Question 5:
What are the environmental and health impacts of LCDs?

Like CRTs, LCDs had impacts associated with each impact category; this section presents a summary of the results. Table 5.1 identifies the processes that contribute most significantly to each impact category.

Table 5.1. Summary of most significant LCD processes

Impact category	Most significant process	Associated life stage	Percent contribution to category score
Natural Resource Impacts			
renewable resource use	water use in LCD module manufacturing	upstream	38%
nonrenewable resource use/depletion	natural gas extraction	upstream	65%
energy use	electricity consumed for LCD use	use	30%
solid waste landfill use	coal waste from electricity generation	use	44%
hazardous waste landfill use	landfilled LCD monitor	end of life	97%
radioactive waste landfill use	low-level radioactive waste from electricity generation	use	44%
Abiotic Ecosystem Impacts			
global warming	sodium hexafluoride in LCD module manufacturing	manufacturing	29%
stratospheric ozone depletion	HCFC-225 in LCD component manufacturing	manufacturing	34%
photochemical smog	non-methane hydrocarbons from natural gas production	upstream	45%
acidification	sulfur dioxide from electricity generation	use	31%
air quality (air particulates)	particulate matter from energy generation used for steel production	use	45%
water eutrophication (nutrient enrichment)	nitrogen from LCD module manufacturing	manufacturing	67%
water quality: BOD	BOD from LCD module manufacturing	manufacturing	61%
water quality: TSS	TSS from LPG production for LCD glass manufacturing	manufacturing	66%
radioactivity	plutonium released from energy generation used for steel production	upstream	96%
Human Health and Ecotoxicity			
chronic human health effects - occupational	LPG used for LCD glass manufacturing	manufacturing	58%
chronic human health effects - public	sulfur dioxide from fossil fuels burned for electricity generation	use	68%
aesthetic impacts (odor)	phosphine from LCD module manufacturing	manufacturing	89%
aquatic ecotoxicity	phosphorous from LCD module manufacturing	manufacturing	98%
terrestrial ecotoxicity	sulfur dioxide from fossil fuels burned for electricity generation	manufacturing	68%

[a]Acronyms: liquified petroleum gas (LPG), hydrochlorofluorocarbon (HCFC), particulate matter with diameter less than 10 micrometers (PM10), biological oxygen demand (BOD), total suspended solids (TSS).

Natural Resource Impacts

Renewable resource use. Renewable resources are materials found in nature that generally are replenished through natural processes. The most significant examples are water and forest products. The manufacturing life stage accounted for over 75 percent of the renewable resource use. The most water-intensive manufacturing steps were LCD monitor manufacturing and the production of liquified petroleum gas (LPG) used in glass manufacturing.

Nonrenewable resource use/depletion. Nonrenewable resources are materials, such as metals or fossil fuels, that are not readily regenerated naturally. The vast majority of nonrenewable resource use (97 percent on a mass basis) is associated with the depletion of fossil fuels. The largest single process step is the depletion of natural gas in the materials processing life stage.

Energy use. This impact category considers only the energy consumed during a display's life cycle; it does not include the releases associated with energy production. (Those effects are reported under other appropriate impact categories.) The electricity consumed during LCD use is the largest single contributor to the energy use results. Other energy-intensive processes include LCD glass manufacturing, which uses LPG and electricity, and natural gas production, which uses unprocessed natural gas.

Solid waste landfill use. By consuming space in a landfill, solid waste necessitates the use of open land. Most of the solid waste (65 percent by weight) is associated with electricity production for LCD use. This solid waste material includes coal waste, dirt/sludge, and fly/bottom ash. Like CRTs, LCDs are calculated to reduce solid waste landfill use in the end-of-life stage, because the incineration of some LCDs and the resulting energy offsets the solid waste impacts of landfilled displays and fossil fuel-derived energy.

Hazardous waste landfill use. Hazardous waste consists of materials regulated under the Resource Conservation and Recovery Act. This material has the same space requirements as solid waste and also demands additional safety and environmental protection precautions. The landfilling of LCDs produced most of the impacts in this category, even though only five percent of LCDs were expected to be landfilled. Hazardous waste from LPG production and acetic acid from LCD monitor manufacturing represent the remaining amount.

Radioactive waste landfill use. Like hazardous waste, radioactive waste contributes to the consumption of open land and creates safety and environmental challenges. The wastes in this impact category are low-level radioactive waste and depleted uranium generated during electricity production at nuclear power plants.

Abiotic Ecosystem Impacts

Global warming. Gases such as carbon dioxide and methane trap heat in the atmosphere. It is believed that by increasing the concentrations of these gases, humans are causing the atmosphere to grow warmer and induce global climate change. Several processes contributed to the global warming impact of LCDs. Sulfur hexafluoride used in the LCD module manufacturing process contributed 29 percent of the global warming potential of LCDs. Most of the remaining impacts were caused by carbon dioxide released during electricity generation for LCD use and during natural gas production.

Stratospheric ozone depletion. The stratospheric ozone layer blocks harmful ultraviolet (UV) sunlight from reaching the earth's surface. Chemicals such as chlorofluorocarbons may destroy ozone in the stratosphere, causing an increase in UV radiation on the earth's surface. Roughly 60 percent of the impacts in this category were caused by hydrochlorofluorocarbons (HCFCs) used in manufacturing LCD panel components. Unlike the CFCs that contributed significantly to CRT ozone depletion impacts, the HCFCs used to manufacture LCD panel components are not scheduled for phaseout until 2015. Another 27 percent of ozone depletion impacts was contributed by electricity generation for LCD use, which released bromomethane during the combustion of coal.

Photochemical smog. Photochemical smog is produced in the atmosphere by the reaction of hydrocarbons and nitrogen oxides in the presence of sunlight. Smog may cause or aggravate health problems, toxicity in plants, and deterioration of materials. Approximately 75 percent of the photochemical smog results were caused by natural gas production in the materials processing life-cycle stage. Important releases included methane, benzene, and other non-methane hydrocarbons.

Acidification. The release of acids into the air causes acid precipitation, which in turn harms surface water, soil, and plants. Roughly 40 percent of the impacts in this category were caused by sulfur dioxide and nitrogen oxides released during electricity generation for product use. Other important processes include natural gas production, which released nitrogen oxides, ammonia, and sulfur oxides; and LCD module manufacturing, which produced nitrogen oxides, ammonia, hydrofluoric acid, and hydrochloric acid.

Air quality (particulate matter). Particulates in the air, especially those that have a diameter smaller than 10 micrometers, can cause respiratory illnesses in humans and animals. The largest contributor to this impact category was steel production in the materials processing life stage. This process accounted for 45 percent of the particulate matter released by weight. Natural gas production contributed an additional 25 percent to the overall amount of particulate matter.

Water eutrophication (nutrient enrichment). In most surface water, the level of biological activity is limited by the concentration of nitrogen and phosphorous. When these two nutrients are released to water, fast-growing organisms such as algae outcompete established organisms such as fish. Most of the nutrient enrichment (94 percent) was caused during the LCD module manufacturing process; nitrogen and phosphorous were both released.

Water quality (BOD). Organic chemicals that are released to water ultimately lead to a depletion of dissolved oxygen, which in turn reduces the survival rate of organisms such as fish. One measure of this impact is biological oxygen demand (BOD). The LCD module manufacturing process generated most of the BOD output from the LCD life cycle; it accounted for 61 percent of the score in this impact category. LPG production was another significant source of BOD.

Water quality (TSS). In turbid (cloudy) water, only a fraction of the usual amount of sunlight penetrates the water. As a result, less sunlight reaches plants and other dependent organisms and less biological activity occurs. Total suspended solids (TSS) indicates the magnitude of this effect

for a stream of wastewater. LPG production generated the largest amount of TSS; 66 percent of the TSS resulted from this process.

Radioactivity. Radioactive materials released to the environment can cause cancer in humans and animals. As with CRTs, nearly all of the estimated radioactivity impacts of LCDs were associated with steel produced in countries that reprocess nuclear fuel. Only a small amount of radioactivity is released by nuclear power plants in the United States.

Human Health and Ecotoxicity

Chronic human health effects – occupational. Workers might experience health effects, including cancer, from long-term exposure to materials associated with computer displays. Liquified natural gas, which is used in LCD module manufacturing, was the single most significant material for this impact category. The sulfuric acid used in the same process also was significant. Together, these two chemicals accounted for 81 percent of the score.

Chronic human health effects – public. Members of the general public might be at risk of developing adverse health effects, including cancer, due to air or water releases from a life-cycle stage of computer displays. The SO_2 released during electricity production was the largest contributor to the public health effects category. The largest share was attributed to electricity consumed for LCD use (68 percent of the score), and another 21 percent was attributed to electricity use in LCD manufacturing.

Aesthetic impacts (odor). Some air emissions may be released in concentrations that are detectable by smell. Odor does not by itself represent a human health or environmental problem, but it is considered a nuisance. Most of the odor generated in the LCD life cycle was attributed to phosphine, which was emitted in the LCD module manufacturing process. Hydrogen sulfide released during LPG production also contributed a small amount to the total impacts.

Aquatic ecotoxicity. Organisms that live in water, particularly fish, can be harmed by toxic chemicals released to water. Nearly all of the aquatic ecotoxicity impacts were from phosphorous, which was released to wastewater during the LCD module manufacturing process.

Terrestrial ecotoxicity. Organisms living on land can be adversely affected by toxic chemicals in the air or in surface water. Results for this impact category are based on the effects on rodents. As with the public health impact category, SO_2 from electricity generation is the primary source of toxicity to land-based organisms. The electricity used in the LCD use life stage accounted for 68 percent of the indicator score, and the electricity used in manufacturing accounted for an additional 21 percent.

Comparison across LCD life stages

Figure 5.1 indicates the number of impact categories for which each life stage was the largest contributor. As with CRTs, manufacturing and product use most frequently were the largest contributors for an impact category. Glass manufacturing and the associated fuel requirements were a significant cause of impacts in the manufacturing life stage. Other materials used in LCD

manufacturing, such as phosphorous- and nitrogen-containing compounds, were also important contributors to some of the impacts related to water quality. In the product use life stage, energy consumption significantly affected several of the impact categories.

Figure 5.1. Distribution of Largest LCD Impacts