U.S. Competitiveness in Environmental Technologies and Services 5

The United States' environmental goods and services (EGS) industry appears to be competitive in most sectors. Environmental industries in Japan, Germany, and several other Western European countries are also strong. They compete with U.S. companies in all sectors of the industry in all parts of the world. Indeed, foreign firms and technologies have garnered noteworthy shares of the U.S. environmental market through direct exports, licensing of technologies, and acquisitions of U.S. firms. Also, newly industrialized and developing countries are building their own capabilities to meet part of their domestic environmental needs and to compete in export markets. Thus, competition is likely to increase.

This chapter discusses international competitiveness in environmental technologies and services. It begins with an overview of the limited data on trade in this area. This is followed by a discussion of competitiveness factors. Most of the chapter consists of brief sector analyses of eight major areas.

ENVIRONMENTAL TRADE

Several estimates of international trade in environmental goods and services are discussed below. Because of data limitations, these estimates should be approached with caution.

Information on EGS trade, profits, and productivity is limited, making analysis of competitiveness difficult. The Standard Industrial Classification (SIC) and international Harmonized Code (HC) systems used to tabulate trade data do not conform well to EGS categories. For example, the United States, the European Community (EC), and Japan put industrial air pollution control devices in different categories, making direct

Table 5-I—Estimates of Environmental Exports ($ billion current dollars)

	OECD[a]	Env. Bus. Int.[b]		EPA[c]	JSIMM[d]
	Net goods, services, & licenses 1990	Total products 1992	Total services 1992	Net equipment 1991	Total equipment 1991
United States	4.0	6.9	3.6	1.11	NA
Germany	10.0	11.0	NA	0,72	NA
Japan	3.0	5.0	NA	0.48	0.35
France	0.5	NA	NA	0.01	NA
United Kingdom	0.5	NA	NA	0.29	NA

SOURCES AND NOTES: NA denotes data not available.

a OECD, *The OECD Environment Industry: Situation, Prospects and Government Policies,* OCDE/GD(92)1 (Paris: OECD, 1992). Includes income from technology licenses.

b Environmental Business International, San Diego, CA.

c U.S. EPA, "International Trade in Environmental Protection Equipment," EPA 230-R-93-006, July 1993. Based on trade categories considered environmental by authors.

d Japan Society of Industrial Machinery Manufacturers, May 1992.

comparison difficult.[1] In some cases, categories include environmental products and nonenvironmental goods.[2] And many products-e. g., pumps, motors, chemicals, measuring devices—have environmental applications not identified in trade statistics. Furthermore, data for existing environment-related categories have only recently become available; EC data prior to 1988 are more highly aggregated, and U.S. data prior to 1989 did not conform to the HC system that permits comparability across nations.[3]

Table 5-1 summarizes trade estimates from 4 sources. The estimate shown for the Organisation Economic Cooperation and Development (OECD) is for net exports of environmental products and services, including income derived from licenses.[4] The study concluded that Germany was the largest environmental exporter, producing $10 billion of trade surplus, of which half came from exports to other European OECD countries. The United States and Japan followed, each with several billion dollar surpluses. Britain, France, the Netherlands, and Sweden were also believed to be net exporters. Major importers of EGS were not identified.

The estimate by Environmental Business International in table 5-1 also ranked Germany, the United States, and Japan as the world's three largest environmental exporters, respectively.[5] Its analysis is limited to product exports for the three

[1] U.S. categories include HC 8421390010 Dust Collection and Air Purification Equipment, 8421390020 Electrostatic Precipitators, and 8421390030 Industrial Gas Cleaning Equipment 'not elsewhere specified or indicated. The European Community has additional categories, whereas Japanese trade statistics combine these categories with 8421390050 Gas Filtering or Purifying Machinery to form an aggregate category containing an unknown proportion that is not related to air pollution control.

[2] HC 8421210000 Water Filtering or Purifying Machinery and Apparatus and 8417800000 Industrial or Laboratory Furnaces and Ovens, Including Incinerators are two examples.

[3] The National Trade Data Bank (U.S. Department of Commerce), Eurostat (EC), and Japan Trade Monthly were consulted.

[4] OECD, *The OECD Environment Industry: Situation, Prospects and Government Policies,* ' OCDE/GD(92)1 (Paris: OECD, 1992). OECD's definition of EGS includes water and effluent treatment, waste treatment and disposal, air pollution control, contaminated land reclamation, noise control, and environmental services. It does not include trade and markets in cleaner production and energy efficiency products or services except for some pollution prevention consulting services explicitly identified as environmental consulting.

[5] Grant Ferrier, Environmental Business International, presentation to Environmental Business Council of the United States conference, Washington, DC, June 7-9, 1993. Environmental Business International is the publisher of the *Environmental Business Journal.*

countries and U.S. environmental service exports.[6] The study, using information from fins, concluded that about 20 percent of U.S. environmental goods production was exported. As for U.S. services, the study concluded that under 10 percent of solid waste management revenues and under 5 percent of revenues for engineering/ consulting, hazardous waste management, and analytical services originated abroad.

An Environmental Protection Agency (EPA) study that examined official trade statistics came to markedly different conclusions.[7] As shown in table 5-1, it concluded that the United States was the largest exporter of environmental goods, earning $1.1 billion of surplus out of total exports of nearly $1.7 billion in 1991. Germany was second with over $700 million in surplus from $1.5 billion of exports. Japan followed, with almost a half-billion dollar surplus from almost $700 million in exports. However, due to data limitations, the EPA study understates environmental trade in some respects and overstates it in others. As discussed above, many trade categories include goods that have both environmental and nonenvironmental applications. For instance, the study did not analyze product categories that include many types of treatment chemicals, analytical and control instruments, refuse handling equipment, and pumps and valves, and other goods. At the same time, trade codes for gas separation and purifying equipment, liquid filtering and purification equipment, and industrial and laboratory furnaces (including incinerators) were included even though industry uses much of the equipment in these categories for nonenvironmental purposes. (EPA did not estimate trade in environmental services or revenue flows from technology licenses; official trade data are not suited to such analysis.)

Table 5-2-Japanese Production and Exports of Environmental Equipment ($ million 1991)

Year	Total production	Exports	Percent Exported
1987	4086.0	160.9	3.9
1988	5211.3	170.1	3.2
1989	5314.0	589.5	11.1
1990	5262.0	365.5	6.9
1991	8054.6	350.2	4.3

SOURCE: Japan Society of Industrial Machinery Manufacturers, May 1992.

The Japan Society of Industrial Machinery Manufacturers collects data on Japanese environmental equipment production and exports but not imports (see table 5-2). Its information indicates that between 3 and 11 percent of Japanese manufactured pollution control equipment (for air, water, wastes, and noise/vibration control or treatment) was exported during the years 1987-1991.[8] For 1991, about $350 million of a total of $8 billion of environmental machinery production was exported. This figure is smaller than EPA's calculation of Japanese exports and is far smaller than estimates from OECD and Environmental Business International.

The U.S. Department of Commerce tracks production of some industrial air pollution control equipment (see table 5-3 and figure 5-l). U.S. production of these items grew from $600 million to $900 million (1991 dollars) from 1987 to 1991.[9] During those years between 10 and 16 percent of production was exported.[10] Unfortunately, similar data series for U.S. water pollution and waste-related equipment trade and production are not available.

[6] License revenues are not included nor were import levels calculated.

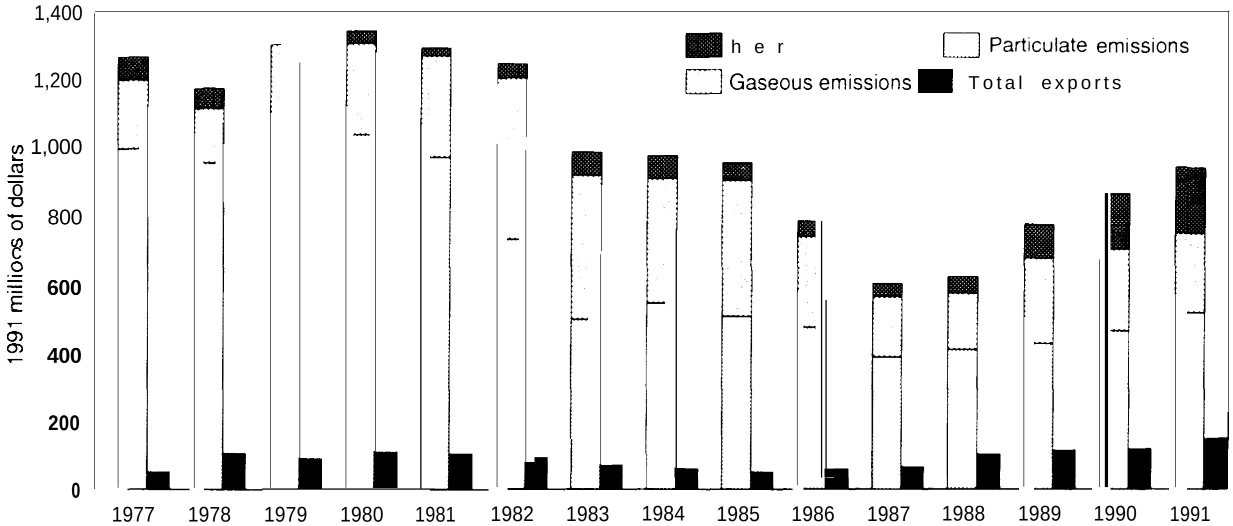
[7] U.S. Environmental Protection Agency, "International Trade in Environmental Protection Equipment: an Assessment of Existing Data, ' EPA 23@ R-93-006, July 1993.

[8] Japan Society of Industrial Machinery Manufacturers, May 1992.

[9] U.S. Department of Commerce, Bureau of the Census, "Current Industrial Reports: Selected Industrial Air Pollution Control Equipment, ' MA35J, various issues.

[10] Ibid., and U.S. Department of Commerce, National Trade Data Bank.

Figure 5-1—Selected Industrial Air Pollution Control Equipment—U.S. Production and Exports



SOURCE: Bureau of the Census and National Trade Data Bank, U.S. Department of Commerce.

Table 5-3-Recent U.S. Production and Trade in Selected Industrial Air Pollution Control Equipment ($ million 1991)

Year	Production	Exports	Imports	Trade surplus
1989	772.2	113.9	78.8	35.1
1990	861.9	119.3	76.1	43.2
1991	936.6	149.0	74.9	74.1

SOURCE: U.S. Department of Commerce, Bureau of Census and National Trade Data Bank.

Data from environmental equipment manufacturers is too limited to compare productivity and quality trends among firms from different counties. The growth in joint ventures, licensing agreements, international acquisitions, and foreign branch operations further complicates national comparisons and efforts to define national policies for environmental industries.[11] Is issuance of a license a strength because it indicates ownership of a technology that will yield royalty income? Or does licensing indicate forgone returns from manufacturing (including exports and export-related jobs)? As in other industries, there are cases of foreign-owned firms employing Americans to make products for export and the U.S. domestic market, and cases of American firms with significant manufacturing operations abroad.

Export Related Employment

From a national perspective, economic benefits of a strong environmental industry include income and jobs that come from exports (or from avoiding imports) and revenues derived from licenses and operations abroad. However, because most EGS is not internationally traded, the export-related employment from growing environmental markets abroad is difficult to estimate. A major portion of expenditures for large environmental projects, such as wastewater treatment plant construction, landfill or incinerator development, or power plant scrubber installation, is for local construction and assembly and for low-value materials that can often be more cheaply provided locally. For instance, estimates from the United States indicate that over half of

11 For more on the blurring of national corporate identifies, see U.S. Congress, Office of Technology Assessment, *Multinationals and the National Interest: Playing by Different Rules*, OTA-ITE-569 (Washington, DC: U.S. Government Printing Office, September 1993).

municipal wastewater treatment capital expenditure is for construction, as is about three-quarters of public water supply treatment capital spending.[12] In developing countries, where labor is often cheap and capital in short supply, such projects may be more labor-intensive than in more industrialized countries. This, in turn, may limit ancillary exports of construction machinery associated with environmental infrastructure development. Much environmental spending is for day-to-day operation of water and wastewater utilities and refuse collection and disposal. These jobs, too, are staffed locally.

Thus, international trade is centered on relatively sophisticated manufactured goods, engineering and project management services, and technology licenses. The most significant opportunities for growth in U.S. EGS exports probably lie in these areas. While export related growth in the number of jobs in such areas will probably be modest, many of these jobs are likely to be high-wage jobs in management, engineering and other technical professions, as well as some manufacturing jobs.

While most environmental technologies are well-established, a small high-technology sector does exist. The technological trajectories for new approaches such as bioremediation and advanced biological treatment,[13] supercritical fluid extraction and oxidation, new and improved catalysts, and advanced monitoring technology, among others, are hard to discern.

Over time, the environmental technology landscape may shift considerably toward pollution prevention and cleaner production. Business opportunities may expand for producers of cleaner technologies that prevent pollution, supplanting some demand for end-of-pipe pollution control, waste disposal, and remedial clean-up in advanced industrialized countries (see box 3-B for an example). Also, fast growth in industrial production and infrastructure in many developing and newly industrialized countries and reconstruction in Central and Eastern Europe open up opportunities for firms able to integrate cleaner and more efficient processes and equipment into new and replacement capital stock. Designers and equippers of cleaner power plants, chemical works, pulp and paper mills, smelting operations, steel mills, oil refineries, assembly plants, and other industrial facilities can position themselves to benefit from the growing interest in sustainable development.

FACTORS AFFECTING COMPETITIVENESS

The competitiveness of a country's environmental firms is determined by a variety of factors. Some factors are fairly specific to environmental businesses, including domestic environmental regulations and the use of development assistance to promote environmental goals. Other factors are shared with other industries, including cost of capital, export promotion policies, workforce skills, industrial structure, and strength of industry associations.

The U.S. environmental industry enjoys a variety of strengths and suffers from a number of weaknesses that affect its performance in the global marketplace. Emerging threats and opportunities will determine its performance in the future. Table 1-1 in chapter 1 presented a short list of major strengths, weaknesses, opportunities, and threats for the U.S. environmental industry. Several factors impinging on U.S. and foreign

12 William T. Lorenz & Co., *1992 Update—Water Pollution Control Industry Outlook* **(Concord, NH: William T. Lorenz & Co., April 1992), pp. 244, 287.**

13 See U.S. Congress, Office **of Technology Assessment,** *Biotechnology in a Global Economy,* OTA-BA-494 (Washington, DC: Government **Printing Office, October 1991) ch. 8 for an analysis of environmental applications of biotechnology.**

environmental industry competitiveness specifically are discussed below.[14]

Strength of Domestic Regulations

Countries with the strongest regulations and enforcement—which can include environmental liability, reporting requirements, and environmental fees-create markets for new and improved types of EGS. Domestic environmental firms can be in a better position than foreign firms to develop products and services to help domestic industries comply with environmental requirements. If comparable regulations are later adopted in other countries, these companies may be favorably positioned to export to the new markets.

The strength of the United States, Germany, and Japan in environmental technologies-along with the disproportionately strong position of several smaller countries, including the Scandinavian nations, the Netherlands, and Switzerland—supports the thesis that countries with the strongest domestic requirements are the most competitive providers of EGS. The relative growth in strength of Japanese and German firms in (sulfur dioxide (SO_2) and nitrogen oxides (NO_x) control technologies during the 1980s, when their domestic standards became stronger than U.S. requirements, as well as the relatively strong position of American hazardous waste remediation technologies, further supports this point.

But the situation is complex. The strong performance of recently privatized British and French water and wastewater treatment fins, despite tighter environmental requirements elsewhere in Europe and in the United States, is one example. In the automobile catalyst business, two of the largest companies are U.S. fins, as might be expected because the United States has the largest market and, with Japan, the strictest standards. But the single largest firm is headquartered in the United Kingdom, despite a history of much weaker requirements in Britain and Europe. And Japanese firms have smaller market shares despite Japan's strict vehicle emissions standards.

Form of Domestic Regulations

Two countries with the same numerical emissions or effluent standards for a given pollutant may still provide different incentives for companies to develop and market innovative environmental technologies.[15,16] Technology approval and permitting procedures, if lengthy and expensive, can be burdensome to developers seeking to bring new technologies to market. Some American environmental technology developers claim to have gone abroad because of difficulties in obtaining proper permits to continue R&D in the United States (see box 5-A).[17] Uncertainty in permitting innovative technologies may dissuade venture capitalists and other investors from funding environmental technologies in the vital stage between the laboratory and proven commercial application.[18]

Technology-based standards that mandate or favor the use of specific technologies or ap-

14 For discussion of broader factors affecting competitiveness, see U.S. Congress, Office of Technology Assessment Op. cit., footnote 11, and U.S. Congress, Office of Technology Assessment, *Competing Economies: America, Europe, and the Pacific Rim*, OTA-ITE-499 (Washington, DC: U.S. Government Printing Office, October 1991).

15 Two reports of the National Advisory Council for Environmental Policy and Technology (NACEPT), an advisory group to EPA, examine the effect of U.S. permitting and compliance policy on environmental technology and innovation: U.S. EPA, "Permitting and Compliance Policy: Barriers to U.S. Environmental Technology Diffusion,'' EPA 101/N-91/001, January 1991; and U.S. EPA, ''Transforming Environmental Permitting and Compliance Policies To Promote Pollution Prevention: Removing Barriers and Providing Incentives To Foster Technology Innovation, Economic Productivity, and Environmental Protection" April 1993.

16 Another OTA assessment is examining characteristics and implementation issues of alternative environmental regulatory approaches.

17 Grant Ferrier, president, Environmental Business International, Inc. and Editor-in-Chief, Environmental Business Journal, testimony at hearings before the House Merchant Marine and Fisheries Committee, Subcommittee on Environment and Natural Resources, Feb. 25, 1993.

18 Dag Syrrist, Technology Funding, testimony at hearings before the Senate Committee on Environment and Public Works May 21, 1993.

Box 5-A-Regulations and Environmental Technology Innovation

How to accommodate research, development, and demonstration of new technologies is an important issue in pollution control and waste treatment laws.[1] If permitting is too easy, enforcement loopholes could develop; if too strict, innovation could be dampened. This can impede the ability of regulated industries to install technology to lower compliance costs (see ch. 9) and diminish incentives for environmental companies to develop and commercialize new technologies in the United States. The U.S. Clean Air and Clean Water Acts have no testing permit provisions and rely on ad hoc administrative procedures that lack predictability. The RD&D permitting provision of the Resource Conservation and Recovery Act (RCRA) are little used. Firms complain that the procedures needed forgetting a permit are time consuming, inflexible, and costly. Commercialization of innovative technologies can also be made difficult by inflexible and costly procedures for demonstrating the efficacy and safety of new approaches.

Some U.S. innovators have taken environmental technologies abroad because of burdensome U.S. regulatory standards. One example is offered by a major company that is developing a vitrification technology that turns wastes into a stable glass.[2] An early use of t he technology is for hazardous fly ash, but it may be applicable to a wide variety of hazardous wastes. Under RCRA rules, any material derived from a hazardous waste is itself considered to be hazardous until the material is delisted following tests to show that it is non-hazardous. This provision is necessary to protect public health and the environment. However, delisting is a lengthy, expensive, and uncertain process often taking 2 to 3 years, or longer. EPA requires separate delisting procedures for each individual type of waste mixture vitrified rather than allowing delisting of a family of materials. Since waste streams often vary in composition, the separate delisting procedures for each mixture likely to be encountered during treatment places an expensive and time-consuming burden on technology innovators. In this company's case, further development of the technology was moved to Europe, where a subsidiary is working with a European firm in what they perceive to be a friendlier climate for hazardous waste treatment R&D. If the technology is successfully commercialized, the foreign partner will benefit from technological expertise and financial gains that might have stayed in the United States.

1 National Advisory Council For Environmental Policy and Technology, *Permitting and Compliance Policy: Barriers to U.S. Environment/ Technology Innovation,* U.S. EPA, EPA 101/N-91/001, January 1991.

2 This paragraph based on discussions with a senior company representative on May 4 and 19, 1993.

preaches for pollution control can have mixed effects on environmental industry competitiveness. For instance, many environmental regulations in the United States, Germany, and Japan are based on best available technology (BAT) or similar criteria. BAT-type standards can guarantee a large market in a short time to vendors of favored technologies and help environmental equipment manufacturers achieve economy-of-scale benefits. However, such standards, if not frequently updated, can freeze existing environmental technologies and discourage innovation. Performance-based standards that do not favor particular types of hardware can allow environmental technology innovation-although even here permitting procedures and administration may still favor a particular reference technology. Also, as in the case of technology-based standards, if performance-based standards are not regularly updated, incentives for innovation may weaken.

Environmental taxes or fees may provide incentives for performance better than standards require and for technical innovation. So might tradable emissions or effluent permits that allow polluters to trade pollution rights. The likely extent of their impact on innovation is difficult to predict. While these approaches might provide incentives for technological innovation, they may also diminish the possibility of large uniform markets for new environmental products and services. Lack of experience with these new regulatory approaches means that empirical data on their efficacy and their effects on innovation are limited. However, they do allow more cost-effective achievement of environmental goals as compared to other regulatory approaches.

The division of environmental standard-setting and enforcement authority among national, regional, and local authorities can affect innovation in environmental technologies and the ability of environmental firms to achieve scale economies. The U.S. federal system places major responsibility on States for administering environmental requirements. The ability of States to sanction flexible regulatory approaches and, in some cases, to impose stronger-than-Federal standards may spur environmental innovation. German states and Japanese prefectures can sometimes require adherence to higher-than-national standards. However, varied standards and permitting procedures fragment the environmental market and can slow the development and diffusion of new environmental technologies.

Fiscal and Other Incentives

The stick of environmental regulation can be supplemented with the carrot of subsidy or other kinds of incentives. To help regulated industries comply with environmental requirements, some countries and states provide tax credits, accelerated depreciation, or low-cost loans for the installation of environmental equipment. (These mechanisms, widely used in Japan, Germany, and the Netherlands, are discussed in ch. 7.) Such incentives can help secure markets for the developers and vendors of environmental technologies. Sometimes they promote innovation. For instance, the Netherlands has a tax-incentive regime (accelerated depreciation) that applies to early installers of listed innovative environmental technologies (both pollution prevention and end-of-pipe controls). As such equipment becomes commercially established, the technology is supposed to be removed from the list. (It is too early to evaluate this approach.)

Incentives can help jump-start industries. In the United States, Federal and State tax credits, combined with high energy prices, stimulated an alternative energy industry in the 1970s. Germany and Japan employ subsidies to build markets for clean energy technologies.[19] The U.S. Public Utility Regulatory Policy Act helped create a market for electric power co-generators. The United States has also pioneered demand side management (DSM) for promoting electricity-use efficiency. State utility commissions, in some cases, allow utilities to make a profit on energy saved. Some utility commissions' costing procedures penalize more polluting energy sources and reward selection of cleaner energy. DSM has stimulated the creation of energy service companies that earn money through improving the energy efficiency of clients.

Another innovative approach is the use of bounties for early developers of technologies that meet new environmentally superior standards. A consortium of 24 electric utility companies, in cooperation with the Electric Power Research Institute, EPA, and Department of Energy (DOE) recently ran a contest in which a refrigerator manufacturer that met future Federal energy efficiency standards and other performance criteria without use of CFCs won $30 million.[20]

19 For example, Japan's Ministry of International Trade and Industry (MITI) has budgeted nearly $40 million for fiscal year 1994 to subsidize two-thirds of the cost of residential photovoltaic systems. MI'IT's goal is 70,000 systems installed by 2000. *Nihon Keizai Shimbun*, Aug. 22, 1993.

20 John Holusha, "whirlpool Takes Top Prize in Redesigning Refrigerator, " New *York Times,* June *30, 1993,* p. D4.

As discussed in the previous section, environmental taxes and tradable pollution allowances might, as supplements to conventional environmental regulations, influence sales and development of environmental technologies.

Firm Size and Financial Strength

Most environmental companies in the United States (roughly 34,000, not including water utilities) and Europe (10,000 or more fins) are small to medium-sized enterprises (SMEs).[21] Some SMEs that offer innovative technologies or services successfully enter foreign markets, often through licensing or joint venture arrangements. However, large, well-capitalized companies have significant advantages in marketing abroad. They can spend significant time and effort investigating foreign markets. They can buy local market access by acquiring local companies or taking large equity stakes in joint ventures. They can afford to conduct R&D (although they might actually do little) or acquire innovations from others. These companies also have better access to capital than smaller fins.

Larger firms can supply customers and clients with integrated services or one-stop shopping. U.S. companies such as WMX Technologies (formerly Waste Management, Inc.) and Air & Water Technologies are attempting to develop such capability. Others offer environmental products and services complementary to core businesses. For example, a number of major international producers of boilers and power generation equipment also sell air pollution abatement equipment. Various engineering and construction firms design and install environmental equipment as part of their general design and construction businesses. Other large environmental companies are divisions of strong multinational conglomerates such as Asea Brown Boveri (ABB), General Electric, Metallgesellschaft, Hitachi, Mitsubishi, and Kawasaki, among others.

Promotion of Techniques and Standards

The respect accorded abroad to domestic standards and technological solutions can contribute to competitive position. The United States is widely regarded as a leader in many categories of environmental technology. EPA is widely respected abroad, and some U.S. professional society standards and guidelines, such as those of the American Water Works Association and the Water Environment Federation, are observed abroad. American firms sometimes contend that EPA's inability or unwillingness to certify their products as meeting U.S. standards leaves them at a disadvantage compared to some foreign firms that claim certifications from their governments. As is discussed in chapter 2, an expanded Federal role supporting demonstration and independent evaluation of American environmental technologies is under consideration. If undertaken, such programs could disseminate objective performance and cost evaluations of U.S. products but avoid potential problems (and, perhaps, loss of credibility) from government endorsement of particular technologies and companies.

Countries sometimes pattern their environmental regulations after those of another country whose environmental firms may thus derive an advantage over rivals that meet somewhat different home country standards. Training programs, technical assistance, and grants and loans for equipment might influence the standards and

21 *Environmental* Business *Journal,* vol. 5, No. 4, April 1992; ECOTEC Research and Consulting, "The European Pollution Control and Waste Management Market: An Overview,' Birmingham, UK, January 1992. Studies of Japanese environmental industry structure have not been found, The Conference for Promotion of High Technology Pollution Control Equipment, an affiliate of the Japan Society of Industrial Machinery Manufacturers, listed 130 engineering and manufacturing enterprises as members in 1990. Members, including divisions of Japanese conglomerates and affiliates of foreign firms, are certified as being capable of producing EGS that meets Japanese environmental standards,

practices employed by the recipient country. The United States and other countries have technical assistance and training programs. Japan's funding of environmental research centers in several Asian countries, including the outfitting of Indonesia's central environmental reference laboratory,[22] could affect these countries' environmental standards and practices.

Export Awareness and Support

The very large U.S. domestic environmental market supports a strong U.S. environmental industry, yet it also dampens the desire of many U.S. firms to pursue export markets and attracts foreign environmental fins.

U.S. companies interested in exports frequently face difficulties accessing private finance or Federal assistance. Some companies that win export orders do not cultivate long-term relationships with foreign customers or find partners able to provide service in export markets—thus hurting future export prospects. Export awareness and support in the environmental sector is discussed extensively in chapter 6.

Environmental exports are sometimes impeded by tariff and nontariff trade barriers. Promotion of liberalized trade in the context of the General Agreement on Tariffs and Trade (GATT), the North American Free Trade Agreement (NAFTA), and other trade negotiations may diminish such barriers.

Financing

Project financing is a large factor in the ability of environmental firms to obtain contracts, particularly in cash-strapped developing countries and the restructuring nations of Central and Eastern Europe and the former Soviet Union. The attractiveness of financial packages is often more important than the technological credentials of competing environmental companies. Loan aid or mixed credits from Japan and several European countries is often perceived to be linked to commercial benefits for home country fins. U.S. bilateral assistance places less emphasis on capital projects likely to generate equipment exports than does European and Japanese development assistance. The use of tied aid and mixed credits is a contentious issue discussed in the OTA background paper *Development Assistance, Export Promotion, and Environmental Technology*.[23] The use of official financing sources to win business for a donor country firm in a developing or restructuring country can have long-term competitive implications that go beyond the scope of a specific project. Projects can generate continuing business for spare parts and supplies. Early entrance into an emerging market can establish familiarity and brand loyalty that in turn yield future business.

Appropriate Technologies, Products, and Service

Customers in developing countries often cannot afford technologies designed to meet the more rigorous environmental requirements of the United States, Japan, and Northern Europe. Even if they can afford state-of-the-art technologies, they may lack the financial resources and trained personnel needed for adequate operations and maintenance. Cheaper, more easily maintained technologies can be environmentally preferable to complex technology that is unused or falls into disrepair due to poor operation and maintenance.

Customers in some developing countries admire U.S. environmental technology but regard it as too expensive and complex, a problem that also faces Japanese, German, and other industrial country competitors. Japan has begun a program to adapt flue gas desulfurization technologies for

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22 BAPEDAL (Indonesian Environment Agency) Briefing to U.S. Environmental Technology and Business Mission Participants, Jakarta, Oct. 26, 1992.

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

developing Asian markets.[24] Some technologies available or under development in the United States—for instance, engineered wetland wastewater treatment-are relatively low-cost. Of great potential are pollution prevention and cleaner production technologies that often offer more cost-effective avoidance of environmental damage than do conventional pollution controls. Energy-efficiency improvements-both supply and use-could limit environmental impact, save money, and promote development in less-developed countries.[25] Relatively low-cost options are also available for reduction of wastes and for decreasing use of toxic substances.

However, a tension may develop between sale and transfer of low-cost environmental technologies to developing and restructuring countries, and the desire to increase export income through the sale of more expensive technologies that can also generate more sales of parts, supplies, and service.

Research, Development, and Demonstration

New environmental technologies, whether related to cleaner production, end-of-pipe controls, or remediation, are products of research and development (more thoroughly discussed in ch. 10). A country's private sector, university, and government R&D system can contribute to its environmental industry's competitiveness. The R&D endeavor, however, extends beyond the laboratory bench and the pilot plant to the demonstration and testing needed to convince potential customers of the economy and efficacy of new technologies. And attention to manufacturing technology is important for achieving continuous improvements in product quality and price. As made clear in the recent past, with consumer electronics, automobiles, memory chips, and many capital goods, possession of the most able scientific research establishment does not ensure commercial predominance.[26]

Germany and Japan are this country's principal rivals in environmental technology R&D and related energy technology research. Japanese environmental technology is chiefly under the direction of the Ministry of International Trade and Industry (MITI). German environmental technology R&D is mainly under the Federal Ministry for Research & Technology and its state equivalents. Both Germany and Japan have a history of industrial policies that feature public-private coordination and research consortia. These approaches are less extensively used in the United States.

The U.S. Government provides more than $1.7 billion per year for R&D related to the environmental technologies covered in this report, but this support is scattered and uncoordinated.[27] American public-private partnerships have increased, however. For example, several cost-shared Department of Energy programs support development and commercialization of environmentally pertinent energy technologies and less wasteful industrial processes. EPA evaluates and disseminates information on innovative contaminated site remediation technologies; somewhat smaller programs fund evaluations of municipal solid waste and industrial waste reduction tech-

~ *International Environment Reporter,* "Japan To Work With China in Developing Cheap Desulfurization Units for Plants, " July 29, 1992, p. 497.

25 U.S. Congress, Office of Technology Assessment *Fueling Development: Energy Technologies for Developing Countries, OTA-B516* (Washington DC: U.S. Government Printing Office, April 1992), pp. 5-12.

26 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) provides an analysis of manufacturing competitiveness.

27 The Congressional Research Service concluded that Federal environmental technology R&D support amounts to $2.5 to $3 billion annually, but this includes support for areas not addressed in this assessment such as agricultural technology, technology for assessing toxicological and other health effects, and modeling and monitoring of ecological and geophysical processes. U.S. Congress, Congressional Research Service, "The Current State of Federal R&D: Environmental Technologies, 92-675 SPR, Aug. 25, 1992.

nologies. Other examples are discussed in chapter 10. However, R&D consortia among environmental fins, regulated industries, and government to address widespread environmental problems by industrial sector remain uncommon in the United States.

SECTOR DESCRIPTIONS AND ANALYSES

These are only a few of the factors that affect the competitiveness of the American environmental industry. As is shown in the brief case studies that follow, these factors weigh differently on different EGS sectors and technologies. Some of the cases pertain to environmental technologies that are capital-intensive, while others are not. Some technologies are new and changing rapidly, while others are mature. In each case, the role of tough regulations, technological sophistication of companies, and access to capital will have varying effects on firms in the industry. It is often difficult to say which countries' industries are ahead.

Design and Construction Services[28]

Such environmental projects as wastewater infrastructure, waste treatment facilities, and large air pollution abatement installations require substantial design and construction management. A large international business exists to provide such design and construction services.

Engineering firms are not only important for designing discrete add-on pollution controls and waste disposal facilities. The engineering consulting industry also could play a key role in incorporation of pollution prevention and cleaner production into whole plant design and process engineering (see box l-B). Although explicit waste minimization and pollution prevention activities now make up less than 5 percent of U.S. environmental engineering consulting business, this segment is likely to grow quickly .29 Cleaner production may increasingly be integrated into engineering design such that the proportion of design activities attributable to environmental concerns becomes more difficult to identify.

American companies are strong competitors in providing design services. This can have ramifications for U.S. manufacturers, as they may have a better chance of winning orders for American-designed facilities than for foreign-designed projects. This may not be because of any explicit preference for American goods by U.S. designers so much as their greater familiarity with those goods.

U.S. design firms are internationally prominent in environment-related projects; a long list of companies are involved.[30] Some of these companies provide a wide range of architecture and engineering services. Others specialize in environmental projects such as wastewater system design.[31] Subsidiaries of other environmental firms such as Metcalf & Eddy (part of Air & Water Technologies), Wheelabrator, and Rust International (both part of WMX Technologies) also perform international engineering services. There are overlaps between the design and contracting categories, as some construction firms also provide engineering services.

As for construction contractors, U.S. firms (including a U.S.-based ABB subsidiary) are the

28 This section does not discuss engineering design conducted by manufacturing industries for their product and process development. National Research Council, *Improving Engineering Design : Designing for Competitive Advantage* (Washington DC: National Academy Press, 1991) assesses the state of engineering design in U.S. manufacturing industry. U.S. Congress, Office of Technology Assessment, *Green Products by Design: Choices for a Cleaner Environment,* OTA-E-541 (Washington, DC: U.S. Government Printing Office, September 1992) discusses environmental aspects of product design.

29 "E/C Firms Position for Prevention, " *Environmental Business Journal, vol. 6, No. 8,* August 1993, p. 1.

30 *Environmental Business Journal,* vol. 6, No. 4, April 1993.

31 Even more specialized engineering design is provided by some vendors of proprietary air pollution control and wastewater treatment technology. In some cases, technology vendors have no in-house manufacturing at all; their products are engineering and intellectual property.

Table 5-4-Largest Winners of International Contracts in Selected Market Sectors

	Sewer/waste	*Hazardous waste*
1.	Bouygues (France)	Parsons Corp. (U. S.)
2.	Parsons Corp. (U. S.)	Bechtel Group (U. S.)
3.	Mitsubishi Heavy Industries (Japan)	ABB Lummus Crest (U. S.)
4.	Bilfinger+Berger Bauaktieng.(Ger)	Bouygues (France)
5.	Foster Wheeler (U. S.)	Foster Wheeler (U. S.)
6.	NCC Internation (Sweden)	The Badger Co. (U. S.)
7.	Consolidated Contractors (Greece)	CEGELEC (France)
8.	Kajima (Japan)	Jacobs Engineering Group (U. S.)
9.	Skanska International Civil Engineering (Sweden)	Bilfinger+Berger Bauaktieng. (Ger.)
10.	The Badger Co. (U. S.)	Spie Batignolles (Italy)
	Water	*Power*
1.	DUMEZ (France)	CRSS (U. S.)
2.	Bechtel Group (U. S.)	Mitsubishi Heavy Industries (Japan)
3.	Fiatimpresit (Italy)	Spie Batignolles (Italy)
4.	SGE Group (France)	Bechtel Group (U. S.)
5.	Impresit-Girola-Lodigiani IMPREGLIO (Italy)	DUMEZ (France)
6.	Bouygues (France)	ABB SAE Sadelmi (Italy)
7.	Hochtief (Germany)	Guy F. Atkinson (U. S.)
8.	Girola (Italy)	John Brown/Davy (U. K.)
9.	GTM-Entrepose (France)	CEGELEC (France)
10.	Morrison Knudsen (U. S.)	Ansaldo (Italy)

SOURCE: *Engineering News Record*, Aug. 24, 1992, p. 37.

eight largest winners of international contracts.[32] In four categories relevant to environmental infrastructure, several U.S. firms are among the top 10 winners of contracts (see table 5-4). U.S. firms also appear in the top 10 four and eight times, respectively, in the manufacturing and industrial/petroleum markets.[33] French, British, Italian, German, and Japanese contractors are the largest rivals. Swedish and Greek firms also appear on these listings.

Beyond the top 10 listing, there are many other U.S. construction companies with significant international presence engaged in environmental projects or projects with major environmental components. 34

Among the more important issues affecting the competitiveness of firms in this industry is the availability of financing. This is particularly important for projects in developing countries and the cash-poor nations of Central and Eastern Europe and the former Soviet Union. Bilateral development assistance and loans from the World Bank and other multilateral lending institutions are important sources of funds in these markets. As has been mentioned, significant controversy surrounds the use of tied aid and mixed credits as means for countries to link development assistance to sales by home country businesses. These issues are discussed extensively in the previously cited OTA background paper, *Development As-*

32 "The Top International contractors," *Engineering News Record*, **Aug. 24, 1992, p. 38.**

33 **"Firms Set Sail For Hot Markets,"** *Engineering News Record*, **Aug. 24,** 1992, **p. 37,**

34 **Environmental Business** *Journal*, vol. **5, No. 4, April 1992, p. 3;** *Engineering News Record, Aug.* 24, 1992, **PP. 38-45.**

sistance, Export Promotion, and Environmental Technology .35

Some in the engineering industry point to the U.S. Trade and Development Agency (TDA) support for project feasibility studies as being particularly useful in their pursuit of opportunities abroad. Other countries also recognize the value of feasibility and prefeasibility studies—which can help determine which firms win bids for project development, Japan allocated $226 million for this function in 1992, while TDA's fiscal year 1993 budget was $40 million.[36] The United States and other countries have created special funds attached to the World Bank for feasibility studies that some believe help win World Bank contracts for contributing nation fins. Use of feasibility studies is further discussed in chapter 6.

Stationary Source Air Pollution Control

This sector of the environmental industry includes designers and manufacturers of devices to control air emissions from power plants, incinerators, and industrial facilities. American companies remain competitive but are struggling against very strong air quality industries that have developed abroad. In addition, foreign companies, directly and through licensing, have made significant inroads into the U.S. domestic market. Air pollution control technologies-particularly sulfur and nitrogen oxide controls-illustrate how the competitiveness of different countries' environmental firms can be affected by differences in regulations.

The timing and stringency of air regulations in the three major air pollution control markets-the United States, Japan, and Germany-have determined the sequence of air pollution control technology development. In the mid-1970s, U.S. regulations to control sulfur dioxide (SO_2) created a market for flue gas desulfurization (FGD) scrubbers. Soon, however, the domestic market for scrubbers stagnated, as most existing industrial and utility sources of SO_2 were shielded from the need to retrofit with FGD and new powerplant construction slowed from weak electricity demand growth.

Although early FGD had cost and reliability problems, the approach was adopted abroad. Japan embarked on a strong program of FGD installation and retrofit in the 1970s and 1980s. This was followed in Germany in the mid-1980s by requirements ensuring that virtually all major sources of SO_2 in former West Germany would be outfitted with FGD within the decade. German standards (called TA Luft) for SO_2 and other air pollutants are periodically updated to reflect new state-of-the-art control technologies. They are models for air regulation in Switzerland, Denmark, Italy, and the Netherlands.[37]

The FGD market is again growing in the United States as the 1990 Clean Air Act Amendments are implemented. FGD accounts for about 32 percent of U.S. stationary source air pollution control equipment revenues in 1992, about $1.7 billion.[38] The law requires that SO_2 emissions in 2000 be half of what they were in 1980. According to an analysis for EPA, a cumulative revenue increase of $1.6 to $4.8 billion will accrue to SO_2 control equipment suppliers over the years 1992-2000 because of the Amendments.[39] However, the estimate is sensitive to a number of assumptions

35 U.S. Congress, Office of Technology Assessment, *Development Assistance, Export Promotion, and Environmental Technology, op. cit.,* footnote *23.*

36 ibid., p. 43.

37 *International Environ* merit *Reporter,* "New National Guidelines Available for Setting Emissions Limits for Industry," July 15, 1992, pp. 466-467.

38 Environmental Business International, 1993 Survey of APC Equipment Manufacturers, San Diego, CA.

39 ICF Resources, Inc. and smith Barney, Harris Upham and Co., Inc., *Business Opportunities of the New Clean Air Act: The Impact of the CAAA of 1990 on the Air Pollution Control Industry* (Washington, DC: ICF Resources, Inc., August 1992), p. III-38.

about the cost of control, the use of low sulfur coal, and other factors. Continued sluggishness of the economy may slow the rate of investment in FGD by utilities and industrial polluters.

In 1993, American companies continue to produce their own proprietary FGD technologies but no longer dominate the global market. German, Scandinavian, and Japanese suppliers aggressively compete with U.S. providers internationally, including growing Asian and Central and Eastern European markets. They are also advancing into the U.S. market. While the largest and third largest FGD suppliers to the U.S. market, Babcock and Wilcox and General Electric, are U.S.-based and use U.S. technology, the Swedish-Swiss conglomerate ABB is the second largest supplier.[40] ABB combines the assets of Flakt, a Swedish air pollution control subsidiary, with Combustion Engineering, a major U.S. supplier of FGD and other air pollution controls, which it purchased. Numerous other U.S. suppliers license FGD technology from Japanese and European firms, and there is a U.S.-Japanese joint venture marketing Japanese-developed FGD technology. Innovative foreign-developed FGD technologies are being demonstrated in DOE's Clean Coal Technology Program and, in one case, was installed in Poland via a U.S. licensee with Federal support.[41,42,43] Foreign technologies licensed by U.S. firms can yield income and jobs in the United States. For instance, Joy Technologies (U. S.) won a contract worth over $100 million to install four FGD units in Taiwan.[44] The technology, which Joy has also sold in Canada, was developed by a German firm.[45]

Control of nitrogen oxides (NO_x), a precursor of smog and acid rain, from stationary sources did not receive major attention from U.S. regulators in the 1970s and 1980s. Thus, markets for selective catalytic reduction (SCR)---a U.S. invented technology-and other NO_x control technologies did not materialize in the United States. Instead, the frost commercial market for SCR materialized in Japan. Japan claims to operate over three-quarters of the world's stack gas denitrification and desulfurization facilities.[46] Germany is the second largest market for SCR as that country's power plants and industrial boilers retrofit NO_x controls. As with SO_2 controls, the 1990 Clean Air Act Amendments are spurring U.S. markets. California air quality requirements are an additional impetus. Some of the earliest U.S. installations of SCR are in California, although the current national NO_x control market only accounts for 2 percent of 1992 U.S. stationary source air pollution equipment revenues (on the order of $100 million).[47]

Japan is the dominant provider of SCR technology. Several Japanese conglomerates, including Kawasaki, Mitsubishi, Hitachi, and Ishikawajima Harima, license SCR to U.S. and European air pollution control companies.[48] There are also a number of joint ventures between U.S. and Japanese fins. However, SCR is one of the more expensive NO_x control options available. U.S. companies have been developing Selective Non-Catalytic Reduction (SNCR) and other technolo-

[40] The McIlvaine Co., "A is Pollution Management: Utility Air Pollution Awards Scorecard," No. 116, November 1992.

[41] Daniel Kaplan, ' 'Georgia Power Begins Tests On Innovative Fiberglass Scrubber," *Energy Daily, Nov. 9, 1992,* p. 4.

[42] Daniel Kaplan, ' 'TVA, DOE Test promising Scrubber Alternative," *Energy Daily,* Oct. 28, 1992.

43 Daniel Kaplan, ''DOE, Poland Asks Industry for CCT Help,' *Energy Daily*, Sept. 22, 1992, pp. 1-2.

44 *Waste Tech News*, vol. 5, No. 4, Jan, 25, 1993, p. 9.

45 *Waste Tech News*, vol. 4, No. 15, July 13, 1992, p. 9.

46 " World's Emission Purification Techniques," Coal Technical Research Institute, in Ministry of Foreign Affairs, 'Japan's Environmental Endeavors," April 1992, p. 10.

47 Environmental Business International, 1993 Survey of APC Equipment Manufacturers, San Diego, CA.

48 *panorama of EC Industry*, "The Environmental Services Industry, " p. 139.

gies that are less effective but also less expensive than SCR. Combustion modifications, such as low-NO_x burners, are the lowest cost control options. While Japanese dominance of SCR is a concern, particularly as North America and Europe try to clean up their smoggiest regions, U.S. providers may be at par or ahead on a number of lower cost control technologies that may garner a large proportion of the NO_x control market in areas not requiring as strict measures.

The competitive situation in some other air pollution control sectors is less clear. Particulate control, often using fabric filters and electrostatic precipitators, is a relatively mature technological sector in which U.S. companies remain active and successful sellers abroad. In the United States, particulate controls constitute 55 percent of stationary source air pollution control equipment revenues.[49] In most other countries that proportion would be higher because fewer controls are needed on other types of emissions.

In contrast to particulate controls, control of VOCs and toxic air pollutants is relatively new and the market is immature. U.S. and German regulations are more stringent than Japanese requirements for these pollutants; California's regulations may be the strictest. Activated carbon adsorption, incineration, and catalyst-based systems for VOC control are available in the United States and Europe from major vendors. Calgon Carbon (U. S.) and Lurgi (Germany) are among major suppliers of activated carbon systems. Biofilters for VOC and odor control are very new approaches under investigation in Germany, the Netherlands, and the United States.

Licensing, joint venture, and multinational operations make assessment of competitiveness and national economic benefits difficult. The snapshot of growing U.S. use of foreign technologies should be understood in the context of growing technological interdependence. German and Japanese companies license environmental technologies to each other as well as to U.S. firms. American companies do sell air pollution control technology in the home markets of major competitors and derive benefits from ownership of subsidiaries in those markets. It is difficult to generalize about the economic implications of foreign ownership of American air pollution control firms. The American subsidiary may be limited by the parent in its export opportunities, or conversely, the parent company might open new export markets for its U.S. subsidiary. Employment implications of licensing and joint ventures in air pollution control maybe relatively modest—most FGD and other large pollution abatement projects involve large amounts of local fabrication and construction that do not involve much international trade. However, profits, royalties, and income from engineering design work conducted in the home market can be substantial. Some air pollution control company executives suggest, as a rule-of-thumb, that perhaps 30 percent of expenditures for major installations are for internationally tradable engineering services and sophisticated components, while 70 percent is for local materials and assembly.[50]

Controlling air pollution from large power plants and other large facilities entails major expenditures. Hence, availability of financing is often an important determinant of successful sales to developing countries. Japan's MITI, through its Green Aid Plan, has targeted Asia for technical and financial assistance in air pollution control including FGD. The Plan will include adaptation of FGD to lower cost and removal efficiency levels appropriate for some countries.[51] MITI has also announced plans to lease air pollution control equipment to address acid rain problems. However, a number of American companies already

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49 Environmental Business International, 1993 Survey of APC Equipment Manufacturers, San Diego, CA.

50 OTA staff discussions with air pollution control company executives.

51 *International Environment Reporter*, "Japan to Work With China in Developing Cheap Desulfurition Units for Plants," July 29, 1992, p. 497.

produce less expensive lower efficiency control technologies.

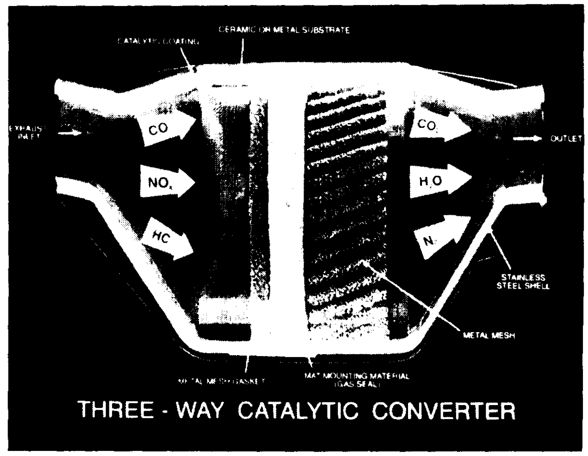
Competition in the air pollution control sector comes not only from rival producers of air pollution abatement products but also from alternative technology developers and vendors. In the stationary source area, cleaner production technologies, including low-NO_x burners, gas turbines, several clean coal technologies, and recovery and replacement of organic solvents in industrial processes, may limit or even obviate some types of air pollution control equipment. Some issues related to competitiveness in clean energy production are discussed in a subsequent case analysis.

Mobile Source Air Pollution Control

Estimates of the U.S. mobile source control market range from $6 billion to $8.2 billion.[52,53] The global vehicle emissions control market has been estimated as $12.5 billion and may grow to $29 billion by **2000.**[54] The market includes catalytic converters, diesel filters, inspection and maintenance equipment, evaporative emissions controls, and some engine controls. U.S. manufacturers are active exporters and also have subsidiaries and licensees abroad. U.S. members of the Manufacturers of Emission Controls Association reported that they sold $250 million of catalyst and filter technologies outside the United States and Canada in 1992; these firms projected such annual sales to reach $400 million by 2000 which could add 2,000 new jobs.[55]

The United States pioneered strong vehicle emissions controls. The introduction of the catalytic converter, removal of lead from gasoline (necessary for catalytic converter operation), and desulfurization of diesel fuel were undertaken in the 1970s in response to emissions standards of the 1970 Clean Air Act. Japan quickly adapted some of its requirements to meet U.S. standards, in part to qualify Japanese-made automobiles for export to the United States. Both countries required oxidation catalysts starting in model year 1975 and then, several years later, required more effective three-way catalysts.

It was not until the late 1980s that more than a handful of other countries required catalytic converter use.[56] By 1993, the European Community had adopted EC-wide catalytic conversion



JOHNSON MATTHEY

First required by the United States in the 1970s, use of catalytic converters to control automotive emissions has become a worldwide business. The three-way catalytic converter shown here is used in a growing number of countries. Recent tightening of U.S. standards may require further developments in the technology.

52 Farkas Berkowitz & CO., "The Fifth Annual State-of-the-Industry Report,' Washington DC, 1993.

53 U.S. Department of Commerce in ICF Resources and Smith Barney, Harris Upham and Company Inc., *Business Opportunities of the New Clean Air Act: The Impact of the CAAA of 1990 on the Air Pollution Control Industry,* op. cit., footnote 39, p. I-2.

54 Michael P. Walsh, ''Motor Vehicle Pollution Control: The Global Market—Summary, " Arlington, VA, Oct. 5, 1993.

55 Bruce Bertelsen, "Clean Air Act Spurs Growth of U.S. Motor Vehicle Emission Control Industry," *Clean Air Technology News* (published by the Institute of Clean Air Companies and Manufacturers of Emission Control Association) summer 1993, pp. 2-3.

56 H&W Management Science Consultants, 'International Mobile Source Emissions Controls Market Study: Update No. 1," prepared for the Manufacturers of Emission Control Association, August 1990. Australia, Austria, Canada, Denmark, Norway, Sweden, and Switzerland adopted catalytic converters in the late 1980s.

requirements, although delays were permitted for a number of member states, and larger cars had to meet an earlier 1989 deadline. Two NICs, Taiwan and South Korea, adopted these requirements by 1991. Mexico is phasing in catalytic converters and unleaded gasoline. Over the course of the 1990s a number of other countries in Central and Eastern Europe, Asia, and Latin America will likely adopt similar requirements. Diesel emissions controls using catalysts and particulate traps are also a growing market as the United States, EC, and other countries compel their use.

The most significant force for improving catalytic conversion technology is the set of California vehicle emissions regulations that will be phased in over the next two decades. While the ultimate goal of the California program is commercialization of zero emission vehicles—to account for 10 percent of in-state automobile sales by 2003—intermediate standards for low emitting, very low emitting, and ultra-low emitting vehicles might be met by improved catalytic converters used in conjunction with gasoline or alternative fuels. Several other States may follow suit with these requirements. California regulations and proposed Federal requirements are also driving catalytic converter development for small engines (e.g., lawn mowers, chain saws, snow blowers); limited application has already occurred in Europe.[57]

A handful of major producers dominate the global catalytic converter business. The largest supplier of catalysts is Johnson Matthey, a British firm with major U.S. operations, estimated to have a 27 to 28 percent market share.[58] Two American suppliers, Allied Signal and Engelhard, each garner about a fifth of the market with domestic and overseas plants. Degussa of Germany (which has an American plant) is estimated to have less than 10-percent share, with the remainder split among a number of Japanese and Taiwanese companies. W.R. Grace (U.S.), which supplies industrial catalysts, and other companies are trying to enter the market by developing devices that will meet future California requirements. The substrates on which catalysts lie—usually ceramic or stainless steel—are made by a number of U. S., Japanese, and European firms. Corning is a major producer of ceramic substrate with a plant in Germany and a license to a Japanese manufacturer. Several American companies including Donaldson Co., Corning, and 3M, and the Canadian firm Engine Control Systems are active in the diesel control markets.

American producers are strong competitors in the catalytic converter market and strict California standards may drive them to produce more effective catalysts that could become national and foreign standards. However, other automobile producing nations also have strong incentives to develop emissions control systems that will meet tightening U.S. Federal and State standards so that their exports qualify for the American market. Japanese, German, Swedish, and Canadian companies and governments have significant R&D programs for vehicles powered by alternative fuels, fuel cells, and electricity. Some foreign companies have been working on projects designed to address California's automotive requirements.[59] Some of these alternative vehicle technologies could eventually obviate emissions control technologies.

USCAR, a collaboration involving the U.S. Government, the Big Three U.S. automobile manufacturers (General Motors, Ford, and Chrysler), and component suppliers, is an important effort toward creating the clean car while revitalizing the U.S. automobile industry (see ch. 10). The Advanced Battery Consortium and a low-emissions vehicle initiative are components of USCAR.

[57] Julie Edelson Halpert, "Cleaner Garden-Variety Engines," *New York Times*, Sept. 26, 1993, p. F1O.

58 Stephen Lipmann, "U.S. Environmental Companies' Competitive Strategies: Eleven Case Studies,' OTA contractor report, March 1993.

[59] South Coast Air Quality Management District, Technology Advancement Office, 1992 Progress Report, July 1992.

U.S. companies' strength in this sector has benefited the United States through export earnings, license royalties, and profits. The employment benefits are less clear when catalytic converters are often imported into the United States already attached to the automobiles.

Water and Wastewater Treatment Technologies

The U.S. water and wastewater treatment market is relatively mature, yet in much of the world basic water sanitation is an acute need. The provision of drinking water and treatment of domestic and industrial effluents are not only prominent in the plans of less developed countries but are also important priorities for environmental investment in the rapidly industrializing countries of the Pacific Rim and Latin America. As discussed in chapter 4, multibillion dollar water and sewer projects are underway or planned in many of these countries. A high priority on water is evident in the environmental plans of Central and Eastern European countries. Even within the OECD countries, there is some room for improvement in the water and wastewater treatment sector. For instance, centralized sewage treatment is provided to only 44 percent of Japanese residents[60] versus 75 percent in the United States. A number of EC countries will need to make significant investments to meet EC water standards. And U.S. regulations continue to tighten.

OECD estimated the global market for water and wastewater treatment goods and related services at $60 billion in 1990.[61] Most spending related to water and wastewater projects is for locally provided construction labor, lower value materials, and operations. In the United States, about 75 percent of municipal water treatment and over 50 percent of municipal wastewater treatment capital expenditures are for construction; the remainder are for engineering and equipment.[62] Of the portion of water industry-related expenditures that is likely to be internationally traded, much will accrue to engineering and construction firms for design and construction management. However, there is significant commerce in equipment and supplies such as aerators, falters, pumps, flow meters, monitoring instruments, and chemicals for treatment systems. This section centers on competitiveness of suppliers of such goods and technologies. There is an overlap with the engineering/construction industry and water supply utilities-firms in both of these service sectors have major interests in equipment manufacturing fins. Also, because of site-specific conditions, engineering services are often integral to equipment sales.

U.S. drinking water and wastewater standards are among the world's most demanding; German, Dutch, French, and Scandinavian country standards are also high. Standards of U.S. professional associations, including the Water Environment Federation and American Water Works Association, are used abroad. And U.S. water technologies are respected abroad. The Water and Wastewater Equipment Manufacturers Association row), an industry association with about 70 member firms accounting for nearly $1 billion of annual sales, reports that the majority of its members sell abroad—mainly secondary and tertiary wastewater treatment equipment and disinfection systems.[63] U.S. companies, among them Nalco Chemical, Betz Laboratories, and

60 *Environment and Development: Japan's Experience and Achievement,* **Japan's National Report to the** United **Nations** Conference **on Environment and Development** (UNCED), **December 1991, pp. 32-33.**

61 OECD, **op. cit.,** footnote **4.**

62 William **T.** Lorenz **& Co., op. cit.,** footnote 12.

63 Dawn Kristof, President, Water and Wastewater Equipment Manufacturers Association, personal communication, **June 2, 1992.**

W.R. Grace, are major international providers of water treatment chemicals and services.[64]

Over the last decade Swiss, Swedish, French, and British companies have been active in acquiring U.S. water and wastewater equipment companies.[65] Of the 10 largest U.S. providers of treatment equipment, 5 are European-owned.[66] And while U.S. companies license technologies abroad, some observers believe that there is a net influx of foreign water and wastewater treatment technologies into the United States.[67] European firms also export directly into the U.S. market.

Despite good reputation and interest in exporting, a number of factors impede the U.S. water and wastewater equipment industry's competitiveness. The 70 members of WWEMA average under $15 million in annual sales and operate with low profit margins.[68] The estimated 2,400 or more other companies in the sector are yet smaller.[69] Low profit margins leave limited resources for R&D and for exploring foreign markets. In some regions, such as Southeast Asia, local environmental firms feel that the United States has been late in entering the market and that Japanese and European firms have the advantage of greater familiarity.[70] Some of these firms believe Japanese and European providers offer better after-sales service than U.S. suppliers. As in other environmental sectors, U.S. companies have difficulty competing in developing country markets against some foreign suppliers with superior access to confessional aid finance.

With multibillion dollar projects planned or underway in a number of developing countries (see ch. 4), aid can serve as a lever to shift business--both equipment supply and engineering/construction services-to a donor country's fins. The lever may be the formal or informal tying of aid to spending in the donor country or it may be training, technical assistance, and other support that makes recipients more familiar with-and more likely to choose-technologies and vendors from the donor country. Except for projects in Egypt ($2 billion over 14 years in the water sector),[71] recent U.S. development assistance has not emphasized large capital projects that can generate exports, unlike aid from Japan and several European countries.[72] Japan's reported commitment of $1 billion to a $4 billion, 10-year Brazilian clean-up of Rio de Janeiro's Guanabara Bay,[73] its funding of environmental centers in Indonesia and other Asian countries, and other forms Green Aid may yield commercial benefits to Japanese fins. The United States and European countries also consider potential commercial benefits of aid.

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64 Rick Mullin, "Water Treatment Chemicals and Services," *Chemicalweek*, May 13, 1992, pp. 32-40; Michael Roberts, "Europe: New Laws, New Markets," *Chemicalweek*, May 13, 1992, pp. 46-47.

65 Dawn Kristoff, op cit., footnote 63.

66 "EBJ's Top Water/Wastewater Equipment Companies," *Environmental Business Journal*, vol. 6, No. 3, March 1993, p. 5. The listing does not include revenues from treatment chemicals, instruments, pipes, and valves.

67 "Water/Wastewater Markets Remain Diverse," *Environmental Business Journal*, vol. 6, No. 3, March 1993, pp. 1,3-5.

68 Dawn Kristoff, op. cit., footnote 63.

69 *Environmental Business Journal*, vol. 5, No. 4, April 1992, p. 7. Twenty-five publicly traded companies averaged $259.5 million in 1991 revenues and 2,500 privately held companies averaged $2.4 million.

70 Environmental Management and Research Association of Malaysia, Briefing for Participants of U.S. Environmental Technology & Business Mission, Kuala Lumpur, Malaysia, Oct. 30, 1992.

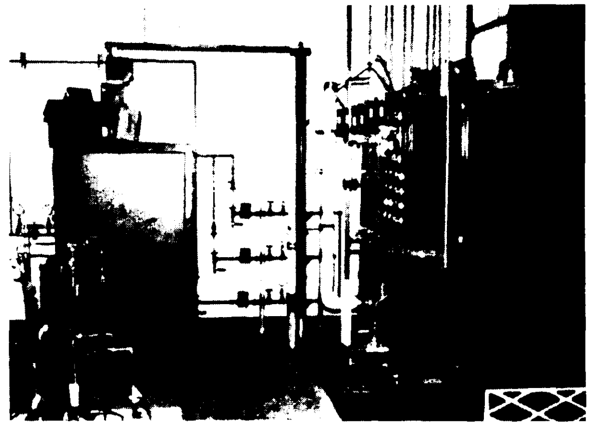
71 Project in Development and the Environment, *Profile of the Environmental Business Sector in Egypt* (Washington, DC: October 1992), p. 19.

72 U.S. Congress, Office of Technology Assessment, *Development Assistance, Export Promotion, and Environmental Technology*, Op. cit., footnote 23.

73 U.S. AID, *Environmental Market Conditions and Business Opportunities in Key Latin American Countries*, Business Focus Series (Arlington, VA: October 1992), p. 50.

Judging form the limited data that is available from the U.S. Department of Commerce,[74] the performance of U.S. water and wastewater equipment exporters in emerging markets has been mixed. U.S. and Japanese firms each supply about a third of Taiwan's import market. U.S. suppliers provide the majority of Mexico's imported water and wastewater equipment but fare no better than German, Swedish, and British rivals in the Brazilian industrial wastewater market. The correlation between aid and exports can explain the strength of U.S. suppliers in Egypt, Japanese companies in China, and French firms in Tunisia; in each case the largest aid donor is the largest provider of imported water-related goods and services.

Among foreign competitors in the water and wastewater market, the French and recently privatized British water utilities have emerged as particularly important players. Compagnie Generale des Eaux-Dumez and Lyonnaise des Eaux from France, and several British companies (Severn Trent, Northwest Water, Wessex, and Thames Water among the largest) have utility operating experience and healthy financial positions. They offer customers integrated water industry services ranging from equipment to design to operations. Some of these companies also provide construction services. They have diversified into the waste disposal sector and have been active acquirers of companies in the United States and elsewhere. In contrast, it is difficult for the American water and wastewater industry to match the integrated services. The U.S. water and wastewater industry is more fragmented-most designers and contractors do not operate water facilities,[75] water and sewer utilities are usually local government entities or small private firms that only operate in a limited service area, and equipment suppliers often lack operating experience.


U.S. DEPARTMENT OF ENERGY

Advanced water treatment technologies such as this ultraviolet/ozone disinfection unit are at an early stage of deployment.

Competition is very tough for American firms providing water and wastewater equipment, and continues to increase as newly industrialized and developing countries expand their environmental industries' capability for providing water-related equipment for their domestic markets and for export.

Advanced systems; Advanced water and wastewater systems may move toward alternatives to chlorine disinfection, such as ozonation and ultraviolet irradiation. New biological methods for sewage and industrial effluent treatment could find growing application. The use of polymer water treatment chemicals is increasing. Ion exchange for metals recovery and membrane-based systems (ultrafiltration and reverse osmosis) will likely find greater industrial uses for some add-on treatment and in-process waste minimization and water conservation. Organic contaminant destruction by incineration or other oxidative processes may expand as controls on VOCs and air toxics tighten. Engineered wetlands

[74] Various industry sector analyses from the National Trade Data Bank, Department of Commerce country desk officers, and U.S. AID Business Focus Series reports are sources for market share data.

[75] There are some exceptions. Some U.S. environmental firms, including Metcalf & Eddy (part of Air & Water Technologies) and Wheelabrator Technologies (affiliated with WMX Technologies) do operate a few facilities in addition to offering engineering services.

and similar nature-based aquatic treatment systems offer low-cost options for small communities in both industrialized and developing countries; however, the employment and income associated with export of the know-how to build such systems is likely to be quite modest.

Advanced water technologies may not be limited to markets in advanced industrialized countries. For instance, RMA Dornier, a subsidiary of Deutsche Aerospace, is introducing ion exchange in Malaysia as a cost-effective alternative to conventional treatment and disposal of metal-laden effluents from that country's growing electronics industry.[76] In another example, new bacterial degradation technology from Micro-Bac International (a Texas based firm) is used by a quarter of Brazil's chicken processing industry for wastewater treatment, as well as by a number of sewage systems; applications for individual buildings and households and for toxic wastes are under development.[77]

The competitive situation in advanced and alternative treatment approaches is hard to assess, for the market is at an early stage. Even in countries with the most stringent regulations, effluents are regulated using traditional indicators of water quality such as pH, turbidity, biological and chemical oxygen demand (BOD and COD), and total dissolved solids. Regulation of toxic chemicals is still evolving and markets are immature. U. S., German, and other European companies are competitive suppliers of ion exchange resins. Calgon Carbon and Nalco Chemical are among major U.S. suppliers of activated carbon systems for removal of many organic compounds from water and air. Lurgi, a major German competitor in air pollution control, is also a large supplier of activated carbon, providing systems in 50 countries.[78] Membrane systems, ultraviolet and ozone disinfection, ion exchange, real-time monitoring of effluents, engineered wetlands, and other newer developments are only in the early stages of use.

Solid and Hazardous Waste Industry

The waste sectors consist of service companies that collect, treat, recycle, and dispose of wastes, and firms that produce and market the equipment and technologies needed by waste service companies. Types of technologies and equipment used in the industry range from garbage trucks and balers to sorting machines for mixed recyclable to incineration technology and specialized treatment technologies for hazardous wastes.

Among service providers, the U.S. domestic solid waste industry has undergone significant consolidation over the last two decades, as many small local refuse collectors and landfill operators were acquired by large waste service companies. WMX Technologies (formerly Waste Management, Inc.) and Browning Ferris Industries (BFI) are the two biggest U.S. solid waste service fins. Laidlaw (Canada) and Attwoods (U.K.) have significant U.S. operations. Europe is also developing a more concentrated waste service industry, comprised of companies whose main business is waste handling and disposal and firms that are waste subsidiaries of major water (e.g., Compagnie Generale des Eaux, Lyonnaise des Eaux, and Severn Trent) and electric (e.g., RWE, the largest German electric utility) utilities.

WMX and BFI are part of the consolidation trend abroad. Out of WMX's $8.6 billion in total 1992 revenues, almost $1.7 billion arose from operations outside of the United States. WMX has waste services in 20 countries in Europe, Asia, and Latin America, including hazardous waste facilities in operation or under construction in the Netherlands, Hong Kong, Singapore, and Indonesia. The firm recently acquired a 90-percent

76 EnviroPro '92 Conference and Trade Show, Kuala Lumpur, Malaysia, Oct. 30, 1992.

77 International *Environment Reporter,* "U.S. Biotechnology Used to Treat Sewage, Industrial Waste in Brazil," Sept. 23, 1992, pp. 599-600.

78 Metallgesellschaft AG, 1990/91 Annual Report.

interest in Sweden's largest hazardous waste company.[79,80] BFI is the second largest American international waste service competitor, although its services are limited to nonhazardous wastes. It has operations in nine foreign countries and is pursuing additional international opportunities.[81] The large U.S. waste service companies bring to the international market their extensive experience in operating facilities and handling diverse wastes under strict U.S. regulations. Both WMX and BFI have significant financial strength and good access to capital. WMX is attempting to reorganize itself into an integrated environmental service company incorporating air, water, and waste services under one roof.

Another American waste service competitor of note is Safety-Kleen. It is the largest recoverer of used solvents and motor oil in the United States and believes itself to be the largest solvent recycler in the world.[82] Collected solvents and oils are recycled, rerefined, or burnt for energy in industrial furnaces. The company is also a major provider of parts cleaning equipment, particularly to the automotive repair industry. Safety-Kleen has brought its recovery services to several European countries and has several licensees in the Pacific Rim, including Japan. The company owns Germany's largest solvent recycler and biggest parts-cleaning service firm.[83]

Smaller hazardous and specialized waste-related companies in the United States have been entering foreign markets. U.S. companies may have the advantage of operating under tough toxic waste regulation for longer than foreign rivals. The Resource Conservation and Recovery Act of 1976 was the first comprehensive U.S. Federal law regulating hazardous wastes, The later passage of Superfund legislation further propelled the U.S. hazardous waste industry by making improper disposal of hazardous wastes a very expensive risk for companies. No other country imposes hazardous waste liability burdens as great as those under Superfund. Interestingly, growth of the hazardous waste industry may ultimately be limited by increasingly stringent hazardous waste standards. As the costs of disposal and liability grow, generators have increased incentives to practice pollution prevention through avoidance of toxic compounds and minimization of hazardous residuals. Some waste service firms also offer waste minimization services.

Although the U.S. waste service industry is highly competitive worldwide, it is not without rivals. Canada's Laidlaw has a noteworthy presence in the United States and has entered Europe. The Danish firm I. Kruger, a subsidiary of Compagnie Generale des Eaux (France), was chosen over a U.S. company to establish an integrated hazardous waste facility in Malaysia. Berzelius Umwelt-Service AG, a subsidiary of Metallgesellschaft of Germany, is a major recycler of industrial materials, including metal-laden wastes, plastics, and used foundry sand. The firm has a 45-percent stake in Horsehead Resource Development Co., the largest U.S. recycler of electric arc dust.[84] Although the United States and Japan host significant recycling R&D efforts, growing German recycling requirements and disposal regulations, which could be adopted by other European countries, may further propel German expertise and technology in the area. Japanese firms do not appear to be prominent in providing waste services internationally.

In the equipment and technology sector of the waste industry, American suppliers face tougher

79 Lipmann, op. cit., footnote 58.

80 *Waste* Tech *News*, vol. *4, No. 19,* Sept. 7, 1992, p. 9.

81 BFI was recently awarded a $400 million 25-year joint venture contract to build and operate a landfill in Hong Kong. "Browning-Ferris Gets Contract to Operate a Hong Kong Dump," *Wall Street Journal,* June *29, 1993,* p. A8.

82 Lipmann, op. cit., footnote 58.

83 Ibid.

84 Metallgesellschaft 1990/91 Annual Report.

competition. Swiss, German, and French firms successfully market comporting and recycling machinery in the United States. European and Japanese companies are major providers of waste incineration technology. With less land available for landfills, Europe and Japan incinerate more of their waste than does the United States. Von Roll of Switzerland and Martin of Germany are major international providers of incineration technology. Deutsche Babcock licenses incineration technology in Japan.[85] Japan has numerous incinerator builders; Ebara, a major engineering-construction concern and an important provider of fluidized bed incinerators, maybe the largest.[86] Numerous U.S. waste-to-energy firms rely on European-licensed technologies .87

There have been some U.S. successes in the equipment field; for instance, Detroit Stoker's grate system is a significant U.S. contribution to incineration technology.[88] Wheelabrator is building a facility in Germany. Basic Environmental Engineering has licensed combustion technologies that will be used in a tire burning waste-to-energy facility in Britain.[89] U.S. companies are also successfully marketing recycling and waste-handling equipment and landfill liners abroad.

For hazardous wastes, new treatment technologies may provide viable alternatives to conventional incineration and treatment. With a number of alternative technological approaches in various stages of development and early commercialization, it is difficult to predict commercial leadership. Supercritical fluid extraction and oxidation—which uses carbon dioxide or water at high temperature and pressure to remove or destroy organic materials-is one approach under study in the United States. Molten Metal Technologies (U. S.) is developing a molten iron bath system for destroying wastes and recovering materials. A U.S.-Mexican joint venture enterprise is considering this technology for a planned Mexican hazardous waste treatment facility.[90] Vitrification—turning materials into a glassy substance—is still another approach. A number of innovative treatment technologies being developed for contaminated site clean-up (see next section) may be applicable for waste treatment.

Contaminated Site Remediation

The United States has more experience than any other country in dealing with contaminated land and groundwater. Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund) of 1980 to bring some order to Federal laws on toxic substance clean-up and compensation.[91] The law applied joint and several liability retroactively on site owners, former operators, waste generators, and waste haulers associated with hazardous wastes found in abandoned or inactive sites. A Hazardous Substance Response Fund (Superfund) was created to clean up sites in cases where parties responsible for contamination cannot be located or are unable to pay. A number of States have adopted mini-Superfunds. Although subject to extensive criticism as inefficient,[92] the

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85 Kawasaki Heavy Industries, 1992 annual report.

86 Masato Ishizawa, "Fluidized Bed Incinerators Drawing Interest," *The Nikkei Weekly*, Sept. 12, 1992.

87 William T. Lorenz & Co., *1991 Update—Solid Waste Control Industry Outlook* (Concord, NH: William T. Lorenz & Co., June 1991) p. 486.

88 Ibid., p. 446.

89 *Waste Tech News*, vol. 4, No. 19, Sept. 7, 1992, p. 6.

90 "Mexican, U.S. Businessmen Plan to Build Treatment Plant in Mexico," *International Environment Reporter*, Jan. 15, 1992, p. 7.

91 Frederick R. Anderson, Daniel R. Mandelker, and A. Dan Tarlock, *Environmental Protection: Law and Policy* (Boston: Little, Brown and Co., 1984), p. 568.

92 See, for instance, U.S. Congress, Office of Technology Assessment, *Coming Clean: Superfund Problems Can Be Solved*, OTA-ITE-433 (Washington, DC: U.S. Government Printing Office, October 1989).

Superfund Act propelled the emergence of a hazardous waste remediation industry. Other specialized remedial services have sprung up in response to regulations and concerns about leaking underground storage tanks, asbestos, and lead paint.

America's focus on remedial environmental clean-up has heightened in the last several years as it has become clear that it will require billions of dollars in annual expenditures for many years to manage environmental contamination at various Department of Energy (DOE) and Department of Defense (DOD) installations. DOE's estimated fiscal year 1994 outlay for environmental restoration and waste management will be over $5 billion, while DOD plans to spend about $2 billion for the same purpose.[93] Federal site contaminants range from common fuels and solvents often found at civilian sites to radioactive substances, explosives, and propellants.[94]

European and Japanese remediation laws and programs are less extensive than those of the United States. Hazardous waste remediation experience in Europe has thus far been limited to Germany, France, Great Britain, the Netherlands, Denmark,[95] and perhaps other Nordic countries. Japan and Western Europe are still assessing the extent of soil and groundwater contamination in their countries. Germany's eastern states, the restructuring countries of Central and Eastern Europe, and the former Soviet Union offer formidable remediation challenges and, if money can be found, business opportunities.

Competitiveness is hard to assess in this sector, where there are many technologies to handle many types of contaminants. Incineration and solidification are conventional techniques, but newer innovations-including bioremediation, vitrification, vapor extraction, thermal desorption, soil cleaning, and chemical treatment, among others—are vying for markets.[96] Site characterization technologies, including monitoring technologies and groundwater modeling systems, are also being advanced.

Firms in the U.S. industry range from very small, technology-based entrepreneurial firms to large waste and engineering companies. Despite new technologies, much remediation work involves labor-intensive activity such as earthmoving and construction. U.S. technologies appear to fare well as international markets arise. Japan's Environment Agency plans soil contamination research using U.S.-developed technologies.[97] Terra Vac Corp., an early developer of vapor extraction technology, is an example of a small U.S. firm exporting remediation services. The company has joint venture partners and business activities in Western Europe, Japan, and the Czech Republic.[98] WMX's European and Asian hazardous waste facilities may be positioned to serve remediation markets.

Foreign competitors are now emerging, however. For example, Metallgesellschaft (Germany) established a remediation and hazardous waste management subsidiary in 1989. It has won industrial and military site decontamination con-

93 Executive Office of the President, Office of Management and Budget, *Budget of the United States Government,* Fiscal Year 1994, pp. App.-461, App.-462, *App.-57O.*

94 See U.S. Congress, Office of Technology Assessment, *Complex Cleanup:* The Environmental *Legacy of Nuclear Weapons Production, OTA-O-484* (Washington, DC: U.S. Government Printing Office, February 1991) for discussion of clean up of DOE's nuclear weapons facilities.

95 ECOTEC Research& Consulting, "The European Pollution Control and Waste Management Market: An Overview, " January 1992, p. 24.

96 See U.S. EPA, 'Cleaning Up the Nation's Waste Sites: Markets and Technology

tracts within Germany and, in partnership with Messerschmitt, is seeking munitions site decontamination business in Russia.[99] Heidemij Reststoffendiensten, a Dutch company, is operating an 80,000-ton-a-year soil washing facility in the Netherlands.[100] The plant could be the world's largest. German technology is being tested by a U.S. firm for cleaning up groundwater at March Air Force Base in California.[101] As their remediation markets grow, European and Japanese competitors are likely to expand their remediation technology capabilities, using their own technologies or adapting and improving those developed in the United States.

The strong U.S. emphasis on remediation has created an environmental industry sector that has the potential to export its products, services, and technologies. But, in much of the world, including developing and newly industrialized countries, Central and Eastern Europe, and the former Soviet Union, it is not clear whether or when clean-up of existing contaminated sites will receive much emphasis. The Environmental Action Program developed by the OECD and World Bank for environmental aid to the former Eastern Bloc places high priority on air pollution, drinking water, and nature conservation; the absence of remediation as a priority is striking.[102] The plan was adopted by almost 50 environment ministers from Europe, the United States, Canada, and Japan. However, privatization of state-owned enterprises in eastern Germany and other parts of Central and Eastern Europe may propel some remediation markets as authorities seek to make facilities more attractive to investors, Many developing countries have had a relatively short history of hazardous chemical-intensive industies and activities, so they may have few sites requiring remediation. While particular sites could present extraordinary hazards or have leaked chemicals and fuel that may be recovered for use, remediation will usually be a lower priority than prevention and control.

Cleaner Energy Technologies

Energy extraction, conversion, and use is the major contributor to a wide variety of environmental ills, ranging from the global build-up of greenhouse gases to regional acid rain and smog to local air pollution and oil spills. Demand for energy and requirements for energy-related investment are likely to increase substantially over the next two decades. For instance, an analysis done for the U.S. National Energy Strategy in 1991/1992 projects that over $2 trillion of investment, amounting to over 1,000 gigawatts of capacity, in the electric power supply sector will occur outside the United States during the years 1991-2010.[103] A little over half of this investment may occur in developing countries, about a quarter in OECD countries (other than the United States), and the remainder in Central and Eastern Europe and the former Soviet Union,

The World Bank estimates that non-OECD electricity capital investments may reach $1 trillion during the 1990s.[104] Whether or not growth in demand for electricity or energy occurs at such a rapid pace, there is greater realization of the need to address the environmental problems caused by energy development. Business opportunities will arise for pollution abatement equipment, more efficient and cleaner energy extrac-

~ Metallgesellschaft Annual Report 1990/91.

100 *Waste Tech News*,, vol. 4, No. 24, Nov. 16, 1992, p. 6.

101 Environmental Science& Technology, vol. 27, No. 10, October 1993, pp. 1957-1958.

102 Marlise Simons, "West Offers Plan To Clean Up East," *New York Times, May 4, 1993,* p. A13.

103 us. Department of Energy, "National Energy Strategy Technical Annex 5: Analysis of Options to Increase Exports of U.S. Energy Technology," 1991/1992, p. 7.

104 World Bank, ''Capital Expenditures for Electric Power in the Developing Countries, " KEN Energy Series Paper No. 21, February 1990, in World Bank, "The Bank's Role in the Electric Power Sector, ' draft, Industry and Energy Department, Box 5.

tion and conversion technologies, and more efficient energy end use.

This section discusses competitiveness in cleaner energy technologies, in particular electricity supply, and features several classes of electric power technologies including gas turbines (also called combustion turbines), advanced coal technologies, and several renewable energy technologies. While some of these technologies offer certain advantages even in the absence of environmental benefits, their environmental attributes can spur their development and use. For example, gas turbines and combined cycle power plants that combine steam and gas turbine cycles can offer advantages in cost, efficiency, and flexibility of use over conventional steam plants; however, significant advantages also accrue from their cleaner performance, including lower pollution abatement costs, easier permitting, and less difficult facility siting. These environmental benefits are major factors in the adoption of these technologies and could be viewed as environmental business opportunities.

COMBUSTION OR GAS TURBINES

New gas turbine technologies offer extensive environmental and operational advantages over conventional steam turbine power plants. For more advanced models and configurations, such as combined cycle (linking gas and steam turbine cycles), steam injected, and intercooled steam injected, electrical generating efficiencies of 45 to over 50 percent are possible, in contrast to 30 to 35 percent for conventional steam plants.[105] Net energy efficiencies may exceed 80 percent if cogenerated heat is recovered. Improved efficiency translates into less environmental damage per unit of electrical generation or capacity; carbon dioxide emissions are less than those from conventional power plants, while particulate, VOC, and SO_2 emissions can be very low. (Controls for NO_x may still be necessary.) Gas turbines can be economically and quickly installed in small increments-in contrast to large, capital-intensive, centralized steam plants. Advanced gas turbines may have the flexibility to be configured for both peaking-power and base-load performance. Natural gas, oil, and gasified coal and biomass can be used as fuels.

There are about 15 manufacturers of gas turbines in the world;[106] the United States fares well in this business. General Electric (GE) is the largest supplier, with roughly half the U.S. domestic market and, with its European and Japanese business associates, who assemble turbines using key GE components, about the same proportion of the world market.[107] The company has had success in selling gas turbines in the home markets of competing nations; 56 percent of European orders in 1991 accrued to GE and its associates[108] and Japan has been a good GE gas turbine customer. Pratt & Whitney and Westinghouse are other U.S. gas turbine suppliers. So far GE and Pratt& Whitney dominate the production of aeroderivative gas turbines (derived, in part, from jet engine technology) that are expected to be in growing demand.[109] Major foreign competitors include ABB, Siemens (Germany), and Rolls Royce (U.K.), which have been increasing their U.S. market share.

International partnerships and licensing arrangements are proliferating. GE's overseas associates include major Japanese and European engineering firms and machinery manufacturers,

105 Oak Ridge National Laboratory, *Energy Technology R&D: What Could Make a Difference?*, vol. 2 (ORNL-6541/V1/P2) December 1989, pp. 41-46; and R.H. Williams and E.D. Larson, "Aeroderivative Turbines for Stationary Power," *Annual Review of Energy*, vol. 13, 1988, pp. 429-489.

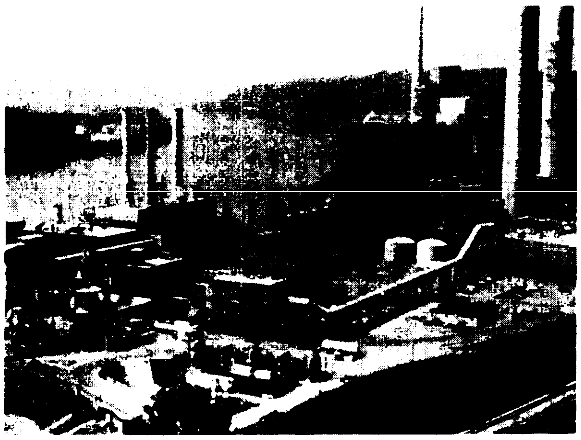
106 U.S. Department of Energy, op.cit., footnote 103, pp. 46-47.

107 Eugene Zeltman, General Electric, personal communication, Feb. 3, 1993.

108 "GE Forms New European Marketing Arm," *Energy Daily*, Oct. 21, 1992, p. 4,

109 Jim Clarke, "EPRI Official: Interest in Advanced Turbines Increasing," *Energy Daily*, June 26, 1992, p. 4.

U.S. DEPARTMENT OF ENERGY



Ohio Power Co. Tidd Plant, Brilliant, Ohio. Pressurized fluidized bed combustion is one of a variety of technologies being demonstrated under DOE'S Clean Coal Technology Program. Clean coal technologies may have growing markets as coal-dependent countries around the world address environmental concerns.

Westinghouse has partnerships and agreements with Rolls Royce, Mitsubishi, and Fiat Avio (Italy). Rolls Royce has a separate partnership with ABB in Europe. And Pratt & Whitney has a partnership with Siemens. General Electric Co. of Great Britain is linked with Alsthom of France. Competition has intensified as the number of gas turbine manufacturers has grown. Several of the partnerships just noted were forged to challenge GE's and Pratt & Whitney's position in the aeroderivative market. Firms in newly industrialized countries might enter the market as well.

ADVANCED COAL COMBUSTION AND CONVERSION TECHNOLOGIES

Fluidized bed combustion (FBC) and coal gasification are two major types of clean coal technologies that may see considerable market development as ways are sought to make coal use more compatible with environmental protection. Along with several other new cleaner combustion technologies, they are being developed and demonstrated under the U.S. Department of Energy's Clean Coal Technology Program. The program is a Federal-private cost-sharing effort to demonstrate new ways of using coal cleanly, including precombustion coal cleaning, advanced combustion and conversion, and postcombustion cleanup. Over $2.7 billion of Federal money is committed to five rounds of demonstrations from fiscal year 1986 through fiscal year 1995.[110] Of $4.6 billion committed to 41 projects at the end of 1992, 40 percent was from DOE and 60 percent from industry.[111] Other DOE and Electric Power Research Institute (EPRI) research has been important in advancing combustion technologies in the United States.

Two major variants of fluidized bed combustion are Atmospheric FBC (AFBC) and Pressurized FBC (PFBC). Both can effect high rates of sulfur removal and are alternatives to conventional pulverized coal plants using flue gas desulfurization. AFBC has been employed for biomass and waste combustion, and can use low quality fossil fuels like lignite and oil shale.[112] PFBC, a less mature technology, offers higher efficiency in less space than either conventional or AFBC plants. These technologies may be viable for repowering existing plants as well as for new installations.

U.S. vendors of AFBC systems face considerable competition from Europe and Japan. India and China are developing AFBC for their domestic needs. Less complex variants of AFBC have been built mainly for biomass burning and waste incineration. For larger utility scale applications, the emphasis has been on more advanced circulating AFBC. Lurgi (Germany) and Ahlstrom/Pyropower (Finland) have led with 40 and 30 plants, respectively, in operation or under con-

110 U.S. Congress, Congressional Research Service, "DOE's Clean Coal Technology Program: Goals and Funding," CRS Issue Brief IB88071, updated July 20, 1993,

111 Daniel Kaplan, "DOE Looks to Future in Final Clean Coal Technology Solicitation' *Energy Daily*, Dec. 10, 1992, p. 4.

112 E. Stratos Tavoulareas, "Fluidized Bed Technology, " *Annual Review of Energy and Environment*, vol. 16 (1991), pp. 25-57.

struction by 1990.[113] Two Swedish companies are prominent competitors; one has licensed its technology to U. S., Japanese, and Spanish fins. Keeler/Dorr-Oliver and Foster Wheeler are the major U.S. providers of AFBC technology. Combustion Engineering, a U.S. subsidiary of ABB, is another supplier and a participant in DOE's clean coal technology demonstration program. [114] Other AFBC variants are being developed by U.S. and German companies.[115]

PFBC is an immature technology that is not yet commercially available. ABB has dominated the field as supplier of all three major PFBC demonstration projects (in Spain, Sweden, and the United States).[116] Demonstration units have been sold to Japan and the former Czechoslovakia. ABB hopes to sell commercial-sized facilities in the United States and Japan. Deutsche Babcock (Germany), Foster Wheeler, and Air Products and Chemicals are working together to demonstrate a PFBC system in DOE's clean coal technology program.[117] Ahlstrom/Pyropower, using Finnish technology, hopes to become a PFBC supplier, with a U.S. demonstration plant planned for completion later in the decade.[118]

Integrated gasification combined cycle (IGCC) is another clean coal approach. Gas is derived from coal while polluting ash and sulfur are left behind, The gas, like natural gas, can be burned relatively cleanly and at high efficiency in a combined cycle power plant. Most existing coal gasification projects produce gas for chemical feedstock rather than for electric power production. The gasification process may be adaptable for gasification of biomass as well. IGCC produces far less waste than fluidized bed combustion because sorbents are not needed to absorb sulfur from the combustion chamber. This is also an advantage over FGD on conventional power plants. There are only a handful of gasification processes in competition from U. S., German, Dutch, and British firms.[119] Japan's government and electric utilities are working together to develop coal gasification and liquefaction technologies. [120] The major processes that appear to be making commercial inroads are from Texaco, Dow, Shell (Netherlands), and British Gas/ Lurgi.[121] The Texaco process seems to be most used; there are facilities in the United States, Japan, and Germany using the process, mostly for chemical feedstock production. Texaco has received contracts in China and Italy, and is working with Venezuela to promote IGCC use with heavy Venezuelan oil for the U.S. and Caribbean markets.[122] Several DOE clean coal demonstrations feature IGCC.

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113 Ibid.

114 S. B, Alpert, ''Clean Coal Technology and Advanced Coal-Based Power plants, ' *Annual Review of Energy and Environment,* vol. 16 (1991), pp. 1-23.

115 Ibid.

116 Robert Smock,' 'Pressurized Fluid Bed Demonstration Units Operate Successfully, " *Power Engineering,* vol. *97, No. 3,* March *1993,* pp. *42-45.*

117 R.C. Rittenhouse, "Clean Coal Technology: Where Does It Go From Here?,' *Power Engineering,* Vol. 97, no. 7, July1993, pp. 17-22.

118 Ibid.

119 Oak Ridge National Laboratory, Op cit., footnote105, p. 27.

120 Agenc, for Industrial Science and Technology, *Shikenkenyusho Kenkyu Keikaku 1992 (Oct. 1992), as reported in Foreign Broadcast Information Service, Foreign Media Notes, FB* PN 93-330, July 28, 1993.

121 Alpert, op. cit., footnote 114, p. 20.

122 George Lobenz, "Texaco, Venezuela Sign Accord Linking Orimulsion, IGCC,'' *Energy Daily,* June 18, 1992, p. 3,

RENEWABLE ENERGY[123]

Renewable energy sources, other than hydroelectric, make up only a small portion of commercial electric power generation today. However, that proportion is likely to grow, perhaps rapidly. Technological improvements that have lowered costs, concerns about greenhouse gas emissions, and continuing worries about the safety of nuclear power add to renewable energy's appeal. Renewable energy is key for pursuit of sustainable development. Photovoltaic cells (PVs) and wind turbines are among the renewable energy technologies that might make important contributions to power supply in coming decades.

The United States pioneered development of PVs, which found early applications in space as satellite power sources. Today, PVs are being used for remote location power production—which is particularly important in developing countries without widespread national power grids-and are being evaluated for some utility applications. U.S. PV manufacturers face very strong competition from their Japanese, German, and other European counterparts. The world's largest manufacturer of PVs is Siemens Solar Industries, a U.S. subsidiary of Siemens (Germany), which recently bought ARCO Solar in the United States.[124] The company accounts for over half of U.S. production, of which it exports 75 percent.

U.S. and Japanese producers each garnered about one-third of the global market in 1992; up from one-quarter for U.S. producers and down from half for Japanese producers in 1986.[125,126] European production grew from about 15 percent to nearly 29 percent in that period. Some Asian competitors have built up production experience by making PVs for calculators, watches, and similar devices. They now produce cells and modules for remote sites, residential use, and utility demonstration in competition with U.S. manufacturers. There are at least a dozen U. S.-owned PV manufacturers. Several, including Solarex (an Amoco subsidiary), Mobil Solar, and Texas Instruments, are parts of large companies. Energy Conversion Devices (ECD) has formed a partnership with Canon (Japan), called United Solar Systems Corp., to manufacture PVs in the United States.[127] ECD has separate PV joint ventures in India and the former Soviet Union. The United States, Germany, and Japan are the leading funders of research, development, and demonstration of PV technology; several European countries have lesser efforts.

Wind turbines are providing utility power today, with most installations in California, Hawaii, and Denmark. Several improvements in design, materials, and siting may make wind a cost-effective electric power source in a large area of the United States and abroad.[128] DOE's goal is to achieve price reductions from a current average of 8 cents per kilowatt-hour to 5 cents by the mid-1990s, a cost similar to that of a new fossil fuel plant. U.S. Windpower (a subsidiary of Kenetech) claims to have already achieved this goal with a new variable speed turbine.[129] U. S., Danish, Belgian, Dutch, Japanese, German, and British companies make utility-scale wind turbines. By the late 1980s, several Danish manufacturers were supplying over 50 percent of U.S.

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123 A forthcoming OTA assessment, Renewable *Energy Technology: Research, Development, and Commercial Prospects*, will analyze technological and commercial aspects of renewable energy including competitiveness issues.

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

125 *Photovoltaic* News, vol. 12, No. 1, January 1993, p. 1.

126 *Photovoltaic News*, vol. 11, No. 2, February 1992, p. 1.

127 Lipmann, op. cit., footnote 78.

128 Carl J. Weinberg and Robert H. Williams, "Energy From the Sun," *Scientific American*, vol. 263, No. 3, September 1990, pp. 146-155.

129 "NREL Launches Solar Projects" *Energy Daily*, Nov. 4, 1991, p. 4; Kimberly Dozier, "USW Touts Wind Turbine Breakthrough," *Energy Daily, Nov. 6*, 1991, pp. 1-2.

wind-based generation capacity.[130] Mitsubishi entered the U.S. market in 1987. Belgian and British machines also operate in the United States. While there are a number of U.S. wind turbine manufacturers, U.S. Windpower has been the dominant U.S.-based supplier of utility-scale machines, accounting for over 90 percent of U.S. manufactured machines.[131] U.S. Windpower has been working on projects in Europe, Latin America, Egypt, and New Zealand. At least nine other U.S. companies are working with DOE's National Renewable Energy Laboratory on cost-shared wind energy technology development projects.[132]

Pioneers in commercialization of renewable energy technology do not necessarily enjoy commercial success. In California, LUZ International developed several solar thermal electric power plants. The technology uses mirrored troughs to focus sunlight on tubes containing liquids that are then used to generate steam for electric power production; natural gas is used as a supplemental fuel. The LUZ facilities are the largest commercial solar thermal electric plants in the world. The company achieved economies of scale as its facilities grew; its latest 80 megawatt units generate power at 8 cents per kilowatt hour versus 24 cents for its first 15 megawatt unit in 1984.[133] However, despite this progress, the company has gone bankrupt. Research, development, and demonstration of other solar thermal systems continues in the United States and abroad.

The American renewable energy industry is technologically strong and competitive-but so are foreign suppliers. As in other arenas of environmental technology competition, some foreign suppliers obtain more favorable financing

CYNTHIA CHEAK/KENETECH

U.S. manufactured wind turbines at the Altamont Pass, California. Technical advances are making renewable energy sources more economically viable. U.S. producers of such technologies face tough foreign competition in the U.S. and international markets.

from home governments than do U.S. firms. This is particularly important in developing countries, which are an important export market for U.S. renewable energy products.

Help for manufacturing R&D and development of domestic markets can be important determinants of competitiveness. Japan and Germany have strong programs for R&D, demonstration, and evaluation of renewable and other alternative energy technologies. They also employ tax incentives and subsidies to encourage installation of renewable energy and other environmentally preferable energy technologies (e.g., fuel cells). For example, Japan's Ministry of International Trade and Industry (MITI) has earmarked nearly $40 million for fiscal year 1994 in a multiyear program to subsidize two-thirds the cost of household PV installations; the goal is to have

[130] Oak Ridge *National* Laboratory, op. cit., footnote 105, pp. 145-147.

[131] Ibid

[132] "NREL Launches Solar Projects," *Energy Daily, Nov.* 4, *1991,* p. 4; "NREL Funds Wind Turbine R&D Efforts," *Energy Daily,* Dec. 4, 1992, p. 4.

[133] Michael Lotker, "Barriers to Commercialization of Large-Scale Solar Electricity: Lessons Learned From the LUZ Experience," Sandia National Laboratory contractor report, SAND91-7014, November 1991.

70,000 systems installed by 2000.[134] **The 70,000** systems would amount to about 340 percent of the world's current annual PV production capacity. These countries' technology policies balance efforts for improving the supply of new technology (R&D) and demand for new technology (market creating incentives).

DOE is cooperating with renewable energy technology manufacturers, electric utilities, and other industries to promote manufacturing R&D and utility applications of renewable. (See ch. 10.) The PV Manufacturing Technology Program's goal is to prevent loss of the PV industry to Japanese and German manufacturers by helping domestic companies improve their manufacturing capability. PVUSA—Photovoltaics for Utility Scale Applications-is helping to develop utility PV markets through testing of various manufacturers systems and identification feasible utility applications. Other cost-sharing U.S. government-industry programs exist for wind and geothermal R&D. A number of State utility commissions' rules for incorporating social costs of pollution could help the U.S. market and industry.

END-USE ENERGY EFFICIENCY

Improvement of energy use efficiency as an international market opportunity is still in a nascent state. The energy efficiency sector is very diverse, including products ranging from instruments and controls to high-efficiency appliances, heating, lighting, cooling, and motors to insulation and improved windows. Although highly uncertain, global trade in energy efficiency products and services is estimated at $8.4 billion per year during the period 1990 to 2000, doubling to $16.8 billion annually in the decade leading to 2010; about half of that market is expected to be in less-developed countries.[135] U.S. AID estimates that U.S. companies can realistically capture only about 8 percent of the global energy efficiency export market and 10 percent of the annual exports to developing countries.[136] Japanese and European firms provide tough competition for American companies.

Japanese and German producers are already strong exporters of many capital goods, some of which incorporate energy efficiency improvements that have helped those countries' industries achieve higher energy efficiencies than some American sectors. More often than U.S. companies, Japanese and European companies have already established substantial presence in developing countries.[137] Low-cost manufacturers in Taiwan, South Korea, and other rapidly industrializing countries provide additional competition for U.S. companies, or, at least, U.S.-based manufacturing. Indeed, the United States is itself a net importer of some energy-efficient products, such as compact fluorescent lighting ballasts.[138] As in other environment and energy sectors, the availability of financing affects the performance of U.S. vendors vis-à-vis foreign competitors in developing country markets. U.S. suppliers are expected to be most competitive in supplying higher technology energy efficiency products including industrial process controls and instrumentation, as well as industrial and residential energy load management systems and controls (e.g., thermostats). However, German and French suppliers are also competitive in these sectors.

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134 *Nihon Keizai Shimbun*, Aug. 22, 1993, as cited in Foreign Broadcast Information Service, *pacific Rim Economic Review*, vol. *2, No.* 18, Sept. *8, 1993,* p. *7.*

135 U.S. Department of Energy, op. cit., footnote 103, pp. 67-6*.

136 Ibid., pp. 68-69.

137 Ibid., p. 69.

138 International Institute for Energy Conservation, *Seizing the Moment: Global Opportunities for the U.S. Energy Efficiency Industry* (Washington, *DC:* International Institute for Energy Conservation December 1992), p. 4.

Industrial Pollution Prevention and Cleaner Production

As in the case of energy end-use efficiency, this business is less a sector than an agglomeration of providers of many types of goods, services, and technologies that are usually integrated into production processes and are often hard to tease out as separate items. Nonetheless, as discussed earlier in this chapter and in chapter 8, pollution prevention and cleaner production present important environmental market opportunities.

In some cases, equipment and technology used for pollution prevention is similar to some forms of conventional add-on environmental controls. For instance, activated carbon, ion exchange, and membrane-based technologies may be used for in-process pollution prevention, for recovery of materials for recycling, or for end-of-pipe or remedial separation of pollutants for destruction or disposal. The same vendors provide their products for application across this continuum of environmental activities. In other cases, the pollution prevention technology may only be weakly associated with conventional environmental products; extended cooking in the paper and pulp industry or improved process controls in most industries are examples, The design of many other industrial products and processes are strongly affected by environmental concerns and, thus, are environmental business opportunities. For example, environmental considerations are leading to changes in painting and coating technologies including development of high efficiency paint sprayers; powder coatings; ultraviolet, infrared, and microwave paint curing; and alternative paint formulations.

While assessment of competitiveness in cleaner production as a whole is difficult, because the area is so broad, assessments could be made of particular components such as cleaner painting, metal cleaning, pulp and papermaking, or as described above, electric power generation. As in most of the sectors discussed, the United States, Germany, and Japan are the major players with competition from several smaller Northern European states. Regulations have certainly propelled many cleaner production development activities. The phase-out of CFCs has inspired searches for alternative solvents, for solvent-free options, and for closed-loop processes that avoid solvent release; the United States appears to be a strong contender in this area. California's stringent air pollution regulations have spawned partnerships among government, energy utilities, and industry for low emissions processes and fuels. The winners in clean production innovation-in addition to public health and the environment--can be both the regulated industry that seeks cheaper ways to comply with regulations and suppliers of cleaner production technologies that may find growing markets for their innovations domestically and abroad.

CONCLUSION

The strength and form of environmental regulations in the home market are major determinants of environmental industry competitiveness. However, a variety of other factors, including development assistance policies, export promotion, support for R&D and technology demonstration and diffusion, and industrial structure also influence environmental industry competitiveness.

The United States is competitive in many environmental industry sectors but faces growing competition from foreign companies, most seriously German and Japanese fins. The internationalization of environmental industries and lack of data, and the early stage of deployment for some environmental technologies, make definitive assessments of competitiveness difficult, In a number of sectors, including stationary source air pollution control and wastewater treatment, foreign companies are making significant inroads in the U.S. domestic market through exports, technology licensing, and acquisitions of U.S. fins. In addition, newly industrialized and developing countries are increasing their environmental industry capability. Pollution prevention, cleaner technology, and energy efficiency provide significant business opportunities that can often allow higher degrees of environmental protection at lower cost than many end-of-pipe environmental controls; such opportunities should not be overlooked in policies for environmental industrial support.