

**COMPETITIVE IMPLICATIONS OF ENVIRONMENTAL REGULATION:
A CASE STUDY ON
DOW CHEMICAL COMPANY AND I,I,I**

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CASE A

INTRODUCTION

June 26, 1990, Jeff Sullivan, Dow Chemical Product Manager for 1,1,1 Trichloroethane (1,1,1), reviewed his options. Jeff knew that despite his efforts, impending regulations might soon drastically reduce his business. Ratification of the London Amendments to the Montreal Protocol (MP) on Substances that Deplete the Ozone Layer was expected by the end of the week. Previous protocol negotiations had focused on chlorofluorocarbons (CFCs), yet 1,1,1 could be added to the phase-out schedule because of its ozone depleting properties.

For the past six months Jeff had worked to dispel charges by environmental groups, such as the Natural Resources Defense Council (NRDC), which had portrayed the product as "Public Enemy Number 1,1,1" and listed Dow Chemical in its "Who's Who of Ozone Depleters" (See Exhibit 1). He had attended congressional hearings and spent countless hours with reporters and environmentalists in defense of a product with a strong safety record, wide-spread use throughout industry and strong international sales potential.

Past regulations, especially the 1970 Clean Air Act, had worked in Dow's favor since 1,1,1 was a popular substitute for other chemicals that were regulated, such as volatile organic compounds (VOCs). Companies using high VOC solvents and paints switched to 1,1,1 in order to meet National Ambient Air Quality Standards thereby increasing 1,1,1 sales. However, now 1,1,1 itself was targeted for substitution. To 1,1,1's advantage, there were still many developing countries, including India and China, that had not signed the MP. Those that had signed were granted a ten-year delay before the required phase-out would go into effect. Consequently, market opportunities in developing countries were still promising.

High-level EPA officials had been suggesting to industry that they voluntarily freeze production and propose a phase-out schedule. Yet Dow viewed 1,1,1 as an important business that could be used as a bridge to new alternatives. Jeff's boss would want Jeff's evaluation of the impact of the Protocol's decision on 1,1,1 business. What support should they offer their existing customers? What should their strategy be for developing countries? What was the potential for continuing regulations?

1,1,1 TRICHLOROETHANE

1,1,1 (known by over 56 different names, e.g., 1,1,1, TCA, methyl chloroform, MCF) is an all-purpose solvent, popular with industry because of its powerful cleaning properties, low toxicity, low flammability, low potential for photochemical reactions, relatively high stability, and its recyclability. It was developed in the mid-1950s and became a popular replacement for trichloroethylene (TCE) that was under question for human toxicity. In 1990, approximately 780 million lbs. of 1,1,1 were produced annually by Dow Chemical Company, PPG Industries, Vulcan Materials, and ICI (85% for emissive purposes), (Chemical Marketing Reporter,1990), (See Exhibit 2) In 1988, U.S. production of 1,1,1 was greater than all CFC production combined. In 1987, Toxic Release Inventory (TRI), an EPA-mandated report, showed 149 million pounds of potentially ozone depleting 1,1,1 were released from 2,432 industrial facilities in the 48 contiguous states and Puerto Rico (Daily Report for Executives,1990).

Producers of 1,1,1

Dow Chemical Company

The second largest chemical company in the U.S., Dow produced basic chemicals and plastics, industrial specialty and household chemicals, and drug and agricultural products. To protect itself from increased foreign competition and economic downturns, Dow had increasingly shifted its business toward specialty chemicals and consumer products. By the late 1980's, Dow marketed 2,000 different products. By 1989, Dow Chemical had grown into a company with \$22 billion in assets and net sales of \$17 billion per year (See Exhibits 3 and 4). The company had approximately 750 million pounds of 1,1,1 annual capacity.

PPG Industries

Initially formed in 1883 as the Pittsburgh Plate Glass Company, PPG Industries was a global producer of flat glass, fiberglass, coatings and resins, chemicals, and medical electronics. It was a leading supplier of products to chemical processing, petroleum refining, commercial and residential construction and transportation markets. PPG was also a major producer of chlorine, selling nearly two-thirds of its annual output to the paper and textile industries. By 1989, PPG had grown into a company with \$6 billion in assets and net sales of almost \$6 billion per year (See Exhibits 3 and 4). It had approximately 350 million pounds of 1,1,1 annual capacity.

Vulcan Materials Company

Vulcan Materials was the largest United States producer of construction aggregates including crushed stone, sand, gravel, and slag (a waste product of the steel industry) for use in the construction of roadways, commercial buildings, and houses. Vulcan also produced chlorine, chlorinated solvents, caustic soda, and caustic potash for water treatment, pulp and paper processing and metal finishing and textile industries. By 1990, Vulcan Materials Company had \$1 billion in assets and net sales of \$1 billion per year (See Exhibits 3 and 4). In the early 1980's, Vulcan had 18% of the US solvents market and approximately 65 million pounds of 1,1,1 annual capacity.

Use of 1,1,1

In 1990, approximately 32 % of 1,1,1 was used for metal degreasing, 19% for cold cleaning, 11% in aerosols, 9% in the production of adhesives, 9% for cleaning in the electronics industry, 7% as a chemical intermediary, and small percentages as a cleaning solvent for coatings, inks, textiles, film and other miscellaneous applications. (See Exhibit 5).

The primary use of 1,1,1 was as a cleaning solvent for both machinery and manufactured materials across many industries. The electronics, medical, defense and aerospace industries used vapor degreasing for their precision cleaning processes. Contaminants to be removed included metal dust created during cutting, drilling and grinding; lint; waxes and fingerprint oils.

Cleaning Processes

Cleaning, an essential part of the production process, removes contaminants and prepares raw materials, parts and equipment for machining, electroplating, bonding and coating. This process may be divided into two general categories: vapor degreasing and cold cleaning. Vapor degreasing uses boiling solvent vapors to remove contaminants in either a batch or in-line process (See Exhibits 6 and 7). A batch vapor degreaser consists of an open-top steel tank, while in-line systems are generally enclosed. Both have a heat source at the bottom to boil the solvent and cooling coils near the top to condense the vapors. Hot vapor condenses on the cooler metal component suspended in the vapor zone, causing the solvent to dissolve and draining contaminants or soils into a liquid reservoir. Tanks range in size from bench top models to tanks large enough for automobiles and vary in price from \$40,000 to \$200,000 (Tooling and Production, pg. 30). An

EPA estimate reported that there are 2 1/2 times as many batch-type units as in-line cleaners (Tooling and Production, pg. 30.). Cold cleaning is conducted at room temperature, or slightly above, through immersion, soaking, spraying or wiping.

Emissions occur from this process due to evaporation of the solvent from the tank, from the cleaned components, equipment leaks, and spills during storage or transfer. (See Exhibit 8). In cold cleaning, emissions also occur from the disposal of the solvent and cleaning rags.

SCIENCE OF THE ATMOSPHERE AND OZONE

The primary constituents of the earth's atmosphere, nitrogen (78%) and oxygen (21%), are highly stable gases. Minor constituents, or trace gases, include several inert gases such as argon, neon, helium, krypton, xenon, and several reactive gases such as carbon dioxide (CO₂), methane (CH₄), nitrous oxide (NO_x), sulfur dioxide (SO₂) and ozone (O₃). Oxygen supports and sustains various forms of human and animal life, while nitrogen and carbon dioxide are essential to plant life. Changes in the trace gases of the atmosphere are at the root of today's smog, acid rain and climate changes.

The atmosphere is divided into three layers extending outward from the earth: the troposphere, the mesosphere, and the stratosphere. Ozone exists in both the troposphere and stratosphere; however, its characteristics and environmental effects are quite different in each.

In the troposphere, ozone is created when solar radiation reacts with gases such as volatile organic compounds (VOCs), such as those from paints or industrial solvents, NO_x and hydrocarbons, from vehicle exhaust or with the burning of vegetation. Tropospheric ozone has been regulated in the United States since 1970 under the Clean Air Act. It is frequently the largest constituent in the photochemical smog prevalent in many large cities throughout the world, often causing eye and lung irritations and damage to crops and trees.

A layer of ozone exists in the stratosphere in dynamic equilibrium that transforms harmful ultraviolet radiation to heat. Until recent decades, the amount of ozone in the stratosphere remained fairly constant in balance between natural production and loss. However, new industrial processes have increased the amount of chlorine and bromine in the stratosphere. Ultraviolet light breaks the chlorine atom free from CFCs (compounds of chlorine, fluorine and carbon) and from 1,1,1 to create highly reactive chlorine free radicals that act as catalysts to convert O₃ to O₂. These catalysts then release the chlorine atoms to repeat the cycle. In this way, every chlorine atom ultimately eliminates thousands of ozone molecules.

Ozone is an extremely rare constituent of the atmosphere; only ten of every million molecules of air are ozone (National Oceanic and Atmospheric Administration, 1992). However, it absorbs a significant amount of the sun's ultraviolet rays, thereby protecting the earth from high levels of UV exposure. Scientific studies show that increased levels of ultraviolet radiation have the potential for extremely serious and wide-ranging damage to human, animal, and plant life. The EPA estimated that there could be over 150 million new cases of skin cancer in the U.S. by 2075 and 18 million additional cases of eye cataracts (EPA, "Protection of Stratospheric Ozone" p.47-49). In addition, ozone depletion may suppress immune systems, reduce crop productivity, and damage phytoplankton and other organisms that live near the surface of water (Raon, 1990).

Scientific Research into Ozone Depletion

In the mid-1970's, using theoretical calculations, Sherry Rowland and Mario Molina, two University of

California scientists, predicted that because of CFCs' extremely high stability, they could drift into the stratosphere and accelerate the natural depletion of ozone. To test this hypothesis, scientists over the next ten years conducted laboratory tests, launched balloons carrying test equipment to the stratosphere, and built simulation computer models.

Late in 1985, a British team of scientists announced the results of multi-year research indicating the annual occurrence of a hole in the stratospheric ozone layer over Antarctica. Based upon corroborating measurements from both balloon-borne and satellite-borne instruments, the hole extended over the entire Antarctic continent. In 1986, an International Ozone Trends Panel, composed of over 100 scientists from 10 countries, led expeditions to Antarctica to conduct research using ground-based instruments, balloons and aircraft. The results of the expedition indicated that concentrations of stratospheric ozone over Antarctica had dropped by over 50% from the normal level. On March 15, 1988, the panel issued a report stating that in addition to the depletion over the Antarctic, a mid-latitude depletion had also occurred which "may be wholly or in part" due to an increase in trace chemicals, primarily CFCs (The Environmental and Energy Study Institute, 1994).

REGULATION

Montreal Protocol

In March 1985, 43 nations, 16 of which were developing countries, were hosted by the United Nations Environmental Program at the Vienna Convention (VC) for the Protection of the Ozone Layer. The conference adopted a resolution to develop a protocol for CFCs "that addresses both short and long term strategies to control equitably global production, emissions and use of CFCs, taking into account the particular situation of developing countries as well as updated scientific and economic research." The VC gained agreement that the change in the ozone layer posed danger to humans and the environment; therefore, countries should cooperate in the exchange of research and meet on a regular basis to discuss the state of the ozone layer. The convention started a process that accelerated research into the required scientific, economic, environmental and technical assessments that were used to make amendments in London in 1990.

From March 1985 to September 1987, numerous workshops were held in Montreal by working groups of both NGOs and government organizations to determine regulatory levels, phase-out schedules and GATT-compatible trade sanctions. Much of the discussion focused on addressing the different production and consumption requirements of industrialized and developing countries. In order for the protocol to become binding on all signatories, and to have its desired impact on the atmosphere, a minimum of 11 parties, representing 2/3 of CFC world consumption, had to ratify the agreement. In September 1987, the Protocol was ratified, controlling 5 CFCs and 3 halons.

By May 1989, scientists had found that the size of the ozone hole over the Antarctic had dramatically increased. At this time, scientists and delegates of the convention began to change their approach to ozone preservation and restoration. Since scientists believed only a limited chlorine burden in the stratosphere was tolerable, and since chemicals had differing ozone depleting potential, the strategy was to control the worst chemicals first. For this reason, regulations focused on chemicals with the longest atmospheric lifetimes and the highest ozone depleting potential. However, as grim scientific reports continued, the strategy shifted to "shaving-off" the peak chlorination concentrations that would occur in the stratosphere. Discussions turned to two other non-regulated chlorine-based chemicals, 1,1,1 and carbon tetrachloride (CTC) in an attempt to reduce total chlorine-loading in the atmosphere (Benedick, 1991). 1,1,1 was proposed due to its large production volume and relatively short atmospheric lifetime, so that restrictions on 1,1,1 would produce

quick results in the race to reduce chlorine-loading. CTC, ignored in earlier rounds of negotiation, perhaps due to its large use as a feedstock, was now proposed due to its high ozone depleting potential.

London Amendments: Adding 1,1,1 to the Protocol

As working groups and delegates began investigating the implications of including 1,1,1 in the MP, the availability of safe substitutes became a focal point to the debate. The MP already required the elimination of CFCs, and 1,1,1 and HCFCs were potential substitutes for the banned chemical. HCFCs have 2-10% of the ozone depletion potency of CFCs. Estimates of 1,1,1's market potential as a feedstock for HCFC-141, a CFC-113 substitute, was as much as 200 million pounds (Chemical Marketing Reporter, 1993).

ALTERNATIVE PROCESSES

Although 1,1,1 had wide-spread use in vapor degreasing processes, the following alternative processes were available (Alternatives for CFC-113 and Methyl Chloroform in Metal Cleaning, 1994). (See Exhibit 9 for an evaluation of their performance).

Aqueous Cleaning

This process uses water as the primary solvent. Aqueous solutions are made up of alkaline salts or acids that remove soil from surfaces, additives to promote cleaning and prevent corrosion, and surfactants which act as detergents to remove soil. Cleaners are diluted with water at ratios of 1 part water to 20 to 50 parts water. The process of washing, rinsing and drying components uses immersion, spray or a combination of both, including agitation and ultrasonics. Equipment costs vary by the level of cleanliness required, the complexity of parts being cleaned, energy requirements and level of automation. Conversion to an aqueous system may require up to 18 months and an average of a \$125,000 (Tooling and Production, pg. 30). High quality rinsewater is essential to this process in order to avoid spotting and adhesion problems in later phases of production.

Semi-aqueous Cleaning

This method uses a non-water solvent followed by a water rinse and typically an additional wash stage. Often an emulsion step follows cleaning. Typical cleaners used in the wash stage include hydrocarbons, alcohols and terpenes. Immersion and spray equipment is used. This process works well for cleaning parts with heavy organic solids.

Pressurized Gas Cleaning

In this process high pressure gas guns are used to remove large particles, such as metal dust, from relatively smooth component surfaces. Gases used include air, carbon dioxide, HCFC-22 and nitrogen.

Supercritical Fluid Cleaning

This process uses special gases that have powerful cleaning properties at high temperatures and pressures. When gases have been heated and condensed to the appropriate state in an extractor, the fluid reacts with and removes contaminants from components. Once the solute-rich fluid exits the extractor and undergoes pressure and temperature changes, separation of the contaminant occurs.

Ultraviolet/Ozone Cleaning

In this method contaminated surfaces are exposed to UV light in the presence of ozone. Contaminant molecules are dissociated by the absorption of light. They then react with oxygen to form simple, volatile molecules such as carbon dioxide, water vapor and nitrogen. This process can be used to remove organic film from surfaces such as glass, metal and silicon.

Gas Plasma Cleaning

This method is typically used as a final clean in a multi-stage process to achieve surfaces completely free of organic contamination in the electronic, medical and automotive industries. The process uses electrically excited, non-toxic gases that combine with organic surface films to form carbon dioxide, water vapor and trace amounts of carbon monoxide and hydrocarbons. A typical system consists of a vacuum chamber, a vacuum pump, a radio-frequency generator, a gas flow module and a microprocessor-based controller.

STAKEHOLDER POSITIONS

The following stakeholders in the debate were at work to affect the results of the MP and the future of 1,1,1.

US Government's Position

The Bush administration had decided to endorse a proposal to freeze 1,1,1 production in 1991, but was divided over the appropriate production level. The EPA was potentially seeking a total ban by 2000, but the Commerce Department was reluctant to support more than a 25% reduction. The EPA had concluded that over the next century, 1,1,1 would account for 35% of the buildup of chlorine in the atmosphere (Business Week,1989). Adding that although the EPA believed that conservation and recycling would decrease 1,1,1 consumption by a significant amount, possibly 20-30%, the phase-out and a search for safe substitutes was necessary.

The White House was also debating a new international fund to help developing countries phaseout ozone-depleting chemicals. Many developing countries had insisted that they would not be able to make the transition without additional financial, as well as, technical assistance. India and China, two countries with development plans that call for substantially expanded use of 1,1,1 said that they would not join the treaty without this assistance (New York Times,1990). (See Exhibit 10)

The Scientists' Position

Scientists continued to call for a policy in favor of the rapid phaseout of CTC and 1,1,1. During congressional testimony, a representative from the Institute for Energy and Environmental Research reported that the MP without 1,1,1 "...will not suffice in 100 years to bring chlorine levels below the danger mark which triggered the Antarctic ozone hole." He further asked the U.S. to give up their "chemical-by-chemical" approach and develop a "comprehensive policy for the entire class of ozone depleting chemicals and also for the production of safe alternatives." (Hearing before the Subcommittee on Oversight and Investment,1989).

As a result of recent intensive research into ozone depleting substances, a UNEP report stated that "Even if the control measures of the MP were to be implemented by all nations, today's atmospheric abundance of chlorine (about 3 parts/billion by volume) will at least double or triple during the next century." (United Nations Environmental Program Report,1989). Depending on the timetable, on emission levels, and on models used to describe chlorine and bromine emissions to the stratosphere, chlorine loading was predicted

to peak at up to 12 parts per billion by 2100 (see Exhibit 11). By 1989, research had confirmed significant stratospheric ozone reductions over the Arctic and reductions of 2-6 % over northern latitudes (Bryner,1993).

NGOs' Position

Campaigns against 1,1,1 had been launched by several environmental groups.

David Doniger, Director of NRDC's ozone protection project, had been an active lobbyist and vocal testifier at Congressional hearings against 1,1,1. In a widely publicized campaign, Doniger claimed that 1,1,1 was one of industry's "best kept secrets." The report listed 2,432 plants nationwide that emitted 149.2 million pounds of 1,1,1, more than twice the number of sources releasing the other protocol controlled chemicals. Doniger argued that, "More 1,1,1 is produced and emitted than any other ozone-depleting chemical and it is still completely unregulated." The report also listed 141 household products such as adhesives, cleaning fluids, hair products and pesticides containing 1,1,1, calling for a consumer boycott of these products.

Greenpeace also initiated a campaign for safe alternatives to protect the ozone layer that would "show policy makers on Capitol Hill that a vast majority of Americans demand whatever steps are necessary to prevent destruction of the ozone layer." The campaign consisted of grass roots activism, canvassing and a campaign to get local chemical users to sign a "Good neighbor" agreement to stop using ozone depleting chemicals. In addition, Friends of the Earth also launched its own international campaign against 1,1,1.

Industry's Position

Although alternatives existed, none of them were considered "drop-ins" or ready-to-use replacements. Industry's response to the potential amendment focused on the lack of "drop-in" substitutes for 1,1,1's excellent cleaning properties, calling for a 2010 preferred cut-off date to come up with acceptable substitutes. Lack of information regarding the trade-offs of substitutes was a concern raised by Dr. Paul Cammer, President of the Halogenated Solvents Industry Alliance (HSIA), who was concerned that many of the proposed alternatives to 1,1,1 were more toxic to workers, contributed to smog, or were flammable or explosive. Further, he claimed that alternative water-based cleaning systems, pushed by environmentalists, would likely increase the need for waste water treatment and increase the demand for fossil-fuel energy, thus contributing to global warming (Chemical Marketing Reporter,1990). Indeed, even the Chairman of the Committee of Energy and Commerce commented at hearings that "some substitutes are being hyped before we really know if they are safe."(Hearing before the Subcommittee on Oversight and Investigation,1989).

Dr. Cammer also argued that, in some circumstances, 1,1,1 is a substitute for CFC-113 as a cleaning agent, and that it is widely accepted that CFC-113 will be the most difficult chemical for which to find substitutes. Milt Blankenship, representing the Society of Plastics Industries, testified at congressional hearings that including 1,1,1 (a feedstock for HCFCs) in the MP could sharply curtail the availability of HCFCs or make them prohibitively expensive.

Others argued that linking CT and 1,1,1 in the policy debate to CFCs was incorrect due to their different chemical properties. For example, 1,1,1 has an atmospheric life of 6-7 years compared to CFC-113's 88-year life. (See Exhibit 12) Many throughout industry argued that 1,1,1's relatively low ozone depleting potential made it a good transition product to replace the CFC.

Dow's scientists were not actively involved in MP issues until 1,1,1 became a topic of interest in MP negotiation (Liffin,1994). Working with HSIA, they published reports arguing that "international action to limit the production and use of methyl chloroform is not desirable, nor is it needed at this time." Relating

the results of a recent study, the report stated that over 73,000 manufacturing facilities used 1,1,1, and that these facilities employed over three million production workers (Part of the Solution,1989). They also joined lobbying efforts with ICI, the largest producer of 1,1,1 in Europe to organize a letter writing campaign to the EPA and Commerce Departments. Statements such as the following from companies across the country filled congressional testimony and the press.

"Available substitutes tend to be flammable, contribute to global warming and contribute to smog and are toxic, and we are not using them," said Rick Renner of 3M Products which uses 1,1,1 in Scotchgard upholstery products" (USA Today,1990)

"Methyl chloroform is used as a solvent for the manufacture of magnetic computer heads and no safe substitute has been found," said a representative from IBM (United Press International,1990).

The U.S. Council for International Business had other concerns regarding the possibility that 1,1,1 would be added to 1990 Clean Air Act Amendments. They argued that unilateral action taken on part of the U.S. government which goes beyond the MP would be "unwarranted and unproductive" (Hearing before the Subcommittee on Oversight and Investigation,1989). Not only would unilateral U.S. action be insignificant in solving the ozone problem, but it would reduce the competitive flexibility of business and might discourage other countries from signing the MP if they perceive that a more stringent U.S. policy would dominate.

In response to regulatory uncertainty, industry had already starting implementing recycling and reuse programs for 1,1,1 since it was likely that no restrictions would be placed on recycled and reused 1,1,1. Also, the International Cooperative for Ozone Layer Protection was formed in 1989, as a non-profit organization of leading electronic and aerospace companies who were major consumers of ozone-depleting substances to facilitate the worldwide exchange of information on technologies, substances and processes for eliminating ozone-depleting solvents.

THE FUTURE

Jeff tried to estimate the market potential of 1,1,1 given the current negotiations in London. The United States, Japan and the Soviet Union supported a phase-out schedule that would require a 20% reduction in 1993, 85% by 1997 and 100% by 2000. However, the European Community was pressing for a quicker phaseout that would require a 50% reduction by 1992, 85% by 1996 and 100% by 2000. Several other countries, including Norway, Australia, and New Zealand were calling for an even faster schedule that would eliminate production by 1997. Talk of tightening the Clean Air Act might have further restricted the domestic market. On the other hand, prices were expected to soar as supply tightened for a product with no clear substitutes. Forecasts as high as \$1/pound by 1995 were projected and there was talk that the Federal government may initiate an excise tax to recover potential windfall profits. (See Exhibit 13 for pricing trends.)

Jeff knew that if 1,1,1 were added to the MP it would be another shake-up to the chemical industry. In September 1988, DuPont had surprised the industry when it declared its intention to get out of the CFC business by the year 2000 and called for renegotiation of the Montreal Protocol to impose a worldwide ban. Jeff's customers, satisfied with 1,1,1's performance, were looking for answers about technological improvements in vapor degreasing, tighter emissions control equipment, greater

industrial recycling of solvents and alternative processes and materials. Jeff needed a plan.

CASE B

RESULTS

Continuing Change

The London meeting ended on June 29, 1990, with agreement from 53 national delegates to freeze 1,1,1 production levels by 1993, to reduce it 70% by 2000, and to end production by 2005. In addition, it called for an end of production of CFCs and halons by the end of the century. The new measures significantly strengthened the 1987 treaty that called for a 50% cut in only certain chlorine-containing chemicals. The London amendments also created a fund to support developing countries in their efforts to transition to non-ozone depleting technology. By August 1995 the Fund had already disbursed \$315 million for more than 800 projects in 80 developing countries (Federal Document Clearing House Congressional Testimony, 1995).

November amendments to the 1990 Clean Air Act froze production of 1,1,1 at 1989 levels for emissive purposes and began an accelerated phaseout in 1993 that will end production in 2002. In addition, a CAA labeling law went into effect in 1993 that required any product containing or manufactured with 1,1,1 to bear a label stating "Warning: Manufactured with (or contains) Methyl Chloroform, a substance which harms public health and environment by destroying ozone in the upper atmosphere."

The Copenhagen Amendments to the MP in 1992 accelerated the phaseout of halons to January 1, 1994, and CFCs and 1,1,1 to January 1, 1996. In addition, it added bromine and HCFCs to the phaseout schedule. (See Exhibit 1)

In 1994, the National Emission Standards for Hazardous Air Pollutants, used in metal cleaning, was passed requiring companies using methylene chloride, perchloroethylene, and trichloroethylene to meet total emissions standards by December 1997.

Dow's Reaction

Mr. Brad Lienhart, business director for chloralkali and derivatives group of Dow, called the enactment of the revised Montreal Protocol and the US CAA "learning experiences" from which the company will ultimately benefit.

In October 1990, Dow Chemical ceased production of 1,1,1 at its Sarnia, Ontario plant and on April 10, 1992, announced it would cease all production for emissive purposes worldwide by December 31, 1995. In April 1994, Dow built up inventory to fill 1,1,1 demand to the end of 1995 and then closed its 500 million-lb-per-year unit in Freeport, Texas. By the end of the year it had converted its 220-million-lb-per-year Stade, Germany plant to trichloroethylene (TCE) which was a feedstock to HFC-134a.

"Dow's decision to include its global operation in the accelerated phaseout supports the company's goal of operating consistently around the world," explained David Buzzelli, Dow's VP and Corporate Director of Environment, Health and Safety. He added, "We're committed to being a responsible corporate citizen, a reliable chemical supplier, and part of the public policy process." (PR Newswire, 1992).

As an outgrowth of regulatory pressures, Dow organized a new business group called Advanced Cleaning Systems (ACS), servicing North America and Europe, charged with the task of identifying and meeting the needs of the surface cleaning industry. Dow decided to create business opportunities by shifting its focus from selling particular solvents to forming alliances with equipment manufacturers in order to offer systems that integrated chemicals, equipment, waste management and waste minimization processes.

Traditionally, Dow dealt exclusively with customers of chemical-based cleaning systems. "An interesting market opportunity resulting from the development of ACS is our involvement with aqueous-based cleaners," states Doug Warner, Marketing Manager of ACS. "Approximately 60% of our business comes from helping these customers design integrated systems that meet their quality and environmental requirements."

Based on proprietary technology, in 1994 Dow introduced the "Invert" line of solvents for non-vapor degreasing applications. Invert uses microemulsion technology to disperse tiny particles of water into the solvent in order to use solvent molecules more efficiently, resulting in a 50% reduction in solvent content and VOCs. Invert 1000 is targeted for the aerosol industry (\$.58/lb.), while Invert 2000 is used in cold cleaning (\$.72/lb.) and Invert 5000 is a base solvent that may be blended with other solvents to create customized cleaners for specific end uses (\$.62/lb.).

In 1995, Dow formed a joint venture with Safechem, a subsidiary of the German oil conglomerate Veba to recover and recycle solvents. Dow's approach in this joint venture has been to design closed-system equipment for the delivery and use of chlorinated solvents.

Market Reaction

In 1991 the Federal government began charging an excise tax on top of 1,1,1's list price, which by the 1995 phase-out date, had increased from \$.14/lb. to \$.54/lb. Although the tax was levied on manufacturers, customers felt the result in higher prices. By 1993, 1,1,1 list prices had jumped by \$.40 /lb. over the prior year, as rumors of an EPA accelerated phaseout and uncertainty regarding supply pushed up prices. In addition, users who attempted to delay their phaseout by building up inventories of 1,1,1 were charged a "floorstock" tax at year-end.

Innovative Processes

Firms have been exploring alternatives to ozone-depleting solvents including: "no-clean" systems, non-solvent processes, environmentally acceptable solvents, aqueous and semi-aqueous systems and closed-loop systems. The "no-clean" option, to simply stop cleaning materials whose performance is not compromised by contamination, sometimes works for electronics circuit boards, but is not usually an option in metal-working and precision cleaning. Non-solvent cleaning processes including blasting with dry ice, steam cleaning, and ultra-violet radiation, were used in specific, limited applications.

Although it was estimated in 1994 that one-third of the vapor-degreasing industry was still using 1,1,1, many had already converted to aqueous systems. A 1994 survey by Dow found that large companies in the United States were twice as likely to use aqueous solvents than smaller companies (Global Environmental Change Reporter, 1995).

Substitute Chemicals

Lack of ready substitutes had led many in industry to other chlorinated solvents that are not regulated as ozone depleters by the protocol or the CAA such as methylene chloride, trichloroethylene (TRI) and perchloroethylene (PERC). It was estimated that approximately 20% of 1,1,1, sales may be replaced by one of these chemicals, however, both TRI and PERC are regulated under CAA as VOCs and Hazardous Air Pollutants (Chemical Marketing Reporter, 1993). Although they are primarily used in vapor degreasing operations they also have selected applications in aerosols, coatings and adhesives operations. Recently, these chemicals, and especially methylene chloride, have come under Occupational Safety and Health Administration scrutiny as possible carcinogens.

Rather than searching for the exact replacement for 1,1,1, many companies are focusing on families of environmentally safe products that match the performance of 1,1,1 in specific applications. For example, Allied Signal is trying to develop a portfolio of products that have boiling points similar to 1,1,1 so that they may be used with existing equipment. The solvent market is now comprised of many companies such as Dow, DuPont, Shell, Union Carbide, Exxon, and Eastman Kodak each producing high-value specialty chemicals for small niches. Most major solvent suppliers now offer computerized conversion assistance tailored to their customers' specific needs.

Substitutes for traditional cold cleaning have been especially difficult as most alternatives are VOCs. Further, those with rapid evaporation have high flammability requiring either additional drying or safety equipment.

The EPA implemented a Significant New Alternatives Policy (SNAP) under the CAA that helps companies evaluate substitute chemicals to make sure that they will not cause greater damage to human health and the environment than the ozone depleters they are replacing.

Recycled Solvents

Recycled 1,1,1 was exempt from regulations, and could therefore have been used after the 1995 cut-off date. However, the phaseout of 1,1,1 greatly reduced solvent recyclers' volumes leading to a wave of consolidations and buy-outs in the industry. To bolster business, many companies are expanding into wastewater treatment and recycling of nonhazardous solvents in conjunction with the increase in aqueous systems.

Competitive Reaction

Both Vulcan and PPG planned to keep their plants onstream well beyond the 1995 deadline by selling for non-emissive purposes in the production of HCFCs. Dow's early exit from the business gave both companies the opportunity to buy additional 1,1,1 capacity. Although in the short-term 1,1,1 sales had remained strong, and each continued to serve developing countries, neither increased production. Both supplemented their 1,1,1 sales with methylene chloride, TRI and PERC.

In 1993, PPG announced a new Micro-Phase 3 product as an environmentally friendly alternative to 1,1,1 based on microemulsion technology.

Vulcan formed a program called the Metal Cleaning Systems to help customers convert to new chemical solvents. "We haven't concentrated on aqueous cleaning because it's not new technology," a representative from Vulcan explained. "This is what we used to do before we got into chlorinated

solvents. This is old, old, old, old stuff." (Chemical Marketing Reporter,1993).

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