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ENVIRONMENTAL TECHNOLOGIES AND COMPETITIVE ADVANTAGE

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In this decade and the coming century, the natural environment will be an important arena for economic competition. Ecological issues regarding energy, natural resources, pollution, and waste offer both competitive opportunities and constraints, and are changing the competitive landscape in many industries. Corporations can gain competitive advantage by managing ecological variables. This paper explains the concept of 'environmental technologies' as a competitive force and a tool for competitive advantage. Environmental technologies offer a new substantive orientation and a management process for minimizing ecological impacts of economic production while enhancing competitiveness of firms. The practical application of environmental technologies is illustrated using a mini case example of 3M Corporation. Strategic implications of environmental technologies for competitiveness are explored.

THE NATURAL ENVIRONMENT: A NEW COMPETITIVE ARENA

Industrial activities of the past half century have created serious ecological problems. The list includes global warming, ozone depletion, loss of biodiversity, natural resource scarcity, air pollution, acid rain, toxic wastes, and industrial accidents (Brown *et al.*, 1991, 1992, 1993). These problems are expected to worsen in the next 50 years when the world population will double to 11 billion. To provide basic amenities to this population using current technologies, world economic production will need to increase by more than five times today's level. This can only worsen our environmental problems (Daly and Cobb, 1989; Commoner, 1990).

There is little consensus on the scale, severity, and human consequences of ecological degradation. There are some who claim that ecosystems are basically healthy, and *laissez-faire* capitalism is ecologically sustainable worldwide (Taylor, 1994). There are others who believe that while there are some serious problems, new technologies will prevent catastrophic ecological degradation, and ensure continued economic growth (Bernstam, 1991; Cole *et al.*, 1973; Lecomber, 1975). But there is now an emerging agreement that a better balance between economic and ecological variables is desirable, and that the time frame for achieving it is the next three decades (Gore, 1992).

There are many philosophies of environmentalism that advocate different solutions to these ecological problems. They include conservation movements that seek to conserve nature and wilderness, 'reform environmentalism' that seeks to change industry incrementally to improve its environmental performance, and 'radical environmentalism' which rejects industrialism and seeks an alternative ecotopian society. One solution that has received positive support from many

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environmental camps is the concept of sustainable development (SD) (World Commission on Environment and Development, 1987).

Sustainable development involves control over population growth, providing worldwide food security, preserving ecosystem resources, and reorienting energy use and industry to ecologically sustainable directions. Sustainability means meeting our current needs without jeopardizing the ability of future generations to meet theirs. It involves pacing the use of resources so that they can be renewed and maintained within a natural equilibrium (Costanza, 1992; Daly and Cobb, 1989).

For the global economy to become ecologically sustainable, it will be necessary to organize business and industry along ecologically sound principles. This will require transformation of corporations, their products, production systems, and management practices. If the world economy shifts towards an ecological orientation, it will change the competitive landscape of industries in terms of consumer preferences and demands, industrial regulations, and competitive opportunities.

While it is too early to forecast definite trends, some signs of these changes are starting to emerge in opinion polls and market research studies. Consumers are becoming more environmentally conscious. A majority of people say they are willing to sacrifice some economic growth for environmental protection.[1] Consumers say they prefer environment-friendly products and packaging and are willing to pay more for them. Nearly 20 percent of adults in the United States and Canada belong to environmental consumer segments of 'True Blue' and 'Greenback' greens (Gallup International, 1992; Stisser, 1994). A 'green market segment' consisting of consumers who prefer ecologically sound products is emerging in a wide range of industries (Ottman, 1992). The demand for environment-related products is estimated to be $120 billion per year currently, and expected to grow to about $200 billion per year by the end of this decade (EPA, 1990).[2] The Japanese government (Ministry of International Trade and Industry—MITI) expects that nearly 40 percent of world economic production by the middle of the twenty-first century will come from energy- and environment-related products and technologies. It has targeted these technologies for commercial development (Gross, 1992; Miller and Moore, 1994; Ministry of International Trade and Industry, 1988).

The competitive landscape is also being shaped by numerous environmental regulations and standards that affect the cost of doing business. These regulatory impacts are readily apparent in natural resource- and energy-intensive, and pollution-prone companies, although they affect other companies as well (Smart, 1992). The 1992 Earth Summit produced several international environmental treaties. These treaties are now being converted into national laws and regulations that will further sharpen global competition.[3] In

[1] This is based on Gallup International's Environmental Opinion Survey. The survey asked people if they would be willing to protect the environment over economic growth. The percentage of respondents saying yes was 59 percent in the United States, 73 percent in Germany, 68 percent in Canada, 56 percent in the United Kingdom, and 58 percent in Japan. Even in low-income developing countries more than 50 percent of people said yes, except for India and Turkey (both 43%) (Gallup International, 1992). In Nordic countries the Business Environmental Barometer survey conducted by the Gothenburg Research Institute, Gothenburg, Sweden confirms these opinions among corporate executives.

[2] The data on environmental product markets are scarce and imprecise. Much depends on what is included in the definition of 'energy- and environment-related products'. There is no SIC code for the environmental products industry. The industries that can be meaningfully included in this group are diverse. They include products and services such as waste management, environmental consulting, energy production and exploration, materials recycling, and pollution control equipment. In addition, many industries have an 'environmental' segment, of environmentally sound products. Examples of these segments include 'recycled paper' packaging in the packaging industry, 'organic' foods in the agriculture industry, or 'energy-efficient' appliances in the appliances industry. Since there are no firm standards of definition for data collection, the figures quoted here must be interpreted with caution. Moreover, it should be noted that a significant part of this market is driven by regulatory requirements.

[3] International treaties are converted into national laws. These laws open up new market opportunities, create demand for new investments, and constrain certain production, product design, and trade practices, all of which affect competitiveness of companies. For example, the International Treaty on Ozone Depleting Substances (popularly called the Montreal Protocol) changed the fundamental competitive characteristics of the chlorofluorocarbons (CFCs) industry, which in the late 1980s was a $700 million business. The treaty was followed up by creation of national laws in signatory countries, which established a schedule for time-phased reduction in the demand for CFCs, eliminating it by 2010. These laws created demand for CFC substitutes, changed the practice of cleaning printed circuit boards in the electronics industry, changed the design of aerosol packaging, and changed the uses of Styrofoam. The Global Warming Treaty calls for basic changes in power production technologies. The national laws that it is spawning have wide-ranging competitive effects, on the costs of power production, pollution control investments, subsidies for energy conservation, location of power plants, and energy trading.

addition, quality management standards recommended in ISO 9000 (International Organization for Standards) are being expanded to include new environmental standards (Smith, 1992).

There are conflicting opinions on the competitive impacts of environmental regulations. Porter (1991, 1994) suggests that strict environmental regulations do not inevitably hinder competitiveness against foreign rivals. They may even enhance competitiveness. Higher environmental standards can trigger innovation and upgrading of technologies, making companies more efficient. For example, in response to the energy crisis of the early 1970s, Japan enacted tough energy management regulations that prompted companies to innovate highly energy-efficient systems (Watanabe, 1992). Moreover, improvements in environmental and public health are shown to lead to more vigorous industrial development (Marshall, 1993).

Opponents argue that environmental protection hurts the world economy and slows down economic growth. They cite the recessions and economic slowdowns in industrialized countries during the past two decades as evidence (Osterfeld, 1992; *The Economist*, 1994).

Regardless of whether environmental regulations hurt or help industry, they influence competitive behavior of firms and the competitive dynamics of industries by imposing new costs, investment demands, and opportunities for improving production and energy efficiency. Environmental regulations and costs are already shaping strategic decisions about sourcing raw materials, locating production facilities, managing energy and wastes, in environmentally sensitive industries, such as chemicals, oil, forest products, metals, and mining (Smart, 1992). All these wide-ranging changes promise to make the 1990s a period of changing competitive opportunities for business (Hitt, Hoskisson, and Harrison, 1991).

One strategic variable that fundamentally changes environmental impacts, risks, and costs of companies is the choice of technologies (Kotha and Orne, 1989). Product and production technologies determine the basic parameters of costs and ecological impacts. They determine the type of raw materials that can be used, production efficiencies, pollution emitted from production processes, worker health and safety, public safety, and management of wastes (Sarkis, 1995).

This paper introduces the concept of 'environmental technologies' and argues that they can be used to gain competitive advantage. The first section defines and describes environmental technologies. The next section discusses a framework for understanding environmental technologies as a strategic asset for gaining competitive advantage. The third section illustrates this framework by describing how 3M Corporation has adopted environmental technology orientation. The final section concludes with benefits of and barriers to implementing environmental technologies, and some implications for strategic management.

ENVIRONMENTAL TECHNOLOGIES

Environmental technologies are defined here as production equipment, methods and procedures, product designs, and product delivery mechanisms that conserve energy and natural resources, minimize environmental load of human activities, and protect the natural environment. They include both *hardware*, such as pollution control equipment, ecological measurement instrumentation, and cleaner production technologies. They also include *operating methods*, such as waste management practices (materials recycling, waste exchange), and conservation-oriented work arrangements (car pooling, flextime), used to conserve and enhance nature.

Environmental technologies are evolving both as a set of *techniques* (technologies, equipment, operating procedures) and as a *management orientation*. As techniques they are used for pollution abatement, waste management, energy, water and material conservation, and for improving technological efficiency of production.

As a management orientation, environmental technologies have spawned environmentally responsible approaches towards product design, manufacturing, environmental management, technology choice, and design of industrial systems. It is this management orientation that is most relevant to strategic management and of central interest to this paper.

Environmental technologies incorporate environmental considerations into many aspects of business operations, and thereby affect the competitive landscape in most sectors of the economy. As a source of new product ideas and material/energy conservation, such as solar heaters and electric cars, they can *create and expand market demand*. As a source of production process improvements, such as cleaner technologies and pollution control, they can *change the production cost* function within firms and industries. By making products and packaging more environmental friendly such as 'all-natural soaps' or 'CFC-free air conditioners', they can enhance product quality and attractiveness. And by reducing waste, pollution, and hazards they can make firms *more attractive to communities*.

The environmental problems addressed by these technologies are widespread; consequently these technologies have wide applicability across industries. Since environmental problems are likely to last a long time, environmental technologies will have sustained impacts. In the coming years we will see these technologies affecting the competitiveness of many industries and countries. In recognition of this important role of environmental technologies, countries such as Japan, Germany, Sweden, and Denmark are targeting them for rapid development.

Environmental technologies are discussed below in terms of five themes. These themes are constructed to capture broad approaches to managing environmental problems. They are constituted of more specific environmental management techniques, such as product design, cleaner production, environmental auditing, costing, and impact assessment. My criteria for creating the broad themes were that they should (1) deal with several key organizational elements simultaneously, (2) be recognized in practice as viable approaches, and (3) have a technological orientation to dealing with environmental problems. Collectively the themes address both internal organizational elements and external interorganizational relations. The five environmental technology themes include:

- Design for disassembly;
- Manufacturing for the environment;
- Total quality environmental management;
- Industrial ecosystems;
- Technology assessment.

Organizations are groups of people pursuing a *vision* (V) by managing systems of *inputs* (I), *throughputs* (T) and *outputs* (O). These VITO elements are nothing but the well-known 'systems view' of organizations. In the systems approach, organizations are represented by Inputs → Throughputs → Outputs, in interaction with their environments (Churchman, 1963; Katz and Kahn, 1968). I have added Vision to this scheme to reflect the values and goals of organizations, which are critical to strategic management.

In the strategic management literature these VITO elements roughly correspond to Porter's value chain elements of inbound logistics, operations, and outbound logistics (Porter, 1985). The systems view of organizations is also reflected in other established management approaches such as activity-based accounting and project management.

The environmental technology themes relate these VITO organizational elements and interorganizational relations to the natural environment. Together the themes cover all key aspects of organizational operations. While each theme has a unique focus, they are not strictly mutually exclusive. They overlap each other, reflecting natural linkages between inputs, throughputs, and outputs.

Design for disassembly seeks to create environment-friendly products by relating outputs (wastes, discarded products) to inputs (raw material) via product design processes. Manufacturing-for-the-environment seeks to eliminate wastes, emissions, and pollution, and improve the efficiency of production processes (throughput systems). Total quality environmental management simultaneously focuses on all organizational inputs, throughputs, and outputs, to improve their environmental performance using quality control principles. The industrial ecosystem concept aims to reduce the collective environmental load of a group of production units through interorganizational cooperation. Technology assessment aims at minimizing the spread of environmentally harmful technologies.

Design for disassembly

Increasing waste, depletion of natural resources, and limited landfill spaces are an important ecological problem. Waste also increases cost of production. In some products, such as used tires, 95 percent of what is discarded as waste is usable energy. Similarly, discarded automobiles have many reusable components and materials. But they are simply scrapped because currently it is too expensive to recover them.

Driven by these concerns, product designers have developed a new design philosophy popularly labeled 'design for disassembly'. This approach seeks to build products that have a maximum useful life, and that are easy to disassemble and recycle. The objective is to maximize the use of materials in the form of products and recycled materials. This design philosophy is in stark contrast to past design approaches that sought planned obsolescence of products, functional redundancy, and overdesigning for aesthetic and product differentiation (Buttner, 1993).

Designers are using design for disassembly to develop many products, including automobiles, computers, home appliances, furniture, consumer electronics, and even prefab homes. Xerox Corporation pioneered in developing modular 'disassemblable' products (copying machines). Since it leases (rather than sells) and takes back most of its products after customers have used them, efficient disassembly and refurbishment methods provide a source of cost reduction and competitive advantage to Xerox. BMW has innovated a fully recyclable automobile. It joined hands with major auto scrapyards in Germany to establish a comprehensive program for auto recycling and material recovery. With this significant competitive advantage, it is now lobbying the government to make auto recycling mandatory for all auto manufacturers (Babyak, 1991; Matysiak, 1993).

Manufacturing for the environment

An important focus of environmental technologies is to improve the ecological performance of manufacturing processes. This is achieved by redesigning production systems to reduce environmental impacts, using cleaner technologies, using higher-efficiency production techniques, minimizing waste at source, and maximizing fuel and energy efficiency (Frosch and Gallopoulos, 1989; Imai, 1986). In addition, regular preventive maintenance, industrial hygiene, and safe working conditions enhance ecological and health conditions within organizations (United Nations Environment Program, 1993; UNESCO, 1992).

The potential for designing manufacturing systems that are environmentally sound is illustrated by Ecover, a Belgian detergent manufacturer. Ecover has created what it calls the 'ecological factory'. The entire factory is made from materials with low energy content which can be separated for recycling when the factory is dismantled. The factory uses alternative energy sources and practices strict energy conservation. It is energy self-supporting. It uses a closed water cycle operating on solar energy, without either a chimney or a waste water discharge pipe (Develter, 1993).

The opportunity for making such dramatic improvements comes only with new buildings and facilities. Converting old facilities to make them environmentally sound is the more commonplace and also the more difficult and costly problem, and a significant focus of the manufacturing-for-the-environment approach (Klassen, 1993; Weissman and Sekutowski, 1991).

Total quality environmental management

Total quality environmental management (TQEM) combines and extends the above two ideas of environmentally oriented product design and manufacturing. TQEM applies a *total systems* perspective and *quality management* principles to environmental problems. It seeks to simultaneously green the VITO elements and continuously enhance ecological performance of firms (Shrivastava, 1995a).[4]

Environmentally responsible vision includes ecocentric values and culture that seek harmonious organization–nature relations. In such a vision nature is not simply a source of expendable resources to be exploited. Instead, nature and organizations are part of a web of mutually interdependent entities. The health and long-term welfare of each depends on the other. Environmental vision is operationalized through concrete environmental missions, objectives, and policy statements (Starik and Carroll, 1991; Throop, Starik, and Rands, 1993).

Organizational inputs include energy, raw materials, labor, and capital. TQEM seeks to manage all these inputs in an ecologically sound manner. It strives for energy conservation, use

[4] Greening here refers to making organizations responsive to ecological and health concerns. It includes environmental management programs, environmental preservation and enhancement, and environmentally friendly products and technologies. Greening seeks to minimize the adverse environmental impacts of organizational activities and aims to create ecologically sustainable organizations.

of renewable energy and materials, and renewal of natural resources. It establishes health- and safety-conscious human resource practices. It seeks ecologically sensible use of capital. Companies implement environmentally responsible input management through energy conservation programs, and waste reuse and recycling programs. They may switch to environmentally safer materials, and inventory management that avoids large quantities of hazardous materials.

Throughputs include the production, storage, and transportation of goods and services. TQEM seeks ecologically efficient throughput systems. This is achieved by using cleaner production technologies, pollution prevention, effluent control, and environmental risk management (Kolluru, 1994).

Organizational outputs include products, packages, and wastes. TQEM seeks to develop environment-friendly products and packages, and minimize waste by reducing total life cycle costs of products from cradle to grave. This involves new product/package designs, and integrated waste management using recycling, incineration, and land filling (President's Council on Environmental Quality, 1992).

TQEM emphasizes a total systems approach to managing the VITO elements. This ensures that companies are not simply adopting 'end-of-the-pipe' pollution control measures. It also prevents shifting environmental effects from one element to another. In line with the total quality management philosophy it encourages continuous improvement (Willig, 1994).

Industrial ecosystems

Industrial ecosystems are a new innovation in designing interorganizational linkages. They consist of a network of organizations linked to each other through an ecological logic. Organizations within the network use each other's wastes, byproducts, and outputs, to reduce the total use of energy and natural resources, and reduce the total waste and pollution from the system. Through interorganizational cooperation they collectively minimize their impacts on the environment. The idea is to mimic natural ecosystems in which several organisms live in mutual interdependence to create stable and life-sustaining ecosystems (Allenby, 1993; Ayres and Simonis, 1992).

In the United States several experiments are underway to create 'waste exchanges' among regional firms. A more elaborate form of industrial ecosystem is a group of companies in Kalundborg, Denmark. The coal-fired Asnaes power plant is the heart of the system. It is linked to an enzyme plant, a refinery, a chemical plant, a wallboard plant, a fishery, and some local farms. These plants use one another's wastes and byproducts as raw materials.

The power plant sells its used steam to the enzyme plant, the refinery, the fishery, and the city, instead of condensing and dumping it. The power plant sells its fly ash to a cement company, and its high-sulfur gas emissions to the chemical plant for making sulfuric acid. It removes pollutants from its smokestacks and sells the limestone-rich ash to the wallboard plant and cement plant, reducing the use of virgin gypsum.

The refinery in turn supplies Asnaes with treated waste water for cooling and desulfurized natural gas for fuel, saving 30,000 tons of coal a year. Local farms use wastes from the fishery and from the enzyme plant as fertilizer.

This industrial ecosystem saves money for all its participants. It cuts the imports of mined gypsum, and conserves water which is pumped from Lake Tisso 7 miles away. It reduces the amount of energy consumed for heating and the need for inorganic fertilizers on farms. It reduces sulfur pollution from the power plant and minimizes cement waste sent to landfills.

This industrial ecosystem is an experimental prototype. It was costly to set up and needed new institutional mechanisms for interorganizational coordination (provided by the city of Kalundborg). At this early stage these considerations act as barriers for many companies to create such ecosystems and embrace environmental technologies more enthusiastically. But as experience of industrial ecosystems accumulates (several are currently being developed), they are expected to become more cost effective and competitive. They will then change the competitive dynamics of industries within bioregions by leveraging ecological efficiencies for network firms (Allenby, 1993).

Technology assessment

A significant element of technology management is the selection of new technologies, and transfer of technologies across organizational divisions, across organizations, and across nations. In choosing and transferring technologies management is increasingly faced with issues of environmental appropriateness of technologies in their new locations. Environmental risks emanating from a technology are a function of both attributes of the technology and attributes of its location.

Technology assessment is an analytical tool used to understand the likely impact of the use of a new technology by an industry, region, country, or society. It examines costs and benefits of the technology, its environmental impacts, its effects on institutions, and its social and political impacts. With respect to the environment it assesses environmental and health risks, impacts of specific projects and facilities, potential for effluents, releases and hazardous wastes, and product life cycle costs (Sucre, 1993). Total life cycle costing helps to include hidden environmental costs and future costs or liabilities.

Technology assessment originated as a policy tool to aid governmental decision making, with regard to technology transfer, technology import policy, industrial licensing, environmental regulations and monitoring, and environmental standards (Coates, 1993; Hoppe and Grin, 1995). It has now expanded into a valuable tool for making business portfolio decisions. In making strategic business portfolio choices companies have traditionally used market share and industry growth rate as key parameters (Boston Consulting Group, 1970; Hofer and Schendel, 1978). Technology assessment expands the selection criteria to include environmental impacts and liabilities associated with business (Ilinitch and Schaltegger, 1993; Kolluru, 1994; Shrivastava and Hart, 1994).

British Petroleum, for example, does technology assessment using futures-scenario analysis technique, to forecast which fuel/energy technologies will be used in coming years. They use this assessment to develop their product plans and investment programs. General Electric does technology assessment in specific countries to judge the market potential for its technologies. By the end of this decade it expects 50 percent of its revenues to come from developing countries (particularly Mexico, China, and India). These countries are at different stages of development, and need different types of technologies. These technology and market assessments provide competitive advantage through better product choices, R&D investments, plant location decisions, and corporate strategies for gaining access to markets.

ENVIRONMENTAL TECHNOLOGY STRATEGIES AND COMPETITIVE ADVANTAGE

Environmental Technologies cover many salient concerns of traditional strategic management. Strategic management is concerned with aligning organizations with their environments (Schendel and Hofer, 1979). Environmental technologies seek alignment of corporate technologies and businesses with the natural environment. Figure 1 depicts the relationships between environmental technologies and strategic management concerns.

In the figure, organizations are represented as a set of visions, inputs, throughputs, and outputs (VITO). Organizations function within a physical (natural) environment, and social environment characterized by economic, social, political, and cultural influences. Environmental technologies are depicted in terms of the five themes discussed above and the arrows depict their multiple influences on the VITO elements.

The resource-based view of the firm argues that companies are a bundle of strategic and operating resources. Companies that can parlay new and unique resources can establish competitive advantage (Barney, 1992; Mahoney and Pandian, 1992; Prahalad and Hamel, 1990).

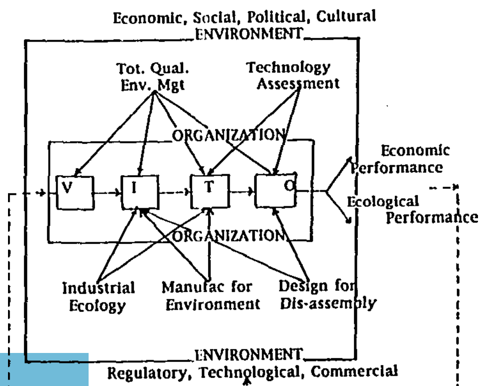

Figure 1. Strategic management and environmental technologies

Environmental technologies are a potential strategic resource because they affect the value chain at multiple points. They are capable of providing firms with unique and inimitable advantages at each stage of the value chain.

In the input system, competitive advantage accrues from materials, labor, and energy conservation. TQEM provides a base for revisioning the organization's role *vis-à-vis* its customers, society, and the natural environment. It allows firms to create new goals, and reshuffle priorities in favor of preserving ecological value with legitimacy. It systematically conserves inputs to minimize costs.

In the throughput system, manufacturing for the environment improves production efficiencies and minimizes waste and pollution. It makes production lean and green. It is a particularly potent source of improved ecological performance in pollution-intensive, energy-intensive, and natural resource-intensive industries. In these industries ecological performance is important both for company image and to minimize environmental liabilities. Lower environmental liabilities make companies a better credit risk and less vulnerable to litigation, both of which can be important sources of competitive advantage.

In the output system or the outbound logistics, environmental technologies create competitive advantage through better product designs and business portfolios, and through savings from better management of wastes. Technology assessment allows firms to incorporate environmental considerations into portfolio analysis, resulting in more robust portfolios. It guides the sharing of production technologies across plants, divisions, and countries. It thus shapes the firm's technological capacity. Technology assessment highlights ecological impacts and risks and can thereby minimize firms' risk exposure and liabilities.

Design for disassembly influences choice of product features and specification. It can create new products of special value to 'green' consumer segments of the industry. It also minimizes packaging, thereby reducing costs and environmental impacts.

Industrial ecosystems provide an ecological method for building interorganizational relations among firms. They involve cooperative strategies for reducing costs by minimizing waste and maximizing resource utilization in a network of firms. In an extension of this idea, companies may form strategic alliances with private and public organizations to deal with competitive and environmental issues common to their industry and bioregion. For example, the electronics industry developed a cooperative consortium to share the circuit boards cleaning technology, to eliminate the use of chlorofluorocarbons in electronics manufacturing. Merck Inc., the pharmaceutical maker, created an innovative partnership with the government of Costa Rica to conserve that country's rain-forest in exchange for rights to do biogenetic prospecting and develop drugs from rain-forest products. With unique access to these biogenetic materials Merck stands to gain competitive advantage over its rivals.

Companies can creatively combine these five environmental technologies to formulate corporate- and business-level strategies. At the corporate level this results in domain choice of products and technologies that are ecologically sustainable. At the business unit level it results in exploitation of ecological efficiencies and use of ecological variables for building competitive advantage (Buzzelli, 1991; Roome, 1992; Stead and Stead, 1992).

Environmental technologies also have competitive significance at the industry level. Just as other encompassing technologies, such as information processing and communications, have wide influences on many industries (financial services, transportation, etc.), so too environmental technologies widely influence all environmentally sensitive sectors of the economy. If used strategically throughout the industry, they may reduce the need for environmental regulations in the industry.

Finally, environmental technologies have competitive potential at the international level. In coming years economic development will be subject to ecological limits. Transfer of products and production systems across national boundaries will require environmental impact assessments. Environmental technologies can give nations unique competitive advantages in global trade and transfer of technologies (Goodland, Daly, and El-Serafy, 1992).

ILLUSTRATIVE CASE STUDY

The environmental technologies orientation is being implemented in corporations in selective ways. It may not be called by that name, or include all the five elements discussed above, but many companies are significantly improving their environmental and competitive performance using environmental technologies (Callenbach *et al.*, 1993; Schmidheiny, 1992; Smart, 1992; Roddick, 1991). Below I describe 3M Corporation's approach to environmental technologies as an illustration of how these concepts are implemented. The sources of information for this case are company annual reports and documents, and published descriptions of its environmental programs (Bringer and Benforado, 1994; Shrivastava, 1995b).

It should be noted that despite the rather positive description of 3M that follows, the company is by no means perfect on all environmental issues. By the very nature of its products, technologies, and size of operations, it creates a major environmental burden. Moreover, much of what is known about the company's environmental programs is provided by the company, and there is no independent outside evaluation of its programs available. Finally, the drive for environmental improvements at 3M is closely tied to regulatory compliance and economic opportunities. Yet, the company is clearly a leader in environmental management, and has successfully parlayed this effort into financial and competitive gains.

3M Corporation

3M is a global, diversified, industrial and consumer products company. In the past 5 years it has been financially successful and regularly featured in *Fortune* magazine's list of America's 'most admired companies'. In 1992 it had revenues of $13.8 billion, and employed nearly 90,000 people in 52 countries.

3M's strategic objectives include moderate growth in sales of 5–7 percent per year. It seeks to improve earnings by cost reduction and productivity improvements. Over 1990–95 it aims to reduce its unit cost—in real inflation-adjusted terms—by 10 percent. This will involve reducing manufacturing cycle time by 37 percent, waste by 35 percent, and energy use by 20 percent per unit of production. Table 1 shows a 5-year summary of financial data.

Table 1. 3M's 5-year financial performance

Year	Sales	Net income	EPS
1992	13.88	1.23	5.63
1991	13.34	1.15	5.26
1990	13.02	1.30	5.91
1989	11.99	1.24	5.60
1988	11.32	1.15	5.09
5-year growth	5.2%	1.6%	2.5%

Sales and net income in billions of dollars.
EPS = earnings per share in dollars.

Organizational antecedents of environmental technologies

The environmental technologies approach apparent at 3M is best understood in the context of three organizational features: the *diversity and changing nature of its products and technologies*, heavy emphasis on the *productivity of labor, capital and resources*, and the availability of *environmental champions*.

3M has a wide product range consisting of specialty chemicals, polymers, and consumer and industrial goods. It invests heavily in R&D and new product development. R&D expenditures in 1992 were over $1 billion (or 7% of sales), and over the past 5 years were $4.3 billion (7% of 5-year sales). Such high R&D expenditure made the company a research leader among broadly diversified firms. It generates at least 25 percent of its sales from products introduced within the past 5 years. From 1993 onwards, it raised this goal to 30 percent of all sales from products introduced in the last 4 years. Due to this continuous stream of new products, its environmental problems are diverse and keep changing.

Inherent in this situation of product diversity and change is the continual development and adoption of new technologies. Creating new technologies from scratch provides an opportunity for incorporating design for disassembly and manufacturing for the environment. It also allows periodic and systematic replacement of environmentally harmful technologies with environmentally benign ones. It mitigates primary barriers to change, which are the sunk costs and organizational inertia of existing technologies.

3M places special emphasis on productivity of labor, capital, and resources. Over the past

5 years its sales grew from $11.3 billion to $13.8 billion. Its net earnings went up from $1.15 billion to $1.23 billion. Sales per employee went up from $117,000 to $160,000—well above the industry par.

This emphasis on productivity makes cost savings a central value in the company. Environmental programs that allow cost savings fit well with this productivity logic and are easy to justify.

Finally, the tradition of innovation at 3M has legitimized the role of internal product and technology champions. Product champions have had a significant influence on the company's investment policies. In the mid-1970s, when environmental issues became salient for the industry, the Production Engineering and Control Department championed environmental technologies. The motivation then was to reduce costs, to comply with increasing regulations, and to postpone some regulatory costs.

Since then, the company has developed many new technologies to minimize use of natural resources, reduce pollution, minimize and recycle wastes, prevent accidents, and make environment-friendly products and packaging. Every environmental project is designed to save money. In fact, for a project to be undertaken it must show environmental improvement *and* economic savings. In 1993, it relaxed this savings criterion for highly innovative environmental technologies.

Environmental technologies at 3M

3M's environmental focus reflects some degree of attention to all the four elements of Vision, Inputs, Throughputs and Outputs, discussed earlier. Its environmental vision is codified in the environmental policy adopted in 1975, shown in Table 2.

Technology is 3M's strong suit. The company successfully leverages this strength to improve ecological performance of its input resource usage, manufacturing operations, products, and waste management. It has expanded its system for product innovation to include environmental innovation. Environmental projects are an integral part of normal operating processes that encourage innovation. Special emphasis is placed on manufacturing technologies, product and packaging design, and waste management.

Table 2. 3M's environmental policy

3M has and will continue to recognize and exercise its responsibility to:

- Prevent pollution at source wherever and whenever possible
- Develop products that will have a minimum effect on the environment
- Solve its own environmental pollution and conservation problems
- Conserve natural resources through reclamation, resource renewal, and other appropriate methods
- Assure that its facilities and products meet and sustain the regulations of all federal, state, and local environmental agencies
- Assist, whenever possible, governmental agencies and other official organizations engaged in environmental activities

The ultimate aim of the company is to achieve zero pollution. This goal may be unrealistic given the products and technologies in its portfolio. Yet, 3M strives towards it with its environmental policies and with detailed standards and guidelines in all environmental areas. The company's manual of environmental policies contains hundreds of specific policies, standards, and implementation guidelines on topics such as pollution control equipment, environmental permits, above-ground tank inspections, office paper recycling, etc.

3M views environmental technologies as the vehicle for minimizing the environmental harm caused by existing technologies. The operational centerpiece of its environmental technology policy is the *Pollution Prevention Pays Program* or the 3P Program. This program addresses many aspects of environmentally harmful inputs, throughputs, and outputs of the company. The main thrust, however, remains on the throughput system or manufacturing, which is the major source of pollution emissions.

3M seeks to prevent pollution at source rather than removing it after it has been created. This is done by product reformulation, process modification, equipment redesign, and recycling/reuse of waste materials.

The 3P Program is structured in terms of projects. Each project must meet four criteria to receive formal recognition and funding. It must:

- eliminate or reduce a pollutant;
- benefit the environment through reduced

energy use or more efficient use of manufacturing materials and resources;
- demonstrate technological innovation;
- save money through avoidance or deferral of pollution control equipment costs, reduced operating and material expenses, or increased sales of an existing or new product.

All employees are encouraged to participate in the program. A 3P Coordinating Committee administers the program. The committee consists of members from 3M's engineering, manufacturing, and laboratory organizations, the corporate Environmental Engineering and Pollution Control Department, and the Industrial Hygiene Group.

In 1988, 3M extended the program by adding a new $150 million investment into pollution control devices. The objective of this '3P Plus' program was to reduce all hazardous and nonhazardous releases to air, land, and water by 50 percent (from 1987 levels) by the year 2000. The company will return to government authorities the pollution credits that accrue to it.

In its first 15 years, 1975–89, the 3P Program completed over 2500 pollution prevention projects. The program resulted in reducing 3M pollution per unit of production in half. It prevented more than 500,000 tons of pollutants, which included 123,000 tons of air pollutants, 16,400 tons of water pollutants, 409,000 tons of solid waste, and 1.6 billion gallons of waste water. As a result the company saved more than $500 million in costs. These costs savings are a vital element of competitiveness, because 3M's strategy is to improve profitability by *cost cutting* in an environment of only modest revenue growth.

Environmentally conscious products, packaging, and manufacturing

Under the broad umbrella of environmental technologies, 3M improves its product designs and the manufacturing systems, to be more ecologically efficient. This is done by adopting principles of design for disassembly and manufacturing for the environment, although these phrases are not used within the company to describe their approach. The objective is to reduce the use of virgin materials and environmentally hazardous substances, increase the use of recycled materials, improve energy and production efficiencies, and minimize polluting emissions and wastes.

The following examples illustrate how manufacturing processes are being transformed. Riker is 3M's pharmaceutical unit. It makes a variety of medicine tablets coated with solvent solution coating. Use of solvents created pollution and was expensive. Riker developed a water-based coating for tablets as a substitute for solvent solution coating. This change eliminated the need to spend $180,000 for pollution control equipment, saved $15,000 per year in materials cost, and prevented 24 tons of air pollution a year. The change over cost the company $60,000. This change produced a better-quality and safer product, in addition to reducing costs and minimizing the use of hazardous chemicals in its production.

Another 3P project that conserved input resources focused on improving the efficiency of resin spraying. A resin spray booth was producing 500,000 pounds of overspray annually. The overspray represented waste of resin. The resin waste had to be collected, transported, and incinerated. The spray booth was redesigned and new spray equipment installed to eliminate excessive spray. The new design cost $45,000 in new investments, but saved the company $125,000 a year. This project enhanced competitiveness of the company by minimizing waste and cutting operating costs.

Another element of 3M's manufacturing for the environment program is accelerating research on eliminating pollution from manufacturing, and boosting recovery and recycling of wastes. The company eliminated the use of ozone-depleting substances by 1993, well before the deadlines specified by the US Environmental Protection Agency and the Montreal Protocol.

3M's product design philosophy strongly emphasizes minimization of wastes in discarded products and in packaging. Systematic analysis of product features and specifications is undertaken to identify opportunities for waste minimization.

For example, the Aycliffe plant in England makes face masks and respirators for industrial use. Old mask designs involved discarding wastes from the masks into landfills. After its useful life, the mask was also sent to landfills. Redesign of these masks has led to creation of maintenance-free face masks and respirators. The new designs eliminate waste, and allow recycling of the mask parts. The new masks are also more competitive as products because customers find them easier to use and maintain.

This plant also designed a waste-head boiler that absorbs heat from an on-site incinerator. The steam so produced is used to heat the plant. The boiler cost $290,000, but makes annual savings of $170,000. The incinerator prevents 250 tons of solid waste from entering landfills each year. The plant's competitiveness is enhanced by lowering its overall operating cost.

3M's packaging philosophy is to minimize materials, cost, and the time for assembly and disassembly of all packages. Engineers are continually developing new eco-friendly packaging to increase reuse and recycling. They have also decided to eliminate chrome and lead pigments, chlorofluorocarbons (CFCs), and polyvinyl chloride (PVC) from all packaging specifications.

3M laboratories and marketing division has established an Environmental Leadership Program that assesses environmental impacts of technologies and products, and develops more environment friendly products. By appealing to consumers' preference for ecological features, the program enhances the competitiveness of 3M products.

In assessing the usefulness of technologies, the company uses life cycle analysis (LCA) to minimize total life cycle costs. This approach considers all costs associated with products from cradle to grave. These include costs of initial R&D, design, prototyping, manufacturing, recycling, recovery, and disposal. LCA allows the company to anticipate hidden future costs of product and environmental liability, and waste disposal. It enhances the company's ability to contain costs and avoid negative surprises.

Other conservation programs

In addition to the pollution prevention programs, 3M has several programs aimed at energy and resource conservation. Its 20-year-old Commute-a-Van program uses over 120 vans for employee ride sharing. This program has saved over 50 million passenger miles and over 3 million gallons of gasoline, thereby preventing 1100 tons of auto exhaust pollution. Over the years thousands of employees have benefited from this program. The competitive benefit of this program lies in improving employee morale and conserving energy.

3M does periodic energy audits in all its operations. Energy conservation efforts cut energy use in half between 1973 and 1988, while production increased each year. Setback thermostats are installed to control temperature during unoccupied hours. Manufacturing plants reuse hot exhaust from combustion for product dryers and to make steam. The company participates in EPA's Green Lights program, and has adopted high-efficiency lighting fixtures and facility designs. These energy conservation efforts improved the operating efficiency of company facilities, and lowered its energy costs.

In 1972, 3M decided to incinerate liquid hazardous wastes. It established the Chemolite Center incinerator. This incinerator reduces the volume of hazardous wastes by 95 per cent, and the toxicity by more than 99 per cent. Incineration technology is continually upgraded. Heat is recovered from the combustion for use in production facilities.

Together these environmental technologies (see Table 3 for a summary) have shaped the

Table 3. Summary of 3M greening

VITO elements	3M attributes
Vision	Acknowledges its environmental responsibilities, believes in nature conservation, responsive to regulations, believes pollution prevention pays, total systems approach to environmental management
Inputs	Energy conservation, materials recycling, reduce the use of hazardous and virgin materials, eliminated the use of CFCs
Throughputs	Improvement in production efficiency, production process changes for environmental benefits, zero pollution goal, invests in pollution prevention, life cycle analysis to guide cost reductions
Outputs	Environment-friendly product designs, and packaging, reuse and recycling of wastes, incineration of chemical wastes

competitiveness of 3M's operations. They have reduced the use of natural resources and energy, reduced pollution and emissions from manufacturing, and minimized waste. The company has thus achieved a competitive cost structure. Environmental technologies have also enhanced product appeal through design of environment-friendly products and packaging, and reduced product and environmental liability. Finally, the company has gained competitive advantage via improved public image. In addition, these practices set new standards of environmental performance for the businesses in which the company operates. Thus, they influence competitive dynamics of their respective industries.

IMPLICATIONS FOR STRATEGIC MANAGEMENT

The experiences of 3M and other companies suggest that integrating environmental technologies into strategic management offers many competitive advantages, but also faces many barriers. The advantages include the following.

Cost reduction

Environmental technologies offer the opportunity to drive down operating costs by exploiting ecological efficiencies. By reducing waste, conserving energy, reusing materials, and addressing life cycle costs, companies can make large financial gains.

Revenue enhancement

Environmental technologies create possibilities for revenue enhancement in two ways. First, they allow entry into the growing market for environmental products and technologies (estimated at $200 billion per year by the end of this decade). Second, there is a large and growing segment of consumers who want eco-friendly products and packaging in most industries. These 'green' products require environmental technology designs and production systems.

Supplier ties

Both manufacturing for the environment and design for disassembly actively involve suppliers in corporate decision making. They strengthen supplier ties. Stronger ties help in ensuring higher quality of incoming supplies. Companies can influence suppliers to change the design specification of supplies, to reduce costs, and facilitate manufacturing.

Quality improvement

Environmental technologies reinforce the total quality management philosophy. TQEM supports total quality programs and extends them to environmental issues. Technology assessment allows quality concerns to be incorporated in the very early stages of choosing product and production technologies.

Competitive edge

Competitive advantage accrues directly from cost reductions and revenue improvements prompted by environmental technologies. Environmental technologies also offer companies the potential for creating unique and inimitable strategies. Companies can distinguish themselves through these strategies and become environmental leaders. While environmental technology orientation is feasible in all sorts of companies, that does not mean that all companies can become genuinely green with the same level of ease. The Body Shop has created a successful, genuinely 'green' business in an industry (cosmetics and personal care products) dominated by chemical concoctions. Other cosmetics companies in this industry could theoretically also adopt environmental technology orientation. But for some at least, such as Revlon, that would be impractical because they are based on very different market assumptions, mass production and distribution investments, and management values and vision.

Reduction of liabilities

Environmental technologies are sensitive to long-term risks of resource depletion, fluctuating energy costs, product liabilities, and pollution and waste. By introducing environmental technologies that systematically address these long-term issues early, companies can become aware of and manage these environmental risks.

Social and health benefits

Environmental technologies benefit the ecosystem, and the environment of communities in which companies operate. They result in reduced community expenses on health impacts of industrial pollution.

Public image

Environmental technologies are also good for public relations and corporate image. They help companies to establish a social presence in their markets, and gain social legitimacy.

Ahead of regulatory curve

Environmental technology solutions allow companies to get ahead of environmental regulations and establish a firmer footing with respect to environmental and product liabilities. They may allow industry to preempt some regulations. They also allow some leading companies to shape environmental regulations consistent with their own internal policies. These companies stand to gain competitive advantage over rivals.

With all these potential benefits one wonders why more companies do not adopt environmental technologies faster. There are several barriers to their adoption, including the following:

1. *Costs of developing solutions*. Technological solutions for many environmental problems are expensive to develop. They require new research, new technological information, new organizational arrangements, and sometimes new infrastructural services. Environmental technologies may increase up-front costs due to the need for new designs, new setup costs, changeover costs from existing procedures, and personnel training costs. But they can also reduce costs of operations, raw materials and energy, maintenance, waste disposal, pollution control, and environmental liabilities. Perhaps the net result is that environmental technology investments have longer payback periods than conventional investments (i.e., business investments that the company would normally make in doing business, such as investment into plant and equipment, working capital, R&D, and market development). To justify environmental technology investments managers cannot depend on purely economic/cost benefits. They must include long-term ecological and social benefits. This discourages managers who are working on short performance evaluation and career time horizons in highly competitive financially oriented performance review systems.
2. *Lack of know-how and environmental information*. In some environmental areas technological solutions are simply not available at this time. For example, consider the global warming problem caused by excessive carbon dioxide in the atmosphere. There are no financially feasible and politically acceptable solutions currently available. Every proposed solution has some unintended negative effects. In such situations managers prefer to take a wait-and-see attitude.
3. Another barrier to implementing environmental technologies is *organizational inertia*. Organizations are accustomed to doing things in certain set ways. They have stable and longstanding decision routines, standard procedures, and cultural habits for doing things. There is resistance to changing historical patterns of procedures and systems.
4. Finally, multiple and sometimes *contradictory regulation* of environmental issues sometimes acts as a barrier to action. Managers tend to be confused about what is expected of them, and prefer inaction. A recent survey conducted by the *American Lawyer*, a legal profession weekly newspaper, found that nearly 70 percent of the surveyed corporate environmental counsels were confused about environmental laws and believed that their companies were breaking at least some laws (they were not sure which).

Competitive landscape

Despite these and other more specific barriers in individual companies, environmental technologies are being adopted widely and are collectively affecting the competitive landscape. They permit firms to remain *competitive in global markets, reduce costs and production times, and enhance strategic flexibility*. For example, the rules of competition in the global battery industry are changing with increasing regulation of hazardous waste disposal. Lead acid batteries are simply becoming uncompetitive in countries with stringent disposal laws. Environmental technologies as a source of new acid-free batteries and battery disposal systems are allowing some firms, such as Toshiba and Hitachi, to remain globally competitive.

In some cases environmental technologies are the source of cost reduction. A case in point is recycled toner cartridges used in printers and photocopying machines. Canon established the first worldwide system for recycling and refurbishing cartridges with a plant in Dalian, China. Used cartridges can be converted for reuse at a fraction of the cost of a new cartridge. In addition, recycling saves the cost of disposing of empty cartridges.

An example of *industry-wide cost reduction*, coupled with *shorter production time* by environmental technologies, is the substitution of CFCs for cleaning printed circuit boards in the electronics industry. AT&T, Northern Telecom, and other companies have innovated new detergents and changes in production processes that eliminate the use of CFCs. The manufacturing process is redesigned to reduce the need for cleaning, and the little cleaning that is required is done with water-soluble detergents and orange rind. This saves millions of dollars and reduces the overall production time.

As companies build up a repertoire of environmental technologies, they *enhance their strategic flexibility* to deal with increasingly burdensome environmental problems. Firms in the chemical industry provide an example of this enhanced flexibility. Realizing that this industry is prone to environmental hazards, leading chemical companies such as Dow Chemicals, and Du Pont, and the chemical industry (Chemical Manufacturers Association), have developed a strong capability in environmental technologies, including pollution control, waste water treatment, product integrity systems, recycling, storage of hazardous materials, emergency management, and spill management. This technological capability gives the companies and the industry a unique capability to respond to environmental incidents, and to do proactive risk management, risk communication, and liability management (Buzzelli, 1991).

In some industries energy conservation and materials substitution offer competitive potential. The electric utilities industry in the United States is discovering that the cost of conserving a kilowatt hour of energy is, in many situations, significantly lower than the cost of generating it. Southern California Edison plans to meet its next 5 years' demand for energy through conservation measures avoiding adding new generating capacity to its system.

Environmental technology orientation at the national economic policy level is another source of changing competitive landscape. By targeting environmental technologies for development and seeding R&D in these technologies some countries, including Japan, Germany, Sweden, and Denmark, are seeking to establish national competitive advantage for their firms. They are also investing in the creation of infrastructure for environmentally preferable industries, in the form of markets for recycled products, regulations encouraging adoption of environmentally clean technologies, and taxes and subsidies to shape investment in certain environmental and renewable energy sectors.

The use of technology to create competitive advantage is not a new idea. In the 1950s, Schumpeter (1950) argued that technology is the essence of competition. Since then economists and strategists have studied how technology shapes competitive dynamics, particularly in new emerging technological areas (Jelinek and Schoonhoven, 1993; Williams, 1983). Franko (1989) demonstrated that R&D expenditures are an important determinant of corporate strategic performance and global competitive success. Technology is a source of new products and new production methods that can both cut costs and enhance revenues (Tushman and Anderson, 1986).

This paper makes a contribution by reinforcing and extending the argument about the importance of technology for strategic success. It provides a fresh perspective on technology. It focuses on 'environmental technologies' which can produce ecological efficiencies. Environmental technologies, with their focus on design and manufacturing for the environment, influence all key strategic variables. They provide a useful framework for formulating and implementing strategies, particularly in natural resource-based and environmentally sensitive industries, such as agriproducts, automobiles, forest products, minerals and mining, oil and petrochemicals, power generation, and transportation. Many of these industries are old and mature. They consume scarce resources and are highly polluting. They are ecologically unsustainable and need basic reformation through technological innovation. Environmental technologies offer possibilities for such innovation.[5]

Research implications

The implications of environmental technologies for strategic management theory are also far reaching. Two important implications at the industry level and firm level are discussed here. At the industry level, environmental technologies provide a way of fundamentally altering the profitability dynamics of industries. They affect basic cost parameters of resource use, energy use, manufacturing efficiency, waste disposal, and pollution abatement. In an era of increasing environmental awareness and regulations, these costs can be a significant proportion of the total costs.

The impact of environmental technologies on production costs varies from industry to industry. It also varies by age of facilities, nature of technologies in use, regulations, and cost of liability protection. Natural resource, energy, pollution and waste-intensive industries are most amenable to restructuring using enviromental technologies.

In the past, models of industry profitability have focused more on the demand and revenue-related variables. Industry dynamics is often measured by sales volatility, advertising expenditures, market shares, and demand fluctuations, among others. While costs are acknowledged as important they are presumed to change incrementally and uniformly across the industry. Environmental technologies make rapid, quantum, and nonuniform changes in costs possible. This calls for augmenting industry analysis models used in strategy research, to accommodate environmental-related cost elements.

At the individual firm level, environmental technologies affect both corporate domain choice and competitive posture. They provide new bases for creating competitive advantage. They enable companies to create new product markets, and alter consumer demand in existing markets. Consequently, they are a tool for affecting market shares. By catering to ecological concerns of 'green' consumers, companies can attract new customers, improve customer loyalty, and expand the total demand for products.

Environmental technologies also affect many strategic variables, such as economies of scale, energy intensity of production, production efficiency, firm legitimacy, and public image. Strategy theories need to recognize the strategic potential of environmental technologies. Future research should incorporate environmental technologies into strategy formulation and implementation frameworks.

[5] Interestingly, in some mature industries such as automobiles, companies are starting to build competitiveness through environmental technologies. This is an old and mature industry that makes products that consume a nonrenewable resource—petroleum. Autos are an important source of urban pollution. In the 1970s, prompted by regulations and public pressures, auto makers improved fuel efficiency and innovated catalytic converters for pollution control. Now, in the 1990s, some car makers (BMW, Volvo, and Mazda) are aggressively pursuing environmental technologies. BMW is innovating the *fully recyclable car*. Volvo has designed a multifuel vehicle: the *Environmental Concept Car*. Mazda and other car makers are working on *lean-burn technology* for achieving higher fuel efficiency. General Motors has designed an electric car for passenger use. It is true that most of these innovations are at different stages of development and have not been fully implemented. Yet, their competitive potential is keenly appreciated by the companies.

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