APPENDIX B: EXAMPLES OF EXTREMELY HAZARDOUS SUBSTANCES AND SAFER ALTERNATIVES

The following sections give some examples of extremely hazardous chemicals that are common in the U.S. economy and potential alternatives. This is not an exhaustive description of the many uses that these substances are used for, but rather is intended to demonstrate the breadth of use and some of the potential alternatives. Also, it should be understood that applying alternatives to a particular facility and use requires assessment of technical and cost factors, other safety and environmental concerns, and legal issues.

ARSINE GAS

USES:
Arsine gas is widely used in the production of microchips for electronics products.

EFFECTS:
An extremely toxic gas that destroys red blood cells and can cause widespread organ injury and death. Inhalation of arsine can cause impairment of kidney function, damage to the liver and heart, electroencephalogram abnormality, hemolytic anemia, and death due to kidney or heart failure.

SAFER ALTERNATIVES:
While arsine gas is a necessary ingredient in the production of certain microchips, it is not necessary to store large volumes of arsine gas in order to produce the final products. Instead, under scrutiny of local government, microelectronics producers in the Silicon Valley have applied technologies to produce arsine gas at the point of use, to be consumed immediately in production processes, leaving very little in storage, and eliminating the potential for a catastrophic scale of release.

CHLORINE

USES:
Production of chlorinated organics, including PVC and other hazardous chemicals like perchloroethylene, and trichloroethylene, accounted for 76% of national chlorine consumption in 1995. (The production of polyvinyl chloride accounts for about 35% of national chlorine consumption.) Use in water and wastewater treatment systems accounts for 2-4%. Use in bleaching of paper in pulp and paper mills is another common usage. In etching processes, manufacturers use chlorine gas to regenerate spent etchant (ferric chloride and cupric chloride). Chlorine was used as a chemical warfare agent during World War I.

EFFECTS:
In high concentrations chlorine can act as an asphyxiant and cause respiratory distress, chest pain, loss of breath (leading to death), vomiting, filling of the lungs with fluid (pulmonary edema), and pneumonia. Chlorine products also result in the generation of dioxin, one of

the most toxic and carcinogenic compounds. There is substantial evidence of effects of dioxin on the impaired development of children's immune, reproductive, and nervous systems, in particular cognitive and learning abilities. Dioxins are unintended by-products of many chemical and combustion processes which involve chlorine, reaching the environment from industrial air emissions, wastewater discharges, disposal activities, and from burning material that contains chlorine.

SAFER ALTERNATIVES:
Many wastewater and water treatment plants have been switching to safer alternatives. Water and sewer treatment facilities are moving away from elemental chlorine and substituting sodium hypochlorite (bleach). This largely eliminates gas cloud hazards because bleach does not vaporize as quickly or easily as liquid or gaseous chlorine, but it does not eliminate dioxin and other environmental concerns regarding chlorine production and discharges. Ultraviolet light is another substitute suited to wastewater facilities which does not pose the same environmental concerns. Hydrogen peroxide and ozone can be substituted for chlorine in etchant regeneration, but they are not as effective in regenerating the solution, create more waste and have other hazards associated with their use.

There are many possible substitutes for polyvinyl chloride, which is the largest single use of chlorine. For instance, instead of using PVC, many end users are switching to polypropylene or polyolefins –plastics which do not use chlorine. Dow-Cargill placed a new $300 million plant on line in November 2001 in Blair, Nebraska that will make plastics out of sugar.

An international treaty on persistent organic pollutants (POPs) has recommended working toward the elimination of dioxins and the products that lead to their generation. Signatory nations are called on to reduce total releases "with the goal of their continuing minimization and, where feasible, ultimate elimination." The treaty urges the use of substitute or modified materials, products and processes to prevent the formation and release of dioxins.

HYDROGEN FLUORIDE (HYDROFLUORIC ACID)

USES:
Hydrogen Fluoride (HF) is used in an array of industries and uses. It is used and stored in large quantities at roughly half of all oil refineries to generate alkylates, which permit allow vehicles to have better gas milage per gallon. HF is also used in metal surface treatments. The electronics industry uses high purity, 49% hydrofluoric acid solution, to etch silicon. HF is also used to produce uranium.

EFFECTS:
Hydrogen Fluoride has a special capacity to form a self-regenerating toxic cloud that can remain at deadly densities despite the movement of the cloud over long stretches of land. Even slight contact with the chemical can cause severe skin and deep tissue burns, which may occur hours after contact and may not be felt immediately; severely burn the eyes, causing blindness; irritate the nose, throat, and lungs, causing coughing and/or shortness of breath; or cause the build up of fluid in the lungs (edema). Many workers who have been accidentally exposed to HF have died gruesome and painful deaths.

SAFER ALTERNATIVES:
HF in refinery alkylation is technologically unnecessary; safer processes and materials can fill the same purpose. Since the early 1990's alternative technologies have been available for refineries, known as solid acid and fixed bed catalyst technologies, which eliminate the risk of a large scale catastrophic incident from HF. These solid acid catalyst alternatives are inherently safer than traditional HF methods, due to their sharply reduced volatility. Unfortunately, the refining industry has not widely implemented these safer technologies due to the lack of government regulations mandating their adoption. The other half of refineries engaged in alkylation use sulfuric acid, which is also dangerous, though not as hazardous in the movement and concentration of its vapors.

A variety of acids can be used to accomplish metal surface treatments, such as nitric and

sulfuric acids. Texas Instruments has implemented a new metal spraying technique for coating ceramic parts that decreased the need for hydrofluoric acid etching of the ceramic parts prior to metal application.

METHYL ISOCYANATE (MIC)

USES:
Used as an intermediate chemical in production of certain pesticides.

EFFECTS:
A wide array of damage to the lungs, brain, kidneys, muscles as well as gastrointestinal, reproductive, immunological and other systems. Bronchial asthma, chronic obstructive airways disease, recurrent chest infections, and fibrosis of the lungs are the principal effects of exposure-induced lung injury.

On December 3, 1984, Union Carbide Corporation's pesticide factory leaked poisonous gases into the city of Bhopal, India. In one night over three thousand residents were killed and hundreds of thousands of others were injured, many of them permanently. The prevalence of pulmonary tuberculosis among the survivors has been found to be more than three times that of the national average; survivors also have increased early-age cataracts and damaged immune systems.

SAFER ALTERNATIVES:
After the Bhopal disaster, many companies found that they could make the same pesticide products without continuing to store large quantities of methyl isocyanate. Some companies began making their products using different chemical pathways that eliminated the need to use of methyl isocyanate DuPont found a way to avoid keeping 40,000 to 50,000 pounds of MIC that it previously had in storage. Though it produces MIC as an intermediate, the firm immediately consumes it in a closed-loop process. The result is a maximum of two pounds of MIC on-premises at any one time.

AMMONIA

USES: Eighty percent of ammonia is used in agricultural operations, much of it as fertilizer. Ammonia is also used in high pressure refrigeration and in cleaning.

EFFECTS:
Effects of inhalation of ammonia range from irritation to severe respiratory injuries, with possible fatality at higher concentrations. Ammonia is
corrosive and exposure will result in a chemical-type burn. It readily migrates to moist areas of the body such as eyes, nose, throat, and moist skin areas. Exposure to liquid ammonia will also result in frostbite since its temperature at atmospheric pressure is -28°F.

In a 1986 incident in a packing plant slaughterhouse, a refrigeration line ruptured, releasing ammonia. Eight workers were critically injured, suffering respiratory burns from ammonia inhalation, and 17 others were less severely hurt. A freight train crash near the North Dakota town of Minot on January 18, 2002 leaked a cloud of anhydrous ammonia gas that killed one person, injured dozens more and paralyzed part of the town.

SAFER ALTERNATIVES:
Responding to complaints from residents and political leaders, American Electric Power abandoned a plan for large scale liquid ammonia storage to clean the exhaust of its massive Gavin plant in southeastern Ohio. Instead of installing six 60,000-gallon tanks to hold toxic anhydrous ammonia at the plant, the company announced that it would use urea, a dry nitrogen fertilizer that will be converted into ammonia shortly before it is injected into the exhaust. The urea can be more stable in storage, provided it does not come into contact with other substances that it reacts with.

EXTREMELY HAZARDOUS SUBSTANCE	NDUSTRY SECTOR	PROCESS	EXISTING ALTERNATIVES	ALTERNATIVES UNDER DEVELOPMENT
Ammonia		industrial refrigeration	water	
Chlorine	Electronics	etching	Hydrogen Peroxide and Ozone	
	Many	Water Purification	Sodium Hypochlorite Ultraviolet Light Ozone	
	pulp and paper	pulp bleaching	Oxygen gas Ozone Hydrogen peroxide	
	Polyvinyl chloride (PVC)	Plastics production	Polypropylene Polyolefins Sugar-based plastics	
Chlorine Dioxide	pulp and paper	pulp bleaching	Oxygen gas Ozone Hydrogen peroxide	
Ethylene Oxide	Health care	Sterilization	Steam/Autoclave Dry heat Microwave Gamma-Cobalt 60 E-beam Mixed chemical plasma device using peracetic acid Hydrogen peroxide plasma Ozone Vapor phase hydrogen peroxide	

EXTREMELY HAZARDOUS SUBSTANCE	NDUSTRY SECTOR	PROCESS	EXISTING ALTERNATIVES	ALTERNATIVES UNDER DEVELOPMENT
Formaldehyde	construction-plywood, varnishes, laminated and foam insulation	phenolic resins	enzymatic water-based polymerization process (based on horseradish peroxidase and soy peroxidase) pyrolysis(rapid heating in the absence of oxygen) of biomass	
	Electronics	printed wiring boards	Carbon technology graphite tech. organic-palladium tech. tin-palladium tech. non-formaldehyde electroless copper(sodium hypophosphate reducing agent) tech. conductive polymer tech	
	Garment industry	wrinkle resistance		glyoxyl resins butaneteracarboxylic acid sodium hypophosphite polymeric carboxylic acid/citric acid
Hydrogen Chloride	pharmaceutical	neutralizing agent for ph control	other acids or bases	
	food		other acids or bases	

EXTREMELY HAZARDOUS SUBSTANCE	NDUSTRY SECTOR	PROCESS	EXISTING ALTERNATIVES	ALTERNATIVES UNDER DEVELOPMENT
Hydrogen Fluoride	metals and electronics	etching,pickling and cleaning metals		nitric acid hydrochloric acid phosphoric acid alkaline solution plasma etching
	petroleum production	alkylation	Solid acid catalyst	
Phosgene	polycarbonate plastics production	intermediary	diphenylcarbonate	
	polyurethane production	intermediary	carbon monoxide carbon dioxide	
	pesticide production	intermediary	carbon monoxide carbon dioxide	