993 ($327 million was requested for FY 1994).[35] Most of the money went to solar energy technology, including photovoltaics (PV), solar thermal energy, biofuels, and wind energy. The rest went to geothermal energy, electric energy systems and storage, and hydropower. Funding of renewable energy R&D has been quite uneven. It was highest in FY 1979 ($1.24 billion in 1992 dollars) under President Carter, at the height of the oil crisis, much lower under Presidents Reagan and Bush ($92 million in FY 1990 in 1992 dollars), before recently rising again, as environmental concerns increased and the Gulf War heightened energy security concerns.

The National Renewable Energy Research Laboratory in Golden, CO is the major Federal renewable energy laboratory, although other DOE labs, including Sandia and Los Alamos, have long-standing renewable energy research programs. Several R&D programs jointly funded by industry and DOE aim at improving commercial prospects for solar, wind, and geothermal energy. In 1992, the Photovoltaic Manufacturing Technology Program matched $20 million from seven companies with $30 million of DOE funds to improve PV manufacturing processes.[36] The Photovoltaics for Utility Scale Applications (PVUSA) program seeks to promote demand of PV technology by bringing together government, utilities, and suppliers of PV systems and components to field-test systems and identify initial utility markets. A multiyear $75 million program to lower wind energy costs to 5 cents per kilowatt-hour by the mid-1990s awarded its first $5 million (half from industry, half from DOE) to eight companies in late 1991.[37] DOE funds geothermal R&D jointly with industry.

The unevenness in Federal renewable R&D funding has made potential investors wary, Although funding is now increasing, there is no guarantee that it will not be reduced once again.

Energy Efficiency—DOE's Energy Efficiency (EE) (formerly called Conservation) budget for R&D in FY 1993 was $316 million, including $140 million for the transportation sector, $117 million for the industrial sector (including waste

34 Another OTA project, *Renewable Energy Technology: Research, Development, and Commercial Prospects,* due for completion in early 1994, will examine this area extensively.

35 U.S. Department of Energy, *Budget Highlights: FY 1994* (Washington DC: DOE, April 1993), p. 31.

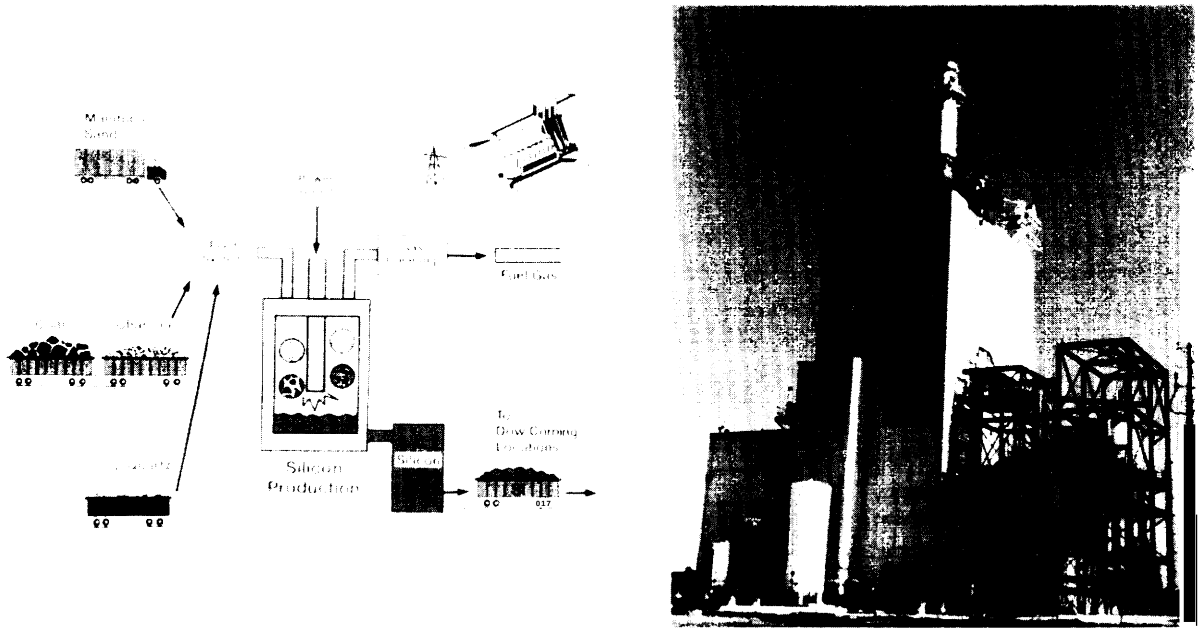
36 Mark Crawford, "Seven Companies Awarded DOE Solar Grants," *Energy Daily,* Apr. 24, 1992, p. 3.

37 "NREL Launches Solar Projects," *Energy Daily, Nov. 4, 1991,* p. 4.

DEPARTMENT
OF
ENERGY

Direct Current, Closed Furnace Silicon Technology

INDUSTRIAL WASTE REDUCTION PROGRAM



U.S. DEPARTMENT OF ENERGY

Silicon production technology demonstration supported by the U.S. Department of Energy, Office of Industrial Technology. OIT supports the development of cleaner and more energy efficient industrial production processes.

minimization, discussed below), $53 million for the buildings sector, and $5 million for the utilities sector.[38] The FY 1994 funding request is $427 million.[39] Improving energy efficiency in these sectors has the potential to make them both less polluting and more competitive.

Waste Minimization—Pollution prevention activities at DOE are directed at reducing wastes at both Federal weapons production sites and in private industry. The latter effort is centered in DOE's Office of Industrial Technologies (OIT). OIT focuses principally on energy conservation in industry, but also addresses waste minimization, particularly in such technological areas as separations, sensors and controls, and materials processing. These programs constitute the major Federal industrial clean technology effort. Moreover, unlike most other Federal and State clean technology efforts targeted at the less-polluting assembly and fabrication industries, much of OIT's effort addresses the more-polluting process industries.

OIT's industrial waste minimization program was funded at $17 million in FY 1993, with expected funding of $23 million for FY 1994. Slightly over half is for waste reduction, while the remainder is for waste utilization. Costs for technology R&D are split evenly with industry; industry interest in participation exceeds supply

[38] *Budget of the United States Government, Fiscal Year 1994* (Washington, DC: U.S. Government Printing Office, 1993), App.-580.

[39] Ibid.

of DOE funds. Some of the projects involve companies and DOE labs. For example, Hughes, Boeing, IBM, Inland Technologies, Honeywell, and other companies have CRADAs with Los Alamos, Sandia, and Pacific Northwest Laboratories for supercritical CO_2 cleaning. Six technologies have been commercialized so far, including an ultrasonic tank cleaning process with Dupont and Merck and a no-clean soldering process developed by Motorola with Sandia and Los Alamos National Laboratories. The program has also investigated waste data needs and institutional barriers to pollution prevention, and has conducted R&D needs assessments.

DOE and EPA jointly manage the National Industrial Competitiveness Through Efficiency: Energy, Environment and Economics program (NICE^3), which provides small research grants to develop technologies that save energy, reduce waste, and improve competitiveness. Funding is modest; $2.5 million was appropriated in FY 1993, but funding for FY 1994 is will likely exceed $7 million, with most of the funds provided by DOE. Other OIT programs have pollution prevention aspects. For example, a number of projects in DOE's Metal Initiative have significant environmental and energy efficiency benefits. DOE has provided over $25 million and the American Iron and Steel Institute has provided over $7.6 million to develop direct steelmaking that would eliminate the highly polluting and energy-intensive cokemaking process. DOE's Metal Casting Competitiveness Research Program supports two applied R&D centers, which are partly funded and administered by industry. One of the projects involves reuse of waste foundry sand.[40]

The Energy Policy Act of 1992 (EPACT, Public Law 102-486) authorizes DOE to expand its industrial energy efficiency and waste reduction programs. For example, it authorizes a 5-year program aimed at cost-effective pollution prevention in industry and a 5-year program on advanced pulp and paper technologies. Several provisions of the Act are directed at improving energy efficiency in industry through advanced technology, thereby reducing adverse environmental impacts of manufacturing. In addition, DOE is investigating a more comprehensive role in promoting cleaner technology.[41]

Several factors limit the effectiveness of DOE's industrial energy efficiency and waste minimization programs. First, DOE has not integrated and coordinated waste programs directed at industrial problems and those directed at Federal weapons facilities problems. The labs' waste programs are more visible within DOE than the industrial waste reduction program efforts.

DOE's energy conservation mission requires its waste reduction projects to provide some form of energy savings.[42] While other factors are considered, such as wastes reduced, cost savings, and resource use reduction, the emphasis on energy savings may cause some high toxicity but low volume waste projects to be overlooked or left to other agencies such as EPA. EPA involvement in the program has been relatively limited, although efforts to increase cooperation are being attempted.

Finally, DOE funds projects principally with individual firms or small groups of companies. Even though some industry organizations have worked with the program to identify technology needs and solutions, the program has not funded ongoing industry consortia to cooperatively develop clean technologies. As a result, widespread industrial involvement and commitment has been harder to attain. However, the program is inter-

~ "Profitable Recycling," *EPRI Journal*, March 1992.

41 For example, see "National Clean Industry Initiative Implementation Plan, Draft,' U.S. Department of Energy, June 8, 1993.

42 National Materials Advisory Board, National Research Council, *Industrial Waste Reduction and Utilization* (Washington DC: National Academy Press, 1993).

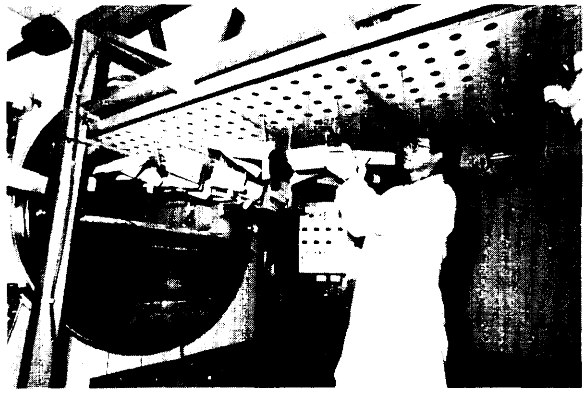
ested in working more with consortia on **industry directed longer term projects.**[43]

DEPARTMENT OF DEFENSE

DOD has several environmental technology R&D programs aimed at addressing the environmental impacts of its own activities, particularly remediation of contaminated sites. The Defense Environmental Restoration Program (DERP) provided about $26 million in FY 1993 to develop technology to assess and clean up contaminated DOD sites.

A program with broader relevance to industry is the Strategic Environmental Research and Development Program (SERDP), which supported $170 million of R&Din FY 1993. Created by the National Defense Authorization Act for FY 1991,[44] SERDP supports not only environmental restoration and waste management R&D, but also pollution prevention technologies. Technology transfer is an explicit part of SERDP's mission. As SERDP is authorized to apply industrial technology to DOE and DOD environmental problems, the program could increase U.S. Government purchases of innovative environmental technology from U.S. fins.

ARPA supports some environment-related R&D, although it is unclear how much. In 1992 ARPA issued a solicitation for up to $12.8 million in clean technology projects related to defense manufacturing. ARPA funds the government's share of SEMATECH as discussed above. ARPA includes environmental technology as one of 11 broad R&D areas that it emphasizes in the Technology Reinvestment program, which in part attempts to put defense technology to commercial use. In particular, ARPA will emphasize environmentally conscious electronic systems manufacturing and environmental monitors.[45]



U.S. AIR FORCE

U.S. Air Force ion vapor deposition R&D. Although most DOD environmental R&D is for remedial clean-up of contaminated sites, some work is dedicated to developing advanced manufacturing processes that lessen environmental impacts.

Many Army, Navy, and Air Force units dealing with materials, construction, and maintenance have pollution prevention R&D programs. Other DOD technology development programs, including the Manufacturing Technology Program (MANTECH) and the Industrial Modernization Incentives Program (IMIP), include modest funding for clean technology projects.

In 1990, DOD established the National Defense Center for Environmental Excellence (NDCEE) a private non-profit organization in Johnstown, PA, to lead and support DOD facilities and the associated industrial base in adopting pollution prevention and addressing other high priority environmental issues. NDCEE identifies, evaluates, demonstrates and transfers environmentally acceptable manufacturing processes to its client base and provides related information services. Issues addressed included waste minimization, air and water pollution control, and waste management and remediation. It also operates a 185,000 sq. ft. demonstration factory to perform

43 In part, this stems from limitations in Fe&~ acquisition regulations governing contracts and from the fact that OIT does not have funds set aside for unsolicited proposals.

44 Public Law 101-510, sec. 1801 (a), codified at 10 U.S.C. 2901-2904.

45 ARPA, "Program Information Package for Defense Technology Conversion, Reinvestment, and Transition Assistance," Mar. 10, 1993, pp. A-1, A-4. The Technology Reinvestment project is an interagency project, with ARPA as the lead agency.

process demonstrations, and training. DOD funded NDCEE initially at $5 million a year, and between 1994 and 1998 plans to provide $150 million.

ENVIRONMENTAL PROTECTION AGENCY

EPA's expenditures for technology development are modest. The CRS study discussed above[46] found that EPA was spending $330 million on R&Din FY 1992, but $240 million of this was for monitoring, assessing health and environmental risks, ecological assessment, and university-based exploratory research. As shown in table 10-3, EPA estimates that it spent $94 million on technology related activities funded through its R&D account in FY 93. (This figure does not include separately funded media program technology related regulatory support activities.)

As discussed in ch. 2, the Clinton administration has proposed a major increase in EPA's role in developing environmental technology. The administration requested $36 million for fiscal year 1994 and plans $80 million for fiscal year 1995 for an EPA-led interagency Environmental Technology Initiative.[47] Up to half (based on Appropriations Report language) of first year funding would be for R&D conducted through other government agencies. But, EPA is still in the early stages of developing a planning and decision process that involves other Federal agencies as well as industry. The initiative is also linked to administration objectives to reduce impediments to technology development and to support export promotion, and to U.S. Technology for International Environmental Solutions for provision of technical assistance and adaptation of U.S. technologies abroad.

EPA is focusing increased attention on the relationship between regulations and technological innovation. An internal Innovative Technology Council has broad agency participation. An outside advisory group to the EPA's administrator, the Technology, Innovation and Economics Committee of the National Advisory Council for Environmental Policy and Technology, has produced several reports and recommendations on the subject.

Most of the SITE program's funds ($17 million for fiscal year 1993) are for demonstrating innovative remediation and monitoring technologies on Superfund sites. Technology vendors operate the technology at their own expense, but EPA bears the costs of preparing sites for the demonstration, evaluating the results, and disseminating the information through bulletins, reports and electronic data bases.[48] The Municipal Innovative Technology Evaluation program (MITE-$1 million for fiscal year 1993) conducts similar evaluations of innovative technologies for recycling or disposing of municipal solid waste. EPA also conducts some R&D through CRADAs with industry (see above).

EPA, along with other agencies, provide a total of $15 million to Hazardous Substance Research Centers at universities, for basic research, technology development, and technology transfer.[49] While most of the centers concentrate on treatment and remediation, the Center for Clean Industrial and Treatment Technologies at Michi-

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~ John D. Moteff, The Current *State of Federal R&D in Environmental Technologies,* Op. Cit., footnote 4, Pp. 47-49.

47 Gibbons, op. cit., footnote 9.

48 U.S. Environmental Protection Agency, "The Superfund Innovative Technology Evaluation (SITE) Program: An Evaluation of Program Effeetiveness" (Washington DC:EPA, Sept. 1992), p. ES-1.

49 Dale Manty, EPA Office of Exploratory Research, personal communication, Sept. 29, 1993.

gan Technological University partly addresses pollution prevention.[50]

EPA support for clean technology development is modest, but could grow as part of the priority placed on pollution prevention by the Administrator. EPA's R&D program has focused on developing tools for assisting pollution prevention implementation, such as opportunity assessment guides and life cycle analysis techniques, and has evaluated pollution prevention technologies. EPA's Office of Pollution Prevention and Toxics manages a design for environment program that has developed collaborative effort with specific small business sectors. (EPA also has a series of 'Green Programs' focused on voluntary adoption by industry of more efficient lighting, computers, appliances, etc.)

Although not an EPA R&D institution per se, the National Environmental Technology Applications Corp. (NETAC), a nonprofit corporation affiliated with the University of Pittsburgh Trust, was established by EPA to support environmental technology commercialization. Starting with $9 million of initial EPA funding but now financed through contracts with private, Federal, and State clients, NETAC provides independent technology evaluation services, and offers technical, marketing, and regulatory assistance to environmental technology innovators.

NATIONAL SCIENCE FOUNDATION (NSF)

CRS identified $36.6 million of NSF support for environmental technology in FY 1992.[51] Through a partnership with the chemical industry's Council for Chemical Research, NSF established the Environmentally Benign Chemical Synthesis and Processing program to stimulate university pollution prevention research.[52] The program allocates only about $2 million annually in research grants. Industrial participation in the research is required.

In addition, some of NSF's Industry/University Cooperative Research Centers (I/U Centers) and Engineering Research Centers (ERCs) investigate environmental technology. The I/U Center for Hazardous and Toxic Substances includes NJIT, Princeton University, Rutgers University, and the University of Medicine and Dentistry of New Jersey, and conducts research principally on waste treatment and remediation. Rutgers also houses a plastics recycling I/U Center.[53] One ERC based at the University of California at Los Angeles is dedicated to research on hazardous materials. The Advanced Combustion ERC at Brigham Young University is another center directly relevant to environmental technology.

Some I/U Centers and ERCs, while not focused explicitly on environment, could contribute to pollution prevention in areas such as improved process monitoring, thin films, steelmaking, and automation. For example, the Center for Process Analytical Chemistry at University of Washington studies problems of chemical process monitoring and analysis. This area is important to improved chemical process control and efficiency and environmental performance.

OTHER AGENCIES

Several other agencies fund R&D for environmentally related technologies pertinent to this assessment. They include the Department of Commerce (including the activities of NIST described above), NASA, and the Bureau of Mines. Within DOC, at least three of the seven NIST Manufacturing Technology Centers (MTCs) provide technical assistance to help industry address environmental concerns, including pollution prevention (see ch. 8).

50 Some of these EPA Centers receive funds from other agencies. For instance, the New Jersey Institute of Technology (NJIT) is part of both an EPA center and a National Science Foundation Industry/University Cooperative Research Center for hazardous and toxic substances.

51 John D. Moteff, The *Current State of Federal R&D in Environmental Technologies,* op. cit., footnote 4, pp. 39-42.

52 Ivan Amato, "The Slow Birth of Green Chemistry," *Science,* vol. 259, Mar. 12, 1993.

53 The New Jersey Commission on Science and Technology also funds these centers.

STATE AND LOCAL PROGRAMS

Many States fund environmental technology through broader technology programs designed to commercialize new technologies and create jobs. Often these programs fund technologies for energy conservation and renewable energy. For example, the New Jersey Corp. for Advanced Technology was recently established to support development and commercialization of environmental technologies. The California Environmental Technology Partnership is another example of a new State environmental technology initiative. In addition, a number of States have coal development programs, some of which concentrate on clean coal technology.

Some programs provide a small amount of support to small business for clean technology R&D. California, Illinois, New Mexico, New York, North Carolina, and Washington fund the development of pollution prevention or industrial waste recycling technologies. The programs concentrate on areas such as metals recovery in plating, painting, and alternative cleaning. California's South Coast Air Quality Management District provides $25 million a year for a wide variety of technology projects, including technologies related to reduced mobile source pollution (e.g., electric cars, electrically heated catalytic converters, natural gas vehicles) and pollution prevention (e.g., low VOC coatings).

U.S. Private Sector R&D

It is difficult to measure private-sector environmental technology R&D, partly because of the definitional issues already discussed. Pollution abatement R&D is only a small share of total industrial R&D. According to the Commerce Department's Bureau of Economic Analysis (BEA), private environmental R&D amounted to about $2.4 billion in 1991 (and $2.2 billion in 1990).[54] To make these estimates, however, BEA assumed that the same ratio existed between total industrial R&D and pollution abatement R&D in 1991 as in 1978, the last year for which this data was broken out by media (e.g., air, water). The ratio of environmental R&D to total R&D probably declined between 1978 and 1991,[55] hence the share of environment R&D in 1991 could be less than the figures reported by BEA. According to NSF, industry R&D for pollution control (including product and process R&D and excluding energy-related R&D) was $950 million in 1990, or approximately 1.28 percent of total R&D expenditures by industry.[56] As discussed below, industry estimates of pollution control R&D (including product and process R&D and excluding energy-related R&D) are higher, suggesting that perhaps as much as 50 to 100 percent more than the NSF estimate is being spent.

The NSF data shows wide variation among sectors. In the electrical equipment industry (SIC 36), which has relatively low environmental compliance costs, pollution control R&D is less than one-tenth of 1 percent of total R&D. However, in the petroleum industry, which has relatively high compliance costs, pollution control R&D in 1992 ($72 million) accounted for 3.4 percent of total R&D. In the pulp and paper industry, which also has relatively high compliance costs, pollution control R&D ($18 million) accounted for 2.4 percent of total R&D. Data generated by industry associations indicate a higher share of R&D arising from environmental considerations. The American Petroleum Insti-

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S4 Gary L. Rutledge and Mary L. Leonard, ''Pollution Abatement and Control Expenditures, 1987 -91,' *Survey of Current* Business, May 1993, pp. 60-61. This compares with about $43 billion in 1991 total private sector environmental compliance costs, including R&D (table 7-l).

55 In large part this may be due t. reduced expenditures (in constant dollars) by automakers on R&D [o reduce vehicle emissions. In 1978 (the last year data was separately available from NSF), automakers accounted for 55 percent of environmental R&D.

56 NSF asks firms to report R&D related to &@@ pollution abatement products or product characteristics or to designing pollution abatement features into processes. Presumably, this would include R&D performed by environmental goods and services firms, clean product R&D (e.g., reformulated gasoline), and cleaner process R&D performed by regulated industry (either end of pipe or pollution prevention), National Science [illegible] *of* [illegible] *Research and Development* (Washington, DC: NSF, various years),

tute reports that the petroleum industry spent $175 million on environmental R&D in 1990, including an estimated $50 million on reformulated gasoline. Nonproduct pollution control R&D amounted to about 6 percent of total R&D.[57] Similarly, the pulp and paper industry reports spending $32.3 million in 1990 on environmental R&D (most nonproduct) or about 4.4 percent of total R&D.[58]

Finally, one source concluded that industry spends approximately 13 percent of R&D funds on environmental technology, or roughly $10 billion; however, the conclusion apparently was based on inaccurate interpretation of a survey by the Industrial Research Institute (IRI). Pollution control R&D is probably closer to the 1 to 2 percent figure .59

The limited evidence that is available suggests that half or more than half of U.S. private environmental R&D is conducted by regulated industry rather than by environmental fins. It appears that environmental firms as a whole are less research-intensive than manufacturing as a whole, which spends approximately 3.3 percent of sales on R&D.[60,61]

Some estimates for environmental equipment firms show R&Din the range of 1 to 2 percent of sales. Research-Cottrell, an air pollution equipment manufacturer, spent between $3 and $5 million on R&D in 1992, or 1.1 to 1.9 percent of sales. Members of the Manufacturers of Emission Controls Association (MECA) expect to perform R&D on catalytic converters and diesel falters amounting to about 1.8 percent of sales of those items.[62] Ionics, a maker of membranes and falters and a designer and builder of water filtration units, spent 2.1 percent of sales on R&D. The Institute of Clean Air Companies, which includes both equipment and service providers, estimates R&D at 3.2 percent of sales, based on a survey of half of its 50 members. (For turnkey system suppliers, the estimate was about 1 percent.)[63] The 18 firms on the board of the Water and Wastewater Equipment Manufacturers Association informally estimated that they spent about 4 percent of sales on R&D.[64] Allied-Signal's Engineered Materials Division, which produces environmental catalysts for vehicles and fixed sites, spent $117 million or 4.8 percent of 1991 sales on

57 This is similar t. the share in the early 1980s, when nonproduct environmental R&D in the petroleum refining and extraction industry (SIC 13 and 29) accounted for approximately percent of total R&D. American Petroleum Institute, *Environmental Expenditures of the United States Petroleum Industry, 1975-19&$* (Washington DC: API, 1985); API, *Petroleum Industry Environmental Performance, 1992* (Washington DC: API, 1992); National Science Foundation Survey *of Industrial Research and Development,* op. cit., footnote 56.

58 National Council of the Paper Industry for Air and Stream Improvement, Inc., *A Survey of Pulp and paper Industry Environmental Protection Expenditures-1990* (New York, NY: NCASI, October 1991).

59 Brian Rushton, "HOW Protecting the Environment Impacts R&D in the United States, ' *Research Technology Management,* May-June 1993, p. 13. The IRI survey asks 246 firms to list the 10 process-related R&D areas expected to be the most important over the next 5 years. Sixty-nine firms responded, listing an average of about 6 areas perfirm. Of 416 total listings, 47 (1 1.4 percent) were in environmental areas. Firms were also asked to report what areas the government should fund, and 13 percent of the responses were for environmental technology. However, the responses do not allow inferences to be made about the relative importance of environmental R&D to firms or the amount spent in industry. Moreover, even if the 11.4 percent figure represents the share of funds, it is as a share of process R&D, not total R&D, and would total approximately $1.9 billion, not the $10 billion reported by Rushton.

60 Unpublished data, National Science Foundation.

61 Data are not available on other nations' environmental industry R&D intensity. However, OECD reported that in 1981, the German pollution control industry was 33 percent more R&D-intensive than the rest of German industry in terms of R&D spending per employee. "Clean Technologies: A Dilemma For Industry," *OECD Observer,* November/December, 1987.

62 MECA members expect to spend $200 million in R&D related to these products "in the 1990s, " and expect domestic sales of these items to 'approach $8 billion between now and the end of the decade, " with foreign sales of $250 to $450 million a year. MECA press release titled "Clean Air Act Spurs Growth of U.S. Motor Vehicle Emission Control Industry," April 1993.

63 Jeff Smith, Executive Director, Institute of Clean Air Companies, personal communication, July 21, 1993.

64 Dawn Kristoff, Water and Wastewater Equipment Manufacturers Association, personal communication, July 12, 1993.

R&D, a high percentage for U.S. manufacturing.[65] Instrument manufacturers probably spend more on R&D than other environmental equipment manufactures. Thermo Instrument Systems, a subsidiary of Thermo Electron that manufacturers analytical and monitoring instrument widely used in environmental applications, dedicates nearly 7 percent of sales to R&D.[66]

Environmental service fins, including waste management firms, appear to spend much less than manufacturers. For example, Waste Management of North America (the solid waste subdivision of WMX Technologies) spent less than 0.25 percent of its $4.3 billion in sales on R&D in 1992. However, some other WMX divisions do spend more for R&D and may transfer technology to Waste Management.[67] Some environmental companies do not conduct formal R&D, but work on product and service development with customers and suppliers. For example, Safety Kleen has been working with other companies in developing better chemical recovery and recycling processes and alternative solvents, although there is no formal R&D division in the company.

Small, R&D-intensive start-up firms might spend more as a share of sales, although total expenditures are likely to be small. These firms are a source of new technology for larger firms that often either acquire the firm or license the technologies. Because of this, formal R&D expenditures by large environmental firms may understate their efforts in obtaining new technology.

Assuming that the U.S. pollution control equipment sector has annual sales of around $30 billion annually and that it spends 2.5 percent of sales on R&D, and that the service sector (excluding water supply, resource recovery, and environmental energy sources) has sales of around $60 billion and spends around 0.2 percent on R&D, then the environmental industry sector would be spending on the order of $750 million to $870 billion per year on R&D. While this figure is just a guess, it does suggest, together with the estimates above, that regulated industry, as opposed to environmental firms, may conduct half or more of the private environmental technology R&D in the United States.

JAPAN

Within the Japanese Government, the Ministry for International Trade and Industry (MITI) has a lead role in supporting energy and environmental technology R&D, although the Environment Agency also funds a small amount (see table 10-4). Most of MITI's effort is managed by the New Energy and Industrial Technology Development Organization (NEDO), a quasi-government organization that funds industry R&D directly. The vast majority of government support for environmental technology R&D is for energy technology, including renewable energy. MITI also supports R&D for more productive manufacturing process technologies that also have related environmental benefits. With the exception of work to develop CO_2 recovery technologies, relatively little is spent on technologies related directly to pollution control and waste remediation.

Mill Programs

MITI's Agency for Industrial Science and Technology and its Bureau of Environmental Protection and Industrial Location manage at least two pertinent R&D organizations: NEDO, and Research Institute of Innovative Technology for the Earth (RITE). MITI's involvement in these programs could enhance potential commercial

65 Stephen Lipmann, "U.S. Environmental Companies' Competitive Strategies: Eleven Case Studies," contractor report prepared for the Office of Technology Assessment, April 1993.

66 Ibid.

67 For example, Wheelabrator, a subsidiary of WMX that develops and operates waste-to-energy, air pollution control, and wastewater treatment facilities, spent about 1.7 percent of 1992 sales on R&D.

Table 10-4--Selected Japanese Environmental Technology R&D Programs

Ministry/program	Funding ($ million)
Ministry for International Trade and Industry	
New Energy and Industrial Development Organization (1993)[a]	
Clean coal	85
Renewable energy	170
Energy efficiency	265
Environmental technologies[b]	20
Research institute of Innovative Technology for the Earth (1993)	88
Agency for Industrial Science and Technology	
Pollution control projects (1992)	10
Direct steelmaking (1993)	50
Environment Agency	
Pollution control projects[c] (1 990)	14

a Only NEDO funding directly related to environmental or environmentally related energy was included. Industrial technology funding, coal resources development and industry rationalization, and production of alcohol was not included.
b $77 million was budgeted for global environmental projects, but $60 million was in turn allocated to RITE.
c In 1990.

NOTE: Exchange rate for 1993 is 110 yen_ $1; 1992120 yen_ $1, 1990145 yen_ $1. See table 10-1 for technologies included in this table.

SOURCES: NEDO and RITE, personal communication, October 1993; Agency of Industrial Science and Technology, "program brochure" 1993; Research and Development Corp. of Japan, "National Laboratones and Public Research Organizations in Japan" (Tokyo: JRDC, 1992).

benefit, and after new technologies are developed, MITI has the capacity to promote exports of resulting goods and services. This can facilitate technology transfer to developing countries through MITI's Green Aid Plan, which is separate from Japan's general development assistance program.[68]

NEDO

NEDO, a quasi-government agency, government-funded and under MITI's supervision, was established in 1980 in response to the 1979 oil shock to promote the development of non-oil energy technologies. As the central organization responsible for coordinating energy and some industrial-related technologies in Japan, NEDO administers, coordinates, and funds research, development, demonstration, and testing of technologies related to its mission. Much of the work is carried out by industry through contracting, although the national laboratories play a small role. Governed by a board of industry representatives, one third of NEDO's employees are corporate employees assigned to the agency for 2 to 3 years, during which time their salaries are paid by the government.[69]

NEDO's FY 1993 budget amounted to about $1.76 billion. Approximately $255 million was for clean coal and renewable energy technologies, including solar, wind, geothermal, ocean energy, alcohol, and biomass.[70] A similar amount was for energy conversion and storage technologies, including superconducting technology for electric power, advanced batteries, ceramic gas turbines,

68 See U.S. Congress, Office of Technology Assessment, *Development Assistance, Export Promotion, and Environmental Technology Background Paper*, OTA-BP-ITE-107 (Washington, DC: U.S. Government Printing Office, August 1993).

69 Curtis A. Moore and Alan S. Miller, The Technology Clearinghouse, "Environmental Technologies and Policies of Japan," contractor report prepared for the Office of Technology Assessment, February 1992, p. 24.

m Personal communication with NEDO official, October, 1993.

CURTIS MOORE

Tokyo Electric Power Company's 11 megawatt phosphoric acid fuel cell is the largest fuel cell installation in the world. Most of Japan's environmental R&D concentrates on improving energy technologies.

and fuel cells.[71] Another $339 million was for industrial technology, of which $77 million was for environmental technologies ($60 million of this went to RITE) .72

Because NEDO seeks to develop new energy technologies to a level where private industries can take over and commercialize them, it funds both development and demonstration projects. NEDO also supports several foreign energy demonstration projects, principally in the Asia-Pacific region, including fuel cells in Thailand and photovoltaics in Australia.

Fuel cells have been a particular focus of NEDO's R&D. Fuel cells, which convert fuel into electricity through chemical oxidation rather than combustion, emit less pollution and are quieter, more compact, and more energy-efficient than combustion engines. Thus, some believe that they will become an important source of electricity in the next century, both in central generating stations and in smaller applications that use both the electricity and the heat generated by the fuel cell. Vehicle applications are also possible.[73] NEDO has funded many fuel cell demonstration projects, including a 4.5-megawatt generator built for Tokyo Electric Power Co. in the early 1980s, and an 1 l-megawatt unit-the world's largest—put into operation in 1990.[74]

The industrial technology program is oriented toward developing advanced technologies that are of use to industry but 'have high development risks and require long lead times. ' '[75] Most of these projects, such as new materials, precision material processing, biotechnology, manufacturing technology, and medical equipment, are in areas not directly related to the environment. However, because advanced industrial process technologies will become increasingly important in pollution prevention, a number of the projects will have environmental implications. For example, large scale advanced chemical processing technology for high purity separations processes, research on ion implantation of metals, and high temperature materials for heat exchangers have potential to lead to cleaner production processes.

Because of an increased concern for global environmental problems, NEDO's industrial technology mission was expanded in 1990 to include technology that protects the global environment. To facilitate this work, RITE was established to fund and conduct research in this area, as a foundation more oriented to the private sector than NEDO (see below).

Many of NEDO's energy and environment programs were grouped into the Sunshine Project (developing new and renewable energy sources), the Moonlight Project (energy conservation), and the Global Environmental Technology Program; now, all three are rolled into the New Sunshine

71 NEDO, *Research and Development Project Plans for FY 1992 [1]* (Tokyo: NEDO, 1992).

72 The remainder was for non-environmentally related coal technology development and two separate NEDO missions, rationalization of the coal industry and production of industrial alcohol.

73 The recent Clinton administration initiative to produce a clean car emphasizes fuel cells.

74 Curtis A. Moore and Alan S. Miller, "Environmental Technologies and Policies of Japan," op. Cit., footnote 70.

75 NEDO, op. cit., footnote 71, p. 7.

Program, with a planned budget equivalent to $13.6 billion over 27 years, from 1993 to 2020 (an average of $500 million per year).[76] This program aims in large part to reduce carbon dioxide emissions, and thus contributes to MITI's New Earth 21 Concept, a 100-year plan to reduce and stabilize carbon dioxide emissions.

RITE

RITE is a public foundation which is commissioned by MITI, related prefectures, and the private sector to fund and conduct R&D, most of it related to global warming.[77] With a budget of $88 million in FY 1993 (about two-thirds provided by NEDO) RITE funds environmental projects, the largest being carbon dioxide separation, recovery, and fixation technologies, and CFC-substitutes, particularly non-CFC refrigerants.[78]

RITE projects typically involve a large number of corporate partners. For example, a project to increase use of scrap in steelmaking involves nine of the largest Japanese steelmaker as well as the Japan R&D Center for Metals. Industry researchers work on RITE projects for about 2 years; they remain at their firms, which continue to pay their salaries, but are given the title of ''RITE researcher and matching funds to support the research. RITE also makes matching grants for research by firms, universities, and other nonprofit organizations ($12 million FY 1991). International participation in RITE projects is encouraged, although only one such project (with Italian collaborators) is underway.

OTHER MIT! GROUPS

Some MITI institutes and laboratories conduct a small amount of environmental technology R&D.[79] AIST administers the National Institute for Resources and Environment (NIRE), partly dedicated to environmental technology. Other laboratories, including the National Institute of Materials and Chemical Research and the Government Industrial Research Institute, conduct some work on environmental technology. In 1992 AIST supported 40 pollution control projects at laboratories, spending the equivalent of $9.4 million .80 However, funding for these projects has declined by approximately half (unadjusted for inflation) since its peak in the 1970s. AIST has helped organize several private research consortia to work with its laboratories on environmental technology, including biodegradable plastics and emission reduction methods. AIST is spending $425,000 in FY 1993 to develop an eco-factory concept, essentially industrial processes to facilitate disassembly and recycling of manufactured goods.[81] Finally, AIST Spent approximately '50 million in 1993 on a project to support development of direct ironmaking.

Another MITI agency, the Agency of Natural Resources and Energy (ANRE), funds relevant research, sometimes in coordination with AIST. For instance, both AIST and ANRE support clean coal and advanced combustion R&D. The Electric Power Development Corp., Center for Coal Utilization Japan, and the Central Research Institute of Electric Power Industry (Japan's equiva-

76 Personal communication with NEDO official, October, 1993.

77 "RITE: Research Institute of Innovative Technology for the Earth, " program pamphlet, undated.

78 Smaller projects include: bioreaction processes to produce chemicals; catalysts capable of reducing unwanted byproducts in chemical processing; biodegradable plastics; steelmaking processes capable of using larger amounts of scrap with less energy consumed; and catalytic NO_x removal from combustion. New Energy and Industrial Technology Organization, *The Innovation of New Technology* (Tokyo: NEDO, October 1992).

79 MITI, "AIST: Agency of Industrial Science and Technology, " program brochure, 1993.

80 ''AIST FY92 Industrial Pollution R&D Outlined,'' as cited in Foreign Broadcast Information Service, *JPRS Report: Environmental Issues*, *JPRS-TEN-93-025*, Sept. 21, 1992.

81 Hisayoshi Sate, ''Ecofactory—Concept R&D Themes, " New *Technology Japan, FY 1992,* special issue published by the Japanese External Trade Organization, 1992.

lent to EPRI) are organizations under ANRE's supervision.

AIST has also supported at least two large scale research projects related to environmental technology.[82] Between 1966 and 1971, AIST spent approximately $55 million (1992 dollars) on the desulfurization project, in large part focused on development of technology related to efficient removal of SO_2 contained in exhaust gases from power plants and other large-scale combustion sources. As discussed in ch. 5, the Japanese are now strong competitors in this technology. More recently, AIST spent approximately $70 million between 1985 and 1990 on the Aqua Renaissance project to develop new technologies for treatment of wastewater. Technologies included microorganisms and high-performance membranes. However, technologically this project did not appear successful and did not achieve its technical objectives.[83] However, interaction between participating companies was facilitated and some of the project teams generated commercially useful equipment.

Environment Agency and Other Programs-Japan's Environment Agency funds research in national research institutes and government ministries. In FY 1990 the Environment Agency funded the equivalent of $13.8 million of R&D in 45 research institutes and 13 ministries. This included work on traffic pollution by the National Police Agency, SO_2 and NO_x sensors by the Science and Technology Agency, and nonpolluting ship hull painting by the Ministry of Transport.

The Japan Sewage Works Agency supports research and technology development ($5 million in FY 1991) in sewage treatment technologies, including advanced wastewater treatment, sewage sludge handling, and small-flow wastewater technologies.[84] Finally, the Clean Japan Center, a quasi-public organization, funds demonstration of recycling and resource recovery technologies.

EUROPEAN PROGRAMS

In Western Europe, environmental technology R&D is supported and encouraged at different governmental levels. The European Commission (EC) supports and encourages cross-border R&D collaborations through the Framework program, while over 20 European countries, including the EC, are involved in the Eureka program. Both programs support environmental technology.[85] Some countries, including the Netherlands and Germany, have substantial environmental technology R&D programs. In all of these cases, environmental technology R&D is supported as part of a broader competitiveness strategy.

International Programs

EC PROGRAMS

The EC funds some R&D, primarily to increase industrial competitiveness.[86] The R&D is international in character, either involving a central EC

82 The Large Scale Program was developed by MITI in 1966 to provide government support for large technology projects of particular national importance. MI'r I's 5th generation computer project is an example.

83 C. Judson King et. al., *JTEC Panel Report on Separation Technology in Japan* (Baltimore, MD: Japanese Technology Evaluation Center, Loyola College, March, 1993), p. 141.

84 Research and Development Corporation of Japan, "National Laboratories and Public Research Organizations in Japan' (Tokyo: JRDC, 1992).

85 For a more complete discussion of EC technology and industrial policy see U.S. Congress, Office of Technology Assessment, *Competing Economies: America, Europe, and the Pacific Rim,* OTA-ITE-498 (Washington, DC: U.S. Government Printing Office, October 1991), ch. 5, especially pp. 209-226.

86 See Commission of the European Communities, *EC Research Funding* (3d ed. 1992), pp. 3-8. EC-level support has increased from 2 percent of the civil R&D budgets of EC member states in 1980 to 5 percent in 1990. Ibid., p. 10.

Table 10-5-European Community R&D Programs Supporting Environmental Technologies

	Years covered	Estimated annual spending on environmental technology ($ million): total	per year[a]	Estimated percent of funds cost-shared with industry or other parties[b]
Framework programs				
Non-nuclear Energies[c]	1991-1994	290[d]	85	86
Environment	1991-1994	170	50	59
Measurements and Testing[f]	1992-1994	20	6.5	36
Other programs				
Thermie (energy technology demonstration and dissemination projects)	1990-1994	NA	170	100

a Thermie figure is for 1993, For the other programs, the figure shown is the total figure in the previous column, divided by the whole or fractional number of years the program is in effect. Two programs started mid-year: Non-nuclear Energies (Sept. 9, 1991), and Environment (July 16, 1991).

b For the program as a whole (not just the environmental technology part). For the Framework programs, this estimate *assumes* that the revisions in Council Decision 93/167/Euratom, EEC, Mar. 15, 1993, printed *in Official Journal of the European Communities, vol.* L 69/45 (Mar. 20, 1993), which kept Framework's total Joint Research Center funding constant, also kept the Joint Research Center funding constant for the specific programs listed. This estimate also assumes that 87 percent of the non-Joint Research Center funding for each program is for cost-shared research (87 percent is the approximate Framework-wide average).

c This program's predecessor was JOULE.

d Includes an estimated $37 million out of a $61 million supplement to Framework energy programs.

e This program's predecessor was STEP/EPOCH.

f This program's predecessor was B.C.R.

NOTE: The figures for spending on environmental technology are rough estimates: OTA estimated the share of each program devoted to the environmental technologies within the scope of this report, based on the EC's program descriptions containing limited or no budget breakdowns. The following shares were used: 95 percent of Non-nuclear Energies, 30 percent of Environmental, 10 percent of Measurements and Testing, and 80 percent of Thermie. See table 10-1 for technologies included in this table. An approximate exchange rate of 1 ECU -$1.22 is used. "NA" denotes not available.

SOURCE: Office of Technology Assessment. Estimates based on Commission of the European communities, *EC Research Funding* (3d *ad.,* January 1992); EC Council decision of Mar. 15, 1993, 93/167/Euratom, EEC, printed in *Official Journal of the European Communities,* vol. L 69/45 (Mar. 20, 1993) (increasing funding levels); EC Council decisions establishing particular programs.

facility or collaborations involving entities from at least two member states.[87] (See table 10-5.)

Much of the EC's R&D is conducted through its Third Framework program, an umbrella R&D program with a total budget of $8 billion, generally covering mid- to late 1991 through the end of 1994.[88] While this program is jointly administered by all of the EC's Directorate-Generals, in practice Directorate-General XII (Science and Technology) plays the lead role. Within Framework, the program for non-nuclear energies provides the majority of funds for environmental technology (an estimated $85 million annually). The program supports renew-

87 The EC seeks projects that can be performed more efficiently **at the EC level.** Ibid., p. 7. To some extent, the EC considers cross-border collaboration as also a good in itself (independent of competitiveness effects), because it promotes the EC'S economic and social cohesion.

88 Formally, the Third Framework Program covers 1990-1994. However, mOSt Of the programs b ecame effective during the third quarter of 1991. See Commission of the European Communities, *EC Research Funding,* op. cit., **pp. 69-100. The Third Framework Program overlapped with the** Second Framework Program during all of 1990 and 1991, and will overlap with the Fourth Framework Program during all of 1994.

able energies, including solar, biomass, and geothermal; fuel cells; more efficient industrial processes; more efficient energy generation from fossil fuels, including fluidized bed combustion; and CO_2 recovery technologies. Much of the environmental technology program focuses on climate monitoring, modeling, and environmental and socioeconomic assessment, areas not considered in this report. However, a share of the program concentrates on environmental technologies directed at reducing pollution (estimated at $50 million annually). For example, the program supports some research on technologies for treating toxic wastes and cleaner production technologies,

Some other Framework programs (not listed in table 10-5) incorporate environmental considerations into their goals. For example, the program for industrial and materials technologies reports that ''environment aspects of products and processes' are included as a ''strategic element. . . in all parts of the program."[89] That program is, for example, coordinating consortia to develop environmentally preferable polymers, e.g., biodegradable plastics.

Framework spending is heavily oriented to helping fins, universities, and research institutes. About 80 percent goes to cost-sharing R&D done by such entities.[90] Projects must be in a "pre-competitive" stage (prior to industrial development).[91]

EC's Thermie program, administered by Directorate-General XVII (Energy), funds energy technology demonstration and dissemination projects (an estimated $170 million in FY 1992). Thermie's goals are to improve efficiency in energy production, distribution, and use; promote renewable energy technologies; develop cleaner ways to use coal and other solid fuels; and develop technologies for oil and gas exploration, transport, and storage. Thermie will fund up to 40 percent of the costs of a first full-scale demonstration, and up to 35 percent for further dissemination of technology already demonstrated.[92] For example, Thermie made an initial award of$183 million toward a demonstration of Integrated Gasification Combined Cycle (IGCC) electricity cogeneration technology providing low emissions of SO_2, NO_x, and CO_2. Six electricity companies (four from Spain, and one each from Portugal and France) were to build a plant in Spain. The project called for a demonstration period during which many types of coal would be tested, after which the plant would operate on locally available coal.[93]

EUREKA

Like the EC's Framework Program, Eureka aims to promote competitiveness through cross-border collaboration. Eureka is driven less by government policymakers and more by participating firms and universities, and projects do not have to be precompetitive. Public funding for Eureka projects comes from national governments. However, in addition to funding, Eureka provides its research participants with access to financing sources and to national and international bodies that make standards or promulgate regulations that could affect a project's commercial success.

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89 Council Decision of Sept. 98, 1991, ''adopting a specific programme of research and technological development in the field of industrial and materials technologies (1990 to 1994), " 91/506/EEC, publ.ished in *Official Journal of the European Communities*, No. L. 269/30, Sept. 25, 1991. (See p. 269.)

90 Commission of the European Communities, *EC Research Funding*, op. cit., pp. 24-25. For firms, the EC normally pays 50 percent of the cost including overhead; for universities, the EC normally pays the entire additional costs related to the research, excluding overhead and most salaries.

91 Ibid., p. 41.

92 Commission of the European Communities, Directorate-General XVII-D, ''Thermie'' (brochure, not dated).

93 Ibid. The Commission is funding the development of an electricity generation technology which reduces CO_2 emissions by 20%. "Press Release", Dec. 5, 1991.

Table 10-6—German Federal Environmental Technology R&D Spending, 1992

Budget category	Environmental technology portion (estimate)[a] ($ million)	Total BMFT funds as percent of total funds	Percent of BMFT funds cost-shared with industry
Environmental technology excluding energy	230	68	36
Renewable energy and energy efficiency	250	100	31
Fossil fuels (includes clean coal)	47	100	**39**

a OTA's estimated the share of R&D spending on environmental technologies covered in this report based on program descriptions without budget breakdowns. The following percentages were used: 100 percent of renewable and energy efficiency; 90 percent of environmental technologies; and 60 percent of fossil energy.

NOTE: Exchange rate used: $1 = 1.5617 DM. International Monetary Fund, *International Financial Statistics,* March 1993, p. 236. See table 10-1 for technologies included in this table.

SOURCE: OTA, based on the German Federal Ministry for Research and Technology (BMFT), *Bundesbericht Forschung 1993* (Bonn: BMFT, July 1993), pp. 71-72 (table II/5), pp. 74-75 (table n/6), pp. 97-98 (table 11/16), pp. 172-177.

In 1992, Eureka had 562 ongoing projects, with a total value of $10.8 billion. Of these, 130 projects, with a total value of $1.2 billion, were classified as environmental. Of these, 29 projects are for cleaner production processes; other categories include environmental monitoring and waste water treatment. Some of the environmental projects are beyond the scope of environmental technologies treated in this report, such as restoration of ancient monuments, and a $250 million project in atmospheric science.[94] An additional 23 projects, with a total value of $610 million, were classified as energy technology. Of these, two were for more efficient power plants, eight for efficiency in energy use, and seven for renewable energy (including five on photovoltaic cells). The rest were for fossil fuel exploration and transportation applications, beyond the scope of this report.

National Programs

GERMANY

The German Federal Government spent an estimated $230 million for environmental technologies, $250 million for renewable energy and energy efficiency, and $47 million for clean coal in 1992 (see table 10-6). Virtually all of the energy-related funding, and most of the rest, went to the Ministry for Research and Technology (BMFT), whose central mission is promoting industrial competitiveness.[95]

Germany attempts to link technology development to technology needs, based on regulatory targets. Many of the energy and environmental technology projects involve applied research and development, as opposed to more basic research. Roughly a third of BMFT's funds go for cost-sharing industrial R&D. BMFT funds technologies for prevention, control and cleanup. Areas of prevention research include optimization of processes, CFC-substitutes, no-chlorine pulp bleaching, and utilization of industrial wastes, including reprocessing of waste acids, alkaline solutions and salts. BMFT also funds air and water treatment technologies. In the past, BMFT supported research directed at removing inorganic pollutants from exhaust gases, including flue-gas desulphurization, denitrification, and fluidized bed combustion. Increasingly, BMFT focuses on technologies for removal of organic contami-

94 *Eureka 1992: Annual Progress Report 1992*, pp. 4, 18.

95 Germany's Länder (states) fund some environment-related R&D, but figures are not readily available.

Table 10-7—Environmental Technology Budget for Selected Programs in the Netherlands, 1992 ($ million)

Research and development		
- Innovation-oriented Environmental Technology Research Programme		**$6**
- Program to promote environmental technology In industry		**21**
- Scheme to Promote the Development of Environmental Technology		**8**
- National Research Programme Into the Re-use of Waste Substances		4
- Water pollution technology		6
- Energy saving/substainable energy/NOVEM programmed		58
- Cleaner exhaust gases		2
	Subtotal	105
Dissemination		
- Environment & energy advisory scheme		**2**
- General provision of information to environmental technology		1
	Subtotal	3
Demonstration/Application		
- Hydrocarbons 2000		6
- Accelerated depreciation for innovative environmental technology		47
- CFC action programme		4
- Grants scheme for clean and low noise lorries and buses		53
- Various demonstration schemes to reduce nitrogen oxide emissions (NO,)		12
- Tender for industrial energy saving		18
- Scheme for an environmental premium for wind energy		1
- Investment subsidy for wind		18
- Subsidy scheme for demonstration projects		3
- Investment subsidy energy saving techniques		103
	Subtotal	265
Total		**373**

NOTE: Exchange rate used: $1 -1.7 guilders. See table 10-1 for technologies included in this table.

SOURCE: Technology *and Environment* (The Hague, the Netherlands: Ministry of Economic Affairs, Technology Policy Directorate, April 1991).

nants, including selective high performance absorbents, catalytic systems, and biofilters.[96]

NETHERLANDS

The Netherlands relies heavily on incentives and subsidies to industry to help them meet environmental requirements, Spending on technology development is significant, given the small size of the country. In 1992, the government spent an estimated $375 million on environmental technologies covered in this report. If multiplied on a per-capita basis, this would be equivalent to over $6.7 billion in the United States[97] (see table 10-7). Moreover, relative to the United States, a greater share of this spending is devoted to environmental technologies, as opposed to energy, and about half of funding on environmental technologies advances pollution prevention.

The National Environmental Policy Plan (NEPP) and NEPP Plus, environmental strategic plans for the Netherlands, have as objectives reducing emissions of pollutants to between 10 and 30 percent of their 1985 levels by the year 2010. The

96 Federal Ministry for Research and Technology, Environmental Research *and Technology, Programme 1989-1994 (Bonn:* BMFT,1989).

97 The Netherlands has *a* population of approximately 14 million people, about 1/18th of the size of the U.S. population. Total environmental technology expenditures, including on environmentally sound agricultural technologies, exceeded $500 million.

Dutch Government believes that a key factor in meeting that goal will be the development and diffusion of environmental technologies. Toward that end, the Economic and Environment Ministries developed a plan, *Technology and Environment,* to lay out technology goals and objectives.

A key feature is close cooperation between government and industry sectors. The environment ministry has appointed a liaison director for each of several industrial sectors with significant impact on the environment, such as steel, chemicals, paper, and agriculture. Representatives from the targeted industry sectors meet with representatives from several government ministries. The meetings are used to apportion responsibilities for carrying out the plan, developing a schedule, working out government assistance, and establishing organizational provisions for cooperation and management. A similar joint process is used to develop a strategy to address specific problems, such as waste stream reduction. These collaborative processes help identify technology needs and opportunities. The Sustainable Technology Development program, funded at $2.9 million a year by five agencies, was developed to promote the integration of environmental goals into longer term technology development (discussed above),

The plan also features programs to promote development, demonstration, and diffusion of environmental technologies, including cleaner production technologies. A number of these programs are run by the Netherlands Agency for Energy and the Environment (NOVEM), a quasi-public organization created in the early 1980s to develop and promote energy conservation technologies. Its mission was recently expanded to include environmental technology. NOVEM is governed by a board with representatives from industry, government, and academia and therefore has close ties to industry. Government's role tends to be limited to policy, strategy, and funding; industry tends to choose and structure individual projects.

The environment ministry manages the Stimulation of the Development of Environmental Technology program, which provides $7.6 million per year to industry and research institutions. About half supports development of cleaner technologies; the other half supports end-of-pipe technology development. Roughly 80 percent of the Ministry of Economic Affairs' environmental technology grants ($20.6 million a year, averaging $750,000 per grant) goes to manufacturing firms to develop technologies that solve environmental problems, including remediation, monitoring, recycling, and packaging. Industry must pay 60 percent of project costs. The Innovation-oriented Environmental Technology Research program funds researchers at universities and institutes in the fields of environmental biotechnology, recycling and pollution prevention.

The Dutch Government supports demonstration of environmental technologies, with about half of these funds committed to demonstration of pollution prevention technologies.[98] The Ministry of Housing, Physical Planning, and Environment supports demonstration projects for new environmental technology. In addition to initial demonstrations, the government cofunds some subsequent demonstrations as the costs decline. For example, the government picked up about half the cost of the first flue gas desulfurization project in Holland (total cost was equal to $61 million).[99] The second project cost $28 million, with government paying one-quarter. Subsequent projects were much less (about $14 million) and had no government support. Demonstration subsidies support other technologies, including wind power and solar power.

The Netherlands also provides accelerated depreciation for environmental technologies that

98 Discussion with environment ministry official, December 1991.

99 The firm that did this, Esmil (part of the Hoogovenes Steel Works), licensed the technology from Japan and is now selling the technology in other countries, such as Spain. (Interview with environment ministry official.)

have been proven technologically sound but are not yet widely used or required by regulation. Through negotiations between the Environment Ministry and industry, about 120 technologies have so far been chosen, including ultrafiltration membranes, catalytic oxidation devices, ultrasonic cleaning, and low-NO_x boilers. For the technologies on the list, companies may write off the cost of purchases in 1 year rather than the usual 10. When a technology is used in sufficient volume to bring down the price, it is taken off the list.